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This volume is dedicated to

## G DALLAS HANNA

on the occasion of his seventy-fifth birthday
by the Academy's Staff and Board of Trustees, with the utmost respect and appreciation for his long service to the Academy and his unfailing devotion to its principles and purposes, and for his outstanding contributions to science.


## PROCEEDINGS

OF THE

## CALIFORNIA ACADEMY OF SCIENCES

Fourth Series

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# G DALLAS HANNA 

by

Robert C. Miller

California Academy of Sciences

Some men find adventure in travel, exploration, and discovery-visiting the far and difficult places of the earth. Others find it in the library and the laboratory, in study and thought and experiment-adventure of the mind. To a chosen few it is given to know both kinds of adventure, and to know them in continuing and brimming measure. One of those few is the subject of this biographical sketch.

G Dallas Hanna was born in Carlisle, Arkansas, on April 24, 1887. He graduated from the University of Kansas in 1911, where he distinguished himself by his proficiency in zoology, paleontology, and chemistry. At intervals thereafter-in a detour to Alaska presently to be described-he took an A.M. degree at the University of Kansas in 1913 and a Ph.D. at George Washington University in 1918.

His first name is G, just like that, no period. This causes no end of confusion among editors and bibliographers. Acquaintances of fifty years' standing have been known to call him Dallas, but most of his friends and
colleagues skirt the question of which name to use by comfortably addressing him as "Doc."

The newly fledged graduate of the University of Kansas promptly obtained a job with the United States Bureau of Fisheries, and was just as promptly assigned to the Bristol Bay area of Alaska, where he arrived in the spring of 1911 at a point on the map labelled Nushagak. His mission seems to have been to find out everything he could about the fisheries, aquatic biology, and miscellaneous wildlife resources of the area, so that the Bureau of Fisheries could plan administrative and conservation measures.

This is pretty remote country even today, and one can imagine the problems of transportation and communication fifty years ago. But the young man from the middle west took to the new life as if he had been born to it. The basic means of transportation being by boat in summer and by dog sled in winter, he quickly became an expert seaman and an expert dog-sled driver.

In the winter of 1912-13 he made an historic trip of a thousand miles by dog sled, from the head of Bristol Bay to Idadorod and return. On the first leg of the trip, from Bristol Bay to Bethel on the Kuskokwim River, he had a companion driving another sled. But on the last and most arduous leg of the trip, up the Kuskokwim River and over a 5000 -foot pass in the Kuskokwim Range in the dead of winter, he went it alone with no companions except his seven sled dogs-animals half-wild and savage, but strong and persevering under the control of a compelling man.

On this trip he collected 800 birds and mammals for the United States National Museum, including ptarmigan, fox, mink, otter, shrews, and snowshoe rabbits. All that science needed was the skin and skulls. The meat he apportioned between himself and his sled dogs. The purpose of this trip was to communicate with Washington and get instructions for the following summer. Idadorod, then a thriving metropolis of 400 people-mostly engaged in placer mining in frozen ground-was the nearest telegraph station!

His new assignment was to the Pribilof Islands-more remote and wet and cold and fog-bound even than Bristol Bay. Here he kept count of the Alaskan fur seal herd-then as now governed by a treaty with the Japanese government-and formed lasting friendships with the local human inhabitants, both Aleuts and the few resident whites, through his interest in them and his ingenuity in suggesting new solutions to the particular problems of an inhospitable environment.

In addition to his duties as custodian and census-taker of the fur seals on their breeding grounds, Dr. Hamna studied the general natural history of the Pribilofs, and published papers on both the birds and the mammals. He also interested himself in the geology and paleontology of the islands, and took up the study of fossil diatoms-a specialty that was to play an important role in his subsequent carcer.

In 1919 he accepted appointment as Curator of the Department of Paleontology (now Geology) in the California Academy of Sciences, at the invitation of the Academy's then director, Barton Warren Evermann, whoin his previous capacity of chief of the Alaska Division of the U. S. Bureau of Fisheries-had acquired first-hand knowledge of Dr. Hanna's brilliant mind and versatile abilities.

Among the first problems he took up in his new position were studies of diatoms, radiolarians, and silicoflagellates, all of which are unicellular organisms-most of them microscopic-with a siliceous skeleton. Being always of a practical turn of mind, Dr. Hanna was aware that these organisms could be useful in the identification of geological strata in the search for oil. His services came into demand by the oil companies, and he began doing part-time work for Pacific Oil Company and Associated Oil Company.

He made arrangements with these two companies to do experimental work with oil-well sediments to determine whether microfossils could reliably be used for the correlation of sediments. This project was approved and work began at the Academy on May 16, 1923. To assist him, Dr. Hanna employed Roy T. Hazzard from the University of California, and subsequently H. C. Driver. By December the work had progressed so favorably that Dr. Hanna suggested that a laboratory be established in the Associated Oil Building. This plan was approved in February, 1924, and on April 3, 1924, the laboratory was completed and ready for work in Room 637, at 79 New Montgomery Street, San Francisco. This is believed to be the first laboratory for micropaleontology established by an oil company on the Pacific Coast. Other oil companies soon followed suit; but there is no question that Dr. Hanna pioneered this type of work, and that he added impetus to it through his scientific investigations and through his training of younger men who later became heads of such laboratories. He also pioneered in the systematic study of the foraminiferal content of oil-well cores. In summary, he laid the foundation for a science that has been universally practised since, and used to great advantage by all major oil companies.

Of his numerous published papers on geology and paleontology, probably the one which has had the greatest influence in the search for oil in California is one of the shortest. It bears the title, "A (ieologic Section in the Center of the San Joaquin Valley, California." (See Bibliography, no. 208.) Mr. J. A. Taff was joint author. This paper described the geologic formations penetrated by three wells drilled for oil in the center of the San Joaquin Valley in Fresno County. The drill holes showed for the first time that formations capable of producing oil were easily within the reach of the drill on the valley floor and that they were thinning rapidly to the east. The publication of this information resulted in extensive drilling throughout the valley and resulted in the discovery of many oil and gas fields; and the drilling is still going on.

Not content with the scientific aspects of drilling for oil, he interested himself also in the purely mechanical aspects. He produced the first and assisted on subsequently improved designs of the Reiber-Hanna well surveying instrument used to indicate the orientation of well cores. Patent no. 1,665,058, issued to him on April 13, 1928, and assigned to the Associated Oil Company, covered his first instrument developed as a "Means for obtaining data in earth bores." (This story is covered in an article by A. T. Parsons, engineer of Frank Reiber, Inc., in the Associated Oil Company's magazine, The Record, for December, 1930.) Although such tools are commonplace now, twenty-five or thirty years ago they were just being put into operation.


Figure 1. Packing into Burl's Creek, southeast Alaska, 1938.

Dr. Hanna's contributions to the oil industry were recognized in part by his election as vice-president of the Society of Economic Paleontologists and Mineralogists in 1928-29, and his election as president of that organization in 1932-33. An equally convincing evidence of the respect in which he is held among his peers is the fact that in 1937 and again in 1938 he was chosen as leader and chief geologist of a joint expedition, sponsored by Tidewater Associated, Standard of California, and Union Oil companies, to conduct detailed geological work in the Cold Bay and Yakataga prospective oil districts of Alaska.

As already mentioned, Dr. Hanna's interest in microfossils, especially in diatoms, antedated his work in petroleum geology. It began while he was stationed on the Pribilof Islands. In 1916, when working on a fossil diatom deposit on St. Paul Island, he designed a new type of "mechanical finger" clamped to his microscope for greater ease in handling and mounting individual diatom specimens for study. This is still the best apparatus available for such extremely delicate work and is in constant use today. His work on the diatom flora of the western part of the United States has been extensive.

His most important work on diatoms has never been published although it is still being used in reference work; it consists of two sizable manuscripts on file in the California Academy of Sciences. The first of these is a collection of all references to diatoms, living and fossil, which had been published up to 1929, covering the mainland area from the Bering Sea to Panama. It includes records of fossil diatoms occurring as far east as Utah and the eastern boundary of British Columbia. This manuscript, dated January 1, 1930, runs 519 pages of typescript and is labelled "An Index to West American Diatoms." The second unpublished work is entitled "An Index to Atlas der Diatomaceen-Kunde, by Adolf Schmidt." The Schmidt Atlas began in 1874 and has been continued by several subsequent German contributors. This index is an authoritative and useful contribution to the literature on diatoms, being more complete than the prior index of this great work. Dr. Hanna's index is dated 1938 and includes 470 pages of typescript. As a result of Dr. Hanna's interest in diatoms, the California Academy of Sciences has one of the best reference libraries on the subject in existence. He is recognized internationally as well as nationally as one of the leading experts on the subject. And even now he is imparting his knowledge and experience to a graduate student under a National Science Foundation grant.

In the course of his study of diatoms, he found it necessary to mount the specimens in a medium of higher index of refraction than any yet available. Canada balsam, the medium most commonly used, did not provide sufficient resolution; he couldn't see the details. The challenge to find something better brought him to a study of other natural resins, and of synthetic resins. Calling on his early proficiency in chemistry, he presently came up with a synthetic resin made from naphthalene and formaldehyde. To this excellent
resin, which had a much higher index of refraction, he gave the name "Hyrax." It is now made and sold commercially by biological supply houses. Later he developed an even better mounting medium which he has called "Pleurax." With an improved mounting medium, plus a method of coating specimens under high vacuum with a film of realgar (an arsenic sulphide), Dr. Hanna proved the possibility of photographing diatoms under magnifications up to several thousand times to show their minute structure in perfect focus. This was a significant breakthrough toward a more complete knowledge of diatom structure.

In recognition of these contributions to microscopy, Dr. Hanna was made a Fellow of the British Royal Microscopical Society. And because of his extensive knowledge of microfossils and micro-techniques, he accepted an appointment in 1928 to serve on the Committee on Micropaleontology in the


Figure 2. At work on diatoms.

Division of Geology and Geography of the National Research Council and also contributed to the work of a companion Committee on Paleobotany.

His interest in improving visibility through the microscope led him into the further study of optics, which he pursued with characteristic thoroughness. This had at least two important consequences.

At the beginning of World War II the United States was extremely short on optical equipment, and in facilities and know-how for manufacture of such equipment. We had depended largely on Germany and Japan for optical supplies, and we were at war with both of them. There was really a critical shortage of such ordinary things as prisms for binoculars and other instruments, not to mention the optical parts for gun sights, range finder's, and related equipment.

Dr. Hanna's initial contribution to the war effort involved the manufacture of Amici or "roof" prisms of which the U. S. Army was in desperate need. These were thumb-sized prisms used in range finders, which bent the light beam 90 degrees and erected the image at the same time. The 90 -degree "roof" angle had to be correct to provide accuracy of one foot in an eightmile distance. There was no known mechanical method of reaching such accuracy-it had to be achieved by hand. Working with a small group of amateur telescope makers and others, he perfected each of the 76 separate processes required to make these prisms, trained the group of people working with him, and delivered 200. All passed the rigorous tests with a 100 per cent acceptance by the Army.

While engaged in this work, Dr. Hanna learned one day that a submarine at Mare Island had been out of commission for several weeks on account of a broken head-prism in its periscope. He asked whether the parts of the broken prism were available. They were. Using these to determine size and angles, he turned out a new head prism over a week-end and the submarine was returned to service. This resulted almost immediately in a contract with the U. S. Navy which kept the Academy exceedingly busy till the end of the war. Twenty-five thousand instruments were repaired or serviced-binoculars, gun sights, navigation instruments-and eleven thousand optical parts were manufactured or repaired in the Academy's shop by a corps of some 50 instrument repair people and a few volunteer glass grinders and polishers, all under Dr. Hanna's direction.

When "black glass" for bearing-circle mirrors used in navigation became unavailable, he ingeniously substituted obsidian, a natural black glass of volcanic origin available in quantity at several locations in California, and found it just as good or better. Under the Navy contract Dr. Hanna and his group handled nearly all optical repair work for the Pacific Fleet and for some 7000 vessels of the Armed Guard (Liberty and Victory ships). When the job was over, the group could boast with pride that in spite of emergencies and close deadlines it "never missed the sailing date of a ship."

After this work terminated at the close of the war, Dr. Hanna and his associates received a "well done" from the Navy in the form of a certificate awarded to the Academy "in recognition of exceptional accomplishment in behalf of the United States Navy and of meritorious contribution to the national war effort."

At the end of the war the Academy found itself with a well-equipped instrument shop and a group of highly skilled optical instrument workers. The Board of Trustees had in the meantime become interested in building a planetarium, and had a sum of money available for that purpose. But they were unable to obtain a star projector. All of these instruments had been built in the Zeiss optical works in Germany, and at the end of the war the Zeiss plant had been dismantled and shipped to Russia. In this dilemma Dr. Itanna suggested, "Why not build the star projector ourselves in our own shop?" The Trustees, after some proper hesitation at so brash a proposal, agreed-and thus the Morrison Planctarium came into being. Now in operation for nearly a decade, it is unique in design with many new features and is universally conceded to be one of the best in the world.

One of Dr. Hanna's most unique and characteristic contributions to this project was the method he devised for making the star plates. Grains of carborundum powder, sorted for relative size to correspond to stars of different magnitudes, were placed in proper position on a flat glass surface by means of a device similar to the "mechanical finger" for mounting diatoms mentioned above. Then the glass was aluminized by an evaporation process in a vacuum chamber, making it opaque. Finally the carborundum particles were brushed off, leaving apertures through which light could be projected, forming the star-images. All previous "artificial stars" had been projected through small round holes in a metal plate so that they appeared on the planetarium dome as circular spots or dises. The stars achieved by the carborundum process were of irregular shape, producing a more realistic night sky.

Dr. Hanna is remarkably ingenious in designing and building special equipment for research—his own or others. Scores, if not actually hundreds, of scientists are indebted to him for advice on how to build or modify equipment to meet their particular needs; and the Academy has had numerous contracts for "research and development" from state, Federal and private agencies that wished to utilize Dr. Hanna's special inventiveness in designing equipment.

A current example of this is his present work on a new and inexpensive method of illustrating scientific papers in full color which has long been a research scientist's unfulfilled dream. Learning of research work along this line by the Eastman Kodak Company, Dr. Hanna went to Rochester, New York, in December of 1954 , to study their process and equipment. With the information obtained at Rochester, he built the necessary equipment in the

Academy's instrument shop and then began a slow but gradually winning battle over many obstacles, both mechanical and optical, that no one lacking Dr. Hanna's persistence and his insistence on perfection could have won. This has been a teamwork job, first with Charles E. Crompton and now with Maurice C. Giles on the photographic side, and with himself and his wife, Margaret M. Hanna, on the multilith reproduction side.

It was not until 1960 that Dr. Hanna felt that the new three-color offset process was sufficiently advanced to provide the first published color illustration, which appeared in the Academy's Annual Report for that year. Since then other color plates, produced by him and his associates in the Academy's photographic laboratory and instrument shop, have been included in several recent numbers of the Academy's Proceedings and Occasional Papers as well as in a number of publications of other scientific societies. Each one has been better than the one preceding, but he is still working toward still greater perfection of the process. The beautiful color frontispiece of the yellow arctic poppy, appearing in A Flora of the Alaskan Arctic Slope, by Ira L. Wiggins and John Hunter Thomas, just published by the Arctic Institute of North America, is an excellent example of this color work.

At this writing, comparable printed color reproductions based on the Eastman offset process are produced nowhere else in the country. The high quality of the color reproductions achieved by the Hanna color team, together with the ability to show extremely fine detail, makes this work a unique contribution to scientific illustration. And one great advantage is that the cost is of a magnitude no greater than for comparable black-andwhite reproductions.

The Academy's work on scientific illustrations in color is already fairly well-known. As one evidence of this, the University of Costa Rica sent the superintendent of its University press to the Academy in the fall of 1960 to study our equipment and methods.

Dr. Hanna is well-known among his friends and associates as an excellent field collector and photographer. He has made many important additions of bird skins, bird eggs, fossil vertebrates and invertebrates, living land, fresh-water and marine mollusks, mineral specimens, plants, and other things to the research collections of many museums, especially the U. S. National Museum in Washington, D.C., and the California Academy of Sciences. Size is no criterion for him as items he has collected range from huge fossil whale skulls to the tiniest of diatoms and radiolaria. The excellence and extent of the fossil invertebrates and recent shells in the research collections of the Academy's Department of Geology, consisting of nearly 38,000 locality numbers, together with a special type collection of more than 12,350 specimens, have developed over the years under his supervision as the department's Curator.

As a research scientist in the field, Dr. Hanna has few if any equals. He takes advantage of opportunities to get into little-known country on collecting trips, short or long, provided there is some worth-while scientific objective to be attained. He is "tops" as a camper, camp cook, and an interesting companion around a campfire-and this without regard to weather or other problems. He has represented the Academy on several major expeditions, including one to Guadalupe Island, Mexico, in 1922, and another to the Revillagigedo Islands, Mexico, in 1925. He was on the Orca expedition to the Gulf of California in 1953. In 1949 he designed the specially massive dredging and trawling equipment used on the U. S. Navy net-tender Mulberry for an Academy-sponsored geological exploration of the sea bottom off central California under the auspices of the Office of Naval Research. Dr. IIama directed operations aboard the Mulberry for the 24 days she was at sea on this project, which resulted in much new knowledge of the underwater geology of the area in depths down to 2000 fathoms. In the following year he spent several weeks on the California Division of Fish and Game fisheries research vessel $N . B$. Scofield, off the coast of northern California collecting marine invertebrates and rocks from considerable depths for a further study of the underwater geology. These are but a few of his longer periods in the field. His collecting trips of shorter duration would make a long list, much too extensive to be covered here.

One of the capstones of Dr. Hanna's recognition as a scientist came in 1959 when his alma mater conferred on him the "Erasmus Haworth Distinguished Alumni Honors in Geology," which was awarded by the University of Kansas and presented to him at the annual meeting of the American Association of Petroleum Geologists held that year in Dallas, Texas.

This account thus far has emphasized Dr. Hanna's practical accomplishments. We will now attempt to show that he is just as impractical as anybody. Witness his papers on "New and Interesting Records of Pribilof Island Birds," "Mammals of the St. Matthew Islands, Bering Sea," "Random Notes on Alaska Snow Buntings," "Extremely Diversified Habitat of a Marine Gastropod," "Fossil Diatoms Dredged from Bering Sea." Dr. Hanna is first and last a scientist, who reports carefully and accurately any observations that come within his field of competence, which, as we have already shown, is a very wide field. His voluminous field notes, meticulously written, often after a long, hard day in the field, cover many years of collecting work and observation. They contain much of interest, both scientific and historical. If the things he finds out happen to have some practical use, he has no objection; but his primary purpose is to discover the facts for themselves.

His love of the far north is a part of his character, and he returns to Alaska at every opportunity. In the summer of 1955 he served as Director of the Arctic Research Laboratory at Point Barrow, and the following summer he returned and spent an entire year (1956-57) at Point Barrow as a
special investigator, accompanied by his wife, Margaret, who served in her special capacity as a geological artist and illustrator. His most recent trip was with Academy Trustee Kenneth K. Bechtel in the summer of 1960, when he revisited St. Paul Island in the Pribilofs where he had been stationed nearly half a century ago.

To close this altogether inadequate account of G Dallas Hanna-the scientist and the man-we can do no better than to quote what a long-time friend and close associate has written:
"The unique qualities of Dr. Hanna's mind and personality, which have made him stand out in the fields of biology, geology, and paleontology, are his keen, critical powers of observation; his clear, analytical mind; his patience and persistence in the face of obstacles; his retentive memory and his ability to associate related facts; his ability to inspire those around him to become interested in what he is doing; the power to inspire in others confidence and belief in their own worth and ability; the personality to make friends of all kinds of people from all walks of life; in experimentation, the attitude of patience to try many things and to discard the failures without regret; the mental attitude to explore all sides of a question and the courage to challenge accepted ideas and viewpoints; the honesty always to give full credit to his co-workers for their contribution in a joint project; the innate modesty to minimize or play down his own part in a joint accomplishment; and in speaking of others, to praise their good qualities and minimize the less admirable ones-to speak well of others or not at all."

Author's Note: In preparing this biographical sketch I have received valued assistance and information from a number of Dr. Hanna's close associates over the years. These include his brother, Marcus A. Hanna, Clifford C. Church, Leo G. Hertlein, Allyn G. Smith, and the late G. Clark Gester and William S. W. Kew. -R. C. M.

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23. Fur-seal census. In Alaska Fisheries and Fur Industries in 1917. Appendix 2 to the Report of the United States Commissioner of Fisheries for the fiscal year 1917, doc. no. 847, pp. 97-123. December 28. [Much other matter on the Pribilof Islands in this report prepared by Hanna.]

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27. Geological notes on the Pribilof Islands, Alaska, with an account of the fossil diatoms. American Journal of Science, ser. 4, vol. 48, art. 18, pp. 216-224. September.
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30. A comparative anatomical discussion of the five species of Cerions involved in the breeding experiments. In Experiments in the breeding of Cerions, by Paul Bartsch. Carnegie Institution of Washington, vol. 14, no. 282, pp. 7-13, pls. 1-6.
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32. Additions to the avifauna of the Pribilof Islands, Alaska, including four species new to North America. Auk, vol. 37, no. 2, pp. 248-254. April.
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35. Pleistocene mollusks from Wallace County, Kansas. Kansas University Science Bulletin, vol. 13, no. 2, pp. 17-19. May.
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43. [Photographs on pages 30, 44, and 59, and note on page 67 by Hanna in] The Story of Matka, by David Starr Jordan. World Book Company, Animal Life Series, no. 1.
44. The Pribilof sandpiper. Condor, vol. 23, no. 2, pp. 50-57, fig. 13. March-April.
45. [Review of] Lake Maxinkuckee, a physical and biological survey, by Barton Warren Evermann and Howard Walton Clark. Nautilus, vol. 34, no. 4, p. 142. April.
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50. Galls and gall insects in Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 16, p. 12. July 24 .
51. Flower exhibit in the Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 17, p. 15. July 31.
52. Pictures of California lilies. Golden Gate Pathfinder, vol. 2, no. 18, p. 15. August 7.
53. [Notes on] A lecture by a plant expert, by Dr. Albert Mann (on diatoms). Golden Gate Pathfinder, vol. 2, no. 19, p. 15. August 14.
54. Steller sea lion group, Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 19, p. 16, 1 fig. July 15.
55. California sea lions. Golden Gate Pathfinder, vol. 2, no. 20, p. 16, 1 fig. August 21.
56. Grizzly bear shot by Dr. Pope with bow and arrow-now being installed in Academy of Sciences Museum. Golden Gate Pathfinder, vol. 2, no. 21, p. 15, 1 fig. August 28.
57. Hair seals in California Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 21, p. 16, 1 fig. August 28.
58. Alaska fur seals. Hamlyn's Menagerie Magazine, ca. August.
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60. Desert bird group, Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 23, p. 16, 1 fig. September 11.
61. The fur-seal group, Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 24 , p. 16, 1 fig. September 18.
62. The white pelican group, Academy of Sciences. Golden Gate Pathfinder', vol. 2, no. 25, p. 15, 1 fig. September 25.
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64. Frederick Morton Chamberlain [Obituary]. Science, now ser., vol. 54, no. 1397, pp. 323-324. October 7.
65. [Sunday afternoon lectures at the Academy of Sciences]. Golden Gate Pathfinder, vol. 2, no. 26, p. 3. October 2.
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70. Progress on Steinhart Aquarium. Golden Gate Pathfinder, vol. 2, no. 29, p. 10. October 23.
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72. The mountain lion group, California Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 30, p. 16, 1 fig. October 29.
73. Epiphragmophora fidelis (Gray) near San Francisco Bay? Nautilus, vol. 35, no. 2, pp. 34-35. October.
74. Frederick Morton Chamberlain [Obituary]. Nautilus, vol. 35, no. 2, p. 60. October.
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77. The tree ferns of Golden Gate Park. Golden Gate Pathfinder, vol. 2, no. 32, p. 16. November 13.
78. [Announcement of] Appointment of Dr. B. W. Evermann, Director, and Mr. Alvin Seale, Superintendant, of new Steinhart Aquarium. Science, new ser., vol. 54, no. 1403, p. 489. November 18.
79. The Roosevelt elk group. Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 33, p. 16, 1 fig. November 20.
80. The Academy of Sciences expedition to South America. Golden Gate Pathfinder, vol. 2, no. 34, p. 5. November 27.
81. The San Joaquin Valley water fowl group, Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 34, p. 16, 1 fig. November 20.
82. Exhibit of painted flowers in California Academy of Sciences. Golden Gate Pathfinder, vol. 2, no. 36, p. 10. December 11.
83. The robins of the Park. Golden Gate Pathfinder, vol. 2, no. 36, p. 16. November 20 .
84. Fur-seal census, Pribilof Islands, 1920. In Alaska Fisheries and Fur Industries in 1920. Appendix 6 to the Report of the United States Commissioner of Fisheries for the fiscal year 1921, doc. no. 909, pp. 104-121, fig. 3. December 12.
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92. [Senior author with Barton W. Evermann of] An exhibit of fur-bearing animals planned by the California Academy of Sciences. Golden Gate Pathfinder, vol. 3, no. 10, p. 15. March 5.
93. [Senior author with William M. Grant of ] Genera of diatoms characteristic of marine and fresh water. Mining in California, California State Mining Bureau, vol. 18, no. 2, pp. 59-76, pls. 1-5, figs. 1-27. February.
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101. Wild flowers exhibited at the California Academy of Sciences. Golden Gate Pathfinder, vol. 3, no. 21, p. 16. May 28.
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107. The quails of the Park. Golden Gate Pathfinder, vol. 3, no. 22, p. 16. June 4.
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111. New exhibit of American game animals. Golden Gate Pathfinder, vol. 3, no. 29, pp. 6-7. July 23.
112. The status of Helix oregonensis Lea. Nautilus, vol. 36, no. 1, pp. 12-14. July.
113. [Notes on diving of cormorants and death of old squaws and harlequin ducks in] Report of E. H. Forbush, Director, Division of Ornithology, Department of Agriculture, Commonwealth of Massachusetts, Bull. 8, pp. 29, 32, 41.
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117. Fossil fresh-water mollusks from Oregon contained in the Condon Museum of the University of Oregon. University of Oregon Publication, vol. 1, no. 12, pp. 1-22, pls. 1-4. August 29.
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120. Why not protect the fur-seal herds of the Southern Hemisphere? Australian Zoologist, vol. 3, pt. 1, pp. 11-13. September 15.
121. The mountain lion group, California Academy of Sciences. Golden Gate Pathfinder, vol. 3, no. 37, pp. 2, 4. September 17.
122. A recent scientific expedition to the islands off the west coast of Lower California. Golden Gate Pathfinder, vol. 3, no. 38, p. 2. September 24. (Also published in The Catalina Islander, vol. 9, no. 37, pp. 6-7. September 22.)
123. [Sunday afternoon lectures at the California Academy of Sciences.] Golden Gate Pathfinder, vol. 3, no. 39, pp. 2, 6. October 1.
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167. [Coauthor with Frank M. Anderson of] Fauna and stratigraphic relations of the Tejon Eocene at the type locality in Kern County, California. Occasional Papers of the California Academy of Sciences, vol. 11, pp. 1-249, pls. 1-16. March 18.
168. [Discussion of] Diatom theory of origin of petroleum in California, by Jun-ichi Takahashi [Sendai, Japan]. Bulletin of the Geological Society of America, vol. 36, no. 1, p. 207. March 30.
169. [Coauthor with E. G. Gaylord of] Correlation of organic shales in the southern end of the San Joaquin Valley, California. Bulletin of the American Association of Petroleum Geologists, vol. 9, no. 2, pp. 228-234, pls. 4-5. March-April.
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173. [Senior author with H. Walton Clark of] Lymnaed auricularia (Limn.) in California. Nautilus, vol. 38, no. 4, pp. 125-127. April.
174. [Report of the] Department of Invertebrate Paleontology. In Report of the Director for the year 1924. Proceedings of the California Academy of Sciences, ser. 4, vol. 13, no. 28, pp. 476-478. May 29.
175. [Coauthor with Barton W. Evermann of] The Steller sea lion rookery on Año Nuevo Island, California, in 1924. Journal of Mammalogy, vol. 6, no. 2, pp. 9699, pls. 8-10. May.
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177. [Senior author with E. G. Gaylord of] Organic shales in southern San Joaquin Valley. Petroleum World (Los Angeles), vol. 10, pp. 66, 68. June
178. [Senior author with Merle C. Israelsky of] Contribution to the paleontology of Peru. Proceedings of the California Academy of Sciences, ser. 4, vol. 14, no. 2, pp. 37-75, pls. 7-8. July 21.
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187. Data on the age and correlation of the Kreyenhagen shale in Fresno County, California. Petroleum Age, vol. 10, pp. 60, 78-80. December.

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Ebror's note: Dr. Hanna's published writings and other scientific contributions have been compiled by members of the Academy's staff from several sources, including a current file maintained in the Department of Geology. It has been made as inclusive as possible from available material.

## PROCEEDINGS

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# CALIFORNIA ACADEMY OF SCIENCES 

## FOURTH SERIES

G Dallas Hanna Anniversary Volume

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June 29, 1962

# SCIENTIFIC RESULTS OF THE GALÁPAGOS-EXPEDITION 1953-54 OF THE INTERNATIONAL INSTITUTE FOR SUBMARINE RESEARCH, VADUZ (LIECHTENSTEIN), LEADER DR. HANS HASS 

# CORALS FROM THE GALÁPAGOS AND COCOS ISLANDS 

by

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During 1953-1954 the Galápagos Expedition of the International Institute for Submarine Research, Vaduz (Liechtenstein), leader Dr. Hans Hass, on board the Xarifa, visited both Cocos Island and the Galápagos Islands in the tropical Eastern Pacific and made various collections. Dr. Georg Scheer, of the Hessisches Landesmuseum, Darmstadt, Cermany, a member of the expedition, collected numerous corals by skin diving. Through his courtesy and patience I have had the opportunity of examining the corals and preparing this report. The major part of the collection is housed in the Hessisches Landesmuseum. Thanks to Dr. Scheer duplicate specimens of many
of the species have been deposited in the Museum of Paleontology, University of California, Berkeley, California, under accession no. 2070. The material at Berkeley includes representatives of Balanophyllia scheeri, new species; Pavona clivosa Verrill; Pavona gigantea Verrill; Pavona varians Verrill; Pavona (Polyastra) ponderosa (Gardiner); Pocillopora damicornis (Linnaeus); Pocillopora damicornis cespitosa Dana; Pocillopora elegans Dana; Pocillopora meandrina Dana; Pocillopora verrucosa (Ellis and Solander) ; Porites excavata Verrill; Porites lobata Dana (?); Psammocora profundacella Gardiner; Psammocora (Stephanaria) stellata (Verrill); and Tubastrea tenuilamellosa (Milne Edwards and Haime).

In identifying this collection of corals a broader species concept, in part following Squires (1959), than used previously (Durham, 1947; Durham and Barnard, 1952), has been employed in the potentially reef-building and taxonomically troublesome genera Pavona, Pocillopora, and Porites. As a result some of the previously employed names are hidden in the synonymies and the list of species in these genera has a marked Indo-Pacific aspect.

Durham and Barnard (1952) have summarized most of the available data on stony corals from Cocos Island and the Galápagos Islands, as well as other Eastern Pacific areas. Vaughan (1906) described 3 species from the Galápagos Islands that were not included in the paper by Durham and Barnard. Since then Squires (1959) has presented an extensive discussion of the corals of the Gulf of California, Durham and Allison (1960, pp. 7076) have tabulated available distributional data on living and fossil corals of the Eastern Pacific at the generic level, and Hertlein and Emerson (1957, pp. 7-8) listed five corals previously unrecorded from Clipperton Island.

Cocos Island is situated a little over 500 kms . southwest of Costa Rica and about 700 kms . northeast of the Galápagos Islands. During most of the year it seems to be in the path of the Equatorial Counter Current. Durham and Barnard (1952) recorded 7 species (table 1) from this area.

The Galápagos Islands are about 1000 miles off the Ecuadorian Coast and are within the path of the westward flowing Peru current although a counter gyral from the Equatorial Counter current is directed toward this area for at least part of the year. Durham and Barnard (1952) recorded 21 species and Vaughan (1906), had described an additional 3 species, making a total of 24 species (table 1) previously known from these islands.

The corals collected by Dr. Scheer include representatives of at least 20 species and varieties, of which 4 have not been recorded from the Eastern Pacific previously. Three of these species (Pavona (Polyastra) ponderosa Gardiner, Porites lobata Dana (?), Psammocora profundacella Gardiner) are members of the Indo-Pacific coral reef fauna. All three, however, are members of genera that were previously known to occur in the Eastern Pacific and that are widespread throughout the warmer parts of the Indian and Pacific Oceans.


Figure 1. Collecting localities, Cocos and Galápagos islands.

Table 1. Corals previously reported from Galápagos Islands and Cocos Island (Vaughan, 1906; Durham and Barnard, 1952).

|  | Galápagos Island | Cocos <br> Island |
| :---: | :---: | :---: |
| Astrangia equatorialis Durham and Barnard | x |  |
| Astrangia gardnerensis Durham and Barnard | x |  |
| Astrangia hondaensis Durham and Barnard (?) | x | x |
| Balanophyllia galapagensis Vaughan | X |  |
| Balanophyllia osburni Durham and Barnard | X |  |
| Caryophyllia diomedae Von Marenzeller | x |  |
| Cladocora debilis Milne Edwards and Haime | x | x |
| Cycloseris mexicana Durham | x | x |
| Desmophyllum galapagense Vaughan | x |  |
| Endopachys vaughani Durham | x | x |
| Flabellum daphnense Durham and Barnard | x |  |
| Kionotrochus (?) avis Durham and Barnard | x |  |
| Kionotrochus (?) hoodensis Durham and Barnard | X |  |
| Leptoseris digitata Vaughan (?) |  | x |
| Lophosmilia wellsi Durham and Barnard | x |  |
| Madracis asperula Milne Edwards and Haime | X |  |
| Madracis sp. | x |  |
| Madrepora galapagensis Vaughan | x |  |
| * Pavona clivosa Verrill | x |  |
| Pavona cf. explanulata (Lamarck) |  | x |
| Pocillopora damicornis cespitosa Dana | x |  |
| Pocillopora elegans Dana | x |  |
| Psammocora (Stephanaria) stellata (Verrill) | x | x |
| Sphenotrochus hancocki Durham and Barnard | X |  |
| Thecopsammia pourtalesi Durham and Barnard | x |  |
| Tubastrea tenuilamellosa (Milne Edwards and Haime) | x |  |
| *Nomenclature corrected to agree with Squires (1959) | 24 | 7 |

An important result of this expedition has been the addition of distributional data (see figure 1 for collecting localities) to the scanty store of information on corals of the tropical Eastern Pacific. The present collection (table 2) adds 11 taxa to the 7 previously recorded from Cocos Island and 7 to the $2 \pm$ previously known from the Galápagos. The addition of 10 species to the coral fauna of these islands emphasizes how little systematic coral collecting has been done in the Eastern Pacific (see: Durham and Barnard, 1952, pp. 3-4; Squires, 1959 , pp. 372-373).

The recorded fatma of the Galápagos Islands (table 3) now totals 30 species, of which only 13 belong to the hermatypic group. Eighteen species, including 14 hermatypic types are now known from Cocos Island. Thirtyeight species, of which 20 are hermatypic, are now recorded from these two island areas. It seems probable that all of the hermatypic species may eventually be found in both areas. Fourteen of the 20 hermatypie species

Table 2. Corals collected by the Galápagos-Expedition 195.3-5\%.

are also known from the coast of the Americas. In addition, the hermatypic species Agaricia sp., Leptoseris panamensis Durham and Barnard, Porites panamensis Verrill, Psammocora brighami (Vaughan), and Solenastrea ecuadoriana Durham and Barnard have been recorded (Durham and Barnard, 1952) from the adjacent mainland coast. It seems probable that most or all of these species may eventually be found in the offshore island areas. Despite the increased distributional data afforded by the present collection it is notable that no additional genera of hermatypic corals were added to the known fauna. Genera such as Acropora, Montipora, Favia, Cyphastrea, and Plesiastrea continue to be unrecorded on the American side of the East Pacific Barrier (see Durham and Allison, 1960, pp. 69, 70-76). Likewise the disappearance from the region of many of the hermatypic genera recorded as fossils (Durham and Allison, 1960, pp. 71-73) from the Pacific shores of the Americas is still enigmatic. For example Durham and Allison list 30
extant genera of hermatypic corals that are known to occur in the fossil record of this region. Although many of these genera are still present in the Indo-Pacific region, only 10 are now living in the Eastern Pacific.

Table: 3. Summary of Corals recorded from Galáagos Islands and Cocos Island.

## Astrangia dentata Verrill

Astrangia equatorialis Durham and Barnard
Astrangia gardnerensis Durham and Barnard
Astrangia hondaensis Durham and Barnard (?)
Balanophyllia galapagensis Vaughan
Balanophyllia osburni Durham and Barnard
Balanophyllia scheeri, new species
Caryophyllia diomedae Von Marenzeller
Cladocora debilis Milne Edwards and Haime
Cycloseris clegans (Verrill)
Cycloseris mexicana Durham
Desmophyllum galapagense Vaughan
Endopachys raughani Durham
Flubellum duphnense Durham and Earnard
Kionotrochus (?) avis Durham and Barnard
Kionotrochus (?) hoodensis Durham and Barnard
Leptoseris digitata Vaughan (?)
Lophosmilite reellsi Durham and Earnard
Madracis asperula Milne Edwards and Haime
Madracis sp.
Madrepora galapagensis Vaughan
Pacone: clirosa Verrill
Parona gigantea Verrill
Parona rotrians Verrill
P'erona cf. єxplanulata (Lamarck)
I'avonu (Polyastra) ponderosa (Gardiner)
Pocillopora damicornis (Linnaeus)
Pocillopora damicornis cespitosa Dana
Pocillopora eleguns Dana
Pocillopora meandrina Dana
Pocillopore remucosa (Ellis and Solander)
Porites excacata Verrill
Porites lobut Dana (?)
Psammocora profandacella Gardiner*
Psammocora (s゙tephanaria) stelluta (Verrill)
sphenotrochus heneocki Durham and Barnard
Theocopstamiu pourtalesi Durham and Earnard
Tubustrot temuilumellosa (Nilne Edwards and Haime)
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| $x$ |  | x |  |
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| 30 | 18 | 19 | 12 |

Description of Collecting Localities (see figure 1) of the Galápagos-Expedition 1953-54 ("Xarifa-Expedition")

Galípagos Islands
Locality 74. Osborn Island, near Hood Island. About 30 m . offshore on northwest coast. Depth 3 m .

Locality 75. From depth of 2 m . along steep shore of northwest coast of Osborn Island.

Locality 76. From west shore of Xarifa Island, near ILood Island.
Locality 79. About 30 m . from beach, south side of southwest point of Gardner Island. Depth between 5 and 6 meters.

Locality 80 . From southeast side of Cardner Island.
Locality 89. Guy Fawkes Islands, near Indefatigable Island. From between the two islets, depth 5 m ., on steep rocks.

Locality 90. North shore of North Seymour Island, from depth of 6 m . on steep shore.
Locality 92. Mosquera Island, between North Seymour and South Seymour Island. Along west side, about 50 m . offshore. Depth 5 m .

Locality 98. East side of Darwin Bay, Tower Island, steep shore.
Locality 100. Near small inlet on north shore of Darwin Bay, Tower Island.

## Cocos Island

Locality 104. From northeast side near Ulloa Island, depth 5 m .
Locality 107. From shore of Wrack Islet, Wafer Bay, northwest side of Cocos Island. Depth 8 m .

Locality 114. From depth of 7 to 10 meters, Wafer Bay, northwest side of Cocos Island.

## SYSTEMATICS

Family Pocilloporidae Gray, 1842
Genus Pocillopora Lamarck, 1816
Type species Pocillopora acuta Lamarck.
Pocillopora damicornis (Limnaeus).
Millepora dlamicornis Linvaeus, 1758, Systema Natura, Ed. 10, p. 791.
Pocillopora lacera Verrill, 1869, Proc. Essex Inst., Vol. 6, p. 100; Durmam and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, pp. 20-21, 26, pl. 1, fig. 4.

Pocillopora damicornis (Linnaeus), Wells, 1954, U.S. Geol. Surv. Prof. Pap. 260, p. 412, pl. 99, fig. 2; Squires, 1959, Eull. Amer. Mus. Nat. Hist., vol. 118, pp. 408409, pl. 34, fig. 2.

Occurrence. Xarifa localities 74, 79 (?), 107, 114. Cocos and Galápagos islands. Recorded from Panama to Indian Ocean. The illustrated specimen (fig. 9) is referred to this species with some doubt because of its extreme "roughness."

## Pocillopora damicornis var. cespitosa Dana.

Pocillopora cespitosa Dins, U.S. Expl. Exped., Zooph., p. 525, pl. 49, figs. 5, 5a.
Pocillopora damicornis var. cespitosa Dana, Hoffmeister, 1925, Carnegie Inst., Wash., Publ. Dept. Mar. Biol., vol. 22, pp. 16-17; Durham and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, p. 20, pl. 1, figs. 3a-3c.

Occurrence. Xarifa localities 74, 89( ?). Galápagos Islands. Recorded from Panama and widely through the Indo-Pacific.

## Pocillopora elegans Dana.

Pocillopora elegans Dana, 1846 , U.S. Explor. Exped., Zooph., p. 532, pl. 51, figs. 1, 1a; Wells, 1954, U.S. Geol. Surv., Prof. Pap. 260, p. 413, pl. 95, fig. 2; Squires, 1959, Bull. Amer. Mus. Nat. Hist., vol. 118, pp. 409-410, pl. 34, fig. 5.
Pocillopora capitata Verrill, 1864, Bull. Mus. Comp. Zool. Harvard Coll., vol. 1. p. 60.
Pocillopora capitata var. robusta Verrill, 1870, Trans. Conn. Acad. Arts Sci., vol. 1, pp. 521-522.
Pocillopora robusta Vermill, Durifam and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, pp. 26-28, pl. 1, figs. 5a-5b, 6.

Occurrence. Xarifa localities 74, 76(?), 107, 114. Cocos and Galápagos islands. Recorded from the Gulf of California to the Indo-Pacific.

## Pocillopora meandrina Dana.

Pocillopora meandrina Dana, 1846, U.S. Explor. Exped., Zooph., p. 529, pl. 50, figs. 3, 3a; Vaughan, 1918, Carnegie Inst., Wash., Pap. Dept. Mar. Biol., vol. 9, p. 78; Squires, 1959, Bull. Amer. Mus. Nat. Hist., vol. 118, pp. 410-411, pl. 34, fig. 4.

Occurrence. Xarifa locality 114, Cocos Island. Recorded from Gulf of California to the Indo-Pacific.

## Pocillopora verrucosa (Ellis and Solander).

Madrepora verrucosa Ellis and Solander, 1786, Nat. Hist. Zooph, p. 172.
Pocillopora capitata var. porosa Verrill, 1869, Proc. Essex Inst., vol. 6, p. 99.
Pocillopora porosa Verrill, Durian and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, p. 26.
Pocillopora verrucosa (Ellis and Solander), Wells. 1954, U.S. Geol. Surv. Prof. Pap. 260, p. 413, pl. 98, figs. 5-6; Duminm, in Hertlein and Emerson, 1957, Amer. Mus. Novitates, no. 1859, p. 7; SQuires, 1959, Bull. Amer. Mus. Nat. Hist., vol. 118, p. 410 .

Occurrence. Xarifa localities $90,100,107$. Cocos and Galápagos islands. Recorded from Gulf of California, Clipperton Island, and westward to Indian Ocean.

Family Thamnasterinde Vaughan and Wells, 1943
Genus Psammocora Dana, 1846
Type species Pavona obtusangula Lamarck.

## Psammocora (Psammocora) profundacella Gardiner.

(Figure 6.)
Psammocora profundacella Gardiner, 1898, Proc. Zool. Soc. London for 1898, p. 537, pl. 45, fig. 3; Vaughan, 1918, Carnegie Inst. Wash., Pap. Dept. Biol., vol. 9, p. 78.

Нypotype, Univ. Calif. Mus. Paleo., no. 30725, Xarifa locality 114.
Occurence. Xarifa localities 92 and 114. Cocos and Galápagos islands. Previously recorded from Funafuti and Fanning Island.

## Subgenus Stephanaria Verrill, 1867.

Type species Stephanocora stellata Verrill.

## Psammocora (Stephanaria) stellata (Verrill).

Stephanocora stellata Verrill, 1866, Proc. Eoston Soc. Nat. Hist., vol. 10, p. 330.
Stephanaria stellata Verrill, 1870, Trans. Conn. Acad. Arts Sci., vol. 1, pp. 545-546, pl. 9 , figs. 4, 4a.
Psammocora (Stephanaria) stellata (Verrill), Durhim and Birnird, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, pp. 29-30, pl. 2, fig. 8.

Occurrence. Xarifa locality 74, Galápagos Islands. Previously recorded from the Galápagos Islands, Cocos Island, IIawaiian Islands, and Panama to the Gulf of California.

Family Agaricidae Gray, 1847
Genus Pavona Lamarck, 1801
Type species Pavona cristata Lamarck.
Pavona (Pavona) clivosa Verrill.
Pavonia clivosa Verrill, 1869, Proc. Boston Soc. Nat. Hist., vol. 12, pp. 395-396.
Pavona (Pavona) clivosa Verrill, Durham and Bariard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, pp. 37, 42, pl. 2, fig. 12.
Pavona (Pseudocolumnastrea) galapagensis Durham and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, pp. 44-45, pl. 3, figs. 16a-16b.
Pavona clivosa Verrill, Squires 1959, Bull. Mus. Nat. Hist., vol. 118, pp. 412-413, pl. 32 , fig. 1.

Occurrence. Xarifa localities 76 and 92, Galápagos Islands. Previously reported from Eeuador, the Galápagos Islands, Panama and the Gulf of California.

## Pavona (Pavona) gigantea Verrill.

Pavonia gigantea Verrill, 1869, Proc. Boston Soc. Nat. Hist., vol. 12, pp. 394-395.
Pavona (Pavona) gigantea Verrill, Durihar and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, p. 43, pl. 3, fig. 14.
Pavona gigantea Verrill, Squires, 1959, Eull. Amer. Mus. Nat. Hist., vol. 118, pp. 413414, pl. 32, fig. 2.

Occurrence. Xarifa localities 79 and 92, Galápagos Islands. Previously recorded from Clipperton Island, and Panama to Culf of California.

## Pavona (Pavona) varians Verrill.

(Figure 3.)
Pavonia varians Verrill, 1864, Bull. Mus. Comp. Zool.. vol. 1, no. 3, p. 55.
Pavona varians Verrill, Vaugilan. 1907, U.S. Nat. Mus. Bull. 59, p. 135, pl. 38, figs. 1, 1a; Wells. 1951, U.S. Geol. Surv. Prof. Pap. 260, p. 442, pl. 152, figs. 3-4.
Pavona (Pavona) cf. varians Verrill, Duriam and Barxard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, p. 43, pl. 3, fig. 15.

Hypotype, Univ. Calif. Mus. Palco., no. 30721, Xarifa locality 114.
Occurrence. Xarifa locality 114, Cocos Island. A widespread species, ranging from the Red Sea and Great Barrier Reef to the Hawaiian Islands and Colombia.

Subgenus Polyastra Ehrenberg, 1834
Type species Polyastra venosa Ehrenberg.

Pavona (Polyastrea) ponderosa (Gardiner).
(Figure 5.)
Agaricia ponderosa Gardiner, 1905, Fauna and Geogr. Maldive and Laccadive Arch., vol. 2, supl. 1, p. 937, pl. 89, figs. 1-2; Vaugiman. 1918, Carnegie Inst. Wash., Pap. Dept. Mar. Biol., vol. 9, p. 140 ; Yabe. Sugiyama, and Eguchi, 1936, Sci., Repts. Tohoku Imp. Univ., Ser. 2, (Geol.), Spec. vol. 1, p. 55, pl. 27, fig. 5, pl. 38, fig. 1, pl. 52, fig. 1.

Hypotype, Univ. Calif. Mus. Palco., no. 30724, Xarifa locality 114.
Occurrence. Tarifa locality 11t, Cocos Island. This species is known from the Maldives to the Bonin Islands.

Type species 1 Iadrepora porites Pallas.

## Porites californica Verrill.

Porites californica Verrill, 1870, Trans. Conn. Acad. Arts Sci., vol. 1, p. 504 ; Durham and Earnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, p. 46, pl. 3, figs. $17 \mathrm{a}-17 \mathrm{~b}$; Squires, 1959 (in part), Eull. Amer. Mus. Nat. Hist., vol. 118. pp. $420-422$, pl. 32 , figs. $3-6$, pl. 33 , figs. $3-4$ (only).
Porites porosa Verrill, 1870, Trans. Comn. Acad. Arts Sci., vol. 1, p. 504.
Porites nodulosa Verrili, 1870, Trans. Conn. Acad. Arts Sci., vol. 1, pp. 505-506: Durham and Barnari, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, pp. $46-$ 47, pl. 3, fig. 18.

Occurrence. Xarifa locality 107, Cocos Island. Previously recorded from Panama to Magdalena Bay and to the head of the Culf of California.

## Porites excavata Verrill.

Porites excavata Verrill, 1870, Trans. Conn. Acad. Arts and Sci., vol. 1, pp. 504-505; Squires, 1959, Bull. Amer. Mus. Nat. Hist., vol. 118, pl. 33, figs. 1-2.

Occurrence. Xarifa locality 107, Cocos Island. Recorded previously from Panama. The calices on one specimen are smaller than those on the type as figured by Squires. Squires suggests that his P. baueri, described from the Tres Marias Islands, is closely related.

## Porites lobata Dana (?)

(Figure 8.)
Porites lobata Dana, 1846, U.S. Expl. Exped., Zooph., p. 562, pl. 55, fig. 1; Vaughan, 1907, U.S. Nat. Mus. Bull. 59, pp. 196-198, pl. 81, figs. 1-1a, 1b; Vaugilan, 1918, Carnegie Inst. Wash., Pap. Dept. Mar. Biol., vol. 9, p. 192.

Itypotype, Univ. Calif. Mus. Paleo., no 30726, Xarifa locality 98.
Occurrence. Xarifa localities 76, 79, and 98, Galápagos Islands. The specimens have deeper calices and the top of the wall more fused than in typical $P$. lobata. They also resemble $P$. paschalensis Vaughan, described from Easter Island, but the calices average smaller in size and the columella is more compressed. P. lobata is widespread in the Central Pacific.

Family Fungiddat
Genus Cycloseris Milne Edwards and Inaime, 1849.
Type species Fungia cyclolites Lamarek.

## Cycloseris elegans (Verrill).

Fungia elegans Verrill, 1870, Am. Jour. Sci., ser. 2, vol. 49, p. 100.
Cycloseris elegans (Verrill), Durham and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, p. 52, pl. 4, figs. 20a-20b; Squires, 1959, Bull. Amer. Mus. Nat. Hist., vol. 118, p. 414.

Occurrence. Xarifa locality 80, Galápagos Islands. Previously recorded from La Paz to Panama.

## Family Rhizangidae d'Orbigny

Genus Astrangia Milne Edwards and Haime, 1848
Type species Astrangia michelinii Milne Edwards and Haime.
Astrangia dentata Verrill.
Astrangia dentata Verrill, 1866, Proc. Boston Soc. Nat. Hist., vol. 10, p. 332 ; Durham, 1947, Geol. Soc. Amer. Mem. 20, p. 28, pl. 5, fig. 6.

Occurrence. Xarifa locality 107, Cocos Island. Previously reported from La Paz to Panama.

Astrangia equatorialis Durham and Barnard.
Astrangia equatorialis Durilam and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, p. 69, pl. 6, figs. 29a-29b.

Occurrence. Xarifa locality 98, Galápagos Islands. Previously reported from the Galápagos Islands.

Astrangia gardnerensis Durham and Barnard.
Astrangia gardnerensis Durhan and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16 , no. 1, p. 70 , pl. 5, fig. 27.

Occurrence. Xarifa locality 75, Galápagos Islands. Originally described from the same bay.

Family Dendrophyllidae Gray, 1847
Genus Balanophyllia Searles Wood
Type species Balanophyllia calyculus Searles Wood.
Balanophyllia osburni Durham and Barnard.
(Figure 2a, d.)
Balanophyllia osburni Durimat and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, pp. 100-101, pl. 15, figs. 63a-63d.

Occurrence. Xarifa locality 74, Galápagos Islands. Deseribed from the Galápagos.

Balanophyllia scheeri Durham, new species.
(Figures 2b, 2c, 4, 7.)
Corallum elongate, tall; attachment base broken but apparently broad; calice round to slightly oval; calicular fossa deep; columella oval in outline, rising slightly above base of fossa, parietal, moderately compact; septa apparently in five incomplete cycles (fig. 2c) ; first cycle septa broadly rounded at top (fig. 2b) inner edge smooth, nearly vertical, fused to columella at depth; second cycle septa narrow at top, usually smooth, descending obliquely to columella; third cycle septa narrow, inner edge dentate; fourth cyele septa more prominent than third cycle, dentate, fused to one another about midway to columella and in turn fused to columella at higher point than first and second cycle septa; fifth cycle septa narrow, fused to include fourth cycle, developed only in outer part of each system; septa considerably thinner than adjacent interspaces, laterally finely granulate; wall porous, with epitheca of varying thickness for one-half to two-thirds height of corallum; costae corresponding to all septae, covered by a row of fine granules; first cycle septa slightly more prominent than others.


Figure 2. a, d. Batanophyllia osburni Durham and Barnard. After hypotype in Hessisches Landesmuseum, no. X 1:74-7. a. Lateral profile of 4 cycles of septa; d. Plan view of part of calice. b, c. Balanophyllia scheeri, n. sp. After holotype, Univ. Calif. Mus. Paleo. no. 30722. b. Lateral profile of 4 cycles of septa; c. Plan view of part of calice.

Diniensions of holotype. Height (incomplete) 22.4 mm ., maximum diameter 9.0 mm ., depth of fossa to top of columella 3.6 mm .

Holotype: Univ. Calif. Mus. Paleo., no. 30722. Paratypes: Univ. Calif. Thus. Paleo., no. 30723 and Hessisches Landesmuseum nos. XI:114-9c, XI:114-9d; all from Xarifa locality 114.

Occurrence. Xarifa locality 114, Wafer Bay, Cocos Island. This species resembles single corallites of Dendrophyllia fistula (Alcock) but differs by the presence of the fifth cycle septa, and the slightly prominent first cycle costae. Balanophyllia galapagensis Vaughan has a shallower fossa, lacks the fifth cycle septa, and has a heavier epitheca.

## Genus Tubastrea Lesson, 1834.

Type species Tubastrea coccinea Lesson.
Tubastrea tenuilamellosa (Milne Edwards and Haime).
Coenopsammia tcnuilamellosa Milne Edwards and Hame, 1848, Ann. Sci. Nat., ser. 3, vol. 10, p. 110, pl. 1, fig. 11.
Astropsammia pedersenii Verrill, 1869, Proc. Boston Soc. Nat. Hist., vol. 12, p. 392. Tubastrea tenuilamellosa (Milne Edwards and Haime), Duriam and Barnard, 1952, Allan Hancock Pac. Exped., vol. 16, no. 1, pp. 105-106, pl. 12, fig. 50d.
Tubastrea aurea Squires, 1959, Bull. Am. Mus. Nat. Hist., vol. 118, pp. 427-428 (pro parte, non Quoy and Gaimard, 1833).

Occurrence. Xarifa localities 74, 89, 10t, 107, and 114. Galápagos and Cocos islands. Previously recorded from San Marcos Island, Gulf of California to the Galápagos. One specimen from locality 114 closely resembles Verrill's Astropsammia pedersenii.

Figure 3. Pavona varians Verrill $(\times 0.83)$. Hypotype, Univ. Calif. Mus. Paleo, no. 30721 , Xarifa locality 114, Cocos Island.

Figures 4, 7. Balanophyllia scheeri, new species ( $\times 1.66$ ) . 2, holotype, Univ. Calif. Mus. Paleo., no 30722 ; 5, paratype, Univ. Calif. Mus. Paleo., no. 30723. Both from Xarifa locality 114, Cocos Island.

Figure 5. Pavona ponderosa (Gardiner) ( $\times 0.83$ ). Hypotype, Univ. Calif. Mus. Paleo., no 30724, Xarifa locality 114, Cocos Island.

Figure 6. Psammocora profundacella Gardiner ( $\times 0.83$ ). Hypotype, Univ. Calif. Mus. Paleo., no. 30725, Xarifa locality 114, Cocos Island.

Figure 8. Porites lobata Dana (?) ( $\times 0.83$ ). Hypotype, Univ. Calif. Mus. Paleo., no. 30726, Xarifa locality 98, Darwin Bay, Tower Island, Galápagos Island.

Figure 9. Pocillopora damicornis (Limnaeus) (?) ( $\times 0.83$ ). Hypotype, Univ. Calif. Mus. Paleo., no. 30727, Xarifa locality 79, Gardner Island, Galápagos Islands.


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## PROCEEDINGS

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# MATING BEHAVIOR AND ACTIVITY-REST PERIODICITY IN PROTOCLYTHIA CALIFORNICA (DIPTERA: PLATYPEZIDAE) ${ }^{1}$ 

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## Introduction

The first direct observation dealing with the mating behavior of flatfooted flies was made by Snow (1894). This involved a single mating pair of the species Calotarsa calceata (Snow). The flies were captured with a lucky stroke of the net as they passed within an inch or two of the observer's eye and therefore too close to be brought into focus. They did not remain in copula in the net, so Snow was unable to contribute any notes on the mating

[^0]
behavior of these flies except to mention that at the time of the capture there were a dozen or so males of this same species engaged in zigzag flight overhead.

Except for occasional observations (e.g., Verrall, 1901; Kessel, 1948) that males of other platypezid species engage in aerial dances, knowledge of the mating habits of flat-footed flies did not progress for another sixty-seven years. In the meantime we had observed the mating behavior of certain balloon flies, species of the genera Empimorpha, Hilara, and Empis (Kessel and Karabinos, 1947; Kessel and Kessel, 1951; Kessel, 1955 and 1959), which belong to the Empididae, a family that most certainly is closely related to Platypezidae. The males of these empidids dance in swarms similar to those of platypezids, and in the case of these balloon flies we were able to observe the female enter the swarm of males, embrace with one of them, and then settle with him on a nearby shrub until the mating activities were completed. The observation of platypezid and empidid males dancing in similar swarms led to the supposition that the females of flat-footed flies, like those of balloon flies, enter the swarms of males to find their mates. But no evidence of such behavior was forthcoming until recently when we were able to observe the mating activities of Platypezina pacifica Kessel.

## Mating Behavior of Protoclythias

Our observations on Platypezina pacifica had barely been published (Kessel and Kessel, 1961) when we discovered flies of another platypezid genus engaged in mating activities. These belonged to the species Protoclythia californica Kessel, and our observations were made at Steckel Park, Ventura County, California.

We arrived at Steckel Park early on the afternoon of December 19, 1961. The first hour of searching yielded no platypezids, but at $1: 55$ o'clock we came upon a mating pair of the species mentioned. They were resting on a horizontal leaf of a Solanum plant which was growing in a protected area near the river and in a spot surrounded by willow trees and bushes.

As on the occasion of our discovery of the mating pairs of Platypezina pacificu, we were startled by so rare a sight. Again our first reaction was to look up for the expected swarm of dancing males, and again there they were directly overhead. The general picture was the same, even to the chimneylike opening in the trees where the males engaged in their erratic zigzag flight. Once more we found the mating flies sitting with their heads directed away from each other, the larger male with his wings extended over those of the female. As before, the flies remained very quiet until they were disturbed, and then only the female responded, moving forward and towing the male behind her. When the insects were taken in the net they remained attached and continued in this mion until they were transferred to the cyanide jar. They are mounted on the same pin, but on separate points, and are deposited in the collection of the California Academy of Sciences.


Figure 1. The mating "chimney" of Platypezina pacifica, surrounded by coast redwoods.


Figure 2. The mating "chimney" of Protoctythia californica surrounded by willows.

Although the general mating pictures for Platypezina pacifica and Protoclythia californica proved to be basically similar, we observed obvious differences pertaining to the trees outlining the "chimney," that vertically open shaft in which the males danced (figs. 1 and 2). ${ }^{2}$ In the case of Platypezina pacifica the trees were coast redwoods (Sequoia sempervirens) while for Protoclythia californica they were willows (Salix sp.). A second difference involved the height of the trees, the redwoods of the Platypezina "chimney" being more than 200 feet tall, while the willows which lined the swarming opening of the protoclythias were only 20 to 25 feet high. It is of interest to note in this connection that we have always found platypezinas associated with areas where coniferous trees are growing, while we have collected many specimens of Protoclythia californica far removed from such forests.

Data are given in table 1 for the Steckel Park collection spot at the time ( $1: 55 \mathrm{P} . \mathrm{II}^{2}$ ) the mating flies were taken. These include altitude of the sun, temperature, relative humidity, light intensity, barometric pressure, and wind velocity.

In order to make certain that the flies which were dancing in the "chimney" actually were males of Protoclythia californica, a net was passed through the swarm. The three specimens that were taken by this stroke were all males of this species. No attempts were made to capture more of the insects at that time and the remainder of the afternoon was spent in observing their actions.

Unlike the swarm observed by Snow (1894) for Calotarsa calceata and those which we have seen for Calotarsa insignis Aldrich and Platypezina pacifica (Kessel and Kessel, 1961), all of which were at a height of fifteen feet or more, the aggregation of dancing males in the case of Protoclythio californica was much lower, the altitude of flight frequently being as low as five feet. This made it possible to observe the behavior of individual insects in the swarm in more detail than had ever been possible in other species.

Reference has been made to the parallels which we have observed between the epigamic behavior of balloon flies and that which we have seen exhibited in platypezids. In our publications dealing with balloon flies we have more than once made the statement that we have observed the female enter a swarm of males, embrace one of them, and then settle with him on a nearby shrub. Also, in our last paper (Kessel and Kessel, 1961) we recorded our observation of a mating pair of Platypezina pacifica descending from the swarm of males and added the comment: "It is evident that the female, like those of balloon flies, had selected her mate from the dancing swarm, and the pair were descending to the groundcover plants to complete their nuptial activities." In these instances we have attributed the initiative in selecting a mate to the female, but from our closer observation of swarming proto-

[^1]Table 1
Generalized data for various times of the day at the "chimney" location in Steckel Park, Ventura County, California, on December 19 and 20, 1961. Pacific Standard Time is given to the nearest 5 minutes and no correction is made for the east-ofmeridian location. Temperature is given to the nearest degree Fahrenheit and relative humidity to the nearest per cent. Light intensity with the meter directed up the "chimney" is recorded to the nearest 50 foot-candles and with it pointed toward the ground under the "chimney" the light intensity is given to the nearest 5 foot-candles. The barometric pressure on both days was 29.6 inches and the wind velocity was never higher than 5 miles per hour.
$\left.\begin{array}{cccccc}\hline \begin{array}{c}\text { Time } \\ \text { P.S.T. }\end{array} & \begin{array}{c}\text { Altitude } \\ \text { of sun }\end{array} & \text { Temperature }\end{array} \begin{array}{c}\text { Relative } \\ \text { humidity }\end{array} ~ \begin{array}{c}\text { Light up } \\ \text { "chimney", }\end{array} \begin{array}{c}\text { Light down } \\ \text { "chimney" }\end{array}\right]$
clythias we are now convinced that the male is not passive in the mateselecting process.

It is evident that in both balloon flies and platypezids mating takes place only in the swarms where the males are waiting for the females to come to them. We have often observed males and females belonging to the same species sitting in close proximity on the same leaf but in only one case did the sexes not ignore one another under such circumstances. The exception occurred when we were collecting in the Botanical Gardens of the University of California at Los Angeles and involved Clythia (=Platypeza) agarici (Willard). A male that was sitting close to a female suddenly jumped on her back but she promptly threw him off. It appears that the female must be stimulated by the recognition of her own special species' pattern of epigamic behavior before she will accept a mate, and that she encounters this pattern only in the swarm of dancing males. She doubtless recognizes them as belonging to her own species by some such specific symbol as the flashes of their balloons (Empis, Empimorpha, IItara), the scintillations of the flags on their feet (Calotarsa insignis), or other decorations and characteristics of their extended posterior tarsi (Calotarsa calceata, Platypezina pacifica, Protoclythia californica). Once she has recognized the swarm as consisting of
males of her species she flies in among them. On a leaf she may not recognize a potential mate, at least she repulses any advances that he may make, but in the proper swarm she is receptive and perhaps even eager. In the case of the balloon fly Empimorpha geneatis Melander we saw the female enter the swarm of males and there embrace with one of them. We presumed at the time that she had taken the initiative and selected a mate, but the joining of the flies happened so quickly once she had entered the swarm that it was impossible to be sure which sex had made the advances.

Because of the lower swarming flight of Protoclythia californica we were near enough to the insects to ascertain that all of the dancing flies were males. It was also easily seen that with even the slightest indication of a breeze they would all face into it, "standing" still in the air or rising and falling with only slow progress forward. When a male had finally reached the periphery of the "chimney" area, he would swing back more or less to the opposite margin of the swarm and once more face into the breeze. When there was no evident air movement, the flies would usually merely turn about and progress slowly through the swarm to the opposite side of the "chimney." It was not possible for us to determine if there was a slight updraft of warmer air in the vertically open shaft. There is opportunity to speculate on the possible relationship between air movements or temperature gradients and the selection of these "chimneys" for nuptial flights.

In watching the swarm of protoclythias we noticed that when a male came closer than about four inches to another fly, the two insects would invariably dart toward each other, only to veer away before contact was made. It seemed as though the males were inspecting one another, each to determine if the other fly was a female. The males were very alert in these actions and any female entering the swarm would have been grabbed by the first male she approached in her line of flight.

The compound eyes of male platypezids are both larger and more complex than those of the female. They are so large, in fact, that they are contiguous along the midline in front. As for the complexity of the eyes themselves, each is divided by a shallow groove into an upper portion possessing larger facets and a lower part having smaller facets. By contrast, the female has her compound eyes widely separated and all of her facets are of uniform size, about equivalent to those of the lower area of the male's eye. There has been considerable speculation as to the significance of these differences. Presumably the more complex eyes of the male give him wider and sharper vision than the female enjoys. It seemed illogical, therefore, to suppose that this more elaborate optical equipment is without significance in the mating behavior of these flies which would certainly be the ease if the male did nothing but dance with his fellows and wait passively for a female to select him. We now know that in the swarm the male darts aggressively at every fly that
comes within range. The first male to recognize the female and to get to her will take her as his mate.

We have presumed that the events leading up to pairing are similar in the balloon flies and the platypezids, and this in spite of the different copu'ation positions which the members of their respective families, Empididae and Platypezidae, typically assume. In the cases of the balloon flies which we have observed the male sits astride the female with his head in the same direction as hers, whereas in the platypezids the male and the female are directed away from each other and with only the tips of their abdomens in contact. These positions seem to be correlated with the nature of the male genitalia which in empidids are characteristically directed upward and forward and in typical platypezids are pointed downward and forward. These would seem to be major distinctions until one considers the fact that the male platypezid, as he approaches the completion of metamorphosis, has genitalia positioned like those of empidids. Only later, but while the fly is still in the puparium, do the genitalia begin to rotate to assume their final direction. By the time of emergence, the rotation is nearing completion of a $180^{\circ}$ movement, and by the time the male is sexually mature the hypopygium is directed downward as well as forward. It is likely that this difference achieved by the $180^{\circ}$ rotation of the genitalia in platypezids requires divergent copulatory positions in the two families. But in no way do the different positions and structures here described indicate that the two families are not closely related as we have believed.

Returning to the consideration of the swarm of Protoclythia californica which we observed at Steckel Park, some of the dancing males continued their activities as late as 3:10 P.M. when the sam disappeared behind the hills (see table 1 for data). However, their numbers had been gradually diminishing before that time. Almost as the sun vanished, the last males disappeared from the "chimney." No platypezids had been seen on the bushes since $2: 55$ o'clock.

Early next morning we returned to the swarming site to ascertain when and under what conditions the males would resume their dancing, but in spite of the fact that the day was clear and sunny like the one before, no flies appeared in the "chimney" until early afternoon. Nevertheless, at 9:05 A.M. (see table 1 for data) we did begin to see protoclythias of both sexes moving about on the leaves of bushes under the "chimney" area, stopping here and there to feed. For approximately the next two hours the flies continued their morning exercise and feeding period. Then came the rest period, beginning as abruptly as had the morning activity period which it replaced.

## Activity-rest Periodicity

Our many years of platypezid collecting during all of the seasons, from Alaska to Mexico and from the Atlantic to the Pacific, had led us to conclude
that the more sun-loving flat-footed flies interrupt their daily activities to take a siesta during the middle of the day. So definite was this feeling that we often found ourselves planning our collecting stops so as to avoid the hour or so before and after noon. When we made a point of looking into the matter we found that our impression agreed with the facts. While those species of Platypezidae which frequent environments of deep shade do not engage in well defined rest periods, all of those forms which are to be found typically in habitats of filtered sunshine seem to resort to a mid-day period of inactivity. Representative of the shade-dwelling forms are Platypezina pacifica, Platypezina diversa (Johnson), Calotarsa insignis, Agathomyia lucifuga Kessel, Agathomyia nemophila Kessel, and Agathomyia sylvania Kessel. Examples of the sum-loving species are Protoclythia californica, Clythia agarici (Willard), Clythia polypori (Willard), Clythia dymka Kessel, Clythia cinerea (Snow), (lythia hunteri Kessel, and Clythia coraxa Kessel. The species of Metaclythia would doubtless fall into this second category. Our experience indicates that the species of Callomyia are intermediate in their sum-shade inclinations.

Reference has been made to our observation that protoclythias indulge in a morning activity period during which they feed and run about on the leaves. It has also been our obscrvation that all of the sum-loving species have such a time of activity and that they exhibit a corresponding period in the afternoon. Their mid-day rest occupies the time between these two. Everywhere we have been impressed by the rather sudden onset and abrupt termination of these periods. We were also impressed by the fact that the activity periods of $C$. cinerea in Alaska are longer than those exhibited by this species in the San Francisco Bay area of California. Similarly, for C. coraxe the activity periods are longer in the San Francisco region than are those which we found for this species in San Diego County, California, some 375 miles to the south. These longer activity periods would seem to be related in some way to the longer days one encounters in our hemisphere as he travels north during the time between the vernal and autumnal equinoxes.

We presumed that such physical factors of the environment as temperature, relative humidity, and light intensity were the stimuli which regulated the activity and rest periods of these flies, but having provided ourselves with thermometer, hygrometer, and light meter we were quickly convinced that the data recorded by these instruments did not reveal the whole story. Too often there had been no changes or only minor ones in the factors just mentioned when there would be a sudden termination to the mid-day rest period. For instance, where at most only an occasional platypezid had been seen during the previous two hours or so, we were suddenly confronted with the problem of which fly to catch.

Considering this matter, we began to think about the discoveries which have been made in recent years in connection with the eircadian phenomena
of insects and other organisms (von Frisch, 1950; von Frisch and Lindauer, 1954; Lindauer, 1954, 1960; Lees, 1960; Pittendrigh, 1954, 1960; Bruce and Pittendrigh, 1957; Harker, 1960; Birukow, 1960; Breamer, 1960; and Renner, 1957, 1958, 1959, 1960). ${ }^{3}$ Could it be that we were dealing with a biological time clock, some internal mechanism which functions with a twenty-four hour periodicity and prompts our flies to become active or inactive, depending upon the rhythm of their particular species? If such an endogenous mechanism does exist, does it act alone, or is it correlated with and triggered by certain periodically recurring exogenous factors?

Renner $(1958,1959)$ has shown that the time-sense of honevbees is based, under normal circumstances, on both endogenous and exogenous elements. He was able to show that while the insects were able to orient themselves in time by means of an endogenous mechanism alone under laboratory conditions, they used both internal and external factors when they were in their natural surroundings. It seemed reasonable, therefore, to suspect that our flies, which like the bees are among the highest of insects, may possess a somewhat similar internal clock, a mechanism which is synchronized with one or more recurrent environmental factors.

Aschoff (1960) has applied the term "Zeitgeber" to the sum-total of the recurring components of the environment which serve to synchronize an organism's circadian rhythm with its surroundings. Adapting this word to our English terminology, it should be pointed out that the zeitgeber must be periodically operative. An exogenous timer of this type might include alternating factors such as light and darkness, continuously changing factors such as the daily course of temperature, or even short signals which occur only once or twice in a twenty-four hour period. However simple or complex the zeitgeber may be, its function is to determine phase, to synchronize any multiplicity of circadian clocks that may be present within an organism, and to synchronize and keep in phase all of the individuals of the species which are in the environment under consideration. As Aschoff has also pointed out, this last function of the zeitgeber implies that all of the individuals of the species have the same sensitivity to the timer, because if this were not the case the organisms would not be in phase and one would not find what we call a species' pattern.

We may suppose that the rest and activity periods of platypezids indicate a circadian periodicity which is triggered by a zeitgeber but, as we have already suggested, the exogenous timer in this case must involve an environmental component other than temperature, relative humidity, and light intensity. Some or all of these may contribute to the zeitgeber, but we are convinced that some other factor must be the recognizable exogenous element.

In considering what the missing component might be, we thought about

[^2]our observation that those species of platypezids which inhabit deep woods lack a mid-day rest period. We also recalled the longer activity periods of sun-loving platypezids as one travels northward to Alaska during the longer days of summer. We wondered, therefore, if the altitude of the sun could be the critical element of the zeitgeber which had been missing from our data. Perhaps the time-sense of our flies which lets them know when to begin and when to terminate their morning and afternoon activity periods is dependent upon a circadian periodicity which is triggered by a "built-in" sextant. In order to test this hypothesis of a sun-oriented rhythm we decided to add a sextant to our equipment. Dr. G Dallas Hamna of the California Academy of Sciences advised us to use a bubble sextant inasmuch as we would usually be working where it would be impossible to observe the horizon. We are indebted to Dr. Hanna for the loan of such an instrument, the one we have been using to obtain our sun-altitude readings.

The rest period for Protoclythia californica at Steckel Park on December 20, 1961, began at approximately 11:00 A.MI. At that time a male alighted on the Solanum plant under the "chimney" where the copulating pair had been captured the day before. He walked about for a second or two and then settled down near the edge of the leaf with his head directed toward its tip (fig. 3). This was a characteristic stance and position on the leaf for a platypezid during the mid-day rest period as we had observed it in several


Figure 3. The observed male of Protoclythia californica may be located sitting along the margin of the large leaf where he was difficult to see and maintained his position for the entire midday rest period.
species of Clythia. These insects always seem to rest at or very near the edge of the leaf and with the head pointed toward its tip. Often they take up a position at the very tip of the leaf. The protective value of these marginal sites is evident when one considers the hazards to which the leaf margin is subject and the leaf scars which result therefrom. The fact that the fly sits with his body parallel to the leaf veins also adds to his protection. While at such times the insects show no interest in feeding and are not easily disturbed, collecting them during this rest period is not ordinarily profitable because they are so easily overlooked.

It was evident almost immediately that the male before us had settled down for his mid-day rest. At noon he had shown absolutely no movement and no other platypezids had been observed. This inactivity continued until 12:55 P.M. when the first signs that the rest period was ending became evident. While the male under observation still sat undisturbed, two other males were noticed walking about on other plants in the area. A third male was observed dancing alone in the "chimney." Data for the several times mentioned in this account are given in table 1.

At 1:05 P.M. the male under special observation shifted himself and walked around to the opposite side of the leaf, this time taking up a position with his head directed toward the petiole. Shortly thereafter he flew away but we were unable to observe whether or not he entered the "chimney." By this time there were several flies dancing there and by $1: 15$ o'clock their number had increased to more than a dozen.

Our observations at Steckel Park indicate therefore that the mid-day rest period for Protoclythia californica on December 20, 1961, began at approximately 11:00 A.M. and terminated shortly after 1:00 P.MI. Because of the symmetrical shape of the sun's altitude curve, each altitude achieved during the day, except that of noon, occurs twice that day, once in the morning and once in the afternoon. Therefore, the altitude of the sun at 11:00 A.MI. and at 1:00 P.M. would be the same on any one day, providing one is dealing with solar time. Our data given in table 1 are only approximate as noted in the explanation. These generalized data, plus the fact that for the most part we are dealing with a single set of observations made in one place under one set of conditions, justify only generalized conclusions. We present these here in the nature of a preliminary report.

The sextant reading taken at 11:00 o'clock when the male under special observation began his siesta was $31^{\circ} 20^{\prime}$. At the time he flew away, the sun had declined to an altitude of $30^{\circ} 35^{\prime}$. Because the male in question did not "wake up" until after some of the other protoclythias in the vicinity had become active, we must conclude that not all of a species' individuals in an area begin and end their rest period at the same instant. It may seem to the collector in the field that they do, but it is evident that we must allow a little individual variation even in response to a biological clock such as we are
dealing with here. Allowing this at the beginning and again at the end of the rest period, we approximate the angle of 30 degrees as the altitude of the sun which indicates the onset and the termination of the siesta time, as well as the conclusion of the morning and the beginning of the afternoon activity periods.

It has been stated that the first protoclythias observed in the morning appeared at 9:05 o'clock at which time the angle of the sun was $20^{\circ} 10^{\prime}$. It has also been noted that the last flies seen in the afternoon disappeared at $3: 10$ $o^{\prime}$ 'clock when the angle of the sun was $17^{\circ} 45^{\prime}$. Until then some of the males had been dancing in the "chimney" although their numbers had been diminishing for some minutes. The last flies to be seen walking or running about on the leaves had been observed 15 minutes carlier. Because no swarming of the males occurred during the morning and this phenomenon has been shown to be a part of the mating behavior, we may regard it as something special which is not entirely regulated by the same factors which control the regular activity periods. While it is true that some of the males remained in the swarm until the sun disappeared behind the hills, the last flies seen walking about and feeding on the leaves had been observed at $2: 55$ P.M. when the angle of the sun's altitude was $19^{\circ} 40^{\prime}$. This figure agrees well with the $20^{\circ} 10^{\prime}$ of the sextant reading when the insects began their activity-feeding period in the morning. Our data, therefore, lead us to the generalization that the times of activity for Protoclythia californica occupy the periods when the altitude of the sum is between the angles of 20 and 30 degrees.

Owing to the lower maximum altitude of the sun and its less abrupt ascendancy and descendancy during the longer summer days in more northern latitudes, there is a longer period each morning and afternoon in such regions during which the angle of the sun is between 20 and 30 degrees. On this basis one would expect that the activity periods of the sun-loving species of platypezids would be correspondingly extended so as to both begin earlier and last later. This result would be in accord with our observations that the activity periods of Clythia cinerea in Alaska are longer than those of the same species in California at the same time of the summer. This extension of the activity periods obviously reduces the length of the rest periods. In fact we may suppose that for those platypezids which respond to the same sun angles in the same ways as do protoclythias, the mid-day rest period would not only be abbreviated in Alaska, but actually eliminated wherever the altitude of the sun does not pass above the 30 -degree mark.

Examination of table 1 does not suggest that the temperature factor is directly involved with the onset and termination of the activity periods. The same may be said for the data given in the two light-intensity columns. On the other hand the figures on relative humidity reveal that there was an abrupt 5 per cent drop in the value of this factor between $10: 30$ and 11:00 A.M., just prior to the begimning of the mid-day rest period. However, the
data show no immediate return at the conclusion of the rest period to the higher relative-humidity reading of 72 per cent obtained at $10: 30$ o'clock. This figure was reached by $2: 55$ P.M. but that was when the afternoon activity period was ending, not beginning. We may conclude, therefore, that the data support our general field impressions. Relative humidity, like temperature and light intensity, seems to play no direct role in the regulation of the activity and rest periods of platypezids. Possibly, acting together with temperature and barometric pressure to determine the saturation deficit, it may participate in the zeitgeber. There is little doubt, however, that the data here reported point to the angle of the sun's altitude as the time signal or chief exogenous regulator of the circadian activity-rest periodicity in platypezids.

Granting that these flies do possess such a circadian periodicity, one may well ask what the value of it could be to the species. By its very nature, such a rhythm involves innate factors, so we must conclude that it is a physiological phenomenon with a genetic basis. The species' pattern of restricted feeding-activity periods, with rest intervals between them, is likely to possess a survival value. In considering what this advantage to the species might be, it is logical to determine first what are the chief natural enemies of the flies. There seems to be no doubt that there are birds, those species which frequent the marginal woods which also constitute the filtered-sun habitats of the platypezids here being considered. If the birds, too, have periods of greater and less activity, then it is advantageous to the flies to avoid those intervals when the birds are more active. When platypezids are running about, they are among the most obvious of insects considering their small-to-medium size. So unique is their manner of movement, running to and fro in a series of darts and stops, that it is often easy to spot one of them from a distance of many feet. While this attention-attracting behavior constitutes a welcome advantage to the entomologist who is searching for these relatively rare insects, it would seem to constitute a real disadvantage to the flies in the matter of their bird predators. But this disadvantage would be overcome, in part at least, if the flies would alternate activity periods with the insectivorous and omnivorous birds which occupy the same habitat.

On our extensive collecting trips, during which we camped out most of the time, we have gained the impression that in general birds are early risers and, after the night's fast, spend the first several hours of the morning in search of food. When there is an abundance of food, many of the birds cease their hunting in the middle of the morning and retire for a rest period. Contrasting platypezids with birds, we have seen that these flies are late risers and do not make their appearance in numbers until the middle of the morning, or about the time that the number of feeding birds is noticeably diminished. It is apparent, therefore, that while the flies are feeding, many of the birds are likely to be resting. Late in the morning and continuing
until the early afternoon comes the platypezids' mid-day rest period during which time there may be another surge of active birds. Once again, in the carly afternoon, fewer birds are in evidence and the flies come out for an activity period. General feeding time for the birds comes once more in the late afternoon, but by this time the platypezids have disappeared for the day.

In order to see if there might be some credibility to this hypothesis, we decided to keep a record of the birds which visited the feeding station at our home in Novato, California, on a particular day which happened to be February 17, 1962. The feeding platform is located in ideal platypezid territory along the margin of virgin woods where we have often observed flat-footed flies of several species. The trees making up the woods are mostly oaks and California laurels, and underneath them is an understory of low bushes. All birds visible in the immediate area at the time of a count were included, regardless of whether they were on the platform, or on the ground, or in the bushes. For the period between 8:00 and $10: 00$ A.MI. and after $3: 00$ P.M., the counts were made every 15 mimutes. From $10: 00$ A.M. to $3: 00$ P.M. they were made every 5 minutes.

The results of the count (table 2) fit in well with the hypothesis which we have proposed. The expected morning surge was very evident with its average of 17.4 birds per count. Then as the morning activity period for the flies began at $9: 00$ o'clock, the number of birds dropped off abruptly. For the entire fly-activity period ending at 11:00 A.M. the birds figures remained rather low with an average of $2.4 t$ per count. During the mid-day rest period for the flies, from 11:00 until 1:00 o'clock, there was a substantial increase of some 50 per cent in the average number of feeding birds present to give a figure of $3.7 t$ per count. Between $11: 30$ and $11: 55$ there was a noticeable rise in the counts, with a maximum number of 12 birds representing 4 species (junco, brown towhee, titmouse, and chickadee). These figures indicate that it would be worthwhile for the platypezids to abstain from engaging in their attention-attracting movements during this period of greater activity for the birds. For the afternoon activity periods of the flies, from $1: 00$ to $3: 00$ o'clock, the average number of birds per count dropped to 2.56 . During this interval the birds which we saw appeared to be more lethargic and one even seemed to be asleep on the feeding platform for several minutes. After 3:00 o'clock, when the second fly-activity period of the day was ended, there was no evident increase in bird numbers until about 4:15 P.MI. At $4: 45$ o'clock when the last count was made, there had been an increase to 10 , perhaps representing the beginning of the expected surge in numbers of the evening feeding period of the birds. Although the average number of birds per count had increased to 3.12 between $3: 00$ and $4: 45$, this increase was so slow in coming that as far as danger from birds is concerned these figures give little reason for the flies to go into hiding as early as 3:00 P.M. Of course, if the activity periods of these insects are determined on the lower

Table 2
Number of birds observed at different times of the day at a feeding station located at Novato, California, and recorded on February 17, 1962, together with the average number of birds per count for the several periods which are indicated.

| P.S.T. | Number | Period and average | P.S.T. | Number | Period and average |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 8:00 A.M. | 12 |  | 12:35 | 3 |  |
| 8:15 | 15 | Morning bird- | 12:40 | 2 | Mid-day rest |
| 8:30 | 22 | activity | 12:45 | 4 | period for |
| 8:45 | 18 | period. | 12:50 | 4 | flies (cont.) |
| 9:00 | 20 | Average 17.4 | 12:55 | 4 |  |
| 9:15 | 4 |  | 1:00 | 0 |  |
| 9:30 | 3 |  | 1:05 | 3 |  |
| 9:45 | 1 |  | 1:10 | 6 |  |
| 10:00 | 7 | Morning fly- | 1:15 | 3 |  |
| 10:05 | 0 | activity | 1:20 | 1 |  |
| 10:10 | 2 | period. | 1:25 | 2 |  |
| 10:15 | 4 | Average 2.44. | 1:30 | 4 |  |
| 10:20 | 2 | Decrease in | 1:35 | 2 |  |
| 10:25 | 5 | bird activities. | 1:40 | 2 | Afternoon fly- |
| 10:30 | 2 |  | 1:45 | 2 | activity |
| 10:35 | 3 |  | 1:50 | 2 | period. |
| 10:40 | 2 |  | 1:55 | 3 | Average 2.56. |
| 10:45 | 1 |  | 2:00 | 3 | Decrease in |
| 10:50 | 1 |  | 2:05 | 3 | bird activities. |
| 10:55 | 2 |  | 2:10 | 2 |  |
| 11:00 | 0 |  | $2 \cdot 15$ | 3 |  |
|  |  | ............................. | 2:20 | 2 |  |
| 11:05 | 5 |  | 2:25 | 3 |  |
| 11:10 | 4 |  | 2:30 | 3 |  |
| 11:15 | 1 |  | 2:35 | 2 |  |
| 11:20 | 1 |  | 2:40 | 1 |  |
| 11:25 | 0 | Mid-day rest | 2:45 | 5 |  |
| 11:30 | 4 | period for | 2:50 | 3 |  |
| 11:35 | 12 | flies. | 2:55 | 3 |  |
| 11:40 | 8 | Average 3.74. | 3:00 | 1 |  |
| 11:45 | 4 | Increase in | ........ |  | ................... ... |
| 11:50 | 6 | bird activities. | 3:15 | 1 |  |
| 11:55 | 6 |  | 3:30 | 2 |  |
| 12:00 M | 2 |  | 3:45 | 0 | Evening bird- |
| 12:05 P.M. | 2 |  | 4:00 | 2 | activity |
| 12:10 | 0 |  | 4:15 | 5 | period. |
| 12:15 | 4 |  | 4:30 | 4 | Average 3.12. |
| 12:20 | 2 |  | 4:45 | 10 |  |
| 12:25 | 5 |  | .......... |  |  |
| 12:30 | 3 |  |  |  |  |

level by a particular angle of the sun's altitude as we have postulated, then this could not be decreased for the afternoon period without likewise de-
creasing it for the morning period. And this would put the flies into greater jeopardy by forcing their early activities into conflict with the morning surge of feeding birds.

It is recognized, of course, that to be wholly significant the counts of birds observed feeding at different times during the day should have been made in the same place and same time of year as the fly study with which they are compared, not 300 miles or so more to the north and 2 months later as they were. But because it was impossible to make the counts at Steckel Park on December 20, these less-desirable data from Novato and recorded on February 17 are substituted.

Our comments concerning the attention-attracting movements of platypezid flies as they run about on leaves in their unique jerky tempo, deserve additional comment. One cannot help but wonder why such a jeopardyinviting activity has been maintained by these flies. Its disadvantages are so obvious when we consider the matter of bird enemies. Does this habit seemingly have any conpensating advantages?

Howlett (1921) is of the opinion that it does have such advantages. While he agrees that the unique movements of flat-footed flies are attention arresting, and therefore can hardly make these insects less conspicuous to such important enemies as birds, nevertheless he believes that they have a protective value in that they make the capture of the fly more difficult than if it were sitting still or "standing" in the air. Howlett also cites the cases of several arthropods which supposedly obtain protection by means of their obvious tetanic actions. He refers to several of these which, when disturbed, cause the body to vibrate so rapidly that the observer sees only a blurred area. He thinks that it is likely that in platypezids "the rapidly alternating translatory motion of the whole insect may be another means of achieving a similar result."

While Howlett attempts to make a convincing case of these points, our observations indicate that he is wrong in his major premise that the dartingstopping movements of platypezids are executed only when the flies are disturbed by the movement of some object in the vicinity. Over and over again we have cautiously approached a likely looking "platypezid bush" from behind good cover and from our vantage point observed several flies variously engaged. While at the moment some were quietly feeding, the others were moving about in their to-and-fro fashion searching for food. A few minutes later and without cause for alarm, the feeders might be running and the runners quieted down. We can hardly agree, therefore, with Howlett's contention that the movements are wholly defensive maneuvers.

Platypezids are often extremely quick in movement. This is particularly true of their departure flights, that is, when they leave the immediate vicinity, not just move to an adjacent leaf. They may have been "floating" in the air in zigzag fashion, "standing" practically motionless in the air, or
running or sitting on leaves. In any case their departure is instantaneous, without any discernible preparatory movements or attitudes. It is also instantaneous in the actual departure which is so rapid that the eye can very seldom follow it. It can be truthfully said in almost every instance that "if you saw it leave it was not a platypezid." Most frequently the fly leaves completely, that is, it does not just fly a few feet or yards and then settle down or return.

Very few, if any, of the dipterans that we have encountered have this habit of complete and rapid departure, or at least utilize it at all frequently. In the platypezids it is used on many occasions: when they are disturbed by a sudden breeze, another insect, a bird, or a falling twig or leaf, sometimes even by abrupt exposure to bright sun or heavy shadow. It is also used when a person causes a disturbance by close approach, considerable movement, or shaking the foliage. Significantly, however, the same method is followed when the most critical observation can discern no disturbing condition; this is just the usual manner in which platypezids depart from any particular spot.

A point of special interest in connection with the departure flight is the fact that it can take place in the midst of any of the fly's normal activities. As already mentioned, flies leave from a place in the air or from a leaf. Furthermore, when from a leaf this flight may occur in an entirely typical manner whether the fly has been busily feeding at one spot, running rapidly over a leaf, or remaining very quict during a rest period. In any of these cases the fly is there and the next instant it is not. It should be pointed out, however, that quite logically these flies spontaneously take flight less often and are disturbed least by external factors when they are quietly feeding or in a rest period, or when it is relatively dark and cold. Departure flights are more frequent and most easily caused by disturbance when the flies are running on leaves, or "standing" in the air, or when the light intensity and temperature are high.

In considering the subject of external disturbance of platypezid activity, aside from the relation of actual departure flights, it can be said that any one of many nonextreme factors may bring about a change of activity. This is most easily seen when a fly is busy feeding in one spot and, when disturbed only slightly, begins to rm in typical jerky fashion over the leaf. It should be remembered in this connection that the fly's feeding activity on the leaf consists normally of two phases, one of more or less rapid running and at the same time testing for the presence of food and the momentary stopping to actually take food when it is found in tiny amounts, the other phase involving feeding at one spot of greater abundance. When the flies are undisturbed these two phases alternate with no regular pattern whatsoever. The two phases together make up the general pattern and shift according to the circumstances. One of the conditions which seem capable of serving as the
stimulus for a temporary shift to the rumning phase, yet without breaking the pattern, is some slight external disturbance such as the casual yet obvious approach of a person. Howlett's observations, limited to a study of two platypezids, led him to interpret this shift to the rumning phase as a special defensive maneuver.

Perhaps the rumning behavior of flat-footed flies does have some such protective value as Howlett has suggested. Our opinion, however, is that this is of minor importance, if indeed it has any such significance. Instead, we are convinced that the advantage to the species of this display of so much haste and such an expenditure of energy is correlated with the search for food. Platypezid flies are not predaccous, so they need not run rapidly to catch prey. But they do glean their nourishment from inconspicuous accumulations on such flat surfaces as leaves, and because of the limited quantity of this food often available to them they have survived by the utilization of an innate capacity to scrounge for their food. Such scrounging becomes most efficient when the movements are rapid and to the point of discovery.

That platypezids utilize their characteristic jerky movements when they are completely undisturbed and their only motivation is the search for food was made very clear to us by the following laboratory observations. Larvae of both Calotarsa insignis and Clythia agarici had been collected in large numbers and placed in rearing cages. When it came time for the insects to emerge as adults, so many of them appeared that after we had mounted and preserved all that we could use, a hundred or more flies of each species were left over. So we decided to release them in the laboratory and to observe their behavior.

The room was a small one measuring about 7 by 14 feet. There were no windows and the only natural light was from a small skylight at one end of the ceiling. Artificial illumination was provided by two overhead fixtures and a desk lamp. Many of the flies had emerged as long as two days previously and none of them had received nourishment. When these hungry flies were released they dispersed and within a few minutes they seemed to be everywhere, on the floor, bookease, collection case, filing cabinet, and desk. And everywhere they exhibited the same to-and-fro, stop-and-go search for something to eat. As we had expected, few of them went to the skylight; instead, most of them went to the lower levels of the room, particularly the desk and the floor. It is of interest to note that this preference for the lower levels agrees with their lower-story habitats in woods.

Although all of the flies seemed to us to ignore our presence and to be concerned only with their search for food, one might argue that the reverse was true and that in conformity with Howlett's theory they were exhibiting their incessant erratic movements because they were in artificial surroundings and very much disturbed. But this possibility was eliminated very soon when some of the flies on the desk happened upon the eleared area where
we had just eaten our sandwich lunch. All of the crumbs had been brushed up and nothing of food value remained as far as we could see. But to the flies there were spots of nourishment present and they stopped to feed on them. The insects were so intent on their feeding that they were undisturbed when we placed an open-base-type binocular microscope over them and brought them into focus. By this means we were able to see them feeding in house-fly fashion on the film spots of food which they had discovered on the desk. But finishing in one spot they were always in a hurry to find another, and in so doing fell into their familiar pattern of movement.

We are therefore convinced that these peculiar motions indulged in by platypezids are not defensive measures such as to make them more difficult to capture or to scrutinize, but rather are only a part of their search-for-food pattern. If by such movements the flies also run the danger of attracting the attention of birds, that is a hazard which the species must endure. Tf this hazard has been reduced by the expedient of alternating feeding periods with birds, this constitutes a survival factor worth perpetuating. But the business of getting food must go on.

## Sumpiary

The mating behavior of Protoclythia californica here described involves only the second occasion on which mating pairs of flat-footed flies have been studied; the first observations dealing with Platypezina pacifica having already been reported by us. Owing to the lower height of the willow trees which outlined the swarming "chimney" of P. californica as compared with the very tall redwoods of the platypezina "chimney," the level of the swarm was much lower in the case of the protoclythias. This made it possible to study them at very close range and thereby gain a clearer picture of the epigamic behavior of these flies. It is evident that the mating behavior of these two species is essentially the same and presumably it is representative not only of the two genera to which they belong but also of the family Platypezidae.

The males gather in swarms to dance in a "chimney" outlined by trees. Here they wait for individual females to approach the swarm. While the females have always been observed to ignore or repulse the advances of males in other situations, they are positively erotropic once they recognize that the swarm represents their own species. The receptive female enters the swarm of males and is grabbed by the first one she approaches in her line of flight. Copulation is initiated in the swarm and union is accomplished with the heads of the flies pointing in opposite directions. The female assumes the initiative in flight, the male being towed backward as the pair descend to complete their nuptial activities on a lower-story shrub below the "chimney." The female continues to haul the male around as she walks over the leares in search of a suitable resting place. The peculiar mating position assumed by
these flies seems to be correlated with the nature of the male genitalia which are rotated 180 degrees so as to be directed downward and forward.

Long experience in collecting flat-footed flies convinced us that the more sun-loving species which inhabit the areas along the margins of woods have well defined morning and afternoon periods of activity, with a rest period occupying the mid-day interval between them. We were impressed by the rather sudden onset and abrupt termination of these periods and also by our observation that the activity periods for a particular species are longer in the more northern latitudes.

It is our opinion that the activity-rest periodicity of these flies is regulated by a circadian rhythm which functions as a biological clock on a twentyfour hour basis. Scarching for the exogenous factors which may trigger this presumed endogenous mechanism, we concluded that temperature, relative humidity, and light intensity do not qualify for this role. Only the altitude of the sun seems to be identifiable as an exogenous timing element.

Observations made at Steckel Park, Ventura County, California, on December 20, 1961, indicate that the activity times of this species coincide with the periods when the sun's altitude is between the angles of 20 and 30 degrees. On the day and at the place stated, the morning activity period lasted approximately from 9:00 to $11: 00$ o'clock, the rest period from $11: 00$ until $1: 00$ o'clock, and the afternoon activity period from $1: 00$ to $3: 00$ P.M.

In consideration of what value this periodicity may possess for the flies, we propose that it is advantageous for them to alternate activity periods with birds, which are their chief predators. Our general impression, gained during much field work and supported by limited data, is that birds tend to be early risers and spend the first hours of the day in search of food, after which they may retire for a rest period. Platypezids, by contrast, are late risers and do not make their appearance in numbers until the middle of the morning, so while the flies are feeding many of the birds are resting. When the flies take their mid-day siesta, there may be another increase of feeding birds. As the birds once more become less active in the afternoon, the flies appear again for an activity period. General feeding time for the birds is evident again in the late afternoon, but by this time the platypezids have retired for the day.

Platypezids characteristically attract attention by their to-and-fro stop-and-go movements as they run about on leaves. It was proposed long ago that these darting-stopping movements are exceuted only when the flies are disturbed and that they have the protective value of making capture more difficuit. We cannot agree with this viewpoint. Instead, we hold that the jerky running of these flies is merely a phase of their feeding activity, a part of their search-for-food pattern. Adult platypezids glean their nourishment from inconspicuous accumulations on such flat surfaces as leaves and, because of the limited supply, they must often scrounge for their food. Such
scrounging becomes most productive when the movements of the search are rapid and the testing stops are brief.

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## PROCEEDINGS

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## TWO GNAPHOSID SPIDERS FROM ARKANSAS ${ }^{1}$

by<br>Harriet Exline ${ }^{2}$<br>Research Associate<br>California Academy of Sciences

Rachodrassus echinus Chamberlin (1922; Kentucky) was proposed with a brief description and without illustration; Drassylus covensis is a new species. Both were collected by Otis Hite in pitfall traps in the forest litter of Cove Creek Valley, Arkansas, during April and May, 1961. In so far as has been determined, genitalia of spiders of the family Gnaphosidae are described here for the first time.

I am indebted to Dr. Willis J. Gertsch, American Museum of Natural History, for checking identifications, and to Dr. Herbert W. Levi, Museum of Comparative Zoology, Harvard University, for sketches of the palpus and epigynum of the type and allotype of Rachodrassus echinus Chamberlin and the epigynum of the type of "R. chera Chamberlin."

[^3]

## Family GNAPHOSIDAE

Rachodrassus echinus Chamberlin.
(Figures 7-12.)
Rachodrassus echinus Chamberlin, 1922, Biol. Soc. Wash., Proc., vol. 35, pp. 146, 160. Male holotype and female allotype from near Mammoth Cave, Kentucky, in Museum of Comparative Zoology. Type species of Rachodrassus. The specific name is a Latin noun in apposition, meaning "sea-urchin."
Rachodjassus chera Chimberlin, 1922, Biol. Soc. Wash., Proc., vol. 35, p. 161. Female holotype from near Mammoth Cave, Kentucky, in Museum of Comparative Zoology.
Male. Carapace yellow covered with gray hair-like setae that lie prone and face mid-line between thoracic groove and ocular area, and a few erect setae. Legs, palpi, mouthparts and sternum yellow, thickly covered with prone and erect setae. Abdomen dull yellow with an irregular gray pattern, venter grayish yellow, spinnerets clear yellow.

Carapace with steeply inclined sides, equally high from behind thoracic groove to near eye region, which is lower; evenly rounded on sides, but narrowed anteriorly. Chelicerae short, somewhat geniculate; anterior margin of fang groove with three teeth, posterior margin with two teeth, all well separated and sharp. Clypeus narrow, less than a radius of anterior lateral eye. Anterior eyes in procurved row, anterior medians smaller than other eyes, separated by a radius, nearer anterior laterals. Posterior eyes in a straight row; median eyes round, slightly smaller than laterals, and nearer each other than laterals. Median ocular area a little wider behind than long. Legs moderately robust with many long spines; relative length 4,1,2,3. Fourth

Figure 1. Drassyllus covensis Exline, new species, male palpus, ectal view.
Figure 2. Drassyllus covensis Exline, new species, male palpus, ventral view.
Figure 3. Drassyllus covensis Exline, new species, epigynum of female.
Figure 4. Drassyllus covensis Exline, new species, female genital plate, dorsal view.
Figure 5. Drassyllus covensis Exline, new species, bulb of male palpus expanded, dorsal view; a) median apophysis showing the two segments, c) conductor, e) embolus, f) fulcrum or terminal apophysis.
Figure 6. Drassyllus covensis Exline, new species, abdomen of male.
Figure 7. Rachodrassus echinus Chamberlin, abdomen of male.
Figure 8. Rachodrassus echinus Chamberlin, female epigynum.
Figure 9. Rachodrassus echinus Chamberlin, genital plate of female, dorsal view.
Figure 10. Rachodrassus echinus Chamberlin, male palpus, ectal view.
Figure 11. Rachodrassus echimus Chamberlin, male palpus, ventral view.
Figure 12. Rachodrassus cchinus Chamberlin, tip of bulb of male palpus, lateral view: a) median apophysis, aa) accessory apophysis of tegulum, c) conductor, e) embolus, f) fulcrum or terminal apophysis.

tibiae with two mid-dorsal spines, third tibiae with one; all tibiae with three pairs of ventral spines.

Abdomen slender, without scutum. Anterior spinnerets very long, stout, separated by their radius. Posterior spinnerets shorter, slender, with very short terminal segment.

Palpal tibia longer than patella, with a short, robust, ventrally pointed apophysis. Tarsus long, narrow, with bulb thick. Bulb with terminal fulcrum (terminal apophysis) bent back in a double curve at tip; embolus heavily sclerotized, broad, with three distal teeth, the median one bearing duct; conductor membranous; median apophysis large, with a broad basal tooth and distal hook. A dorsal projection of the tegulum has a large, membranous folded tip. When expanded artificially, at least, the fulcrum envelops and grasps the embolus.

Total length, $6.5 \mathrm{~mm} ., 5.5 \mathrm{~mm}$. without chelicerae and spinnerets. Carapace 2.3 mm . long, 2.0 mm . wide. First leg: femur, 2.1 mm .; patella-tibia, 3.0 mm .; metatarsus, 1.6 mm ., tarsus, 1.2 mm . Second leg: femur, 2.0 mm .; patella-tibia, 2.5 mm .; metatarsus, 1.4 mm .; tarsus, 1.1 mm . Third leg: femur, 1.7 mm .; patella-tibia, 2.2 mm .; metatarsus, 1.5 mm .; tarsus, 1.0 mm . Fourth leg: femur, 2.3 mm .; patella-tibia, 2.9 mm .; metatarsus, 2.6 mm .; tarsus, 1.2 mm . The eight males range from 5.5 mm ., in total length, to 6.5 mm .

Female. Color, pattern, and structure similar to male. Chelicerae more geniculate; posterior eye row a little recurved, and eyes farther apart; ocular area much wider behind than in front; first tibiae with only two pairs of ventral spines, second tibiae with two pairs and one distal; anterior spinnerets separated by a diameter.

Epigynum swollen with a long, wide anterior fold, with deep grooves bordering it laterally. A pair of conspicuous horizontal ridges posterior to fold. Grooves anterior to ridges are confluent with grooves on each side of anterior fold. A pair of large, contiguous, heavily sclerotized, oval seminal receptacles lies in the posterior half. Three small, deep, sclerotized depressions occur, one over each seminal receptacle and one between them. If the genital plate is removed, dissected, and cleared, a slender, irregular tube can be seen on each side, opening at the anterior end of the groove bordering the anterior fold. At the level of the lateral ridges, this enters a large sclerotized oval body, and passes posteriorly to the seminal receptacle, where it becomes affixed as a wide, sclerotized anterior part. The structure and function of the parts are not entirely understood. The tube is only wide enough for the duct of the embolus to enter. There seem to be no openings anterior to the lateral ridges into the sclerotized bodies. The lateral ridges may act as a lock for the combined radix and embolus, the duct of the latter becoming free and following the grooves to the small anterior opening.

Total length, $6.8 \mathrm{~mm} . ; 6.1 \mathrm{~mm}$. without chelicerae and spinnerets. Cara-
pace, 2.6 mm . long, 2.1 mm . wide. First leg : femur, 1.7 mm .; patella-tibia, 2.6 mm .; metatarsus, 1.1 mm .; tarsus, 0.8 mm . Second leg : femur, 1.7 mm .; patella-tibia, 2.6 mm. ; metatarsus, 1.1 mm .; tarsus, 0.8 mm . Third leg : femur, 1.6 mm .; patella-tibia, 2.2 mm .; metatarsus, 1.4 mm .; tarsus, 0.8 mm . Fourth leg : femur, 2.3 mm .; patella-tibia, 3.0 mm .; metatarsus, 2.4 mm .; tarsus, 1.2 mm . The five females range from 5.6 mm . to 6.8 mm . in length.

Rachodrassus chera Chamberlin is synonymized with $R$. echinus as a paucity of spines was the basis for separation of $R$. chera, and the spination of the ventral tibiae proves to be quite variable. The epigyna of the two nominal species are very similar, although the grooves of that of $R$. chera are darker. One female taken in Arkansas also has darkened grooves, filled with chitin or a resinous material. Rachodrassus flavus Chamberlin and Woodbury (1929, p. 134, pl. 2, figs. 1, 2; erroneously given as plate 1), from Utah, has the anterior eye row straight; the male palpus seemingly is simpler than that of $R$. echinus, with a flat tibial apophysis rounded at the tip; and the female epigynum has a quite different appearance.

Drassyllus covensis Exline, new species.
(Figures 1-6.)
Holotype male and allotype female from Cove Creek, Washington County, Arkansas, collected by Otis Hite, May 13, 1961, in collection of California Academy of Sciences. The specific name is a Latinized adjective based on the type locality.

Male. Carapace, mouthparts, sternum, and some leg segments pale orange with light gray infusions. Distal part of femora, patellae and tibiae mostly dark gray. Abdomen grayish white, nearly covered with a blackish gray pattern; basal scutum orange overeast with blackish gray. Venter pale with a pair of large grayish black patches uniting in front of spimnerets.

Carapace low, evenly arched, highest at posterior end of thoracic groove, wide with sides evenly curved, somewhat narrowed anteriorly; sparsely covered with setae that incline toward thoracic groove. Clypeus vertical, height about equal to diameter of anterior median eyes. Posterior eye row procurved; posterior median eyes oblique, very slightly larger than posterior laterals, all separated by less than a radius. Shape and spacing of eves somewhat variable. Anterior median eyes smaller than others, separated by nearly a diameter. Median ocular area a little longer than wide, slightly wider behind.

Chelicerae geniculate, slender, with elongate boss. Anterior margin of fang furrow armed with $3-5$ small dark teeth; posterior margin with three well spaced, pale denticles.

Legs with metatarsi and tarsi slender, tibiae IV slightly enlarged. Tibiae III and IV without median dorsal spines. Two, a basal and median, ventral
spines on tibiae I and II; three pairs of ventral spines on tibiae III and IV. Spines on anterior tibiae are not present on all males. Legs 4,1,2,3 in relative length.

Abdomen with triangular scutum on basal half. Anterior spinnerets separated by their diameter. Posterior spinnerets equal to anteriors in length, much more slender, with a short terminal segment.

Palp with patella longer than tibia without apophysis. Tibial apophysis extending a third cymbial length, broad at base, tapering to a point, bent dorsally near tip. In ventral and lateral views of the unexpanded bulb, the conspicuous structures are parts of the two-jointed, protruding median apophysis. The long, slender, curved embolus lies against the cymbium. The terminal apophysis or fulcrum is short, blunt at tip with notched margin, only the tip showing in ventral view. The conductor, invisible in the unexpanded bulb, is a thin plate with only the edge sclerotized, lying between the median apophysis and embolus.

Total length, 4.6 mm . including chelicerae and spinnerets. Carapace, 1.9 mm . long, 1.5 mm . wide. First leg: femur, 1.5 mm .; patella-tibia, 2.0 mm .; metatarsus, 1.0 mm .; tarsus, 0.8 mm . Second leg : femur, 1.3 mm .; patellatibia, 1.6 mm .; metatarsus, 0.7 mm ; tarsus, 0.7 mm . Third leg: femur, 1.0 mm .; patella-tibia, 1.3 mm .; metatarsus, 0.7 mm .; tarsus, 0.6 mm . Fourth leg : femur, 1.5 mm .; patella-tibia, 2.1 mm .; metatarsus, 1.5 mm .; tarsus, 0.8 mm . Nine males range from 4.6 mm . to 5.3 mm . in length.

Female. Pattern and colors not so distinct as in male. Structure essentially the same: differs by having clypeus slanting and not quite so high; posterior median eyes about a radius apart, nearer lateral cyes; first tibiae without ventral spines, second tibiae with one spine. Epigynum large, flat, highly sclerotized. Openings lateral about midway, seemingly leading into selerotized bursae. Tube from each bursa forms an anterior lateral loop, bordering bursa medially and forming a postero-lateral loop leading to seminal receptacles on posterior edge of epigynum. Seminal receptacles contiguous, with a dorsal thickening from which the fertilization tubes originate. Total length, 6.3 mm . Carapace, 1.9 mm . long, 1.4 mm . wide. First leg: femur 1.4 mm .; patella-tibia, 1.9 mm .; metatarsus, 0.9 mm .; tarsus, 0.7 mm . Second leg: femur, 1.3 mm .; patella-tibia, 1.6 mm .; metatarsus, 0.7 $\mathrm{mm} . ;$ tarsus, 0.6 mm . Third leg: femur, $0.9 \mathrm{~mm} . ;$ patella-tibia, $1.3 \mathrm{~mm} . ;$ metatarsus, 0.7 mm .; tarsus, 0.6 mm . Fourth leg: femur, 1.5 mm .; patellatibia, 2.1 mm .; metatarsus, 1.5 mm .; tarsus, 0.7 mm . A second female measures 5.0 mm . length.

Drassyllus corensis is closely related to D. dentelifer Chamberlin (1936, p. 13, figs. 1, 2) from Florida. In the latter the tibial apophysis is not so long, the position of the embolus is more ventral, the median apophysis is shorter, the abdomen is darker and without pattern, the lower margin of the
chelicera has only two teeth, the posterior tibiae bear a median dorsal spine, and the posterior median eyes are very large.

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# DISTINCTIVE "CONGRID TYPE" FISH OTOLITHS FROM THE LOWER TERTIARY OF THE GULF COAST (PISCES: ANGUILLIFORMES) ${ }^{1}$ 

## by

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Introduction
"Congrid type" sagittae characterize some Recent, presumably anguilliform, fishes (Frost, 1926) and range as fossils at least from the lower Eocene. They show genetic unity in the groups containing them, although relationships even at the ordinal level have not been satisfactorily established.

Two nominal species in the Gulf Coast Tertiary are known from otoliths of this trpe: "Congermuraena" sector" (Koken) (1888, pp. 292-293, pl. 17. figs. 14-16; as Otolithus (Platessae)) and "Conger" brevior (Koken) (1888, pp. 293-294, pl. 18, fig. 7; as O. (Congeris)). "Congermuraena" sector, described as ranging from Claiborne Eocene to Vicksburg Oligocene, includes a complex of species that will be treated in a later paper. "Conger" brevior, described from the Jackson Eocene of .Jackson, Mississippi, is redescribed from suites of well preserved specimens from Eocene and Oligocene strata of Mississippi and Alabama.

[^4]Five new species are proposed here, from Eocene-Oligocene beds of the Gulf Coast, in order to make names available for these fossils. All are referred to the very broadly based form-genus "Conger," although only one (C.? vetustus) shows a close resemblance to otoliths of the Recent genus Conger Schaeffer. At least three genera are represented by the described species, but comparative material now available does not justify an attempt at generic allocation.

## Acinnowledgments

Assistance in various phases of research on fossil fish otoliths has been acknowledged in an earlier paper (Frizzell and Lamber, 1961). To that list we would add: Mr. Emmett Adams, Jackson, Mississippi, who accompanied Frizzell to the Moody's Branch outcrop in Jackson; Mr. C. O. Ketler, Hiwannee, Mississippi, for locality information; Miss Winnie McGlamery, formerly of the Alabama Geological Survey, for data on collecting localities; and Messrs. J. G. McVay and J. A. McClinton, Lone Star Cement Corporation, St. Stephens, Alabama, who made it possible to collect at the St. Stephens quarry.

Morphology of Congrid Type Sagitta
The congrid type sagitta (figure A) has a typically ovate outline, highest toward the anterior and lowest at the posterior end, with dorsal dome (D) developed in some forms. The sulcus is not divided, although caudal and ostial regions (CR and OR) are recognized. An anterior border (AB) separates the ostial region from the anterior margin, and a characteristic ostial channel (OC) opens onto the dorsal margin or anterodorsal slope.

## Collecting Localities

The otoliths described here were found in samples from the following localities:

OLiGOCENE, Vicksburg group.
Byram marl. Old Byram, Hinds County, Mississippi (type locality); bank of Pearl River below suspension bridge; irregular beds of shell drift within sandy shell marl of formation. Collectors: D. L. Frizzell, August 31, 1957; D. L. and II. E. Frizzell, August 21, 1959; C K. Lamber, November 26, 1959. (Stations F-57-5; F-59-1C; CKL-59-8, 9.)

Vicksburg, Warren County, Mississippi; small road cut on gravel road adjacent to north boundary of National Cemetery, ca. 30 yards east of U.S. IIighway 61 ; highly glanconitic, indurated shell marl containing stringers of non-indurated broken shell material. Collector: C K. Lamber, November 27, 1959. (Station CKL-59-16.)

Glendon limestone. Quarry of Marquette Cement Company, about one mile southwest of Brandon, Rankin County, Mississippi; glauconitic shell marl above basal limestone stratum of formation; various places within quarry limits. Collectors: D. L. Frizzell, November 26, 1959; C K. Lamber, November 26, 1959. (Stations F-59-13, 15; CKL-59-3, 4, 7.)

Mint Spring marl. National Cemetery, Vicksburg, Warren County, Mississippi (type locality); falls of Mint Spring Bayou at south boundary of cemetery; fossiliferous shell detritus about $11 / 2$ feet above basal contact (with Forest Hills formation). Collectors : D. L. Frizzell, November 23, 1959; C. K. Lamber, November 27, 1959. (Stations F-59-6, 7, 8; CKL-59-12, 13.)

Red Bluff clay. Hiwannee (formerly Red Bluff), Wayne County, Mississippi (type locality); bank of Chickasawhay River; shell marl pockets in plastic green clay near low water level. Collectors: D. L. Frizzell and A. R. Troell, Jr., August 4, 1960. (Station F-60-11.)

Red Bluff equicalent. Quarry of Lone Star Cement Corporation, ca. 2 miles northeast of town of St. Stephens, Washington County, Alabama; greenish to white glauconitic marl, forming lowest calcareous unit in quarry; sample taken 6-10 inches below over-lying 4-5 foot very light gray indurated limestone. Collector: D. L. Frizzell, September 3, 1957. (Station F-57-8.)

EOCENE, Jackson group.
Danville Landing shale. Duty, Catahoula Parish, Louisiana; bank of Ouachita River at Duty ferry landing, east of town and off Louisiana Mighway 124 ; lower shell marl bed of formation exposed at low water level. Collectors: D. L. Frizzell, C K. Lamber, and W. C. Horton, November 24, 1960. (Stations F-60-A2; CKL-60-2.)

Moody's Branch marl. Riverside Park, Jackson, Mississippi (reassigned type locality) ; basal greensand of formation, with abundant disseminated fossil fragments, just above the blue clay of underlying Cockfield formation. Collectors: E. Adams and D. I. Frizzell, November 24, 1959. (Stations F-$59-9,10,11$.)

Montgomery Landing, Montgomery, Grant Parish, Louisiana; east bank of Red River, 500 to 1,000 yards downstream from ferry landing (locally known as Creole or "Creola" Bluff) ; light, extremely shelly marl. Collectors : D. L. Frizzell, C K. Lamber, and W. C. Horton, November 23-24, 1960. (Stations F-60-A1; CKL-60-1.)

Yazoo County, Mississippi; bank of Techeva Creek (also "Tesheva" on U.S.(G.S. maps) at bridge on Mississippi Highway 433, just north of town of Midway, which is northward from Benton; blue to blue-gray marly sandstone containing shell debris. Collectors: D. L. Frizzell and A. R. Troell, .Jr., July 31, 1960. (Station F-60-3.)

EOCENE, Wilcox group.
Bashimarl. Meridian, Lauderdale County, Mississippi; bank of drainage ditch on south side of "Bypass 80 "; lenticular bed of non-indurated shell debris overlying a bed of conspicuous white sand. Collectors: D. L. Frizzell, November 28, 1959; D. L. Frizzell and A. R. Troell, Jr., August 2, 1960. Stations $\mathrm{F}-59-16$; $\mathrm{F}-60-8$.)

# SYSTEMATIC DESCRIPTIONS 

Order ANGUTLLIFORMEs
Family Congridae

## Genus Conger Schaeffer, sensu latissimo

Except for Conger? vetustus, that may be congeneric with Recent species of the genus, the species here described are not believed to belong to the genus Conger s.s. of the living fauna. "Conger" (in quotes) is a form-genus, applied only provisionally, that will be revised when more becomes known of the otoliths of Recent anguilliform fishes.

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" Conger'' brevior (Koken).
(Figures 4 a-b, 10 a-d.)
Otolithus (Conger) brevior Kokmx. 1888, Deutsch. Geol. Ges., Zeitschr., Bd. 40, pp.
    293-294, pl. 18, fig. }7
O. (Conger) brevior (Koker). Posthumus, 1924, Foss. Cat., no. I, pars 24, p. S.
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Description. Sagitta medium size (maximum length observed, 7.1 mm .). somewhat ovate with pronounced angularity, moderately high (height/length ratios, 61 to 67 per cent), moderately inflated, greatest height slightly anterior to vertical midline. Dorsal margin rising from sharply rounded anterior margin in low asymmetrical arch, with greatest curvature in posterior portion; posterior margin sharply rounded to join broad asymmetrically arched ventral margin; greatest curvature of ventral margin near position of greatest height. Inner face moderately convex, smooth, with prominent sulcus but lacking area; sulcus undivided, separated from anterior by broad border, extending from about anterior fifth of sagitta to near posterior third; sulcus opens onto dorsal margin through ostial channel; ostial region slightly to moderately excavated, elongate, contiguous with caudal region and sometimes set off from it by faint constriction of sides, its anterior margin truncate; ostial channel considerably posterior to anterior margin of ostial region, moderately long, with subparallel sides, slightly flaring dorsally to open onto dorsal margin near position of greatest height; caudal region deeply excavated, with subparallel sides, slightly longer than ostial region on most specimens; crista superior faintly developed or absent;


Figure A. Structures of the congrid type sagitta. A-area; AB-anterior border; CR-caudal region of sulcus; D-dorsal dome; OC-ostial channel; OR-ostial region.
crista inferior moderately marked, region above sulcus convex, lacking area. Outer face somewhat convex, flattened in central region, sculptured with weak undulations especially in marginal regions. Dimensions (in mm.) :

| $\frac{\text { Length }}{2.5}$ |  | Height |  |
| :---: | :---: | :---: | :---: |
|  |  | 1.6 |  |
| 3.3 |  | Thickness |  |
| 4.4 |  | 0.6 |  |
| 4.7 |  | 0.9 | 0.8 |
| 4.9 |  | 3.0 | 1.3 |
| 5.3 | 3.6 | 1.4 |  |
| 5.4 | 3.3 | 1.3 |  |
| 5.4 | 3.4 | 1.6 |  |
| 5.5 | 3.7 | 1.3 |  |
| 6.3 | 4.2 | 1.3 |  |
|  |  | 1.4 |  |
|  |  | 2.1 |  |

Comparisons of sagittae. "Conger" brevior is very similar to "C." sanctus, new species, that occurs with it in the Oligocene but not in the upper Eocene. "Conger" brevior, however, is less evenly ovate or elliptical and has no area. Distinction of these species must be based on comparison of suites of specimens, unless they are perfectly preserved.

The species differs from "C" dissimilis, new species, in the less nearly ovate outline and the projection of the ostial region forward of the ostial channel. The position of the ostial channel also distinguishes "C." meridies, new species.

A number of species related to "C" brevior have been described from Tertiary deposits of other areas, under the names Conger, "Otolithus (Brotulidurum)," "O. (Congeris)," "O. (Congridarum)," "O. (incertae sedis)," Heterenchelys, and Uroconger. The relationship of most of these to "C." brevior cannot be established without comparison of specimens with sulcus and ostial channel perfectly preserved. For example, Priem compared " $O$. (Congeris)" papointi (1906, pp. 275-276, text figs. 40-45) and later "O. (Congeris)" dwergieri (1914, pp. 249-250, text fig. 9) with "C." brevior. Neither comparison is valid, as Priem's illustrations are of eroded specimens and Koken's type figure is completely inadequate.

Type locality. Eocene, Jackson group, Moody's Branch marl; Jackson, Mississippi.

Raxge and distribution. Oligocene, Vicksburg group: Byram marl, old Byram and Vicksburgh, Mississippi; Glendon limestone, Brandon, Mississippi; Mint Spring marl, Vicksburg, Mississippi; Red Bluff clay, Hiwannee, Mississippi, and equivalent strata at St. Stephens, Alabama. Eocene, Jackson group: Moody's Branch marl, Montgomery, Louisiana, and near Midway, Mississippi.

Remirfs. The type figure shows an immature specimen that could belong to this population or to that of "C." sanctus, new species. It is specifically unidentifiable. We are applying the name "C." brevior to this form, as

Figure 1. "Conger" sunctus Frizzell and Lamber, new species, holotype; Vicksburg group, Alabama; length, 9.0 mm . 1a. Inner face of right sagitta. 1b. Outer face.

Figure 2. "Conger" meridies Frizzell and Lamber, new species, holotype; Wilcox group, Mississippi; length, 4.3 mm . 2a. Inner face of right sagitta. 2b. Outer face.

Figure 3. "Conger" fornicatus Flizzell and Lamber, new species, holotype; Jackson group, Louisiana; length, 3.6 mm . 3a. Inner face of right sagitta. 3b. Outer face.

Figure 4. "Conger" brevior (Koken) ; Vicksburg group, Mississippi; length, 5.5 mm. 4a. Inner face of left sagitta. 4b. Outer face.

Figure 5. "Conger" dissimilis Frizzell and Lamber, new species, holotype; Jackson group, Louisiana; length, 4.5 mm . 5a. Inner face of left sagitta. 5b. Outer face.

Figure 6. Congcr? vetustus Frizzell and Lamber, new species, holotype; Jackson group, Louisiana; length, 4.4 mm . 6a. Imner face of right sagitta. 6b. Outer face.
"C." sanctus has not been identified at the type level of the nominal species. Details of the sulcus, as shown by Koken, are due to erosion of the anterior boundary of the ostial channel. The horizontal position of the sulcus, in his figure, is believed to be an error of the artist.

"Conger'" dissimilis Frizzell and Lamber, new species.
(Figures 5 a-b, 12 a-d.)
Description. Sagitta small to medium size (maximum length observed, 6.8 mm .), somewhat ovate in outline, high (height/length ratios, 71 to 80 per cent), moderately inflated, greatest height near anterior third of sagitta. Dorsal margin rising from rounded anterior margin in undulating high arch (or small dome) to meet sharply rounded posterior margin; ventral margin broadly and asymmetrically arched with greatest curvature coincident with

position of greatest height. Inner face moderately convex, smooth, with prominent sulcus and sometimes slightly developed area; sulcus undivided, separated from anterior by narrow border, extending from near anterior eighth of sagitta to near posterior third; sulcus opens onto dorsal margin through ostial channel; ostial region slightly excavated, contiguous with caudal region and sometimes set off from it by slight constriction of sides, its anterior margin rounded; ostial channel slightly posterior to anterior margin of ostial region, short to medium long, with nearly vertical sides, moderately flaring dorsally to open onto dorsal margin anterior to position of greatest height; caudal region moderately to deeply excavated with subparallel sides, of about same length as ostial region; cristae inferior and superior well marked; area slightly to very slightly impressed, somewhat triangular, extending upward into dorsal arch or dome. Outer face moderately convex, thickest at center, with poorly developed rugosities and pustules toward margins. Dimensions of holotype and selected paratypes (in mm.):

Figures 7-12. Diagrammatic sketches of inner face.
Figure 7. "Conger" sanctus Frizzell and Lamber, new species; holotype and paratypes. 1a. Holotype, reversed; Vicksburg group, Alabama; length, 9.0 mm . 1b. Reversed; Vicksburg group, Mississippi; length, 5.6 mm . 1c. Vicksburg group, Mississippi; length, 6.0 mm .1 d . Vicksburg group, Alabama; length, 4.2 mm .

Figure 8. Conger? vetustus Frizzell and Lamber, new species; holotype and paratypes. 8a. Holotype, reversed; Jackson group, Mississippi; length, 4.4 mm .8 b . Reversed; Jackson group, Louisiana; length, 4.2 mm .8 c . Reversed; Jackson group, Louisiana; length, 3.6 mm . 8d. Reversed; Jackson group, Louisiana; length, 2.8 mm .

Figure 9. "Conger" fornicatus Frizzell and Lamber, new species; holotype and paratypes; Jackson group, Louisiana. 9a. Holotype, reversed; length, 3.6 mm .9 b . Reversed; length, 3.0 mm . 9c. Reversed; length, 2.8 mm . 9d. Reversed; length, 3.1 mm .

Figure. 10. "Conger" brevior (Koken); Vicksburg group, Mississippi. 10a. Same as figure 4 ; length 5.5 mm .10 b . Length, 5.4 mm . 10c. Length, 5.3 mm . 10 d . Reversed; length, 4.7 mm .

Figure 11. "Conger" meridies Frizzell and Lamber, new species; holotype and paratypes. Wilcox group, Mississippi. 11a. Holotype, reversed; length, 4.3 mm . 11b. Reversed; length, 3.6 mm . 11c. Length, 2.7 mm . 11d. Length, 2.5 mm .

Figure 12. "Conger" dissimilis Frizzell and Lamber, new species; holotype and paratypes; Jackson group, Louisiana. 12a. Holotype; length, 4.5 mm . 12b. Length, 5.3 mm . 12c. Reversed; length, 4.6 mm . 12d. Reversed; length, 4.3 mm .

| Length | Height | Thickness | Remarks |
| :---: | :---: | :---: | :---: |
| 2.6 | 1.9 | 0.9 |  |
| 3.8 | 2.9 | 1.1 |  |
| 3.8 | 3.0 | 0.9 |  |
| 4.3 | 3.4 | 1.3 |  |
| 4.4 | 3.5 | 1.3 |  |
| 4.5 | 3.4 | 1.3 | Holotype |
| 4.6 | 3.6 | 1.5 |  |
| 5.2 | 4.0 | 1.5 |  |
| 5.8 | 4.1 | 1.7 |  |
| 6.8 | 5.0 | 1.5 |  |

Comparisons of sagittae. "Conger" dissimilis differs from "C." brevior (Koken) and "C." sanctus, new species, by its higher outline, greater convexity, and in lacking a marked anterior projection of the ostial region beyond the ostial channel. It is separated from "C." meridies, new species, by its greater relative height and angularity in outline. As with "C." brevior (see above), comparison with described extra-American forms is unprofitable at this time.

Type locality. Eocene, Jackson group, Moody's Branch marl; Montgomery ferry landing, Montgomery, Louisiana.

Range and distribution. The species is known only from the type locality.
Remarks. The specific name is a Latin adjective indicating the lack of similarity of this form to the sagittae of associated species.

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"Conger" fornicatus Frizzell and Lamber, new species.
(Figures 3 a-b, 9 a-d.)
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Description. Sagitta small (maximum length observed, 3.6 mm .), somewhat triangular in outline, very high (height/length ratios, 77 to 88 per cent), slightly inflated, greatest height at or forward of vertical midline. Dorsal margin rising from acutely rounded anterior margin in slightly incurved arch to form high dorsal dome, then descending in slightly incurved arch to join sharply rounded posterior margin; dorsal dome highly developed, somewhat quadrate, with bevelled top sloping toward anterior margin; ventral margin broadly arched, with greatest curvature slightly forward of position of greatest height. Inner face almost flat, smooth, with prominently developed sulcus and area; sulcus undivided, separated from anterior by moderately broad border, extending from about anterior sixth to posterior third of sagitta; sulcus opens onto dorsal margin through ostial channel; ostial region slightly excavated, short, contiguous with caudal region and usually set off by slight constriction (on well preserved specimens), its anterior margin truncate; ostial channel slightly posterior to anterior margin of ostial region, moderately long; anterior boundary of ostial channel nearly
straight, bending forward at termination, posterior boundary bending backward and upward; caudal region deeply excavated, with subparallel sides, longer than ostial region; cristae superior and inferior well developed, with crista superior following configuration of posterior boundary of ostial channel; area very prominent, deeply impressed, variable in outline (usually somewhat triangular), extending high into dorsal dome. Outer face smooth, slightly to moderately convex, thickest at center and in region of dorsal dome. Dimensions of holotype and selected paratypes (in mm.) :

| $\frac{\text { Length }}{1.9}$ | $\frac{\text { Height }}{1.6}$ | $\frac{\text { Thickness }}{0.5}$ | Remarks |
| :---: | :---: | :---: | :---: |
| 2.0 | 1.6 | 0.5 |  |
| 2.7 | 2.1 | 0.6 |  |
| 2.7 | 2.4 | 0.7 |  |
| 2.8 | 2.0 | 0.7 |  |
| 3.0 | 2.1 | 0.8 |  |
| 3.0 | 2.3 | 0.8 |  |
| 3.1 | 2.4 | 0.8 |  |
| 3.6 | 2.7 | 1.0 |  |
| 3.6 | 2.8 | 0.9 | Holotype |

Comparisons of sagittae. "Conger" fornicatus is distinguished by its characteristic outline from all other forms known to us, including those illustrated in available literature.

Type locality. Eocene, Jackson group, Danville Landing shale (lower shell marl bed), Duty ferry landing, Duty, Louisiana.

Range and distribution. The species is known only from the type locality.
Remarks. The specific name fornicatus is a Latin adjective indicating the arched appearance of the sagitta produced by the development of the dorsal dome.

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"Conger"' meridies Frizzell and Lamber, new species.
(Figures 2 a-b, 11 a-d.)
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Description. Sagitta medium small to medium size (maximum length observed, 6.7 mm .), somewhat ovate with pronounced angularity, moderately high (height/length ratios, 59 to 73 per cent), slightly to moderately inflated, greatest height at or anterior to vertical midline. Dorsal margin rising from sharply rounded anterior margin in moderately asymmetrical arch with greatest curvature at position of greatest height; posterior margin rounded with development of rugosities, joining broadly and asymmetrically arched rentral margin with greatest curvature at position of maximum height. Inner face smooth, slightly convex, with prominent sulcus but lacking area; sulcus
undivided, separated from anterior by very narrow border, extending from about anterior tenth to near posterior third of sagitta; sulcus opens onto dorsal margin through ostial channel; ostial region moderately excavated, short, contiguous with caudal region and sometimes set off from it by slight constriction of sides, its anterior margin rounded; ostial channel slightly posterior to anterior margin of ostial region, moderately long, directed upward and slightly backward, expanding in central region before constricting somewhat and opening onto dorsal margin at position of greatest height; caudal region longer than ostial, deeply excavated, with subparallel sides, expanding and rounded at posterior end; crista superior well marked, intensifying outline of sulcus; crista inferior slightly less developed; area absent. Outer face moderately convex on most specimens, thickest at center, with undulating surface along margins. Dimensions of holotype and selected paratypes (in mm.):

| $\frac{\text { Length }}{2.5}$ | $\frac{\text { Height }}{1.7}$ |  | Thickness |  |
| :---: | :---: | :---: | :---: | :---: |
| 2.7 | 1.6 | 1.1 |  |  |
| 3.3 | 2.0 | 1.0 |  |  |
| 3.3 | 2.1 | 0.9 |  |  |
| 3.6 | 2.4 | 0.9 |  |  |
| 3.6 | 2.6 | 0.9 |  |  |
| 3.8 | 2.8 | 1.1 |  |  |
| 4.3 | 2.8 | 1.1 |  |  |
| 4.3 | 2.9 | 1.1 | Remarks |  |
| 4.8 | 3.2 | 0.9 |  |  |
|  |  | 1.0 |  |  |

Comparison of sagittae. "Conger" meridies is lower, less convex, and less angular in outline than "C." dissimilis, new species. It somewhat resembles "C." brevior (Koken) and "C." sanctus, new species. Those, however, are distinguished by an anterior prolongation of the ostial region of the sulcus, forward of the ostial chamnel, that is much less developed in " $C$." meridies. As with "C." brevior (see above), similarities to extra-American forms cannot be determined at this time.

Type locality. Eocene, Wilcox group, Bashi marl; Meridian, Mississippi.
Range and distribution. "Conger" meridies is known only from uncommon otoliths at its type locality.

Realaks. The specific name, the Latin word for a geographic meridian, is in recognition of the trpe locality of the species: Meridian, Mississippi. It is a noun in apposition.

[^5]Description. Sagitta moderately large (maximum length observed, 9.0 mm .), somewhat ovate in outline, moderately high (height/length ratios, 62 to 72 per cent), moderately inflated, greatest height variable in relation to position of vertical midline. Dorsal margin rising from sharply rounded anterior margin in low nearly symmetrical arch; posterior margin moderately rounded to join arched ventral margin. Inner face moderately convex, smooth, with prominent sulcus and shallow area; sulcus undivided. separated from anterior by narrow border, extending from about anterior eighth of sagitta to near posterior third; sulcus opens onto dorsal margin through ostial channel; ostial region slightly excavated, elongate, contiguous with caudal region and sometimes set off by slight constriction of its sides, its anterior margin truncate; ostial channel very much posterior to anterior margin of ostial region, moderately long to long, with subparallel sides, slightly flaring dorsally to open onto dorsal margin slightly anterior to position of greatest height; caudal region deeply excavated, as long as ostial region, with nearly parallel sides; crista superior marked above candal region, degenerate along ostial region; crista inferior well marked; area variable in outline and size (predominantly elliptical), slightly to moderately impressed. Outer face slightly to moderately convex, flattened in central region; sculpture lacking or consisting of irregular undulations or bosses adjacent to margins. Dimensions of holotype and selected paratypes (in mm.) :

| $\frac{\text { Length }}{2.5}$ | $\frac{\text { Height }}{1.8}$ |  | Thickness |  |
| :---: | :---: | :---: | :---: | :---: |
|  | 0.8 |  |  |  |
| 3.3 | 2.1 | 0.8 |  |  |
| 4.2 | 2.7 | 0.9 |  |  |
| 4.8 | 3.1 | 1.1 |  |  |
| 5.6 | 3.8 | 1.2 |  |  |
| 5.7 | 3.6 | 1.3 |  |  |
| 6.0 | 4.1 | 1.4 |  |  |
| 6.1 | 4.0 | 1.5 |  |  |
| 9.0 | 5.6 | 2.3 | Holotype |  |

Comparisons of sagittate." Conger" sunctus is extremely like "C."brevior (Koken), but is distinguished by the presence of an area and by the slight difference in outline. "Conger" meridies, new species, and "C." dissimilis, new species, also lack the area and differ in outline, as well as having less well developed projection of the ostial region anterior to the ostial chamel.

As with "C." brevior (Koken) (see above), similarities to extra-American forms cannot adequately be determined from the literature. One species from the European upper Oligocene ("C." fallax (Koken), 1891, p. 139, pl. 10, fig. 3; as Otolithus (incertae sedis)), however, appears to be extremely similar to " $C$." sunctus, and the two may prove to be identical.

Type locality. Oligocene, Vicksburg group, Red Bluff clay equivalent; St. Stephens Quarry, St. Stephens, Alabama.

Range and distribution. Oligocene, Vicksburg group: Glendon limestone, Brandon, Mississippi; Red Bluff clay, Hiwannee, Mississippi; Red Bluff clay equivalent, St. Stephens, Alabama.

Remarks. The specific name sanctus (Latin for "sacred") refers to the type locality at St. Stephens Quarry. It is an adjective.

Conger? vetustus Frizzell and Lamber, new species.
(Figures 6 a-b, 8 a-d.)
Description. Sagitta small to medium large (maximum length observed, 4.8 mm .; one broken specimen has an estimated length of 7.3 mm .), sublanceolate, low (height/length ratios, 40 to 50 per cent), moderately inflated, greatest height at or slightly anterior to vertical midline. Dorsal margin rising from acute anterior margin in low arch; posterodorsal slope with one or more pronounced coarse rugosities (in well preserved specimens) before meeting acute posterior margin; ventral margin broadly arched. Inner face moderately convex, smooth, with prominent sulcus and area; sulcus undivided, separated from anterior by moderately broad border, extending from about anterior fifth to posterior third; sulcus opens onto dorsal margin through ostial channel; ostial region prominently excavated, short, contiguous with caudal region and sometimes set off from it by constriction of sides, its anterior margin rounded; ostial channel slightly posterior to anterior margin of ostial region, short and very wide; anterior boundary of ostial channel nearly straight, bent forward at termination, posterior boundary extending far backward near dorsal margin; caudal region deeply excavated, with subparallel sides, more than twice length of ostial region; crista superior well marked, bending to follow configuration of posterior boundary of ostial channel; crista inferior marked, especially below caudal region; area deeply impressed, predominantly elongate-elliptical. Outer face smooth, moderately convex, thickest along horizontal midline. Dimensions of holotype and selected paratypes (in mm.):

| $\frac{\text { Length }}{2.5}$ | $\frac{\text { Height }}{1.1}$ |  | Thickness |
| :--- | :--- | :--- | :--- |
| 2.6 | 1.2 | 0.6 | Remarks |
| 2.8 | 1.4 | 0.6 |  |
| 3.0 | 1.2 | 0.7 |  |
| 3.6 | 1.5 | 0.6 |  |
| 4.2 | 1.8 | 0.6 |  |
| 4.4 | 1.8 | 0.7 |  |
| 4.7 | 1.9 | 0.7 | Holotype |
| 4.7 | 0.7 |  |  |

Comparisons of sagittae. Conger? vetustus is unlike other forms yet encountered in the American lower Tertiary. The sagitta resembles that of Conger conger (Linnaeus) of the Recent (Chaine, 1938, pp. 234-241, pl. 17). It differs from the adult sagitta of C. conger in having a shorter, narrower, better defined, and more sloping sulcus, and the anterior end is more sharply rounded. The sagitta of $C$.? vetustus, however, is extremely similar to that of juvenile $C$. conger as figured by Chaine.

Type locality. Eocene, Jackson group, Moody's Branch marl; Riverside Park, Jackson, Mississippi.

Range and distribution. The species is known from the Moody's Branch marl of Jackson, Mississippi, and Montgomery, Louisiana. It is rare at both localities.

Remarks. The similarity of $C$ ? vetustus to otoliths of young Conger conger (see above) may have some phylogenetic significance. It suggests that C.? vetustus belongs to a lineage that is ancestral to living species of Conger s.s.

The specific name is a Latin adjective meaning ancient.

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# THE HERPETOLOGY OF NEPAL： <br> A HISTORY，CHECK LIST， AND ZOOGEOGRAPHICAL ANALYSIS OF THE HERPETOFAUNA 

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## INTRODUCTION

Herpetological collecting in Nepal has been sporadic and the literature describing the Nepalese herpetofauna has appeared irregularly and infre－ quently for more than a century．Prior to 1948 little was known of the fauna of the country beyond the centrally located capital of Katmandu，but during the last few years the remote regions have become more readily accessible and several important collections of animals and plants have been made．

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Motivation for the present paper, in which we attempt to collate all hitherto published data dealing with Nepalese amphibians and reptiles, was derived from a joint interest in Himalayan zoogeography on the part of the authors. Nepal lies at the crossroads of four major faunal units. The Mediterrancan and West Chinese divisions of the Palearctic Region meet the Indian and Indochinese subregions of the Oriental Region, and an understanding of the Nepalese fauna is basic to a study of the evolution and distribution of the high altitude fauna of southeast Asia.

The present report is divided into three parts. The first, a history of herpetological work in Nepal, is based on a collation of published works reporting on collections of amphibians and reptiles obtained in that country. A check list of amphibians and reptiles known to occur in Nepal follows; in this list all literature containing Nepal records are noted in the respective species synonymies and are the only citations so listed. The third section of this report represents a zoogeographical analysis of the herpetofauna of Nepal. In view of the fact that this analysis is based upon an incomplete knowledge of the country's fauna, we have prepared a detailed table (table I), in which all species known to occur in Nepal and adjacent areas, or in adjacent areas but which have not yet been recorded from Nepal, have been listed. The table indicates the geographical relationships of the known fauna, and suggests species which are still likely to be found in the country.

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## IIISTORY

The earliest collector of Nepalese amphibians and reptiles, to the best of our knowledge, was Brian Hodgson who occupied the British Residence in Katmandu during the years 1820 to 1822, and 1824 to 1843 . Although IIodeson was preceded in Nepal by at least two earlier naturalists, Nathaniel Wallich, in 1817, and Francis Buchanan-Hamilton, in 1802-1803, both of whom resided in Katmandu for short periods, there is no evidence that either obtained any amphibians or reptiles for museum specimens.

During his residence in Nepal, Hodgson distinguished himself as an authority in many disciplines, among which his researches in ethnology, Buddhism, ornithology, and mammalogy are preeminent. In addition to his normal diplomatic duties he found time to publish 127 papers on zoological subjects, although none dealt with amphibians or reptiles. His prime contribution to the field of herpetology was through his collection of Nepalese fama, the specimens of which, presented to the British Museum in 1858, included 9,512 specimens of birds, 903 mammals, and 84 reptiles, and a
number of drawings of which there were 1241 sheets of birds, 557 sheets of mammals, and 55 sheets of reptiles (Hunter, 1896).

Several years before his final return to England, delayed until 1858, a few of Hodgson's specimens found their way to London and were described by Cantor (1839); they were also included in Gray's Catalogues of the British Museum herpetological collection (1844-1850). On his arrival in England, Hodgson turned over the bulk of his collections of amphibians and reptiles to Albert Günther who, in a series of three papers (1858, 1860, 1861), described their contents. In 1864, Giinther monographed the reptilian fauna of "British India," incorporating the results of his earlier studies of the IIodgson material in the volume. In addition, he listed a single specimen of the agamid lizard Calotes versicolor, said to have been collected in Nepal by Thomas Hardwicke, and a turtle, Chitra indica, supposedly obtained by the botanist Hugh Falconer who, with Hardwicke, was one of several naturalists to visit Nepal in the early years of British contact with that country. All other Nepalese records given by Günther are attributed to Brian Hodgson.

Hodgson's influence at the Nepalese court enabled him to obtain a unique concession from the Prime Minister to permit Joseph Hooker access to eastern Nepal during the course of the latter's botanical travels in Sikkim. Hooker's collection of amphibians and reptiles are all reported as being obtained in Sikkim; there is no precise indication in known literature sources that he obtained any amphibians or reptiles while he was traveling in Nepal between November 5, 1848 and December 15, 1848 (Hooker, 1854, vol. 1, pp. 186-280).

Although Katmandu was visited periodically by European naturalists (including Hermann Schlagintweit, in 1856) and by Nepalese and Indian collectors during a sixty year period (1858-1906) following Hodgson's work there, there is scarcely any published evidence to indicate that amphibians or reptiles were collected. There is, however, one notable exception. In his lists of amphibians and reptiles in the Indian Museum (1891 and 1892), William Sclater gives Katmandu as the locality for specimens of several species stored in that museum's collections. Unfortunately, there is no indication who collected the material.

In 1907, Nelson Annandale, George Boulenger, and Frank Wall described a substantial collection of amphibians and reptiles obtained in the vicinity of Katmandu by R. Hodgart. Several new records, including two species of frogs, five lizards, and five snakes, are given for Nepal. Subsequently, in a series of papers published by Wall (1907-1924), a number of snakes were recorded for the first time from the country. Included among these is Psammodynastes pulverulentus, the only indication for its occurrence in Nepal being a distribution map published by Wall, in 1910, in which the locality Butal $[=$ ? Butwal $]$, Nepal, is given as a collecting site.

In 1913, Boulenger described a small collection of amphibians and reptiles taken at the extreme eastern frontier of Nepal, immediately adjacent to the Darjeeling District of Bengal, collected by N. H. Stevens. Two new snake records were included.

With publication of the reptile volumes in the Fauna of British India series (1931, 1935, and 1943), the widely scattered literature on reptiles of southern Asia was brought together for the first time. The three volumes on reptiles, written by Malcolm Smith, stand as the single most important contribution to Asian herpetology published to date. In preparing these works it was obviously impractical for Smith to give detailed locality, collector, date, and available ecological information for all the material he examined. Consequently, specific consideration of the reptiles of any one region, for example Nepal, is not possible in these volumes, and resort must. be made to the original literature. Regretfully, a comparable volume dealing with the amphibians of southern Asia has not been published.

Since 1948 , Nepal has been visited by numerous expeditions, and there are few portions of the country which have not been investigated by persons interested in the fauna and flora. Nevertheless, the published literature suggests that only a few expeditions have obtained amphibians and reptiles in the course of their activities.

In 1949, an expedition under the leadership of II. W. Tilman explored the Langtang Iimal, north of Katmandu. Herpetological collections were made by Oleg Polunin and were deposited in the British Museum where Nalcolm Smith examined them and prepared a report published in 1951. An interesting ecological analysis of this Himalayan area was prepared by Polunin and published as an appendix to Tilman's "Nepal Himalaya" (1951).

Western Nepal was visited, in 1952, by an expedition sponsored by the British Museum and the Royal Horticultural Society. Oleg Polumin accompanied this group and again secured a number of amphibians and reptiles which are of special interest because of the altitude records. Malcolm Smith and James C. Battersby of the British Museum described this collection in 1953. Six new records of amphibians and reptiles in Nepal were reported on in this paper.

In 1954, the California-IImalaya Expedition to Makalu traversed eastern Nepal in the vicinity of the Arun River (a descriptive summary of this expedition was prepared by Houston and Long [1955] and a discussion of high-altitude ecology by Swan [1961]). The collections of amphibians and reptiles, made by Lawrence Swan, and including eight new records and a new species of frog from Nepal, were deposited in the Natural History Museum of Stanford University. Alan Leviton, George Myers, and Lawrence Swan reported on this collection in 1956 and, as an addendum to the paper, the authors also described a small collection of amphibians from Katmandu and Pokhara obtained by Alan Taft earlier that year.

Recently, a few specimens of Natrix piscator were collected by the joint Harvard-Yale universities expedition to central Nepal. In addition, several snakes and frogs from Nepal were obtained for the Chicago Natural History Museum by Dr. Robert L. Fleming in the vicinity of Katmandu. These collections are reported in this paper for the first time. Collections of amphibians and reptiles made by L. W. Swan during 1960 in eastern Nepal between Katmandu and Darjeeling are not reported in this paper.

## CHECKLIST OF NEPALESE AMIPIIIBLANS AND REPTILES²

## Class AMPHIBIA

## Order Salientia

Family Bufonidae

Bufo andersoni Boulenger.
Bufo andersoni, Leviton, Myers, and Swan, 1956, p. 4 (above Tamur River [1000 ft.]).
Range in Nepal. Eastern ${ }^{3}$ (Tamur Valley).
Bufo himalayanus Günther.
Bufo himalayanus Güntuer, 1864, p. 422 (type loc.: Nepal and Sikkim). Boulevger, 1882, p. 305 (Nepal). Smith, 1951, p. 727 (Thangjet [5000 ft.]; Syarpagaon [Langtang Khola, $8000-9000 \mathrm{ft}$.]; Rasua Garhi District). Saitil and BatTERSBY, 1953, p. 703 (Jumla [7600 ft.]).
Bufo melanostictus (nec Schneider) Günther, 1860. p. 165 (Nepal); 1831, p. 220 (Nepal).
Range in Nepal. Central (Thangjet ${ }^{4}$, Syarpagaon, Rasua Garhi) ; Western (Jumla).

Bufo melanostictus Schneider.
Bufo metanostictus, Sclater, 1892, p. 27 (Katmandu). Bovlenger, 1907, p. 149 (Chitlong; Soondrijal). Levitox, Myers, and Swan, 1956, pp. 4 and 14 (near Khandbari [7000 ft.]; near Dhankuta [6000 ft.]; near Num [5000 ft.]; near Yetung [8500 ft.]; Kalimati).
Chicago Natural History Museum 83096 (Patan).
Range in Nepal. Eastern (Dhankuta, Khandbari, Num, Yetung); Central (Chitlang, Kalimati, Katmandu, Sundarijal, Patan).

[^7]
## Family Microhylidae

Microhyla ornata (Duméril and Bibron).
Microhyla ornata, Levitox, Myers, and Swan, 1956, p. 5 (Khandbari [4000 ft.]). Range in Nepal. Eastern (Khandbari).

## Family Pelobatidae

Scutiger sikkimmensis (Blyth).
Scutiger sikkimensis, Saiti, 1951, p. 727 (Langtang Village [11,000 ft.]). Sмitи and Battersby, 1953, p. 703 (Khola north of Maharigaon [13,500 ft.]). Range in Nepal. Central (Langtang Village); Western (Maharigaon).

## F'amily Ranidae

## Rana breviceps Schneider.

Rana breviceps, Leviton, Myers, and Swan, 1956, p. 5 (Dharan [1000 ft.]). Range in Nepal. Eastern (Dharan).

Rana cyanophlyctis Schneider.
Rana cyanophlyctis, Sclater, 1892, p. 2 (Katmandu). Boulenger, 1907, p. 150 (Soondrijal; Pharping) ; 1920, p. 12 (Nepal). Leviton, Myers, and Swan, 1956, pp. 6, 14 (Tamur River [ 500 ft .]; near Dhankuta [ 4500 ft ]; near Num [6000 ft.]; near Khandbari [4500 ft.]; above Arun River [3500 ft.]; Sandarijal; near Pokhara [Mardi Khola]).
Range in Nepal. Eastern (Arun River, Dhankuta, Khandbari, Num, Tamur River) ; Central (Katmandu, Pharping, Pokhara, Sundarijal).

Rana formosa (Günther).
Rana formosu, Boulexger, 1907, p. 151 (Soondrijal). Smith, 1951, p. 727 (Rasua Garhi [6000 ft.]).
Range in Nepal. Central (Rasua Garhi, Sundarijal).
Rana liebigii Günther.
Rana liebigii Günther, 1860, p. 157, pl. 28, fig. A (Nepal and Sikkim); 1861, p. 220 (Nepal) ; 1864, p. 407 (Nepal). Boulenger, 1913, p. 337 (Sandakpho [11,500 ft.]) ; 1920, p. 80 (Nepal [types]). Smith, 1951, p. 727 (Rasua Garhi [6000 ft.]). Leviton, Myers, and Swax, 1956, p. 6 (near Num [5000 ft.]).
Range in Nepal. Eastern (Num, Sundakphu); Central (Rasua Garhi).

## Rana limnocharis Wiegmanm.

Rana limnocharis, Sclater, 1892, p. 6 (Katmandu). Boulenger, 1907, p. 151 (Soondrijal). Leviton, Myers and Swan, 1956, p. 6 (above Yetung [ 7000 ft.$]$; near Dhankuta [4500 ft.]; Arun River [1000 ft.]; below Yetung [4000 ft.]; near Num [3500 ft.]; above Dhankuta [6000 ft.]).
Range in Nepal. Eastern (Arun River, Dhankuta, Num, Yetung); Central (Katmandu, Sundarijal).
Rana monticola (Anderson).
Leptobatrachium monticola, Boctenger, 1907, p. 149 (Soondrijal). Range in Nepal。 (entral (Sundarijal).

Rana polunini Smith.
Rana polunini Smitir, 1951, p. 727 (Langtang Village [11,000 ft.], Nepal). Range in Nepal. Central (Langtang Village).

Rana swani Myers and Leviton.
Rana swani Myers and Leviton, 1956, p. 4 (Dharan [1000 ft.], Nepal).
Range in Nepal. Eastern (Dharan; may also be represented in Arun Valley (see Leviton, Myers, and Swan, 1956, p. 6]).

Rana tigrina Daudin.
Rana tigrina, Günther, 1860, p. 164 (Nepal); 1861, p. 220 (Nepal). Boulenger, 1907, p. 151 (Katmandu [4000-5000 ft.]; Soondrijal); 1920, p. 19 (Nepal). Leviton, Myers, and Swan, 1956, p. 14 (Kalimati).
Chicago Natural History Museum 83091-8309t (Katmandu).
Range in Nepal. Central (Kalimati, Katmandu, Sundarijal).

## Family Rhacophoridae

Rhacophorus maculatus (Gray).
Polypedates maculatus, Günther, 1861, p. 220 (Nepal).
Rhacophorus maculatus, Leviton, Myers, and Swas, 1956, p, 9 (above Num [5000 it.]).
Range in Nepal. Eastern (above Num) ; Central (without exact locality data ${ }^{2}$ ).

Rhacophorus maximus Günther.
Rhacophorus maximus Günther, 1858, p. 83 (Nepal); 1860, p. 165 (Nepal); 1861, p. 220 (Nepal); 1864, p. 435 (Nepal [5200 ft.]).

Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

## Class REPTILLA <br> Order Crocodilia <br> Family Crocodilidae

Gavialis gangeticus (Gmelin).
Gavialis gangeticus, Güntier, 1861, p. 215 (Nepal).
Range in Nepal. Central (without exact locality dataㄹ).
Order Testudinata
Family Emydidae
Kachuga dhongoka (Gray).
Batagur dhongoka, Günther, 1861, p. 214 (Nepal); 1864, p. 42 (Nepal). Tilcobald, 1876, p. 22 (Nepal).
Range in Nepal. Central (without exact locality data ${ }^{2}$ ).
Kachuga kachuga (Gray).
Batagur lineata (Gray), Gü xtier, 1861, p. 214 (Nepal).
Batagur kachuga, Theobald, 1876, p. 19 (Nepal).

Kachuga kachuga, Smiti, 1931, p. 131 (Nepal).
Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

## Family Testudinidae

Testudo elongata Blyth.
Testudo horsfieldi, Gǘnther, 1861, p. 214 (Nepal); 1864, p. 7 (Nepal).
Smith (1931, p. 143) states,"Modgson obtained a specimen in the Saul forests of Nepal and has left a fine coloured sketch of it in his collection of drawings." It is uncertain whether Smith considered Hodgson's drawing (which Günther described as T. horsfieldi, supra cit.) to be T'. elongata or whether Smith's reference is in error.

Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

## Family Trionychidae

Chitra indica (Gray).
Chitroa indica, GưNTher, 1861, p. 214 (Nepal); 1864, p. 50 (Nepal). Smith, 1931, p. 162 (Nepal).

Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

## Trionyx gangeticus Cuvier.

Trionyx gangeticus, Güntiler, 1861, p. 214 (Nepal); 1864, p. 47 (Nepal). Smith, 1931, p. 167 (base of Nepal foothills).
Trionyx javanicus Gray, Gínther, 1861, p. 214 (Nepal).
Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

Order Squamata<br>Suborder Sauria<br>Family Agamidae

Agama tuberculata Gray.
Agama tuberculata, Annandale, 1907, p. 154 (Chitlong). Smitif, 1935, p. 214 (Kashmir to Katmandu) ; 1951, p. 728 (Chattekhola [Rasua Garhi District], Rasua Garhi [7000 it.]). Silith and Battersby, 1953, p. 703 (Jumla [7600 ft.]).
Range in Nepal. Central (Chattekhola, Rasua Garhi, Chitlang); Westeln (Jumla).

Calotes versicolor (Daudin).
Calotes versicolor, Gray, 1845, p. 243 (Nepal). Günther, 1860, p. 140; 1864, p. 215 (Nepal). Annindale, 1907, p. 153 (Katmandu). Smitir, 1935, p. 189 (Nepal); 1951, p. 728 (Rasua Garhi District). Smith and Battersby, 1953, p. 703 (Lapha [Karnali Valley, 4000 ft.]). Leviton, Myers, and Swan, 1956, p. 10 (above Dharan [1500 ft.], Arun Valley [1000 and 2000 ft .], near Khandbari [3000, 4500 and 7000 ft .], below Yetung [4000 ft.]).
Range in Nepal. Eastern (Arun River Valley, Dharan, Khandbari, Yetung) ; Central (Katmandu, Rasua Garhi).

## Japalura major (Jerdon).

Japalura major, Smith and Battersby, 1953, p. 703 (Barbung Khola, Kakkatgaon [1200 ft. sic], above Rimi [ $10,500 \mathrm{ft}$.], Samala [7500 ft.], Chaudhabise Khola [10,000 ft.]).
Range in Nepal. Western (Barbung Khola, Kakkatgaon, Rimi, Samala, Chaudhabise Khola).

Japalura tricarinata (Blyth).
Acanthosaura tricarinuta, Annandale, 1907, p. 153 (Chandragiri [8000 ft.]).
Japalura tricarinata, Sıith, 1935, p. 169 (eastern Nepal); 1951, p. 728 (Langtang Khola [9500 ft.]). Range in Nepal. Central (Chandragiri, Isangtang Khola).

## Family Gekkonidae

Cosymbotus platyurus (Schneider).
Hemidactylus nepalensis Annandale, 1907, p. 151 (Katmandu).
Platyurus platyurus, Smiti, 1935, p. 102 (Nepal).
Cosymbotus platyurus, Leviron, Myers, and Swan, 1956, p. 9 (Khandbari [4000 ft.]). Range in Nepal. Eastern (Khandbari); Central (Katmandu).

Hemidactylus frenatus Schlegel.
Hemidactylus frenatus, Leviton, Myers and Swan, 1956, p. 10 (Dharan [1000 ft.]). Range in Nepal. Eastern (Dharan).

## Family Scincidae

Leiolopisma himalayanum (Günther).
Lygosoma himalayanum, Axvindale, 1907, p. 154 (Chitlong).
Leiolopisma himalayanum, Smith, 1935, p. 299 (Nepal). Smitil and Battersby, 1953, p. 703 (Jumla [7600 ft.]). Range in Nepal. Central (Chitlang); Western (.Jumla).

Leiolopisma ladacensis (Giinther).
Leiolopisma ladacense. Suith and Battersby, 1953, p. 703 (Balangra Pass, Tibrikot [11,500 to $12,000 \mathrm{ft}$.], Phoksumdo Tal [14,000 ft.], Pemringgaon [16,000 ft.], Kahajeng Khola [18,000 ft.]).
Range in Nepal. Western (Balangra Pass, Tibrikot, Phoksumdo Tal, Pemringgaon, Kahajeng Khola).

Leiolopisma sikkimense (Blyth).
Lygosoma sikkimense, Avxixpale, 1907, p. 154 (Chitlong, Katmandu).
Leiolopisma sikkimense, Sxitir, 1935, p. 301 (Chitlong, Katmandu) ; 1951, p. 728 (Thangjet [5000 ft.]). Range in Nepal. Central (Chitlang, Katmandu, Tangjet).

Mabuya carinata (Schneider).
Mabuya cerinata, Leviton. Myers. and Swan, 1956, p. 11 (Yetung [4500 ft.]). Range in Nepal. Eastern (Yetung).

Mabuya macularia (Blyth).
Tiliqua rufescens (nec Shaw) Gray, 1853, p. 388 (Nepal). Güntimer, 1860, p. 160 (Nepal); 1861, p. 215 (Nepal).
Euprepes rufescens. Gïntuek, 1863, p. 79 (Nepal).
Mabuia macularia. Annandale, 1907 , p. 154 (Terai near Raxaul [Nepal frontier]). Range in Nepal. Central (Raxaul).

Riopa punctata (Gmelin).
Riope punctata, Leviton, Myers, and Swan, 1956, p. 11 (Dharan [1000 ft.]). Range in Nepal. Eastern (Dharan).

## Family Varanidae

## Varanus flavescens (Gray).

Empagusia flavescens, Güvtner, 1860, p. 159 (Nepal); 1861, p. 215 (Nepal).
Varamus flavescens, Güntuer, 1864, p. 65 (Nepal).
Range in Nepal. Central (without exact locality data ${ }^{2}$ ).
Varanus monitor (Limnaeus).
Varanus heraldicus (Gray), Grar. 1845, p. \& (Nepal). Günturr, 1860, p. 160 (Nepal) ; 1861, p. 215 (Nepal).
Varanus dracaent (Gray), Gï̀ntier, 1864, p. 65 (Nepal).
Varames monitor, Surtif, 1935, p. 402 (Nepal). Leviton, Myers, and Swan. 1956, p. 11 (sight record; below Khandbari [4000 ft.], and north of Dhankuta).

Range in Nepal. Eastern (below Khandbari, north of Dhankuta; both sight records); Central (without exact locality data ${ }^{2}$ ).

Suborder' Serpentes<br>Family Boidae

Python molurus (Linnaeus).
Python molurus. GÖxtifer, 1861, p. 215 (Nepal; known from colored drawing). Wall, 1907, p. 155 (Bichiakoh [Nepal terai]). Range in Nepal. Central (Bichiakoh).

## Family Colubridae

Boiga ceylonensis ((iünther).
Dipsadomorphus muchatis (Gï̀tier), Wali, 1924, p. 872 (Chitlong).
Boigu ceylonensis, Smitir, 194\%, p. 251 (Chitlong).
Range in Nepal. Cential (Chitlang).
Boiga multifasciata (Blyth).
Dipsadomorphus multifasciata, Wail, 1907, p. 157 (Chitlong); 1924, p. 871 (Chitlong).
Boige multifasciata, Smith, 1943, p. 357 (Nepal). Range in Nepal. Central (Chitlang).

Boiga trigonata (Schneider).
Chicago Natural History Museum 83087 (Ampipalbhanjan [4000 ft.]);
CNHM 83089 (Katmandu [4000 ft.]).
Range in Nepal. Central (Ampipalbhanjan, Katmandu).
Coluber fasciolatus Shaw.
Coryphodon fasciolatus, Güxtier. 1861, p. 218 (Nepal). Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

Elaphe cantoris (Cantor).
Spilotes reticularis (Cantor), Gëxtirr, 1858, p. 249 (Nepal); 1860, p. 163 (Nepal); 1861, p. 218 (Nepal).
Composoma reticulare, Ginther, 1864, p. 245 (Nepal). Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

Elaphe hodgsonii (Giunther).
Spilotes hodgsonii Gï vtuez, 1860, p. 156 (Nepal and Ladak [15,200 ft.]; 1861, p. 218 (Nenal).
Compsosoma hodgsoni, Gïxtiler, 1864, p. 246 (Nepal). Theobald, 1876, p. 166 (Nepal).
Coluber hodgsonii, Sclater, 1891, p. 31 (Katmandu).
Elaphe hodgsonii, Smiti and Battersby, 1953, p. $70 \pm$ (Tarakot [10,500 ft.]).
Range in Nepal. Central (without exact locality data²); Western (Tarakot).

Elaphe radiata (Schlegel).
Elaphe radiuta, Leviton, Myers, and Swax, 1956, p. 12 (Arun Valley [1000 ft.j). Chicago Natural IIistory Museum 83098 (Hitora [4500 ft.]). Range in Nepal. Eastern (Arm River Valley) ; Central (IItaura).

Liopeltis rappii (Giunther).
Ablabes rappii Günther, 1860 , p. 154, pl. 26, fig. B (Nepal and Sikkim [5340 ft.]); 1861, p. 217 (Nepal); 1864, p. 225 (Nepal).
Ablabes owenii, Gïnther, 1861, p. 217 (Nepal).
Liopeitis rappii, Wall, 1924, p. 865 (Nepal). Siutir, 1943, p. 186 (Nepal). Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

Lycodon aulicus (Linnaeus).
Lycodon aulicus, GÜNTiler, 1860, p. 164 (Nepal); 1861, p. 219 (Nepal); 1864, p. 316 (Nepal). Sclater, 1891, p. 14 (Katmandu). Wall, 1907, p. 152 (Katmandu [4500 ft.]). Smitir, 1943, p. 263 (Nepal).
Chicago Natural History Museum 83090 (Katmandu [ 4000 ft .]). Range in Nepal. Central (Katmandu).

Natrix himalayana (Günther).
Tropialonotus himalayanus Güxtmer, 1864, p. 265, pl. 22, fig. H (Nepal and Sikkim). Theobald, 1876 , p. 178 (Nepal).
Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

Natrix parallela (Boulenger).
Tropidonotus parallelus, Boclexger, 1913, p. 337 (Maikhola Valley [7000-10,000 ft.]). Range in Nepal. Eastern (Mai Khola).

## Natrix piscator (Schneider).

Tropidonotus quincunciatus Schlegel, Gïxtmer. 185s, p. 63 (Nepal); 1860, p. 162 (Nepal) ; 1861, p. 217 (Nepal); 1864, p. 260 (Nepal).
Tropidonotus piscator, Wale, 1907, p. 157 (Pharping [5000 ft.]).
Museum of Comparative Zoology, Harvard College 58224 (Patlikhot); MICZ 58235-58237 (Pokhara, Phewatal).

Chicago Natural History Museum 83081-83082 (Ampipalbhanjan [4000 ft. 7 ) ; CNH 28097 (Patan).

Range in Nepal. Central (Ampipalbhanjan, Patan, Pharping, Patlikhot, Phewatal, Pokhara).

Natrix platyceps (Blyth).
Tropidonotus chrysargus (nee Boie) Güntirer, 1858, p. 70 (Nepal); 1860, p. 162 (Nepal) ; 1861, p. 217 (Nepal). Wall, 1907, p. 156 (Chitlong).
Tropidonotus platyceps, Günther, 1860, p. 162 (Nepal); 1861, p. 217 (Nepal); 1864, p. 264 (Nepal [4000-7000 ft.]). Theobild, 1876, p. 174 (Nepal). Wall, 1907, p. 152 (Pharping [5000 ft.]).

Tropidonotus firthi Wall, 1914, p. 166 (Chitlong).
Rhabdophis firthi (Wall), Wall, 1923, p. 606 (Chitlong).
Natrix platyceps, Smith, 1951, p. 728 (Thangjet [5000 ft.]). Smitif and Battersby. 1953, p. 703 (Jumla [7600 ft.], Khanglagaon [8000 ft.], Balangra Pass [12,000 ft.]).
Range in Nepal. Central (Chitlang, Pharping, Tangjet); Western (Balangra Pass, Jumla, Khanglagaon).

Natrix stolata (Limmaeus).
Tropidonotus stolatus, GïNTHER, 1858, p. 68 (Nepal); 1860, p. 162 (Nepal); 1861, p. 217 (Nepal). Sclater, 1891, p. 39 (Katmandu). Wall, 1907, p. 156 (Gowchar, Pharping [5000 ft.]).
Chicago Natural IIistory Museum 83095 (Katmandu [4400 ft.]).
Range in Nepal. Central (Gowchar, Katmandu, Pharping).
Oligodon albocintus (Cantor).
Atimotes murpurascens (nee Schlegel) GüxTirr, 1858, p. 245 (Nepal); 1860, p. 161 (Nepal); 1861, p. 216 (Nepal).
Simotes punctulutus Gǜvpirer, 1864, p. 217 (Nepal).
Range in Nepal. Central (without exact locality data ${ }^{2}$ ).
Oligodon arnensis (Shaw).
Simotes russellii (Daudin), Gïxthrer 1858, p. 24 (Nepal); 1860, p. 161 (Nepal); 1861, p. 216 (Nepal); 1864, p. 213 (Nepal).
Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

Oligodon erythrogaster Boulenger.
Oligodon erythrogaster Boulenger, 1907, p. 217 (Nagarkote [6000 ft.]). Wall, 1923, p. 321 (Nepal). Smitif, 1943, p. 232 (Nagarkote); 1951, p. 728 (Thangjet [5000 ft.]. Smitil and Battersbr, 1953, p. 707 ( 8 miles west of Tibrikot [8500 ft.]).
Range in Nepal. Central (Nagarkote, Tang.jet); Western (Tibrikot).
Psammodynastes pulverulentus (Boie).
Psammodynastes pulverulentus. Wals. 1910, p. 76 (Butal). Range in Nepal. Central (Butal $\lfloor=$ ? Butwal]).

Pseudoxenodon macrops (Blyth).
Pseudoxenodon macrops, Boulenger, 1913, p. 338 (Maikhola Valley). Range in Nepal. Eastern (Mai Khola).

Ptyas mucosus (Linnaeus).
Coluber dhumna Cantor, 1839, p. 52 (Nepal).
Coryphodon blumenbachii (Merrem), Günther, 1858, p. 111 (Nepal); 1860, p. 163 (Nepal); 1861, p. 218 (Nepal).
Zamensis mucosus, Wali, 1907, p. 157 (Kakani, Gowchar).
Ptyas mucosus, Liviton, Myers, and Sway, 1956, p. 12 (Tamur River Valley [500 ft.]).
Range in Nepal. Eastern (Tamur Valley) ; Central (Gowehar, Kakani).
Sibynophis collaris (Gray).
Ablabes collaris, Gت̈nther, 1858, p. 28 (Nepal); 1860, p. 161 (Nepal); 1861, p. 216 (Nepal) ; 1864, p. 228 (Nepal).
Range in Nepal. Central (without exact locality data ${ }^{2}$ ).
Sibynophis saggittarius (Cantor).
Sibynophis sagittarius, Smitil and Battirsimy, 1953, p. 704 (Dang Plain [1500 ft.]). Range in Nepal. Western (Dang Plain).

Trachischium fuscum (Blyth).
Trachischium fuscum, Gëntum, 1860, p. 161 (Nepal); 1861, p. 215 (Nepal).
Ablabes fuscus. Günther, 1864, p. 225 (Nepal [8500 ft.]).
Range in Nepal. Central (without exact locality dataㄹ).
Trachischium guentheri Boulenger.
Trachischium guentheri. Sclater, 1891, p. 11 (Katmandu). Range in Nepal. Central (Katmandu).

Trachischium tenuiceps (Blyth).
Ablabes tenuiceps, Gënther, 1864, p. 224 (Nepal). Theobald, 1876, p. 154 (Nepal). Trachischium tenuiceps, Wall, 1907, p. 156 (Chandragiri [8000 ft.]). Sulhe, 1943, p. 323 (Nepal). Range in Nepal. Central (Chandragiri).

Xenochrophis cerasogaster (Cantor).
Tropilonotus cerasogaster, Gënther, 1861, p. 218 (Nepal; based on colored drawing). Range in Nepal. Central (without exact locality data²).

Zaocys nigromarginatus (Blyth).
Coryphodon carinatus (part) Güxther, 1858, p. 250 (Nepal); 1860, p. 163 (Nepal); 1861, p. 219 (Nepal).
Zaocys nigromarginatus, Gïxther, 1864, p. 257 (Nepal [7100 ft.]). Tmeobald, 1876, p. 172 (Nepal). Smith, 1943, p. 165 (Nepal). Range in Nepal. Central (without exact locality data ${ }^{2}$ ).

## Family Elapidae

Calliophis macclellandii (Reinhardt).
Elaps univirgatus Gïxther, 1858, p. 231 (Nepal); 1860, p. 164 (Nepal).
Callophis macelellandii, Gïxther, 1861, p. 219 (Nepal); 1864, p. 249 (Nepal). Theobald, 1876, p. 214 (Nepal). Sclatek, 1891, p. 56 (Katmandu). Smitir, 1943, p. 423 (Nepal)
Range in Nepal. Central (Katmandu; see footnote "2" regarding Gianther records, p. 107).

## F'amily Viperidae

Agkistrodon himalayanus (Ciïnther).
Ancistrodon himalayamus, Saith and Battersbs, 1953, p. 704 ( 8 miles west of Tibrikot [8500 ft.], Jumla [9500 ft.], Sialgarhi [9000-10,000 ft.], Turikot [10,000 ft.]). Range in Nepal. Western (Jumla, Sialgarhi, Tibrikot, Turikot).

## Trimeresurus albolabris Gray.

Lachesis gramineus. (part) Wais. 1907, p. 157 (Katmandu).
Trimeresurus albolabris. Smitir, 1943, p. 523 (Katmandu); 1951, p. 728 (Thangjet [5000 ft.], Syarpagaon [9000 ft.]). Range in Nepal. Central (Katmandu, Syarpagaon, Tangjet).

Trimeresurus monticola Günther.
Trimeresurus monticola Güxther, 1864, p. 388, pl. 24, fig. B (Nepal). Sclater, 1891 (Katmandu).
T'rimeresurus maculatus (nec Gray 1842, but Gray 1853), Güxtiner, 1858, p. 266 (Nepal).
Parias maculata. Gi'nther, 1860, p. 164 (Nepal); 1861, p. 220 (Nepal).
Lachesis monticola, Boclezger, 1896, p. 548 (Nepaul). Wall, 1907, p. 157 (Chitlong. Kakani).
Range in Mepal. Central (Chitlang, Kakani, Katmandu).
Trimeresurus stejnegeri Schmidt.
Chicago Natural Itistory Museum 83081-83082 (Ampipalbhanjan [4000
ft.1) ; (N1LAL 83088 ( 25 miles north of Katmandu [ 4000 ft .1 ). Ravge in Nepal. (entral (Ampipalbhanjan, Katmandu).

## RECORDS OF UNCERTAIN STATUS

Amphibia

Family Pelobatidae

Scutiger sikkimmensis (Blyth).
Uncertain additional record. Sclater (1892, p. 30) records this species from the Singalehla Range, Sikkim, from an altitude of $12,000 \mathrm{ft}$. This altitude suggests a collection station on the frontier between sikkim and Nepal.

## F'amily Ranidae

Rana swani Myers and Leviton.
Uncertain identification. Uncertain identification of two small frogs taken from above the Arun River [ 1500 ft .] has been recorded by Leviton, Myers, and Swan (1956, p. 9).

## Reptilia

Family Colubridae

## Coluber monticolus Cantor.

Uncertain synonyary. Cantor's species (1839, p. 52) based on a specimen from Nepal may be a synonym of Oligodon arnensis (fide Boulenger, 1894, p. 229).

Hurriah sanguiniventer Cantor.
Uncertain synonymy. The identification of Itodgson's drawing of a very distinctive snake described by Cantor $(1839$, p. 52) as $I I$. sanguiniventer and based on a specimen from the Valley of Nepal is uncertain. Smith (1943, p. 257) assigns the snake to the genus Lycodon (see also Giinther, 1864, p. 222 ).

Lycodon jara (Shaw).
Uncertain xew record. Smith (1943, p. 260) indicates that this animal is found in the "Eastern Himalayas as far west as longitude $85^{\circ}$." This would place the western limits in the vicinity of Katmandu. We know of no specific records to substantiate this distribution.

Natrix subminiata (Schlegel).
Uncertain new record. Wall (1923, p. 606) indicated that this species was found from "Nepal to Sikkim." No specific collection sites were mentioned by him. Smith (1943, p. 302) states, "The whole of the Indo-Chinese subregion as far as Sikkim in the north-west."

Simotes octolineatus (Schneider).
Uncertain synonymy. Günther (1861, p. 216) recorded a specimen identified as S. octolineatus from Nepal. This certainly is in error for Simotes $[=$ Oligodon $]$ octoimectus is an Indonesian species. Rither (iuntherss identification was in error or there was a mixup in locality data. Perhaps Günther had before him a specimen later referred to as O. erythrogaster by Boulenger, a species known from Nepal which bears a superficial similarity to the Indonesian species in color pattern.

## Spilotes melanurus Schlegel.

Uncertain synonymy. Two half grown specimens identified as S. melanurus were recorded from Nepal by Grünther, 1858, p. 97; 1860, p. 163; 1861, p. 218). That species is known from Indonesia; it has not been taken in the Indo-Burmese region. Either Ciünther's identification was in error or there has been a mixup in locality data.

## Family Elapidae

## Naja tripudians Merrem.

Uncertain new record. Concerning the distribution of Naja tripudians, Ciünther (1861, p. 219) states, "No record from Nepal" but "Hodgson presumes it to be there." Smith (1943, p. 426) indicates that the subspecies N. n. letouthio is found " . . as far west as Nepal;" and in his map (fig. 139, p. 434) both N.n. naja and N. n. koouthia are shown to occur within the frontiers of Nepal. We do not know of any specific records of this snake having been taken in that country though we agree with Hodgson and feel certain it is there.

## Family Viperidae

Trimeresurus viridis (Daudin).
Uncertain synonymy. Giiinther (1861, p. 220) records a specimen of $T$. viridis from Nepal. That nominal species has been placed in the synonymy of T. gramineus, a species common to Peninsular India but which has not been reported from as far north as Nepal. Günther's specimen may belong to T'. stejnegeri, a species which is closely similar to T. gramineus and which has been reported from Nepal.

## THE ZOOGEOGRAPIIY OF NEPAL AND AD.JACENT AREAS

The Indo-Chinese Subregion of the Oriental Region as defined by Wallace (1876) includes large portions of southeastern Asia and extends as a distinct western spur into the forested Himalayas. The fama of Sikkim clearly exhibits affinities with Burma, Thailand, and southern China,
whereas that of the western Himalayas appears to be a composite of faunal elements drawn largely from the Indian Subregion of the Oriental Region and the adjacent Palearctic Region. The country of Nepal (figure 1) bridges an intervening zone between the differing eastern and western Himalayan faunae. It represents an area of diminution, or cessation, of the Indo-Chinese Subregion.

An analysis of the distribution of Himalayan amphibians, lizards, and snakes suggests that the typical Indo-Chinese herpetofauna is essentially intact as far west as Sikkim and the Darjeeling District of Bengal. Fifty-one species found there ( 46 per cent of the local fauna) have a continuous distribution into the mountains; they also extend into Burma and other southeastern Asian portions of the Indo-Chinese Subregion (species designated IE and IW in table I [see appendix] and summarized in figure 2). Thirtytwo additional species ( 29 per cent of the local fauna) are confined to the Himalayas (EH, EW, NE in table I). And a Panoriental and Indian complement of 29 species ( 25 per cent of the local fauna) found in the herpetofauna of the IIimalayas east of Nepal extends from the plains of India into the mountains.

Only 15 typically Indo-Chinese species are known in Nepal, and one additional species, Ophisaurus gracilis, should be found there (on the basis of its presence beyond Nepal in the western Himalayas).

The obvious diminution of the Indo-Chinese fauna to the west of Sikkim is not very likely an artifact resulting from incomplete information and insufficient collection data from Nepal. The fauna of the western IImalayas, from the Nepalese frontier to the vicinity of Simla, is relatively as well known as is the plains fauna of India. If the distribution of the amphibians, lizards, and snakes in the areas contiguous with Nepal is analyzed, a fair approximation of the anticipated Nepalese species may be obtained. Of the widespread Panoriental and Indian species known to ascend into the mountains to the east and west of Nepal (in table I, species designated OR which are also recorded in the West Himalayas and Sikkim-Darjeeling), 8 may be anticipated in the mountains of Nepal. All have been collected there. Similarly, 7 of 9 expected Panoriental-Indian lizards have been collected in Nepal. However, only 12 of 28 anticipated Panoriental-Indian snakes have been obtained. If the same analysis is applied to amphibians, lizards, and snakes that are restricted to the mountains and are found on both sides of Nepal (i. e., in the western Himalayas and Sikkim-Darjeeling, table I, EW, IW and ME), the results indicate a collection of 2 out of 3 anticipated amphibians and all 9 anticipated snakes. A single lizard, Ophisaurus gracilis, which is rare in the western Himalayas falls in this category and has not been obtained in Nepal. In summary then, 10 of 11 anticipated amphibians, 7 of 10 anticipated lizards, and 21 of 37 anticipated snakes have been collected in Nepal. This information may be used as an approxi-


Figure 1. Map of Nepal showing all principal collecting stations at which amphibians and reptiles have been obtained.


mate index of the present knowledge of the Nepalese fama, and sufficient information is available to permit a meaningful assessment of the zoogeography of the country. It is evident then that the dramatic diminution from 51 Indo-Chinese species in Sikkim-Darjeeling to 15 Indo-Chinese species in Nepal is scarcely due to ignorance of that fauna. It is significant that the Indo-Chinese fauna in Nepal is a montane fauna and from the preceding data it can be seen that collections in the mountains of Nepal have yielded 11 of 13 anticipated montane species.

The striking diminution from 51 Indo-Chinese species in SikkimDarjeeling to 15 Indo-Chinese species in Nepal is, in all likelihood, associated with the obvious faunal barrier of the Singalehla Range, on the eastern frontier of Nepal. However, the occurrence of two Indo-Chinese snakes, Natrix parallela and Pseudoxenodon macrops, which have been collected west of this barrier (Mai Khola, southwest of Sundakphu) offers a tenuous suggestion that a gradual decline in Indo-Chinese species may occur in the Ilam district of Nepal or the Tamur Valley. This zone of reduction would be of limited extent inasmuch as collections made in the Arun Valley some 50 miles from the eastern frontier of Nepal reveal a marked change in the herpetofauna. Among 16 species of amphibians and reptiles obtained in this area only one, Cosymbotus platyurus, may be considered as typically Indo-Chinese. It is conceivable that outposts of Indo-Chinese reptiles and amphibians may be localized in isolated forests in the Arun Valley where aspects of the flora and some insects and birds are characteristic of Sikkim. But the primary herpetofauna indicates a more easterly termination of the Indo-Chinese Subregion.

One factor affecting this apparent termination is the greater human population and more extensive cultivation of the land in eastern Nepal. Agriculture and associated deforestation is predominant up to 7000 feet and intact forests are, for the most part, above this level. Along the valley bottom and near the river itself, fields and villages are less frequent and lowland forests in various degrees of preservation are usual in this situation. Deep within the Himalayas where the lowest valley elevations exceed 3000 feet, the valley forests show the greatest similarity to the forests of Sikkim. It is perhaps in such isolated localities that the Indo-Chinese fauna remains relatively distinct.

A second factor affecting the reduction of the Indo-Chinese fauna is the apparent replacement of the Indo-Chinese forms by species typical of the Indian plains. This is clearly emphasized in the Arun Valley by the abundance of lowland species such as Calotes versicolor and Ptyas mucosus; it is even more strikingly demonstrated by the recent discovery of Bufo ander-

Figure 2. Comparisons of faunal groups in Nepal and adjacent areas. Species have been included in eastern, central, or western Nepal if they have been taken in areas both to the east and to the west.
soni, Microhyla ornata, and Elaphe radiata, four plains species reported from the eastern Himalayas for the first time in 1956 (Leviton, Myers, and Swan).

Additional information concerning the fate of the Indo-Chinese fauna may be obtained from an analysis of the well-known herpetofauna of the western IImalayas adjacent to the western frontier of Nepal. Whereas there are 112 species of reptiles and amphibians in the Sikkim-Darjeeling area (figure 2), the mountains between Simla and Nepal hold 54 species, of which five are trpically Indo-Chinese. The major portion of the west Itimalayan herpetofauna is composed of Panoriental-Indian species (31 species or 57 per cent), but there is a sizeable representation of endemic Itimalayan species primarily of Indo-Chinese affinity ( 18 species, 33 per cent). The presence of this latter discrete group obviously distinguishes the western Himalayan fauna, and it does not seem fitting to assign the western IImalayas to the Indian Subregion.

Aside from the ubiquitous Panoriental-Indian forms, the Indo-Chinese species (augmented by the endemic Himalayan species many of which are closely related to typical Indo-Chinese forms) represent a clear majority of the mountain forms in the western Himalayas. Although there is a great reduction in the typical Indo-Chinese fauna in a westward trend from Darjeeling to Simla ( 51 species to 5 species) (figure 2) there is also a concurrent reduction in the total fauna ( 112 species to 54 species). Excepting a few additional species characteristic of the Palearctic, no outstanding new assemblage of amphibians or reptiles appears in the western Himalayas. The Panoriental-Indian fraction remains essentially the same (29 species to 31 species); this draws attention to the fact that the western recession of the fauma is restricted to the mountain forms. It is clear that there is no category to which the western Himalayas may be assigned legitimately except to the Indo-Chinese Subregion. There is a manifest change in the herpetofauna of the Indo-Chinese Subregion at the eastern frontier of Nepal, but unless the 700 miles between Sikkim and Simla is considered a prolonged transition zone, the Indo-Chinese Subregion apparently extends through Nepal as far as Simla in the western Mimalayas.

The boundary lines which circumscribe any zoogeographic province are approximations. Since the time of Alfred Russell Wallace, faunal limits have been indicated geographically with simple lines. Between contiguous major faunal zones, small or large transitional areas have been assumed. In Nepal and the western Himalayas, what may appear outwardly to be a prolonged transition area of the Indo-Chinese fauna is perhaps something different. The dissected mountainous region distinguishes cultivated valley slopes harboring a predominant Panoriental-Indian fauna from the montane and valley forests where a higher incidence of Indo-Chinese and endemic species are in evidence. The frequency and size of these famal pockets
apparently decreases westward with a concurrent decrease in precipitation. But there is no dramatic increase of a new and different fauna; there is essentially a simple diminution of the mountain and forest forms. Beyond Simla, where Palearetic species become frequent, the Indo-Chinese species which still persist may create a minor transition zone of a classical sort within the boundary of Palearctic Region. In summary, it would seem that a transition zone should reflect a decrease of one fauna with an accompanying proportional increase of another fauna as a new province is approached. When there is an alteration of the fauna involving primarily a reduction of this fauna, and there is no accompanying significant increase in a new assemblage of species, the area involved is not in reality a transition zone. The latter applies to the Indo-Chinese Subregion in Nepal and the western Himalayas. The region seems to represent an intermediate condition where a fauna of eastern affinities is in the process of being extinguished while a fauna of western origin has not yet become prominently developed. On the map (figure 3), the protracted and weak extension of the Indo-Chinese Subregion is indicated by localized areas in the mountains which are separated by segments of the Indian Subregion. The very minor inroads of the Palearctic species into the IIimalayas proper to the east of Simla have been superimposed onto the Panoriental-Indian fauna rather than the IndoChinese fauna.

At the present time, 69 species of amphibians and reptiles have been reported from Nepal. Of these, two frogs, Rana polunini and Rana swani, are known to be restricted to the country; both were discovered in recent years. Rana polunini is closely related to $R$. blanfordi and may be a high altitude derivative of the latter widespread IImalayan species. Rana swani shows affinity with Tomopterna ranids in southwest India and is probably a Himalayan representative of a relictual group of frogs which at one time were more widely distributed. Nepal is also the type locality of a few other species whose distributions extend beyond its frontiers (Rhacophorus maximus, Oligodon erythrogaster, and Trimeresurus monticola), and the types of several species have been recorded together from Nepal and Sikkim (Hodgson's and Hooker's collections, respectively).

Some approximation of the number of endemic amphibians and reptiles to be anticipated in Nepal can be obtained by comparing the fauna in Nepal with that of equal areas to the east and west. In the portion of the Himalayas extending from Nepal to the gorge of the Brahmaputra in the east, there are now 14 frogs, 7 lizards, and 9 snakes (total 30 species) which can be considered as restricted to this part of the Himalayas. Nearly all of these species are from Sikkim and Darjeeling, inasmuch as Bhutan and the Assam Himalayas are in a category of ignorance far greater than Nepal. In the western Himalayas, in an area extending from central Kashmir to the western frontier of Nepal, 2 frogs, 2 lizards and 2 snakes (total, 6 species)

may be considered indigenous. From this it follows that the number of endemic forms in Nepal is between 6 and 30 species, with the probability that the number is closer to the former figure.

The large group of typically Himalayan species (table I, EII, EW, WH) is composed for the most part of species having affinities with the IndoChinese Subregion, for example, Trachischium guentheri, a member of a genus with several representatives in the eastern Himalayas and the Khasi Hills. On the other hand Himalayan species such as Elaphe hodgsoni and Leiolopisma himalayanum, which range widely in the far western Himalayas, Kashmir and Ladak, as well as Nepal, likely emanate from areas to the west where there are other representatives of the same genera. These species and a few others with a similar distribution may be considered as having Palearctic affinities. That portion of the Palearctic Region adjacent to western India has been delineated by Wallace as the "Mediterranean Subregion" and species associated with this subregion which enter the Himalayas are identified by the symbol ME in table I.

In addition to the purely mountain species that can be assigned either to the Indo-Chinese or Palearctic faunae, there is an aggregation of species which generally occupy an elevated wet zone in the Himalayas and which are fundamentally related to species in Western China. Preeminent in this group is the high altitude pelobatid frog Scutiger sikkimmensis. Although this zone is best delineated in the Himalayas by a single amphibian species, its identity is supported by many plants (species groups of Rhododendron, Primula, etc.) and birds (particularly pheasants such as the genera Ithaginis, Lophophorus, and Tragopan). In addition, the lizard genus Japalura, with 5 recognized species in west China (other species also present in the Khasi Hills, north Burma and north Viet Nam) and 5 species in the IImalayas, may represent this biogeographic province in the Himalayas. Scutiger sikkimmensis, Japalura major, and Japalura tricarinata are among the few amphibians and reptiles found above 10,000 feet in the outer, wetter Himalayas. These species have not been segregated into a special category in table I, but they have been considered as belonging to a distinct subregion (in figures 2-4).

Other species with a distinct association with the fauna of west China are the frogs Scutiger alticola, Scutiger mammata ${ }^{5}$, and Altirana parkeri. These three species have been collected on the Tibetan Plateau immediately north of Nepal and presumably may be found in those parts of the country which are extensions of the plateau. They are apparently widespread species but not continuous in their distribution, for they are restricted to scattered lakes and streams. Scutiger mammata, or a closely related species, probably

[^8]Figure 3. Zoogeographic subregions of Nepal and adjacent areas.
extends as far as Kashmir. It appears, therefore, that the West-Chinese fauna is divided between a wet Himalayan group and a contingent on the dry plateau of Tibet. The latter group expresses Asian Palearctic rather than Oriental characteristies and the West-Chinese herpetofauna as a whole may be considered as essentially Palearctic. This is emphasized by the distribution of other vertebrate species, including hynobiid salamanders, which, like Scutiger, extend west across Tibet to Afghanistan. Perhaps the West-Chinese Province is in reality identical to the western portion of the Manchurian Subregion of Wallace which was conceived as a vast area embracing most of northern China and Japan with an extension into the Himalayas. A tentative appraisal of this subregion suggests that the mountain fauna of west China is sufficiently distinct to merit the status of a related but distinct subregion of the Palearctic.

Whereas the amphibian representatives on the platean adjacent to Nepal are affiliated with West-Chinese species, the saurian complement (Agama, Phrynocephalus, Alsophylax, ete.) is entirely related to the fauna of Afghanistan, Iran, and the Caspian area. This is the eastern limit of the Mediterranean Subregion as conceived by Wallace, but the invasion of Tibet by members of this subregion may well extend the Mediterranean Palearctic to the borders of Sikang and Szechwan. One of the species typical of this group of Mediterranean-plateau species, Leiolopisma ladacense, has been collected in Nepal near the Tibetan border at 18,000 feet, a record altitude for any amphibian or reptile.

The Tibetan Plateau herpetofama directly north of Nepal and in places actually entering within the frontiers of Nepal is therefore a curious mixture derived from two Palearetic subregions. The amphibians (and perhaps the relictual Tibetan snake, Thermophis baileyi) live near water and have West-Chinese affinities, whereas the lizards have opposite origins and represent a Mediterranean extension into the area. Similarly there is a West-Chinese group of frogs and lizards in the Himalayas proper which are only weakly delimited by altitude from a small group of Himalayan lizards and snakes with Mediterranean affinities (Agama tuberculata, Elaphe hodgsoni, etc.). This Himalayan-Mediterranean fauna is, however, a minority conflux of species among the far more numerous PanorientalIndian, Indo-Chinese, and Himalayan amphibians and reptiles. This confusion of faunal groups is an outcome of both vertical and horizontal patterns of distribution in the mountains; the interaction between these two factors as they relate to the zoogeography of Nepal is shown in figures 3 and 4 .

Figure 4. Altitudinal distribution of Nepalese amphibians, lizards and snakes and of the zoogeographic subregions of the Nepal Himalayas. Some species have been included among the Plateau species that have not been obtained within the borders of Nepal.

The altitudinal distribution of the various faunal groups (figure 4) is characterized by wide overlapping zones rather than discrete altitudelimited belts. Two altitudinal zones which are occupied exclusively by discrete faunal groups are confined to elevations between 11,500 feet and 13,500 feet on the southern exposure of the Himalayas and between 17,000 and 18,000 feet on the Tibetan slope (West-Chinese and Mediterranean subregions, respectively). On the Tibetan slope of the Himalayas and on the plateau below 17,000 feet, as described above, the Mediterranean and West-Chinese faunae occupy similar altitudes but can be distinguished ecologically inasmuch as the lizards have dry habitats whereas the amphibians live near streams and lakes. Below 11,500 feet and above 8,500 feet on the southern flank of the Himalayas, the West-Chinese and Mediterranean species are joined in the Nepal IImalayas by two Himalayan species, Rana leibigii and Rana polumini, which appear to range considerably higher than other species with Indo-Chinese affinities. The elevated distribution of these frogs (and possibly $R$. blanfordi, which has not yet been collected in Nepal), suggests that they may be related to the group of ranid frogs ( $R$. pleuraden, R. phrynoides, and R. boulengeri) which are distributed in the mountains of West-China. If this relationship has any real basis, the IImalayan frogs may have West-Chinese rather than IndoChinese affinities. At the present time they are viewed as exceptional species and have not been considered as part of the West-Chinese fauna.

If a few altitudinal records obtained from the western Himalayas are utilized to reinforce the limited information from Nepal itself, the altitudinal distribution of the Mediterranean fauna in the IIimalayas of Nepal appears more intelligible. Species such as Elaphe hodgsoni and Agkistrodon himalayames appear to range on both the north and south sides of the Himalayas and may be part of both plateau and Himalayan segments of the Mediterranean fama. They ascend to much higher altitudes on the north slope, both species apparently exceeding 15,000 feet. Toward the southern flank of the Himalayas these species and other Mediterranean forms such as Agama tuberculata, Leiolopisma himalayanum, and Natrix platyceps rarely exceed 10,000 feet. These same species, however, are found as low as 3000 feet. Some of these species, particularly Agama tuberculata, appear to occupy rocky, drier areas and to some degree these Mediterranean forms, despite their wide range, are ecologically distinct from the Indo-Chinese, West-Chinese, and Panoriental-Indian species which are altitudinally contiguous. It appears therefore, that the Mediterranean species have wide altitudinal ranges and in western Nepal extend from the southern slopes continuously through the IImalayas to join the Mediterranean fama of the plateau. In eastern Nepal and the eastern Himalayas, the Mediterranean fauna is divided, as is the West-Chinese fauma, into separate IImalayan and plateau portions.

The altitudinal distribution of the Indo-Chinese fauna (including typically Himalayan species) extends from the lower foothills up to 11,500 feet (if Rana liebigii and $R$. polunini are considered). It is, however, primarily confined between 3000 feet and 7000 feet and at these altitudes it is rivalled by the more widespread Panoriental-Indian species. The latter fauna, however, is predominant below 3000 feet.

In many ways the altitudinal distribution of amphibians and reptiles mirrors the altitudinal distribution of vegetation. The dominant forest categories (figure 4) fairly coincide with the range of the Indo-Chinese and Panoriental-Indian amphibians and reptiles which are confined to the Lower, Middle, and Upper Monsoon forests. Mowever, most of these species do not exceed an altitude of 6000 feet, which approximates the altitude of killing frosts in winter. Rhododendron trees of several species extend from below 6000 feet to tree line, which in eastern Nepal reaches a maximum altitude of 13,500 feet. They are, however, more prominent in the deciduous forests $(8,500$ feet to 10,500 feet) and in the zone of conifer forests ( 10,500 feet to 13,500 feet). The altitudinal distribution of japalurid lizards resembles the distribution of rhododendron forests; this vegetation mixes with the Upper Monsoon forests and the deciduous forests. In the latter zone Japalura tricarinata and $J$. major are the commonest reptilian species encountered. The rhododendron-conifer forests coincide strikingly with the range of Scutiger sikkimmensis. In general, it would seem that the Monsoon forests harbor Oriental species (Panoriental-Indian and Indo-Chinese), whereas forests which include rhododendron trees incorporate a WestChinese herpetofauna. The Mediterranean species extend over the altitudinal range of nearly all of these forests but they are primarily non-forest species.

A belt of piedmont forest mixed with swamps and open fields, a foothill and plains region known as the Terai, separates the Himalayas from the true plains of India and Nepal. The amphibians and reptiles of this zone are known primarily from collections obtained in the Terai near the Darjeeling District east of Nepal. With the possible exception of Elachistodon westermanni and Bungarus lividus there appear to be no reptiles or amphibians which are exclusively confined to the Terai zone. The herpetofauna of this intermediate area seems to be composed entirely of PanorientalIndian species although many of the Terai forms do not extend far into the adjacent plains. Examples of this latter fauna which appear to be confined to the plains within 100 miles of the Himalayas are: Rhacophorus taeniatus and R. tuberculatus of Assam, and Boiga forsteni of Bihar and Uttar Pradesh. The Terai fauna and the plains fauna of Nepal are very poorly known and the great majority of collections in this portion of the country were made by Brian Hodgson and his collectors. Comparing the Nepalese plains with the well-known fauna of the adjacent Indian plains, it is found that 5
chelonian species have been collected in Nepal out of 11 species which may readily occur in Nepal. Similarly, 7 of 15 lizards have been obtained and 11 of 37 plains snakes. Perhaps the best indication of the status of collections on the plains of Nepal is reflected in the fact that at the present time there seems to be no published record of the occurrence of the common cobra in Nepal (though Malcolm Smith [1943, p. 43t] shows it to be present in his map). It is obvious that collections on the Nepal plains would rapidly increase the known fauna of the country and, inasmuch as the plains fauna is richer in adjacent Bengal, it may be assumed that most new records of amphibians and reptiles will be obtained from the southeastern corner of Nepal.

Much of the preceding discussion has referred entirely to amphibians, lizards, and snakes as the Nepalese crocodilians and chelonians are primarily plains species and are poorly represented in collections. Only one tortoise, Testudo elongata, collected in Nepal can be considered as typical of the Indo-Chinese Subreqion, the remainder being Indian and Panoriental. The presence of T'. elongata in Nepal and the occurrence of Geoemyda tricarinata and G. trijuga in the Darjecling District immediately east of Nepal point to a curious affinity hetween the eastern IImalayas and the hills of Chota Nagpur over 300 miles south of Nepal and separated from the Itimalayas by the wide plain of the Canges. All of these tortoises, together with two Indo-Chinese lizards (Leiolopisma sikkimensis of the eastern Himalayas as far as central Nepal and Sphenomorphus maculatum of the eastern IImalayas and southeast Asia), are found in the restricted area of Chota Nagpur. The five species do not represent a majority of the reptiles in the area (although they may have some ecological distinction), but as a group of relictual species surrounded by ubiquitous Oriental forms, their presence and significance may be emphasized by referring this isolated pocket to the Indo-Chinese Subregion. The species just cited indicate that a continuous fauna, presumably a forest fauna, likely extended across the Cangetic plains at one time. The hiatus in the distribution of the IndoChinese fauna calls attention to a recession of the subregion and climatic changes of the past. The Chota Nagpur link with the Indo-Chinese Subregion is based on the presence of identical species in the two areas. If genera and allied species are taken into consideration, some representatives of the Indo-Chinese Subregion can be associated with species in Chota Nagpur, the western Ghats of southwest India and the Ethiopian Region. This distribution presumably represents a relictual situation dating from the Tertiary Period, and it would seem that the tortoises and lizards of Chita Nagpur, still specifically linked to the Indo-Chinese Subregion, represent the last segment of this earlier distribution pattern.

It would seem that the fauna of the Gangetic plains is newer and is occupying a region which has been deforested through the agency of a
changing climate which in turn has recently been aided by man. The distributional patterns of animals of central Asia and of the Himalayas also show the effects of climatic change, obviously reflecting a trend toward arid conditions. The narrow altitudinally limited wet and cold zone occupied by Scutiger sikkimmensis harbors populations which are totally isolated from each other by deep tropical valleys, and it is obvious that this West-Chinese fauna was formerly more widely distributed. On the plateau of Tibet, the isolated pockets of amphibians and snakes indicate that this portion of the West-Chinese fauna was at one time also far more extensively distributed. Superimposed on this West-Chinese fauna are the wide-ranging, successful, desert lizards related to the Mediterranean Palearctic. The total pattern clearly suggests the encroachment of an arid environment in central Asia which has depopulated a preceding West-Chinese fauna and isolated a fringe of this fauna on the outer slopes of the Himalayas, which are still wet and cool. The Mediterranean invasion has also involved the southern slopes of the Himalayas, but, as noted earlier, the several species which typify this expansion are as yet a very minor percentage of the total herpetofauna. The climatic modifications on the Gangetic plain are presumably related to the changes in central Asia, and the plains fauna also contains a number of species which evidence Mediterranean affinities. It is significant that the deforested Gangetic plain has been occupied by ubiquitous species from the surrounding areas, leaving few if any relictual species. However, occupation of this area has not been accomplished by any substantial number of Indo-Chinese species. The latter, it seems, have retreated with the forests and remain remarkably discrete in the Itimalayas east of Nepal. In Nepal itself and in the Himalayas to the west, the plains fama has made successful inroads into the IImalayan valleys and the Indo-Chinese fauna in these areas appears to be declining toward a relictual status.

In summary, the zoogeography of Nepal is a complex of interdigitating faunal subregions. The Indo-Chinese fauna (composed of species which range from southeastern Asia into the Himalayas together with the majority of strictly IIimalayan species) becomes greatly reduced on the eastern frontier of Nepal, but continues westward through Nepal, primarily in isolated forest areas which lie between 3000 and 7000 feet. A large group of widespread Panoriental-Indian species extend from the plains and are the dominant species on the plains of Nepal and in the Valleys and the lower foothills. They are also largely coextensive in their altitudinal range with the Indo-Chinese fauna. The plains fauna is also composed of species which do not extend into the mountains. Several species of lizards and snakes which extend from Kashmir into Nepal from the west and which are derivatives of the Mediterranean Subregion fauna, have a wide altitudinal distribution. On the southern slopes of the Himalayas they are found generally below 10,000 feet; but in western Nepal this fauna links
with Mediterranean species of the Tibetan Plateau and on the frontier of Nepal these species ascend as high as 18,000 feet. The Mediterranean fauna in Nepal overlaps the altitudes occupied by the Indo-Chinese and Pan-oriental-Indian species, but they are to some extent ecologically distinct from the latter groups. The highest elevations on the southern exposure of the Himalayas are dominated by a few species with West Chinese affinities. Similarly, on the plateau immediately north of Nepal (and presumably in some places within Nepal itself), there are additional West-Chinese species which are not continuous with the Himalayan forms. The Tibetan Plateau is therefore dominated by wide-ranging Mediterranean lizards which overlap a seemingly relictual group of West-Chinese amphibians. It appears that the West-Chinese and Indo-Chinese faunae are retreating from Nepal and Tibet, whereas there is a concurrent expansion of Mediterranean species from the west and Panoriental-Indian species from the south. With IndoChinese, Indian, and Panoriental faunae of the Oriental Region combining vertically and horizontally in wet and dry areas with two groups of Mediterranean Palearctic species and two groups of West-Chinese Palearctic species, the zoogeography of Nepal is somewhat bewildering. It has a labyrinthian quality which rivals the distribution patterns of any area of similar dimensions on the face of the earth, and it is particularly instructive concerning the manner in which two major zoogeographic regions converge and meet in a montane faunal barrier which is common to both regions.

## APPENDIX

Table I represents a list of amphibians and reptiles known to occur in Nepal and the immediately adjacent areas. Information on the Tibetan, Indian, and Himalayan species and their distribution has been compiled with the aid of an unpublished work by Swan (1947). The area designations and the symbols utilized in the table are as follows:

Adjacent Plains. The plains of India within approximately 50 miles of the southern frontier of Nepal which are essentially continuous with the plains area of Nepal itself.
W. Himalayas. The mountainous area between Simla and the western frontier of Nepal.
W. Nepal, C. Nepal, E. Nepal. Divisions of Nepal into western, central, and eastern portions based upon the drainage systems of the major rivers (see map).
Sikitm-Darjeeling. The mountainous area of Sikkim and the Darjeeling District immediately to the east of Nepal.
Adjacent Tibet. The southern plateau area of Tibet adjacent to Nepal which is north of the primary crest of the Himalayas.
X . This indicates the known presence of the species.
$\mathrm{X} 1,2,3$. These indicate the known presence of the species in Nepal and the number of times it has been obtained by different collectors in the area.
O. This indicates a real expectation of the species in Nepal based on the known presence of the species in areas to the east and the west.
P. This indicates the possible presence of the species in Nepal based on the known presence of the species on the plains of India adjacent to Nepal.
OR. Species with a distribution typically Indian or Panoriental which may be found in wide areas of the plains and mountains of India and may frequently extend into S. E. Asia.
IE. Species with a distribution characteristic of the Indo-Chinese Subregion and which extend into the Eastern Himalayas.
IW. Species with a distribution characteristic of the Indo-Chinese Subregion and which extend into the Himalayas west of Nepal.

EII. Species with a distribution essentially confined to the Eastern Himalayas.
EW. Species with a distribution essentially confined to the Himalayas, including both eastern and western portions.

WH. Species with a distribution essentially confined to the Western Himalayas.
ME. Species with a distribution which appears to extend from the Mediterranean Subregion into the Himalayas as far as the Eastern Himalayas.
TB. Species with a distribution on the Tibetan plateau adjacent to Nepal.

The data presented in table I are summarized for convenient reference in table II. The data have been grouped by areas and major subordinal or ordinal groups of amphibians and reptiles.

A distributional analysis of faunal groups by faunal subregions is presented in table ILI.

Table I
Distribution of Amphibians and Reptiles of Nepal and Adjacent Areas

| AMPHIBIA |  |  |  |  | $\begin{aligned} & \text { W } \\ & \text { W } \\ & \text { N } \\ & \text { 茳 } \end{aligned}$ |  | $\stackrel{\square}{\square}$ | $\begin{aligned} & \text { E } \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| APODA |  |  |  |  |  |  |  |  |
| Coechlindaf |  |  |  |  |  |  |  |  |
| Iehthyophis glutinosis |  |  |  |  |  | X |  | IE |
| URODELA |  |  |  |  |  |  |  |  |
| Shlamandridat |  |  |  |  |  |  |  |  |
| Tylototriton cerrucosa |  |  |  |  |  | X |  | IE |
| ANURA |  |  |  |  |  |  |  |  |
| Brevicipitidas |  |  |  |  |  |  |  |  |
| Wicrohyla ornata. | X |  |  |  | XI |  |  | OR |
| BuFonimat |  |  |  |  |  |  |  |  |
| Bufo andersoni. | X | X | O | O | XI |  |  | OR |
| Bufo himalayanus. |  |  | X1 | X | 0 | X |  | EW |
| Bufo melemostirtus | X | X | O | X 3 | X 1 | X |  | OR |
| Pelobatitiaje |  |  |  |  |  |  |  |  |
| Megophrys major |  |  |  |  |  | X |  | IE |
| S'rutiger atticolta. |  |  |  |  |  |  | X | TB |
| S'eutiger mammata. |  |  |  |  |  |  | X | TB |
| scutiger sikkimmensis. |  |  | X1 | X1 | O | X |  | EW |

Table I (Continued)
Distribution of Amphibians and Reptiles of Nepal and Adjacent Areas


Rhacopioritate

| Philautus ammandali. |  |  |  |  |  | X | EH |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Philautus dubius. |  |  |  |  |  | X | EH |
| Rhacophorus jerdoni |  |  |  |  |  | X | EH |
| Rhacophorus leucomystax...... |  |  |  |  |  | X | IE |
| Rhacophorus maculatus | X | X | 0 | X1 | X1 | X | OR |
| Rhacophorus maximus. |  |  |  | X 1 | 0 | X | IE |

REPTILIA
Chelonia
Emídidate
Geoclemys hamiltoni............................ $\mathrm{X} \quad \mathrm{P} \quad \mathrm{P} \quad \mathrm{P} \quad$ OR
Geoemyda tricarinata ................... X IE
Geoemyda trijuga....................... X IE
Hardella thuriin...... ........... $\mathrm{X} \quad \mathrm{P} \quad \mathrm{P} \quad \mathrm{P} \quad \mathrm{OR}$
Kachuga ahongoka..................................... $\mathrm{X} \quad \mathrm{P} \quad \mathrm{X} 1 \mathrm{P} \quad$ OR

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Table I (Continued)
Distribution of Amphibians and Reptiles of Nepal and Adjacent Areas
```

| Reptilia (Continued) |  |  |  |  |  |  | 莒 | $\begin{aligned} & \text { E } \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Emymbas (Continued) |  |  |  |  |  |  |  |  |
| Kachuga kachuga... | X |  | P | X1 | P |  |  | OR |
| Kashuga smithi.. | X |  | P |  |  |  |  | OR |
| Kachuga tecta................................... | X |  | P | P | P |  |  | OR |
| Testcdinidae |  |  |  |  |  |  |  |  |
| Testudo elongata ............................. |  |  |  | X1 | 0 | X |  | IE |
| Trionyclimat |  |  |  |  |  |  |  |  |
| Chitra indica .................................. | X |  | P | X1 | P |  |  | OR |
| Lissemys punctata .......................... | X |  | P | P | P |  |  | OR |
| Trionyx gangeticus.. | X |  | P | X 1 | P |  |  | OR |
| Trionyx hurum. | X |  |  |  | P |  |  | OR |
| Trionyx leithi.. | X |  | P | P | P |  |  | OR |
| CROCODILIA |  |  |  |  |  |  |  |  |
| Croconitidae |  |  |  |  |  |  |  |  |
| Crocodilus palustris. | X |  | P | P | P |  |  | OR |
| Gavialis gangeticus. | X |  | P | X 1 | P |  |  | OR |
| SQUAMATA-SAURIA |  |  |  |  |  |  |  |  |
| Achaidae |  |  |  |  |  |  |  |  |
| Agama himalayana.... |  | X |  |  |  |  | X | TB |
| Agama tuberculata ............................ |  | X | x 1 | x 2 |  |  |  | ME |
| C'alotes versicolor............................ | X | X | X1 | X4 | X1 | X |  | OR |
| Japalura kumaonensis....................... |  | X |  |  |  |  |  | WH |
| Sapatura major.... |  | X | X 1 |  |  |  |  | WH |
| Japalura tricarinata ...................... |  |  |  | x 2 | 0 | X |  | EH |
| Japalura variegata_.......................... |  |  |  |  |  | X |  | EH |
| Phrynocephalus theobaldi. |  |  |  |  |  |  | X | TB |
| Sitana ponticeriana.. | X |  | P | $P$ | P |  |  | OR |
| Avguidae |  |  |  |  |  |  |  |  |
| Ophisaurus gracilis......................... |  | X | O | O | O | X |  | IW |
| GEKKonimat |  |  |  |  |  |  |  |  |
| Alsophylax tibetanus....................... |  |  |  |  |  |  | X | TB |
| Cosymbotus platyurus........................ |  |  |  | X1 | x1 | X |  | IE |
| Cyrtodactylus fasciolatus............... |  | X |  |  |  |  |  | WH |

Tarbe I (Continued)
Distribution of Amphibians and Reptiles of Nepal and Adjacent Areas

| Squamata Sauria (Continued) Gek konidae (Continued) |  |  |  |  |  |  | $\stackrel{\text { \% }}{\stackrel{\circ}{*}}$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Cyrtodactylus gubernatoris... |  |  |  |  |  | X |  | EH |
| Cyrtodactylus khasiensis. |  |  |  |  |  | X |  | IE |
| Cyrtodactylus lawderamus. | X | X |  |  |  |  |  | WH |
| Gecko gecko. | X |  |  |  | P |  |  | OR |
| Hemidactylus bowringi.. |  |  |  |  |  | X |  | IE |
| Hemidactylus brooki. | X |  | P | P | P |  |  | OR |
| Hemidactylus flaviviridis. | X |  | P | P | P |  |  | OR |
| Hemidactylus frenatus. | X |  |  |  | X1 | X |  | OR |
| Hemidactylus garnoti. |  |  |  |  |  | X |  | IE |

Scincidae

| Leiolopisma sikkimense................... |  |  |  | X 2 | 0 | X | X | EH |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Leiolopisma himalayanum. |  | X | X 1 | X 1 |  |  |  | ME |
| Leiolopisma ladacense. |  |  | X 1 |  |  |  | X | TB |
| Mabuya carinata. | X |  |  |  | X1 | X |  | OR |
| Mabuya macularia | X |  | P | X 2 | P |  |  | OR |
| Mabuya multifasciata. |  |  |  |  |  | X |  | IE |
| Ophisops jerdoni. | X | X | P |  |  |  |  | OR |
| Riopa albopunctata. | X |  |  | P | P |  |  | OR |
| Riopa punctata | X | X | O | O | X1 |  |  | OR |
| Sphenomorphus indicum.. |  |  |  |  |  | X |  | IE |
| Sphenomorphus maculatum.... |  |  |  |  |  | X |  | IE |

Varanidae

| Varanus | flavescens. | X | X | 0 | X1 |  |  | OR |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Varanus | monitor.. | X | X | O | X1 | 0 | X | OR |
| Varanus | alvator | X |  |  |  | P | X | OR |

## SQUAMATA-SERPENTES

Boidae

| Eryx conicus | X | X | P | P |  |  | OR |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Python molurus. | X | X | 0 | x 2 | 0 | X | OR |

Coluibidae


## Table I (Continued)

Distribution of Amphibians and Reptiles of Nepal and Adjacent Areas

| Sñumata-Smpentes (Continued) <br> Coldbridae (Continued) |  |  | $\begin{aligned} & W_{0}^{\tilde{W}} \\ & B Z \end{aligned}$ | $\begin{aligned} & \text { ت̃ } \\ & \text { ت } \\ & \text { む } \\ & 04 \end{aligned}$ |  |  | $\overbrace{\text { ® }}^{\sim}$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Poidte eeylonensis. |  |  |  | X1 |  |  |  | OR |
| Boigu cyunea ........ |  |  |  |  |  | X |  | I |
| Poigat cumodon | X |  |  |  | P | X |  | IE |
| Boigh forstomi | X |  |  | P | P | X |  | OR |
| Boiga gokool..... |  |  |  |  |  | X |  | IE |
| Boitu multifassiata |  | X | O | X1 | O | X |  | EW |
| Boiga ochracea. | X |  |  |  | P | X |  | IE |
| Boiga trigonatu. | X | X | 0 | X1 | O | X |  | OR |
| Chrysopelea ornata. | X |  |  |  | P | X |  | OR |
| Coluber dindema.... | X |  | P |  |  |  |  | OR |
| Coluber fasciolatus. | X |  | P | X1 | 1' |  |  | OR |
| coluber ventromaculatus | X | X |  |  |  |  |  | OR |
| Dendrelaphis cyanochloris. |  |  |  |  |  | X |  | IE |
| Dendrelaphis gorei. |  |  |  |  |  | X |  | IE |
| Irendrelaphis pirtus. |  |  |  |  |  | X |  | OR |
| Dendrelaphis tristis. | N |  |  |  | P | X |  | OR |
| Itinorlon gammei |  |  |  |  |  | X |  | EH |
| Dinodon septentrionulis. |  |  |  |  |  | X |  | IE |
| Elaphe cantoris. |  |  |  | X1 | 0 | X |  | IE |
| Elaphe helena. | X | X | 0 | $\bigcirc$ | 0 | X |  | OR |
| Elaphe horlasomi |  | X | X1 | X2 | 0 | X |  | ME |
| Elaphe porthlyracea |  |  |  |  |  | X |  | IE |
| Elaphe prasina.... |  |  |  |  |  | X |  | IE |
| Elaphe radiata | X |  |  | X1 | N1 | X |  | OR |
| Elapher tacmiura. |  |  |  |  |  | X |  | IE |
| Enhyurlis enhydris | X | X | O | 0 | 0 | X |  | OR |
| Enhydris sieboldi. | X |  | P | P | P |  |  | OR |
| Liopeltis calamaria. | X | X |  |  |  |  |  | OR |
| Liopratis mopli |  | X | O | X2 | 0 | X |  | EW |
| Liopleltis stolicelas |  |  |  |  |  | X |  | IE |
| Lycodon anticus.. | X | X | O | X 1 | 0 | X |  | OR |
| Laycodon fasciatus. |  |  |  |  |  | X |  | IE |
| Lycodon jura... |  |  |  |  |  | X |  | IE |
| L.yconton matkinumai |  | X |  |  |  |  |  | WH |
| Lygrorton striutus | $\therefore$ |  | 1 |  |  |  |  | OR |

Table I（Continued）
Distribution of Amphibians and Reptiles of Nepal and Adjacent Areas

| Squanata－Serpentes（Continued） <br> Colubridae（Continued） |  |  |  |  | $\begin{aligned} & \text { 歌 } \\ & \text { 的苞 } \end{aligned}$ |  | $\stackrel{\stackrel{\sim}{*}}{\stackrel{\sim}{*}}$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0.0 \\ & 0.0 \\ & 000 \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Natrix himalayana．． |  |  |  | X1 | 0 | X |  | IE |
| Natrix parallela ．．．．．．．．．．．．．．．．．．．．．．．．．．．．．．．．． |  |  |  |  | X1 | X |  | IE |
| Natrix piscator． | X | X | O | X4 | 0 | X |  | OR |
| Natrix platyceps． |  | X | X1 | X3 | 0 | X |  | ME |
| Natrix stolata．． | X | X | 0 | X4 | 0 | X |  | OR |
| Natrix subminiata． |  |  |  |  |  | X |  | IE |
| Oligodon albocinctus．．．．．．．．．．．．．．．．．．．．．．．．．．． |  |  |  | X1 | O | X |  | IE |
| Oligodon arnensis． | X | X | O | X1 |  |  |  | OR |
| Oligodon cyclurus．．． | X |  |  | P | P |  |  | OR |
| Oligodon erythrogaster． |  |  | X1 | x 2 | 0 | X |  | EW |
| Oligodon juglandifer．． |  |  |  |  |  | X |  | EH |
| Oligoton melaneus．． |  |  |  |  |  | X |  | EH |
| Pareas macularius．．． |  |  |  |  |  | X |  | IE |
| Pareas monticola． |  |  |  |  |  | X |  | IE |
| Psammodynastes pulverulentus．．．．． |  |  |  | X1 | 0 | X |  | IE |
| Psammophis condanarus． | X | X | P | P | P |  |  | OR |
| Psammonhis leithi． | X |  | P |  |  |  |  | OR |
| Pseudoxenodon macrops． |  |  |  |  | X1 | X |  | IE |
| Ptyas mucosus．． | X | X | 0 | x2 | X1 | X |  | OR |
| Sibynophis collaris． |  | X | 0 | X1 | O | X |  | IW |
| Sibynophis sagittarius． | X | X | X1 |  |  |  |  | OR |
| Tracnischium fuscum． |  | X | $\bigcirc$ | X 1 | 0 | X |  | ETV |
| Trachischium guentheri． |  |  |  | X 1 | 0 | X |  | EH |
| Trachischium laeve |  | X |  |  |  |  |  | WH |
| Trachischium tenuiceps |  |  |  | X 2 | O | X |  | EH |
| Xenochrophis cerasogaster． | X |  |  | X1 |  |  |  | OR |
| Zaocys nigromarginatus．．．．．．．．．．．．．．．．．．． |  |  |  | X1 | O | X |  | IE |
| Dasypeltidae |  |  |  |  |  |  |  |  |
| Elachistodon westermanni．．．．．．．．．．．．．． | X |  |  |  | P | X |  | EH |
| Elapidae |  |  |  |  |  |  |  |  |
| Bungarus bungaroides．．．．．．．．．．．．．．．．．．．．．．．．．．．．． |  |  |  |  |  | X |  | IE |
| Bungaris caeruleus．．． | X | X | P | P | P |  |  | OR |
| Bungarus fasciatus．．．．． | X |  |  | P |  |  |  | OR |
| Bungaris lividus．．．．．．．．．．．．．．．．．．．．．．．．．．．．．．． |  |  |  |  |  | X |  | EH |

## Table I (Continued)

Distribution of Amphibians and Reptiles of Nepal and Adjacent Areas

| Squamata-Serpentes (Continued) Elapidae (Continued) |  |  |  |  |  |  | 莒 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Bungaris niger... |  |  |  |  |  | X |  | IE |
| Bungaris walli | X |  |  | P | P |  |  | OR |
| Calliophis macclellandi |  | X | O | X 2 | 0 | X |  | IW |
| Naja naja | X | X | 0 | 0 | O | X |  | OR |
| Ophiophagus hannah. | X | X | O | O | 0 | X |  | OR |
| Typiliopidae |  |  |  |  |  |  |  |  |
| Typhlops bothriorynchus. |  | X |  |  |  |  |  | EW |
| Typhlops braminus | X |  | P | P | P | X |  | OR |
| Typhlops jerdoni. |  |  |  |  |  | X |  | IE |
| Typhtops oligolepis |  |  |  |  |  | X |  | EH |
| Typhlops porrectus. | X | X | 0 | O | 0 | X |  | OR |
| Viperimam |  |  |  |  |  |  |  |  |
| Agkistrodon himalayanus. |  | X | X1 | 0 | 0 | X |  | ME |
| Trimeresurus albolabris.. |  | X | 0 | X2 | O | X |  | IW |
| Trimeresurus erythrurus.......... |  |  |  |  |  | X |  | IE |
| Trimeresurus monticola |  |  |  | x 2 | 0 | X |  | IE |
| Trimeresurus popeorum.... |  |  |  |  |  | X |  | IE |
| Trimeresurus stejnegeri............. |  |  |  | X1 | O | X |  | IE |
| Tipera russelli...... | X | X | O | 0 | 0 | X |  | OR |

Table II
Distributional Analysis by Areas:
Totals Based on Summary of Data Presented in Table I

## AMPHIBIA

Species collected................................................
Additional species expected ( O ) .................
Adjacent
Plains
Western
Himalayas
West
Nepal
Central
Nepal
East
Nepal
Sikkim-
Darjeeling


Plains species possibly present (P)

CHELONIA


CROCODILIA

| Species collected. | 2 | 0 | 0 | 1 | 0 | 0 | 0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Additional species expected ( O ). |  |  | 0 | 0 | 0 |  |  |
| Plains species possibly present (P) |  |  | 2 | 1 | 2 |  |  |
| SAURIA |  |  |  |  |  |  |  |
| Species collected | 15 | 13 | 5 | 9 | 5 | 17 | 5 |
| Additional species expected (O). |  |  | 4 | 2 | 4 |  |  |
| Plains species possibly present (P) |  |  | 5 | 4 | 7 |  |  |
| SERPENTES |  |  |  |  |  |  |  |
| Species collected | 37 | 31 | 5 | 9 | 4 | 68 | 0 |
| Additional species expected ( O ). |  |  | 19 | 7 | 30 |  |  |
| Plains species possibly present (P) |  |  | 9 | 9 | 14 |  |  |


| Combined |  |
| :---: | :---: |
| Amphibians |  |
| \& Reptiles |  |
| All | Nepal |
| 71 | 32 |
| 49 | 12 |
| 5 | 4 |
| 94 | 7 |
| 9 | 7 |
| 7 | 1 |
| 5 | 5 |
| 7 | 1 |
| 176 | 69 |


(Totals for Table I) Distributional Analysis of Faunal (Groups


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## PROCEEDINGS

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# CENTRODERA SPURCA (LECONTE) AND TWO NEW SPECIES RESEMBLING IT, WITH BIOLOGICAL AND OTHER NOTES (COLEOPTERA: CERAMBYCIDAE) 

by<br>Hugh B. Leech<br>California Academy of Sciences

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## Introduction

Centrodera spurca (LeConte) is one of the few large Cerambycidae attracted to light during the relatively cool evenings of the Pacific Coast of Canada and the United States. Of the species so taken, the only ones likely to be confused with it are those described as new in this paper, plus Ortholeptura valida (LeConte) and O. insignis Fall ${ }^{1}$ (fig. 1).

A big brownish beetle with antennae fully an inch long in the male (fig. 2), crawling up the glass or buzzing through an open window after dusk, is enough to excite most collectors. Having taken the species in British Columbia I grected those which landed on my windows in Mill Valley, California, as old friends, but bottled them just the same. The first came in mid-May, 1948, and it did not take long to build up an adequate series. Those which followed in June and July were not collected, but in late August I finally realized that the beetles on the windows were smaller than usual and had a different facies. Comparison with the earlier set confirmed that there were two species, and examination of material in collections showed that both had been identified as $C$. spurca for many years. In fact the example used for the drawing in R. Hopping's paper on the Lepturini ( 1937 , pl. III, fig. 4) proved to be the new species.

Knowing of my interest in these large centroderas, Willis C. Day collected some at light along the Scott river in northern California in August, 1949 , and they turned out to be a second new species. A larger series of this from adjacent Oregon was soon submitted by Arthur T. McClay. From their known distribution the two new species are allopatric, but C. spurca

[^9]

Figure 1. Males of Centrodera spurca and Ortholeptura valida, two species which are attracted to light in many of the same areas. The short legs and unarmed prothorax distinguish Ortholeptura at a glance.
is sympatric with both of them. The three are almost enough alike to be called sibling species, but probably were confused because C. spurca is so distinctive and easily recognized that nobody bothered to examine a series critically.

## Acknowledgments

It is a pleasure to acknowledge help from the owners of private collections, and the persons in charge of institutional collections, who have loaned specimens for study; their names are listed below with the letters used to designate the collections, many of which are referred to in the text.

In addition, the following persons have generously given their time to answer questions, compare specimens with types, or verify other data:


Figure 2. A male of Centrodera spurca on a leaf of madroño, at night; the beetles are nocturnal.
R. P. Allen, J. Balfour-Browne, W. F. Barr, R. S. Beal, Jr., P. J. Darlington, Jx., W. C. Day, K. M. Fender, L. G. Gentner, G. A. Hardy, J. N. Knull, G. Kuschel, F. Lane, J. D. Lattin, the late G. P. Mackenzie, P. Rubtzoff, J. Sedlacek, the late G. Stace Smith, P. J. Spangler, P. C. Ting. Through the kindness of P. D. Hurd, Jr., I have been able to use a base map prepared for the California Insect Survey of the Department of Entomology, The University of California, Berkeley. E. G. Linsley and J. A. Chemsak have read the manuscript, but the responsibility for any remaining errors is of course mine. Help by members of my family in field work is equally appreciated. E. L. Kessel kindly took two of the photographs.
AIIH A. II. Howden, Ottawa, Ontario.
BMI B. Malkin; collection now in the Chicago Natural History Museum.
CAS California Academy of Sciences, San Francisco; includes specimens from many private collections, such as those of E. C. Van Dyke, F. E. Blaisdell, E. G. Linsley, J. O. Martin, J. W. Green, R. Hopping.

CIS California Insect Surver, University of California, Berkeley (P. D. Ifurd, Jr., J. A. Powell, J. A. Chemsak).

CNC Canadian National Collection, Ottawa, Ontario (H. Howden).
DG D. Giuliani, San Anselmo, California.

| DR | D. Rentz, Novato, California. |
| :---: | :---: |
| GHN | G. H. Nelson, Colton, California. |
| ILR | I. LaRivers, Reno, Nevada. |
| JGE | J. G. Edwards, San Jose, California. |
| JNK | J. N. Knull, Ohio State University, Columbus, Ohio. |
| JS | J. Schuh, Klamath Falls, Oregon. |
| LACM | Los Angeles County Museum, Los Angeles, California (F. S. Truxal). |
| LGG | L. G. Gentner, Medford, Oregon. |
| ML | M. Lundgren, Oakland, California. |
| OHSU | Ohio State University, Columbus, Ohio (J. N. Knull). |
| OSDA | Oregon State Department of Agriculture, Salem, Oregon (K. Goeden). |
| OSU | Oregon State University, Corvallis, Oregon (J. D. Lattin). |
| PMV | Provincial Museum of Natural IIistory, Victoria, British Columbia (G. A. Hardy). |
| RBH | R. B. Hutt, Pullman, Washington. |
| RWD | R. W. Dawson, Pullman, Washington. |
| SDNHM | San Diego Natural IIistory Museum, San Diego, California (G. Marsh and C. F. Harbison). |
| S.JSC | San Jose State College, San Jose, California (J. W. Tilden and J. G. Edwards). |
| SRP | S. R. Piazza, San Jose, California. |
| UBC | University of British Columbia, Vancouver, British Columbia (G. J. Spencer and G. G. E. Scudder; now includes the G. Stace Smith collection). |
| UCD | University of California, Davis, California (A. T. McClay; includes material from his own collection). |
| UI | University of Idaho, Moscow, Idaho (W. F. Barr and A. Walz). |
| USF | University of San Francisco, San Francisco, California (E. L. Kessel). |
| USNM | United States National Museum, Washington, D. C. (P. J. Spangler; selected specimens). |
| UW | University of Washington, Seattle, Washington (M. H. Hatch; the MI. H. Hatch and K. M. Fender collections are included in the University collection). |
| WSU | Washington State University, Pullman, Washington (M. T. James). |
|  | W. E. Hazeltine, W. R. Bauer and J. S. Buckett collected and donated specimens. |

# Genus CENTRODERA J. L. LeConte 

Centrodera LeConte, 1850. Jour. Acad. Nat. Sci. Phila., 2nd Ser. (N. S.), vol. 1, no. 4, p. 325; LeConte, 1862. Proc. Acad. Nat. Sci. Phila., 1862, pp. 38, 41; Lacordaire, 1869. Hist. nat. insectes, vol. 8, pp. 426, 432; Provancher, 1877. Petite faune ent. Canad., vol. 1, pp. 580, 606; LeConte, 1873. Smithson. Miscell. Coll., no. 265, p. 328; LeConte and Horn, 1883. Smithson. Miscell. Coll., no. 507 , p. 313; Wickhax, 1897A. Canad. Ent., vol. 29, no. 4, p. 88; Blatchley, 1910. Coleopt. Indiana, p. 1046, Swaine and R. Hopping, 1928. Nat'l. Mus. Canada, bull. no. 52, pp. 10, 14; Bradley, 1930. Manual gen. beetles, p. 235; Chagnon, 1936. Le Nat. Canad., vol. 63, nos. 8 and 9, p. 205; R. Hopping, 1937. Nat'l. Mus. Canada, bull. no. 85, p. 10; Knull, 1946. Ohio Biol. Survey Bull. 39, pp. 151, 174; Jaques, 1951. How to know the beetles, p. 255.

Centrodera subgenus Apatophysis Chevrolat, Gressitt, 1951. Longicornia, vol. 2, p. 48 .

Parapachyta Casey, 1913. Mem. Coleopt., vol. 4, pp. 216-217.
It was J. Thomson (1864, p. 145) who designated Rhamnusium? decoloratum Harris, 1841, as the type-species of Centrodera LeConte. Swaine and R. Hopping (1928, p. 10) apparently overlooked this, and stated the type-species to be " (Rhagium) decoloratum Harris," by monotypy. In fact, LeConte cited and described two species following his description of Centrodera (p. 325; Centrodera was actually first given in the key on p. 316, but without included species, and cited as Centroderus by error on p.312): 1. C. decolorata, with snynonyms "Rhamnusium? decoloratum! Harris Ins., Toxotus rubidus, Dej. Cat., T. rubidus [rudibus in Haldeman's original description, by a printer's error], Hald. 58," from Niagara and Massachusetts. 2. C. picta, with the reference "Toxotus pictus Hald 58," from Pennsylvania and South Carolina.

It is surprising that IIaldeman and LeConte did not include the generic name Centrodera in their editing of the Melsheimer Catalogue, since in their part of the Preface (1853, p. viii) they stated that so far as known to them their additions to the original manuscript "include all the species published up to January, 1852."

Casey (1913, p. 216) proposed Parapachyta for "Pachyta spurca Lec., a large pallid and coarsely sculptured species of the true Pacific coast fauna." Dr. Paul Spangler has been so kind as to examine Casey's series for me, and reports "In the Casey collection are four specimens under the name Parapachyta spurca LeC. These agree with our C. spurca with the strongly recurved hair on the base of the elytra and the hind margin of the 5th sternite very distinctly margined. Apparently Casey had LeConte's spurca."

Gressitt (1947, p. 191) said that the Old World genus Apatophysis Chevrolat, 1860, probably should be considered a subgenus of Centrodera

LeConte, 1850. Four years later (1951, pp. 48-50) he so placed it, without further comment, and without giving characters to distinguish it from the nominate subgenus.

According to Gahan (1906, pp. 68, 69) a characteristic of the species of Apatophysis is that the males have the antennae "serrate," i.e. segments 5 to 10 "compressed to a sharp edge in front and angulate at the apex." In the two males I have seen, one identified as A. sinica A. Semenor-TianShanskij, the other as A. serricornis (Gebler), both have antennal segments 6 to 10 distinctly produced at the outer apical angle, and the elytra are rather densely covered with fine, short hairs. The females are said to be less pubescent than the males, or even glabrous, and to have the elytra a little shortened, exposing the last one or two abdominal segments, thus resembling prionines. Figures of both sexes of $A$. barbara Lucas are given by Villiers (1946, p. 39, figs. 107, 108).

In the described species of Centrodera the elytral hairs all arise from the coarse elytral punctures. In the two males of Apatophysis mentioned above, it was at once apparent that the elytral vestiture arises from all over the interspaces between the coarse punctures, but few or none actually from them. Dr. Frederico Lane has been so kind as to check this character in the species of Apatophysis in the collections of the British Museum (Nat. Hist.) : A. toxotoides Chevrolat, 1 male (and a female marked ? barbara Lucas), Sahara; A. caspica Semenow, 2 males from Afghanistan, possibly syntypes; A. kamarowi Semenow, 1 male, Turkestan; A. modica Gahan, 2 male syntypes, one marked type; 1 kashmiriana Semenow, 9 males and 3 females, Kashmir; A. montana Gahan, the male type, West Himalayas. He summarizes his notes (letter of April 15, 1962) as follows: "All species of Apatophysis examined have vestiture on the interspaces, and exceptionally a few hairs as well in the coarser punctures." He also suggests that the palpi may offer characters for the generic separation of Apatophysis and Centrodera.

On the bases of the differences in the elytral vestiture, the antennae of the males, the body form and elytra of the females, and the distribution, I believe that the species of Apatophysis are generically distinct from those of Centrodera.

Gressitt cited the type-species of Apatophysis as Leptura serricomis Gebler, 1843; but Thomson (1864, p. 147) designated A. toxotoides Chevrolat, 1860. Actually, the generic name was monotypic upon proposal, since in both Chevrolat's preliminary (1860A, p.96) and formal (1860B, p. 304) descriptions of $A$. toxotoides, no other species was mentioned in combination with the name Apatophysis.

Van Dyke (1927, pp. 102-103) gave a key to the Pacific Coast species of Centrodera, but did not include C. spurca (LeConte).

Swaine and R. Hopping (1928, p. 14, footnote 2) remarked that "The genus Centrodera Lee is doubtfully distinct from Xylosteus Friv."; later (1937, p. 14) R. Hopping wrote "The comparatively small eyes and type of maculation will not allow it [i.e. the only American species, $X$. ornatus LeConte, 1873] to be placed in the genus Centrodera, although C. picta somewhat approaches this species in maculation." Gressitt (1947, p. 191) removed X. ornatus from Xylosteus to the genus Leptorhabdium Kraatz, 1879.

## Male Genitalia

In describing the curved male genital organ of Centrodera spurca (fig. 12 ) one faces the problem of deciding which side is morphologically dorsal and which ventral. Because of the curvature, the organ lies on its side when at rest in the abdomen, and is rotated during protrusion. This problem has been referred to by Lindroth and Palmén (1956, p. 72) who state "The simplest method is no doubt to speak about dorsal side, left side etc. according to the position of the organ when extended and in activity. We propose that, if necessary, the original (morphological) position of the aedeagus and its details be expressed by the terms eu-dorsal, eu-ventral, eudextral, eu-sinistral."

Even this is not as simple as it sounds. Guignot (1931, p. 53), discussing the male genitalia of Dytiscidae, in which the organ rests on its side, wrote "Au moment de l'érection, l'aedeagus, tout en faisant saillie par la fente génitale, tourne de $45^{\circ}$ sous l'influence de ses muscles rotateurs. C'est dans cette position simple d'érection (et non pas au moment de l'introduction dans le vagin de la femelle, car alors le mouvement s'exagère et la pointe du pénis devient presque antérieure) que sont faites toutes les descriptions, et elles deviendraient incompréhensibles, si on ne se figurait pas nettement la position de l'organe. A ce moment la base du pénis est antérieure, la sommet est postérieur, le bord convexe est dorsal et le bord concave ventral; un paramère se trouve à droite et le second à gauche, le tegmen est dorsal et plus ou moins à droite."

But F. Balfour-Browne (1940B, pp. 126-128, figs. 2-4; see comparable figs. in his 1932 book, p. 45, and pp. 23-24, fig. 6, in his 1940A book), also discussing the Dytiscidae, draws the opposite conclusion: that the convex side is ventral, the concave dorsal. His argument is based in large part in conditions in typical hydrophilids, Hydrophilus spp. and Hydrobius fuscipes (Linnaeus), in which the genital organ is flattened dorso-ventrally and lies flat in the abdomen. He states (loc. cit., p. 126, with reference to fig. 1 on p. 127) "An examination of the aedeagus of an IIydrophilid, where there can be no question as to which is the dorsal side, shows that the opening of the ejaculatory duct, the 'gonopore,' is always on the ventral side
below the apex. In the Hydradephaga [which includes the Dytiscidae], the gonopore is on the convex side." On the other hand G. Kuschel, who has made detailed comparative studies of the genitalia in the Curculionidae, and investigations in other families of the Phytophagoidea, has found (verbal communication, 1962), that on the basis of muscular and other attachments of the genital capsule as it lies at rest in the abdomen, the opening through which the intromittent organ is everted is always on the (morphologically) true dorsal side.

The person who has studied the male genitalia of the Coleoptera most broadly is R. Jeannel. The organs were used extensively in Jeannel and Paulian's 1944 classification of the Order, but it is in Jeannel's 1955 paper that the subject is discussed and illustrated most fully. The range of structural variety shown is truly amazing, and suggests at once that it may not be possible to give a statement as to which side is dorsal, and have it apply universally. This is verified in Jeannel's discussion of the tubular type of median lobe, which consists of two longitudinal sclerites, one of which surpasses the other and forms the "apex," as in Centrodera spp. He says (p. 22) "On comprend ainsi que l'apex étant formé tantôt par la paire sternale, tantôt par la paire tergale, l'orifice apical sera tergal ou sternal par rapport à l'apex, selon les cas." In Centrodera the orifice near the apex of the aedeagus is comparable to Jeannel's figure 5 of a trechid, and thus dorsal, i.e. the convex side of the aedeagus is dorsal. This is in agreement with figures by Villiers (1946, p. 8), Ehara in his major paper on the male genitalia of Japanese Cerambycidae (1954), and most others who have illustrated the organs of this family.

There is another basic subject upon which published opinions differ greatly, and that is the nomenclature of the parts of the genital capsule. In the classical study Sharp and Muir (1912) used the very descriptive terms median and lateral lobes, the whole being the aedeagus, but pointed out that the "lateral lobes" are not always lateral, and the term is thus inappropriate; paramere and tegmen were suggested. Jeannel (1955) followed Sharp and Muir. Lindroth and Palmén (1956) and Lindroth (1957) prefer penis and tegmen, the outer parts of the tegmen being the parameres. Snodgrass (1957) uses aedeagus for the median lobe of Sharp and Muir, and parameres for the lateral lobes; I am following his usage. Other views to be considered are found in papers by Gilbert (1953), Wood (1953) and Michener (1956).

In Centrodera decolorata the genital armature is elongate and only slightly curved, so it is able to lie on its ventral (concave) surface when retracted into the abdomen, and is merely extruded, then bent downward and forward, to be in position for copulation. In C. spurca and allies, it is more strongly curved (figs. 12, 16, 17) and is nearly always found lying on its
left side, i.e., with its apex pointing to the right side of the abdomen, though occasionally almost as in C. decolorata. During protrusion for copulation, an armature previously on its side must make a twist of 90 degrees. In C. nevadica and other small western species examined it lies on its left side when retracted.

## Key to the Species of the C'entrodera spurca Group

1. Elytral vestiture (in profile; fig. 3) inconspicuous, the hairs short, strongly recurved, decumbent. Fifth abdominal sternite with hind edge differentiated, narrowly thickened, usually clearly margined apically 2 and narrowly to base


Figure 3. Centrodera spurca. Part of an elytron to show the inconspicuous vestiture of short. recurved. decumbent hairs.
at sides (fig. 5), often emarginate or broadly subcrenulate, especially in female. Elytral apices each normally with small tooth at sutural angle. Outer antennal segments of male smooth, satiny (fig. 6). Larger species, males averaging 22 mm . in length, females 25 mm . An early season species, late March-early August, commonest in June and July; widespread, southern British Columbia and northern Idaho to southern California (fig. 14) ................................................ spurca

- Elytral vestiture not very conspicuous, with some recurved hairs, but most of those in basal half standing out freely at an angle (fig. 4). Fifth abdominal sternite with at most an unobtrusive fine margin at apex in female. Elytral

[^10]

Figure 4. Centrodera dayi. Profile of an elytron, showing the suberect vestiture.
apices not toothed at sutural angles. Outer antennal segments of male slightly to obviously bristling (figs. 7,8 ). Smaller species, males averaging 17 mm . in length, females 18 mm . Later appearing species, June-September, commonest in August; distribution either adjacent to the Cascade mountains from southern Washington to the Klamath mountains and western foothills of the Sierra Nevada of California, or along the coast of California only
2. Front tarsus notably short and broad (fig. 9). Hind tarsus comparatively short, first segment very gradually widened from base to apex, appreciably broadened apically; second segment noticeably triangular, flattened dorsally (fig. 10). Male with short and appreciably cuneate elytra (fig. 11), antennae with segments 6 to 11 and apical half of 5 with exceedingly short, fine, almost decumbent hairs, the general effect at $\times 25$ fairly smooth (fig. 7). Elytra of female almost straight-sided (fig. 11). Known from southern Washington to the foothills adjacent to the Central Valley of California (figs. 14, 15) ..C. dayi

- Front tarsus more elongate, narrower (fig. 9). Hind tarsus with first segment long, parallel-sided, very slightly broadened apically; second segment elongate, very gradually widening from base to apex, rounded on top (fig. 10). Male with gradually narrowing, nearly parallel-sided elytra, outer antennal segments at $\times 25$ bristly (fig. 8). Female with elytra narrowed behind humeri then widened again (fig. 11). Known only from the coast of California (fig. 15) ....C. autumnata


## Centrodera spurca (LeConte)

Toxotus spurcus LeConte, 1857. Rept. ins. coll. survey, p. 63 (this is a preprint of the following item) ; LeConte, 1860. In: Reports expl. survey . . . Mississippi ... Pacific Ocean, vol. 12, part 3, p. 63; Lacordaire, 1869. Gen. coleopt., vol. 8, p. 439, footnote 1; LeConte, 1870. Ann. Mag. Nat. Hist., ser. 4, no. 35, vol. 6, p. 402 .

Pachyta spurca LeConte, Lexg, 1890. Ent. Amer., vol. 6, part 5, pp. 97, 98; Fall, 1901. Occ. Pap. Calif. Acad. Sci., vol. 8, p. 148; Garnett, 1918. Canad. Ent., vol. 50, part 6, p. 212.
Parapachyta spurca LeConte, Cisey, 1913. Mem. Coleopt., vol. 4, p. 216; Hardy, 1926A. Rept. Provin. Mus. (1925), p. C 28, pl. IV, fig. 3; Handy, 1926B. Ceram. Vanc. Isl., p. 5, pl. IV, fig. 3; Essig, 1926. Ins. West. N. Amer.. p. 452; Moore, 1937. Occ. Pap. San Diego Soc. Nat. Hist., vol. 2, p. 88.

Pachyta (Parapachyta) spurca LeConte, Doane et al., 1936. For. Ins., pp. 176-177.
Centrodera spurca LeConte, R. Hopping, 1937. Nat'l. Mus. Canad., bull. 85, p. 11 (in part, but not the fig. [4] on pl. III, for which see C. autumnata); Hardy, 1942. Proc. Ent. Soc. Brit. Col., vol. 39, p. 10.

Evodinus spurcus J. Leconte, Aurivillius, 1912. In: Coleopt. Catal., Pars. 39, p. 188; Sallas, 1936. Ann. Zool. Soc. Zool.-Bot. Fenn. Vanamo, vol. 4, no. 1, p. 73.

Evodinus (Centrodera) spurcus, Samlas, 1936. Ann. Zool. Soc. Zool.-Bot. Fenn. Vanamo, vol. 4, no. 1, p. 82.
Typocerus cervinus Walker, 1866. In: Lord's Nat. Vanc. Isl. and Brit. Col., vol. 2, p. 332.

Centrodera spurca was described as from Steilacoom, Washington Territory; this is in what is now Pierce County, just southwest of Tacoma, Washington. However, on page 23 of the same paper LeConte recorded it from Oregon; this is explained by his statement on page 3: ". . . (and Washington Territory, which is, for purposes of convenience, always included when Oregon is referred to in these pages) ..." The type is a female,


Figure 5. Centrodera spurca. Fourth and fifth abdominal sternites of a female, the fifth distinctly margined.
and there is a female before me which was compared with it in 1949 by P. J. Darlington, Jr.

The type of Typocerus cervinus Walker is in the British Museum (Nat. Hist.), and the museum's Accession Catalogue entry 6t-18 shows "British Columbia Coll. Boundary Commission Collector J. K. Lord Esq." LeConte examined it and synonymized it (1870, p. 402) with his Toxotus spurcus. Frederico Lane was so kind as to compare a female of C. spurca with Walker's specimen, which has three labels on the pin: 1. Type, Brit 64
Colum 18 mm . long, 8.5 mm . wide at the humeri ; the antennae are approximately 21.25 mm . long, the elytra 19 mm ., the fifth abdominal sternite is margined and slightly emarginate apically, and each elytron has a small spur at the sutural apex. These characters are all in agreement with those of a mediumsized female of C. spurca, with which species it was synonymized by LeConte in 1870 and by Leng in 1890.

It is puzzling that Leng, in his 1890 synopses of the Cerambycidae, put C. spurca in Pachyta, since a specimen will trace correctly to Centrodera in his generic key (p.65), which was taken from LeConte and Horn's 1883 "Classification," it in turn having been taken from LeConte's 1873 "Classification."

Male. Form elongate, broadest at humeri, elytra gradually narrowing from base to truncate apex (fig. 11). Length 19 to 26 mm ., average 22.2 mm .; width at humeri 5 to 7 mm ., average 6.02 mm . Elytra pale yellowishbrown, with luminous golden sheen from reflection of their shagreened under surface seen through the almost transparent upper surface (and resembling the glow seen in some well-worn micaceous schist stones); usually with a rounded black or brownish antemedian dot near side, showing dorsally on each elytron but actually on lower surface; thorax, head, antennae, legs, and undersurface a little darker, pale reddish-brown, eyes and tips of mandibles black; pubescence golden yellow. Head densely, irregularly, moderately coarsely punctate dorsally, most coarsely between eyes where, as on clypeus, surface may be somewhat rugulose; each puncture on mandibles, labrum, clypeus, front, occiput, and undersurface of head giving rise to a hair; mid-cranial suture an impressed line from base of clypeus to declevity between eyes; width of vertex between eyes a little greater than width of an eye. Antennae longer than body, usually surpassing apices of elytra by segments 10 and 11, apical (11th) segment usually constricted at apical five-sevenths, giving the illusion of a twelfth segment; segment eleven one and one-half times as long as scape and threefifths longer than first segment of hind tarsus; scape with moderately long appressed hairs, and sparse scattered shorter hairs which stand out at an


Figures 6-8. Ninth antennal segments of males of three species of Centrodera. Fig. 6. ('. spurch; the fine hairs are closely appressed, the sensory hairs stand out clearly. Fig. 7. ('. dayi; the fine hairs are not decumbent yet only partially obscure the longer sensory hairs. Fig. 8. r. antumnata: the fine hairs are semierect and almost as long as the sensory hairs, giving a bristly appearance.
angle of about 45 degrees, segments 2 to 5 with progressively shorter appressed vestiture, segments 6 to 11 with a dense covering of short appressed hairs lying parallel to the length of the segments, with occasional short sensory hairs projecting at about 45 degrees (fig. 6 ), the effect at about $10 \times$ being as of satin, i.e. holosericeus. Inflated disk of pronotum a little more coarsely and closely punctured than is head between eyes, each puncture


## C. SPURCA C. AUTUMNATA C. DAYI

Figure 9. Basal three segments of the front tarsi of Centrodera spurca, C. autumnata and C. dayi to show relative lengths and widths; vestiture and punctation omitted.

C. DAYI

## C. SPURCA C.AUTUMNATA

Figure 10. Basal three segments of the hind tarsi of Centrodera spurca. C. autumnata and $C$. dayi; punctation and vestiture omitted.
with a fine recurved hair, except at sides near base where some of the hairs are long and projecting; lateral tubercles slightly antemedian. Elytral width at humeri, to length, about as is 7.3 to 17.7 ; coarsely closely punctured at base, except on humeri, and progressively less coarsely and more shallowly punctured from base toward apex, each puncture giving rise to a short fine recurved hair; elytral apices truncate, sutural angles usually with a small blunt spine. Abdominal sternites clothed with fine appressed golden hairs which do not obscure surface, and sparse longer and less decumbent hairs, especially at apices of segments and along median line. Fifth visible abdominal sternite distinctly thickened and margined apically, margin extending narrowly along sides nearly to base, apex usually broadly emarginate and a little impressed at middle; pygidium emarginate apically. Hind femur reaching to slightly beyond apical eighth of elytra, vestiture of hind margin short, even; first segment of hind tarsus as long as segments 2 and 3 combined, segment 1 gradually widening from base to apex, segment 2 one and a half times as wide at apex as at base (fig. 10). Male genitalia: On the basis of the orientation accepted in the general discussion of the male genitalia, earlier in this paper, the genital armature lies on its left side in the abdomen. Aedeagus tubular, elongate, curved (fig. 12A), basal third bilobed in dorsal view (fig. 12D); apical twothirds longitudinally divided into dorsal and ventral sclerites which can gape apart but are actually joined by a pliable membrane (figs. 12A, 12B, stippled area), ventral side longer than dorsal, more strongly sclerotized and slightly hooked apically; sclerotized area of apical two-thirds of dorsal side narrowing apically, with area along each side of median line differentiated, i.e. more strongly sclerotized and darkened, ending in slightly spreading bifid prominences (figs. 12A, 12B). Intromittent organ, when everted, about as long as aedeagus, with two irregularly shaped armatures (when the endophallus is retracted and folded within the aedeagus the pair of armatures appear as in fig. 13, but when it is extruded and inflated to to its full dimensions the two armatures are on opposite sides and separated by a distance equal to the length of one of them), and a pair of small, nearly quadrate rasp-surfaced areas. Tegmen elongate, slightly curved, encircling aedeagus (as in fig. 17) at about mid-point, but independently moveable; apical third thickened, flattened, developed into two separate parameres, each with dense reddish-brown hairs on outer edge and apex (fig. 12C) but having only about 50 thin paler hairs on its inner or ventral surface; basal ends not coalesced, but fitting into hollow of basal third of ventral surface of aedeagus, as in fig. 17A.

Female. Length 20 to 30 mm ., average 24.9, width at humeri 6 to 8.5 mm., average 7.3. Form stouter than in male, elytra almost paralled-sided in basal five-sixths. Antennae shorter than in male, barely reaching to
apical sixth of elytra; 11th segment as long as scape, not constricted; antennal vestiture as in male.

Varlation. There are occasional specimens in which the elytra show six or seven narrow paler lines; these are on the lower surface and show


Figure 11. Males (upper row) and females of Centrodera spurca, C. dayi and C. autumnata, respectively.
through to give the appearance of light vittae. Most examples seen have been from the northeastern distribution of the species.

The considerable range in size has been noted above. Some specimens are more reddish- than yellowish-brown, but this may result from differences in methods of killing and preparing for mounting. The antemedian lateral


## CENTRODERA SPURCA

Figure 12. Male genitalia of Centrodera spurca. A. The tubular aedeagus in profile; it consists of two longitudinal sclerites, here shown separated by the inflated pliable connecting membrane (stippled); the dorsal sclerite is on the left and ends in a (bifid) prominence. B. Dorsal view of the apical part of fig. A; the dorsal sclerite with its bifid tip overlies the stippled connecting membrane. C. Dorsal view of the flattened apical third of the tegmen (三parameres; for their normal position in relation to the aedeagus see fig. 17A). D. Dorsal view of the bilobed basal third of the aedeagus, i.e., the upper right part of fig. A.
dot on each elytron varies from a maximum diameter of 1 mm . to the tiniest observable spot, and contrary to R. Hopping's statement (1937, p. 11) is completely lacking in about ten per cent of the beetles studied; it varies also from black to a pale brown. R. Hopping's record (1921, second page) of a series of Pachyta spurca showing "much variation in maculation" surely resulted from a lapse of memory as to the genus and species on the part of F. E. Blaisdell, who recorded the minutes of the meeting.

The apex of the fifth abdominal sternite varies from rather evenly rounded to broadly emarginate. It may be narrowly or weakly margined, but is usually strongly so, especially in the female, in which the margin tends to be broader and less regular than in the male (fig. 5). Of the 1061


Figure 13. Armature of the intromittent organ of the male genitalia of Centrodera spurca, C. autumnata and C. dayi. For C. spurca the paired armatures are shown as they lie partially superimposed when the organ is retracted within the aedeagus; when the organ is everted and inflated during copulation they are on opposite sides of it and separated by a distance about equal to the length of one of them.
specimens of C. spurca examined only four, all females, do not show an appreciable margining; they are from Pullman and Rock Island, Washington, and Hat Creek and Meadow Valley, California. All are easily separated from the species with non-margined fifth sternite by the short recurved elytral hairs.

Distribution. There are not many published records for C. spurca and its synonym Typocerus cervinus Walker; a few of those for Oregon and California may prove to have been based on the new species described in this paper, but I believe over 90 per cent truly refer to C. spurca. All records known to me are listed here in abbreviated form; most of the full references may be found in the Leng Catalogue and its supplements, though many are in the terminal bibliography of the present article. I have not
used any of these records in my maps and tables unless I have seen the actual specimens.

LeConte, 1857, p. 23, "Or."; p. 63, Steilacoom, Washington Territory (reference is to the type specimen; see explanation in first paragraph following the synonymy of $C$. spurca).
LeConte, 1860 -a repetition of the above.
Walker, 1866, p. 332. British Columbia.
Lacordaire, 1869, p. 439. Orégon.
LeConte, 1869, p. 371. Vancouver's Island [and/or] British Columbia.
Gemminger and Harold, 1872, p. 2859. "California. Vancouv. Ins."
Leng, 1890, p. 98. "Cal., Vanc., Nev."
Fall, 1901, p. 148. Echo Mountain, Los Angeles County, California.
Currie, 1904, p. 28. Kaslo, British Columbia.
Harvey, 1907, p. 4. Victoria, British Columbia.
Wright and Coolidge, 1908, p. 68. Towle, Placer County, California, in June and July.
Aurivillius, 1912, p. 188. "Californien, Nevada, Vancouver-insel."
Casey, 1913, p. 217. ". . species of the true Pacific Coast fauna."
Woodworth, 1913, p. 228. California (as Pachyta spurcata [sic!] LeConte).
Gibson, 1917, p. 150. "Swanlake, B. C." (This is Swan Lake, a few miles north of Vernon, British Columbia.)
Garnett, 1918, p. 212. ". . . taken by Fall at Echo Mt., Southern California. Found by Van Dyke at Santa Monica."
Leng, 1920, p. 271. "Nev.-Vanc. So. Cal."
Baumberger, 1921?. St. Helena, Napa County, California. (Date of publication uncertain; page not numbered.)
Hardy, 1926A, p. C28. Victoria, Sidney, Shawnigan, Duncan, British Columbia. British Columbia to California.
Hardy, 1926B, p. 5. (As above.)
Essig, 1926, p. 452. California, Nevada, Oregon, Washington, and British Columbia.
Harvey, 1926, p. 5. (A republication of his 1907 list.)
Canova, 1936, p. 129. Corvallis, Alsea, Junction City, Minam National Forest 20 miles NW. of Bly; all in Oregon.
Doane et al., 1936, pp. 176-177. ". . throughout the Pacific Coast."
Saalas, 1936, p. 73. "Nordamerika."
Hopping, 1937, p. 11. British Columbia, Idaho and California. ". . . probably occurs in Oregon and Washington. Nevada is mentioned in the literature."
Moore, 1937, p. 88. ". . . San Diego in April and July . . . Warner's Spring in July." (California.)

Hatch, 1939, p. 29. Eastern and western Washington.
Hardy, 1942, p. 10. 3.5 miles N. of Victoria, British Columbia.
L. E. Ricksecker, then of Santa Rosa, California, offered C. spurca for sale in his "Price list of Coleoptera of the Pacific Coast, No. 15. January 1, 1897," and probably in earlier lists, though I have not seen them. If he obtained his specimens at his ranch "Sylvania," near what is now Camp Meeker, Sonoma County, he probably had representatives of both true C. spurca and one of the species here described as new.

As known to me from actual specimens, C. spurca occurs across southern British Columbia except for the mainland west of the coast mountains, from southern Vancouver Island (Ucluelet-Nanaimo-Victoria) to the East Kootenays (Creston), with the most northerly record at Salmon Arm, lat. $50^{\circ} 41^{\prime} \mathrm{N}$. , long. $119^{\circ} 18^{\prime} \mathrm{W}$. ; thence through Washington, northern and mid-western Idaho and adjacent Oregon, Oregon just east of the coast range to San Diego via the coast of California, and to the Greenhorn mountains of Kern County via the Cascades and Sierra Nevada, with a few records for western Nevada. The species must occur in northwestern Montana; a single specimen labeled Salt Lake City, Utah, has been seen. Except that there are no records of C. spurca from the British Columbia mainland west of the coast mountains, its distribution is remarkably like that of another cerambycid, Ergates s. spiculatus (LeConte) ; see the map, fig. 8, in Linsley's 1962 paper.

In California, C. spurca is known from the following counties, listed in north-south sequence, first for the coast and adjacent mountain areas west of the Central Valley: Del Norte, Humboldt, Trinity, Mendocino, Sonoma, Lake, Marin, Contra Costa, Alameda, San Mateo, Santa Clara, Santa Cruz, Monterey, San Luis Obispo, Ventura, Los Angeles, San Bernardino, Riverside, San Diego. For the Cascades and Sierra Nevada, Siskiyou, Modoc, Shasta, Lassen, Plumas, Tehama, Butte, Nevada, Placer, Eldorado, Alpine, Calaveras, Tuolumne, Mariposa, Mono, Madera, Fresno, Tulare, Inyo, and Kern. As is obvious from the map (fig. 14) the species should be looked for in the Sierra Juárez and Sierra San Pedro Mártir of Baja California, México.

In the coastal region of California C. spurca has been taken from about 700 fect above sea level at Carmel, Monterey County, to 5800 feet near the top of Junipero Serra peak, the highest point in the Santa Lucia mountains of the same county, and some 40 miles southeast of Monterey. In Mill Valley, Marin County, it occurs down to an elevation of not more than 100 feet above sea level, while in southern California it has been taken at Lake Arrowhead, San Bernardino County, at 5100 feet. In the southern Cascades there are records from about 2280 feet at Dunsmuir, Siskiyou County, to 3200 feet at Hat Creek, Shasta County, 4450 feet at Alturas,

Modoc County, and about 6700 feet at Summit Lake in Lassen Volcanic National Park. In the Sierra Nevada the lowest station seems to be Quincy, Plumas County at 3400 feet, and Twain Harte, Tuolumne County at 3600;


Figure 14. The distributions of Centrodera spurca and C. dayi, plotted from the locality labels of specimens seen during this study; no records from the literature have been mapped unless represented by specimens. Note that the two species have been taken at the same places in sixteen cases.
thence to 7000 feet at Huntington Lake, Fresno County, and to between 8000 and 11,000 feet near Cllacier Lodge, Big Pine Creek, Inyo County, on the east slope of the Sierra Nevada.

Centrodera spurca has not been reported from the Rocky Mountains to my knowledge; it is not in Mank's $193 \pm$ Glacier Park list. Neither is it in the Utah list (Knowlton and Wood, 1950), but there is a female specimen in the Ohio State University collection labeled "Salt Lake City, Utah, X.16.1952. R. E. Rodock. R. E. Rodock Collection." October is an amazingly late date for this species.


Figure 15. The known distribution of Centrodera autumnata, and the California records for C dayi.

Centrodera autumnata Leech, new species.
Centrodera spurca LeConte, R. Hopping, 1937. Nat'l. Mus. Canada, bull. no. 85, p. 11 (in part, including the fig. on pl. III).

A species resembling C. spurca but averaging smaller, with suberect elytral pubescence, bristly outer antennal segments in the male, nonmargined fifth abdominal sternite; appears later in the season, and is restricted to coastal California.

Holotype, male, Mill Valley, Marin County, California, 16.VIII.49, at light (Hugh B. Leech). In the California Academy of Sciences (Entomology).

Length 18 mm ., width at humeri 5.2 mm . Form elongate, elytra very gradually tapering from base toward apex. Color yellowish-brown above and below; tips of mandibles, eyes, and a small oval sublateral spot showing through from lower surface of each elytron just before middle, black; elytra pale yellowish-brown, darkest at base, pronotum and antennae a little darker than elytra, head reddish-brown, tarsal claws and mandibular attachments rufous. Head dull between eyes, otherwise shining; punctures on clypeus irregular in sizes and distribution, those on vertex, occipital area and submental region more regular and denser, each puncture giving rise to a hair; width of vertex between eyes slightly narrower than width of an eye, mid-cranial suture apparent but its course very little depressed. Antennae longer than elytra by length of last two segments, 11th segment one and a half times as long as scape and a little longer than first segment of hind tarsus, scape reaching to beyond hind margin of eye; scape, segments 2 to 4 and basal half of 5 shining, finely punctured, clothed with closely appressed hairs and widely spaced suberect fine sensory hairs; apical half of segment 5 and segments 6 to 11 in their entirety dull, the vestiture dual, consisting of fine decumbent hairs, hard to see, and a dense covering of suberect stiff hairs like the pile of a rug, two-thirds as long as the sensory hairs and projecting at the same angle; the outer segments thus have a bristly appearance as in fig. 8. Pronotum moderately coarsely punctate, punctures sparser on preapical and prebasal transverse grooves, coarsest at sides of disk where some punctures are contiguous, integument there subrugose; vestiture sparse, of fine erect hairs, especially at sides basally, and of shorter decumbent hairs which are less obvious; lateral tubercles blunt, slightly antemedian, prothoracic width at (and including) tubercles 95 per cent of width at base and about one-third greater than width at apex. Elytra widest at humeri, gradually tapering to apices, fastest in apical sixth; width at humeri is to length as 11 is to 26 ; punctures coarse and dense basally except on humeri, discal punctures separated from one another by about one-half their own widths, becoming progressively smaller and shallower toward elytral apices, densest just behind humeri; apices
vaguely truncate, without tooth at sutural angle. The hairs arising from elytral punctures short, standing out at an angle, especially in discal region; elytral surface more opaque than in C. spurca, golden subsurface reflections less evident. Front, middle, and hind tarsi progressively narrower and more elongate, first three segments of front tarsus seven-tenths as long as front tibia; first segment of hind tarsus long, narrow, parallel-sided, very slightly broadened apically (fig. 10), one-third as long as hind tibia; second segment of hind tarsus rounded on top, almost half as long as first. Hind femur reaching slightly beyond apical seventh of elytra, with a series of sparse long hairs along hind margin, from tip of trochanter nearly to apex, hairs from half to three-quarters as long as femur is wide and inclined somewhat toward abdomen. Male genitalia (see fig. 16, and the general dis-


## C. AUTUMNATA

Figure 16. Male genitalia of Centrodera autumnata. A. Profile of the tubular aedeagus, the upper (on the left side) and lower sclerites here shown separated by the pliable connecting membrane, stippled. B. Dorsal view of the apical part of the aedeagus. C. Dorsal view of the parameres.
cussion of the organs in the early part of this paper). Essentially as in C. spurca, but differing as follows. Median line of apical two-thirds of dorsal side of aedeagus much less strongly or not at all differentiated in color, ending in a less prominent knob which is not bifid apically, but with transverse rugae on the depressed neck just before apical bulb. "Floor" of median area of tegmen deeper than in C. spurca, hairs of parameres shorter and paler in color, inner face of paramere with only about 25 hairs. Armatures of intromittent organ as in fig. 13 ; it is possible that their apparent difference in shape from those of $C$. spurca may be due in part to some slight difference in the angle of viewing.

Allotype, female, Mill Valley, Marin County, California, 13.VIII.1949, at light (H. B. Leech) [CAS]. Length 17 mm ., width at humeri 5 mm . Similar to the male but more robust (as in fig. 11), elytra not tapering gradually from base to apex but a little wider at apical quarter than at base, apices rounded. Antennae shorter than body, reaching to apical quarter of elytra (equivalent to third abdominal sternite), segment 11 seven-tenths as long as scape; hairs on segments 6 to 11 and on apical half of 5 appressed, except for the scattered suberect sensory hairs. Fifth abdominal sternite lightly margined at sides near base; intercoxal process of first abdominal sternite a little blunter apically than in holotype.

Paratypes, all from California. Marin County: $550^{\circ} 0^{7}, 7$ 우 오 topotypes, taken by members of my family or myself at our former home at 427 Rose Avenue, Mill Valley (elevation 600 feet), nearly all attracted to lights and collected on the windows of the house, 1948-1956; 10 in May, $5 \delta^{\pi} \sigma^{\pi}$ in July, $40 \sigma^{\pi} \sigma^{\pi}$ and 5 우 우 in August, $11 \sigma^{\star} \sigma^{\star}$ and 2 오 오 in September [CAS]. Also the following from other parts of Mill Valley; $1 \delta^{7}$ 23.VI.1925, $40^{7}$ or $^{7} 22 . V I I I .1925,10^{7} 8 . V I I I .1925,1 \sigma^{7} 3 . I X .1924$ (E. P. Van Duzee) [CAS] ; 1 $\sigma^{7}$ 19.VII.1954, $1 \sigma^{7}, 2$ 와 오 17.VIII. 1950 (E. S. Ross) [CAS]; 1ơ 7.VII.1959, 1 ㅇ 16.VII.1959, 1 o $^{*}$, 1 ㅇ VIII. 1959 (J. Sedlacek) [J. Sedlacek]; 1 우 23.LX. 1950 (F. X. Williams) [CAS]; 1 \& 3.LX. 1950 (D. Kelley)

 3.VIII.1955, 3 ơ ơ 16.VIII.1955, $10^{*}$ 23.VIII. 1955 (all by H. L. Mathis, those for 1955 labeled "Light Trap Collecting") [UCD]; 1o 7.VII.1961, Bootjack Camp, south slope of Mt. Tamalpais (H. B. Leech) [CAS]. Also the following from other places in Marin County; Novato, $1 \delta^{\pi}, 1$ if 16.VIII. 1954, at light (H. B. Leech) [CAS. Observed in copulation on August 17]; 1 $\sigma^{\star}$ 6.IX.1948, $1 \sigma^{\star}$ 18.VIII. 1954 (E. L. Kessel) [CAS]; Umdelelannyoni,
 tas, $1 \sigma^{\pi} 30$. VII. 1921 (F. E. Blaisdell) [CAS]; Lansdale, $1 \delta^{2}$ 30.VIII. 1914 (R. Hopping collection. The pin carries a pink label marked "Pl." and the specimen is the one used by George R. Hopping in making his drawing for
fig. 4, pl. III of R. Hopping's 1937 paper on the Lepturini) [CAS]; Toll House, 2 ƠO Ơ, $^{\text {Ot }} 2$ 우 5.VIII. 1949 (Alice Edwards, J. G. Edwards) [JGE];
 Mathis) [UCD] ; Fairfax, $1 \sigma^{*}$ 25.VIII. 1953 (H. L. Mathis) [UCD]; Strawberry Point, $1 \sigma^{*} 6$. VIII. 1953 (H. L. Mathis) [UCD]; San Anselmo, $1 \sigma^{*}$ 24.VII. 1940 [CAS] ; Ross, $1 \sigma^{8} 3$. VIII.1955, $10^{7}$ 16.VIII. 1955 (H. L. Mathis) [UCD]. Humboldt County: Dyerville, $1 \sigma^{7}$ 18.VIII. 1951 (R. W. Dawson) [RWD]. Sonoma County: Rio Nido, $1 \sigma^{\circ} 31 . V I I .1946$ (D. Giuliani) [DG]; Guerneville, $10^{* 1}$ 11.VIII. 1948 (D. Giuliani) [DG]; Stewarts Pt., $10^{7}$ VI. 1942, $10^{7}$ VII. 43 [CIS]. San Mateo County: La Honda, $1 \sigma^{2}$ 14.VIII. 1925 (U. S. Grant IV) [SDNHAI]. Santa Clara County: Cupertino, $1 \sigma^{\circ}$ 20.VI. 1939 (K. S. Hagen) [CIS]; Los Gatos, $10^{7}$ 16.VIII. 1954 (Sr. Mary Baptista) [USF] ; Alum Rock Park, $10^{7}$ 17.VII. 1949 (S. R. Piazza) [SRP]; San Jose, $10^{7}$ 17.VII.1931, $1 \delta^{2}$ 22.VII. 1931 [CIS]. Santa Cruz County: Big Basin Redwood State Park, 1 o 1.LX. 1953 (P. H. Arnaud, Jr.) [CAS]; Big Basin, $1 \sigma^{\text {o }} 10$. VIII.1933, $2 \sigma^{\top} \sigma^{7}$ 12.VIII. 1933 (W. H. Lange) [UCD], $10^{\text {T }} 17$.VII. 1940 (B. Brookman) [UI] ; Boulder Creek, 3 ơ ơ 6.VIII. 1941 (.J. W. Tilden) [S.JSC], 1 ơ 20.VII. 1949 (W. E. Hazeltine) [CAS], 1 ㅇ 21.VIII. 1935 (B. E. White) [CAS]; Brookdale Lodge, 1o 18.VIII. 1940 (K. Frick) [CIS]; Ben Lomond, $4 \sigma^{\text {® }} \sigma^{\text {h }}, 2$ 우 ㅇ 30.VII. 1959 (D. Rentz) [DR], 1 ठ 3.VIII. 1959 (C. Wemmer) [CAS], 4 ठ ơ 31.VIII. 1962 (C. D. MacNeill) [CAS], 1ठ "1918" (Mary Knowles; R. Hopping Collection) [CAS] ; Mount Hermon, 1 오 16.VIII. 1949 (W. E. Hazeltine) [CAS]; Santa Cruz hills south of Felton, 3 ơ ơ 27.VII. 1961 (G. Follin) [CAS]; Santa
 2 or $^{\text {o }}$ 12.VII.1941, $1 \sigma^{\text {or }}$ 17.VII. 1941 (J. W. Tilden) [SJSC]; Highland District, 2 ㅇ 우 2.IX. 1956 (S. M. Fidel) [UCD]; "Santa Cruz Co.", 1 if VIII. 1916, $2 \sigma^{7} \sigma^{7}$ VII. 1917 (E. R. Leach) [CAS]. Montery County: Junipero Serra Peak, Santa Lucia Mountains, on peak ca. 5800 ft . elev., at light, $40^{7} 0^{7}$ 8.VIII. 1956 (II. B. Leech) [CAS]. Santa Barbara County: Carpinteria, 1 of 1.IX. 1935 (B. E. White) [CAS]. San Bernardino County: Barton Flats, $20^{\circ} 0^{\circ}$ 20.VIII.1936, $10^{\circ}$ 21.VIII. 1936 [CAS]. Riverside County: Idyllwild, $1 \sigma$ VIlI. 1946 (C. Harnage) [UCD]. San Diego County: Newton, 1 ơ 14.VII. 1949 (D. J. \& J. N. Knull) [.JNK] ; Laguna, $10^{7} 22$. VII. 1934 (C. (\%. Searl) [SDNHLD].

Additional specimens studied but not designated as paratypes are the following: Marin County; Mill Valley, 18" 28.VI.1959"at light, first of season" (II. B. Leech), 3 o' ơ 18.VIII. 1950 (II. B. Leech) [CAS]; "Redw. C. Ft. Hills" [=Redwood Canyon foothills near Muir Woods?], $2 \delta^{\pi} \sigma^{\pi}$ 18.VIII.1946, $10^{2}$ 21.VIII.1946 (I). Giuliani) |D(i]. Santa Cruz County; Ben Lomond, 1 \& 3.V1.1946, 1 of 8.VI. 1946 (W. Lee) [CAS]. Santa Barbara County; Santa Barbara, 1 of (F. E. Winters) [CAS].

In addition to those being returned to their owners, paratypes will be deposited in the following institutions: the U. S. National Museum, Washington, D. C.; the Canadian National Collection, Ottawa, Ontario; the British Museum (Nat. Hist.), London; the University of British Columbia, Vancouver; the University of Washington, Seattle; Oregon State University, Corvallis.

Variation. The paratype males vary in size from a length of 14 mm . and a width at the humeri of 4 mm ., to a length of 21 mm . and width of 6 mm ., with averages of 18.2 mm . and 5 mm . respectively; paratype females from a length of 16 mm . and width of 4.5 mm . to 22.5 mm . and 6.75 mm ., with averages of 18.8 mm . and 5.5 mm . There is an appreciable variation in color, from pale yellowish-brown to distinctly reddish-brown. It is hard to tell how much of the variation is natural because all living examples I have seen have been yellowish-brown; I suspect the darker color of some dried specimens results in part from different methods of killing and preserving.

The clypeus may be somewhat flattened, smooth, and impunctate in front as is the labrum, or it may be punctate right up to its front edge. The apex of the scutellum varies from broadly rounded to pointed, and is occasionally slightly irregular but not emarginate. The elytral apices vary from distinctly truncate to rounded, or even incised. Only a single specimen has been seen in which the semi-erect hairs of the basal half of the elytra are so abraded as to give difficulty in the key. The much finer erect hairs of the pronotum are often matted down or worn off, except behind the lateral tubercles; these latter vary from softly rounded protuberances to almost spinous processes. The intercoxal process of the first abdominal sternite of some females is as sharply pointed as in the male, in others it is blunter or even rounded apically. None of these variations is correlated with distribution.

Remarks. Males of C. autumnata resemble those of C. spurca fairly closely in form but average smaller and are commonest later in the season; both have antennae surpassing the elytral apices by the length of the last two segments. Centrodera autumnata is easily recognized by the suberect elytral pubescence, non-margined fifth abdominal sternite, long narrow hind tarsi, fuzzy-appearing outer antemnal segments (see figs. 8, 10). These same characters, except the last, will also separate females of C. autumnata from those of C. spurcu.

Males of $C$. autumnata may be separated from those of $C$. dayi by their more elongate and less triangular elytra, longer antennae with the eleventh segment longer than the first segment of the hind tarsus, and their narrower and more elongate tarsi, especially the front tarsi (figs. 9, 11, 18). Females
of $C$. autumnata are recognized by their narrower and more elongate hind tarsi, with the second segment rounded rather than flattened on top.

Distribution. Centrodera autumnata is known only from the coastal area of California, from Dyerville, Humboldt County to San Diego County (fig. 15). It occurs from virtually sea level at Mill Valley, Marin County, to 5800 feet in the Santa Lucia Mountains of Monterey County, but is unknown from the Monterey coast where C. spurca is not rare. Although its distribution is entirely within the southwestern edge of that of $C$. spurca (figs. 14, 15) and they have nine localities from Sonoma County to Riverside County in common ${ }^{3}$, they must have very different ecological requirements. For instance, at Mill Valley both species are remarkably common, especially $C$. autumnata; yet just across San Francisco Bay in Berkeley and the Oakland hills, where C. spurca is fairly common, there are no records for C. autumnata. A little south of the bay, however, it occurs further east than the Oakland hills (fig. 15).

The gap between the Humboldt County and Sonoma County localities is almost certainly because there has been little collecting at light in the late summer; but similar gaps south of Monterey County are likely to indicate extensive areas of unsuitable habitats. The species should be looked for in the northern mountains of Baja California, México. The finding of C. dayi at Rumsey, Yolo County, some 50 miles due east of the Sonoma County records for ('. autumnata, suggests that their distributions may over lap in the Eel River country.

Centrodera dayi Leech, new species.
? Centrodera hirsuta R. Hopping (Ms., nomen mulum), 1939. In Hatch, Prelim. list Coleopt. Wash., p. 29.

A species resembling C. spurca but which has shorter antennae in the male, shorter front tarsi, suberect elytral vestiture, shorter elytra which are distinctly cuneate in most males, and coarser elytral punctation especially in the apical half. Known from south central Washington to the foothills of the Sierra Nevada in central California.

Holotype, male, Scott River at Klamath River, Siskiyou County, California, 1.VIII.1949, at light (W. ©. Day). In the California Academy of Sciences (Entomology).

Length 19.2 mm ., width at humeri 5.7 mm . Form moderately elongate (as in fig. 11), elytra tapering regularly from humeri to near apices. Color brown, eyes, tips of mandibles and antemedian lateral spot (showing through from underside of each elytron), black; head, thorax, legs, basal four segments of antemnae and basal third of elytra reddish-brown, ab-

[^11]domen, outer antennal segments and apical two-thirds of elytra yellowishbrown. Head shining; punctures of irregular sizes dorsally, less coarse and more evenly distributed on submental area, each giving rise to a hair; width between eyes slightly less than width of an eye; mid-cranial suture clearly, evenly impressed. Antennae reaching to just beyond elytral apices, 11th segment a little shorter than scape but equal in length to first segment of hind tarsus, scape reaching to beyond hind margin of eye; scape, segments 2 to 4 and basal two-thirds of 5 shining, finely punctured, clothed with appressed hairs, and some widely spaced suberect fine sensory hairs; apical third of segment 5 and segments 6 to 11 dull, with a vestiture of nearly decumbent fine hairs from which the sparse suberect sensory hairs stand out clearly as in fig. 7, the whole having a slightly velvety appearance; 11th segment tapering from apical three-fifths to tip. Pronotum strongly inflated between preapical and prebasal transverse impressions, closely and


## C. DAYI

Figure 17. Male genitalia of Centrodera dayi. A. Profile of the tubular aedeagus, with the tegmen in its normal position over it, the parameres covering the apical portion of the dorsal sclerite. B. Apical part of the aedeagus, dorsal view. C. Parameres, dorsal view.
rather evenly punctate, punctures about comparable in size to those at middle of elytra; vestiture of fine mostly appressed hairs, one from each puncture; blunted lateral tubercles slightly antemedian, width of prothorax across tubercles a trifle wider than at base, apex five-sevenths width of base. Apex of scutellum rounded. Elytra widest at humeri, regularly tapering to apical seven-ninths where they are a little less than nine-fourteenths width at base, then more rapidly to apices; width at humeri about sixfourteenths the elytral length; punctures coarse basally, fairly regularly in oblique series of four between traces of costae following courses of the longitudinal tracheae, gradually smaller and shallower from base to apex, those near apex comparable to discal pronotal punctures but shallower; apices subtruncate, without tooth at sutural angle. Each elytral puncture giving rise to a hair, of which those on discal area stand out at an angle, suberect, those at sides and toward apices more nearly decumbent. Front and middle tarsi much broader than hind tarsi (as in figs. 9, 10), front pair notably broad; first three segments of front tarsus six-tenths as long as front tibia; first segment of hind tarsus one-third length of hind tibia, very gradually widening from base to apex, appreciably broadened apically, second segment tlattened dorsally, a little less than two-fifths length of first. Hind femur with a row of sparse hairs along hind margin, from tip of trochanter nearly to apex, hairs less than half as long as femur is wide. Male genitalia as in figs. 13, 17; for general description see C. spurca.

Allotype, female, same data as for holotype but collected on August 7; in California Academy of Sciences (Entomology). Length 17.5 mm ., width 5.7 mm . Generally similar to male but more robust (as in fig. 11). Head and thorax tinged with piceous, elytra more uniformly yellowish-brown, more parallel-sided, less tapering than in male. Antennae reaching to just beyond apical two-thirds of elytra (i.e. not quite to apex of second abdominal sternite); segment 11 is to scape as 2 is to 2.75 ; vestiture of segments 6 to 11 and apical half of 5 appressed, except for seattered suberect sensory hairs. Fifth abdominal sternite exceedingly narrowly margined apically; elytral apices rounded.

Paratypes. Wasifington: Yakma County; Yakima, $10^{7} 10$. VIII. 1931 (A. R. Rolfs. R. Hopping collection) [CAS], 1 ㅇ 10.VII.1936, elevation 1025 feet (R. W. Every ) [CIS|; Selah, 1 ㅇ (Rufus Kiser) [UW]. Walla Walla County; Walla Walla, $10^{\star} 30 . V I I .1952$ (M. C. Lane) |.JNK], $10^{7} 30 . V I I .1947$ (W. C. Cook) [JS] ; Kooskooskie, $10^{7}$ 1.VIII.1932, 1 or $^{\text {2 }}$ 21.V III. 1932 (M. C. Lane) [USNMI]. OREGON: Columbla County; St. Helens, 1 o 21.VII.1936, at light (K. Gray, J. Schuh) [OSU]. Hood River County; Mid Col. Expt. Sta., Hood River, 2 ő ơ 30.VII.1957, 1 iq 3.VIII.1957, 1 or $^{7} 23$. VIII. 1957 (Clive D. .Jorgensen) [OSU], 1 i 3.VIII. 1957 (Clive I). Jorgensen) [RBH] : Mood River, 1 ㅇ 18.VIII.1954, at light (Paul
O. Ritcher) [AHH]. Sheralan Countr; Pine Grove Dist., Maupin, $10^{\circ}$ May-June '52 [UW]. Yamhill County; McMinnville, 1ơ 24.VII.1944, 1 ㅇ 1.VIII.1949, 1 ㅇ 4.VIII. 1952 (K. M. \& D. M. Fender) [UW]. Marion County; Salem, $1 \sigma^{7}$, 1 ㅇ 31.VII.1959, 3 ơ $^{\text {ơ }}, 3$ 우 우 31.VIII.1959, Blk. Lt. Trap (Harold Foster) [OSDA]. Benton County ; Corvallis, 1 ㅇ 7.VII. 1931 (N. P. Larson), 1 우 8.VIII. 1952 (Paul O. Ritcher) [OSU], 1 ㅇ 16.VIII. 1941 (K. M. \& D. M. Fender) [UW], 1 ㅇ 8.VIII. 1925 [USNM, ex Brooklyn Museum Collection] ; Monroe, 10 6. VII. 1931 (N. P. Larson) [OSU], 1 i 23.VII.1931, in moth trap (N. P. Larson) [OSU], $1 \sigma^{2}$ 30.VII. 1931 (Joe Schuh) [JS]. Lane County; Goshen, 10 VIII. 1941 (R. Fauts [sic!]) [BM]. Douglas County; Sutherlin, 1 ㅇ 30.VII. 1944 (Elwood Mabry) [GHN]. Jackson County; Medford, 1 ㅇ 3.VIII. 1946 (C. Fitch) [UCD], $5 \sigma^{\pi} \sigma^{\pi}, 3$ 우 와 11.VIII.1944, $2 \sigma^{\pi} \sigma^{\pi}, 1$ 우 12.VIII.1944, $1 \sigma^{\pi}, 3$ 아 오 20.VIII.1944, 3 우 오 29.VIII.1944, all in light trap (C. Fitch) [UCD]; Talent, $1 \sigma^{\circ}$, 1 우 24. VII.1938, In c. moth bait pan (L. G. Gentner) [LGG, UCD], 1 it 15.VIII. 1940 (L. G. Gentner) [UCD] ; Green Springs, $10^{7}$, 1 ㅇ 27.VIII. 1961 (J. S. Buckett) [UCD]. CALIFORNIA: same data as holotype, $20^{\circ} \mathrm{o}^{7}, 1$ i [CAS], same data but August 10, $2 \sigma^{7} \sigma^{7}$ [CAS]. Siskiyou County; Scott River, 1 \& 10.VIII.1949, collected at light (W. C. Day) [CAS]. Yolo County; Rumsey, 1 ㅇ 5.VIII. 1955 (E. A. Kurtz) [UCD]. Shasta County; Hat Creek, 1 우 26.VII.1951, 1 ㅇ 25.VII. 1952 (G. F. Pronin) [CAS], 1 ㅇ 5. VIII.1942, Flight at light [CIS], $1 \sigma^{7}, 1$ ㅇ 11.VIII.1956, 2 와 오 12.VIII. 1956, 1 ㅇ 17. VIII.1956, 1 ㅇ 18.VIII.1956, 1 ㅇ 19.VIII. 1956 (H. Ruckes, Jr.) [CIS], 1 ㅇ 28.VII. 1957 [CIS]. Plumas County; 4 miles W. of Quincy, 1 \& 26.VI. 1949 (W. R. Schreader) [UCD], 1 \& 16.VII. 1949 (F. Morishita) [CIS] ; Johnsville, $1 \sigma^{7} 30$. VII.1960, $3 \sigma^{3} \sigma^{\text {T, }} 1$ 와 9.VIII. 1961 (J. S. Buckett) [UCD]. Eldorado County; Georgetown [erroneously stated to be Placer County on the label] if 29.VIII. 1948 [DG]. Tuolumne County; Twain Harte, 1 \& 9.VIII. 1958 (D. C. Rentz) [DR], 1 ơ 20.VIII. 1960 (M. Lundgren) [ML]; near Groveland, 1 \& 27.VII. 1954 [CIS].

The following additional specimens were studied, but are too damaged to be made paratypes: 1 topotypic male, 10.VIII. 1949 [CAS]; Mid Col. Expt. Sta., Hood River, Oregon, 1o 21.VILI.1957; Goshen, Lane County, Oregon, $10^{\text {T }}$ VIII. 1941 (R. Fauts [sic!] [BM]; Medford, Oregon, 1 it 11. VIII.1944, Light trap (C. Fitch) [UCD]; Minam N. F. [Oregon], 1 ㅇ 5.VIII.1914, (Or. Ex. Sta. No. 1458) [OSU] ; Placerville, Eldorado County, California, 1 ㅇ 29.VIII. 1948 [DG].

In addition to those returned to their owners, paratypes will be deposited in the Canadian National Collection, Ottawa, and the British Museum (Natural History), London.

Variation. Paratype males vary in length from 14.5 to 19.4 mm ., and in width at the humeri from 4.00 to 5.6 mm ., with averages of 17.3 and 5.2


Figure 18. Last three antennal segments of males and females of Centrodera spurca, C. autummata and C. Alayi; vestiture omitted.
mm . respectively; paratype females vary in length from 13.4 to 20.5 mm ., and in width from 4.7 to 6.5 mm ., with averages of 18.1 and 5.5 mm . respectively. The elytral color varies from a pale yellowish-brown to a decidedly reddish-brown. The apex of the scutellum is rounded in all specimens seen, though it varies a little in width.

The outer antennal segments of the females vary in length more than in related species. Most specimens have segments 10 and 11 as in fig. 18, but 11 may be shorter or longer than 10 , and in some cases they are long enough to be confused with the same segments of the male. The fifth abdominal sternite varies from very narrowly and obscurely margined apically to completely unmargined, in the female; it is unmargined in the male.

Remarks. In a mixed series of the three species, males of C. dayi can usually be picked out because of their short and somewhat triangular elytra; females resemble those of ( $C$. autumnata but are more heavy shouldered and straight sided (fig. 11). The sexes are harder to separate in C. dayi than in the other two species; males have more strongly tapering elytra, longer antennae, and less smoothly vestitured outer antennal segments; antennal segments 10 and 11 are usually appreciably longer in the male.

Centrodera dayi may be separated from C. spurea by its short body form (fig. 11), suberect elytral pubescence, much coarser punctation in the apical half of the elytra, short broad foretarsal segments (fig. 9), shorter antennae, and the bristling vestiture of the outer antennal segments in the male. In males of $C$. dayi antennal segment 11 is barely or not as long as the scape; in $C$. spurca and $C$. autumnata it is as long as or longer than the scape and segment two combined.

The male of $C$. dayi is distinguished from that of $C$. autumnata by its more strongly tapered elytra (fig. 11), much broader fore tarsi (fig. 9), and short antennae which barely reach beyond the elytral apices. Females differ from those of C. autumnata by their stouter build, straight sided elytra (distinctly narrowed behind the humeri then widened again in C. autumnata), and shorter and broader fore tarsi (figs. 9, 11). Both sexes of $C$. dayi have shorter hairs along the hind margin of the hind femur, starting at the tip of the trochanter, than does $C$. autumnata (specimens must be clean to show this properly), and a more evenly inflated pronotal disk.

Distribution. In general, one may say that $C$. dayi follows the Cascade mountains from Washington to California (fig. 14), where it goes due south at least to Yolo County on the west side of the Sacramento Valley (a single record for Rumsey, elevation 300 feet; see fig. 15). Via the end of the Cascades in the Mt. Lassen region it reaches the Sierra Nevada and thence the western foothills, at elevations of 2000 to 4000 feet, to just west of Yosemite National Park.

Its occurrence at Walla Walla, Washington, suggests that it may yet be found in western Idaho. The several localities in and to the northern border of the Willamette Valley of Oregon make one expect it west of the Cascade mountains in Washington, though it is not in the Willapa Bay list of Hatch and Kincaid. More collecting in northwestern California may show its distribution to overlap the northeastern edge of that of $C$. autumnata.

## The Wing Venation of Sonie Species of Centrodera

Swaine and R. Hopping gave a detailed drawing of the basal half of the wing of $C$. spurca ( $1928, \mathrm{pl}$. XI), and a photograph of the wing of $C$. decolorata (pl. XIII, fig. 19). Saalas studied and figured the wings of rep-


Figure 19. Wing of Centrodera spurca.
resentative species of the major categories of Cerambycidae. He remarked (1936, p. 71) that the wing of C. decolorata as figured by Swaine and Hopping does not differ in any significant way from that of species of the genus Rhagium, and that the short extra branching of $\mathrm{Cu}_{1}$ they show ${ }^{4}$ is probably just an anomaly. On the basis of their figure of part of the wing of $C$. spurca, he refers the species without further explanation to the genus Evodinus (1. 73), noting that CuZ is well developed and $\mathrm{Cu}_{1}$ is 3 -branched, as for example in $C$. decolorata.

[^12]An entire wing of $C$. spurca is shown in fig. 19; the wedge-cell is large, and 2 nd $\mathrm{A}_{2}$ goes off just below it (using the venational nomenclature of Forbes, 1923). In C. decolorata, however, $2 \mathrm{~d} \mathrm{~A}_{2}$ goes off from an angle of


Figure 20. The wedge-cell region of a wing of Centrodera decolorata. The venational nomenclature is here according to Forbés, 1923.


Figure 21. The wedge-cell region of a wing of Centrodera decolorata. Venational nomenclature according to Saalas, 1936.
the wedge-cell itself, and this is constant in the eight examples studied; but the branching of the first anal in these same wings is so variable (figs. 20, $21,22,23)$ that three branches cannot be cited as typical. Of the wings examined but not illustrated, one is almost as in fig. 20, two are duplicates of figs. 21 and 22 respectively, while the fourth has a spur as in Swaine and Hopping's illustration (pl. XIII, fig. 19) but the outer branch is bifid as in my fig. 22. Obviously a 3-branched form cannot be considered typical.

The venation of $C$. autumnata is like that of $C$. spurca, but the wedgecell is smaller; in C. dayi it is a little smaller still. In C. sublineata LeConte
and $C$. nevadica LeConte, the wedge-cell is absent and 1 st A is only 2 branched; but in an undescribed species related to the later, in which 1st A is also 2-branched, there is a very small but clearly defined wedge-cell. In the few specimens of $C$. picta I have checked, there is no wedge-cell, 1st A is 3 -branched, but $2 d A_{2}$ is not joined to $2 d \mathrm{~A}$. In the only wing of Apatophysis sp. which I have examined there is no wedge-cell, 1st A is 2-branched, and there is no trace of a cross connection between 1st A and 2d A. These facts seem to present only difficulties to the systematist, but ultimately they may help in finding a key to the puzzle of relationships and generic segregates.


Figure 22. The wedge-cell region of a wing of Centrodera decolorata.


Figure 23. The wedge-cell region of a wing of Centrodera decolorata.

## The Eggs of the Species of the Centrodera spurca Group ${ }^{5}$

Centrodera autumnata. The female mentioned in the paragraphs under the heading "Copulation" later in this paper was put in Bouin's solution, and the abdomen subsequently dissected. It was packed full of large, white eggs, so stuffed in fact that some projected up into the thoracic cavity. All 49 eggs were mature.

The egg: length 2.65 to 3.00 mm ., width 0.80 to 0.95 mm . Form elongate ovoid, one end more rapidly narrowed than the other, apices rounded; chorion dull, covered with minute spines which are sparser at apices, not scattered, but arranged in closely spaced longitudinal lines.

Centrodera dayi. A few eggs, dissected from a dried specimen, were rendered turgid by being soaked in a detergent solution. They appear to be inseparable from those of $C$. autumnata, and have the same spinose chorion.

Centrodera spurca. The eggs of this species are readily distinguished from those of $C$. autumnata and $C$. dayi by their surface sculpture.

The egg: length 2.65 to 2.90 mm ., width 0.70 to 0.80 mm . Fusiform, nearly paralled-sided, apices rounded or slightly truncated. Chorion dull, smooth, with faint net-like reticulation of regular, minute hexagonal cells; no surface irregularities or spines apparent at X112. Color white.


Figure 24. The larva of Centrodera spurca, lateral view.

[^13]
## The Larva of Centrodera spurca

The larvae before me (see mention of them under the heading "Life History") are from 30 to 34 mm . in length, but only one is fully extended and it may not be mature. Judging by the variation in length of the beetles, it is likely that mature larvae vary from 25 to over 40 mm . in length.

Form elongate, cylindrical, virtually without taper except for the last two abdominal segments (fig. 24); integument shining, slightly wrinkled, sparsely clothed with slender copper-colored hairs. Head yellowish-brown, frons in front of the transverse line reddish-brown, becoming black along frontal margin, mandibles black, their articular areas dark reddish-brown to black; clypeus pale yellowish-brown, reddish at base, labrum reddishbrown, pale apically, maxillae and palpi in part reddish-brown. Thorax and abdomen white, prothorax with narrow yellowish-brown band near front margin, band widening laterally; spine-bearing tumidity on ninth abdominal tergum yellow, spine itself brown (figs. 25, 26) ; spiracles and legs brown.

Head suborbicular with scattered slender setae, frons flattened and a little depressed; labrum transversely suborbicular, rounded in front, length


Figure 25. Larva of Centrodera spurca. Abdominal tip in profile, showing the mammilate tubercle on the tumidity at the apex of tergite 9 .
to width as 2 is to 2.5 , whole subcircular margin ciliate, most densely anteriorly; clypeus three times as wide as long; mandibles short, thick, blunt, cutting edge oblique with a flat grinding area adjacent, a slight angle present at inner end of cutting edge; antennae conical, hardly protruding beyond sockets, basal membrane large, not retractile. Three indistinct ocelli present, two close together just below level of antenna, one on a level with antenna and at a distance about equal to width of basal membrane of antenna. Anterior edge of hypostome broadly curved, ventral mouthparts extended; apical (third) segment of labial palpus broader and a trifle longer than that of maxillary palpus, maxillary lobe (lacinia) a little broader than first segment of maxillary palpus, as long as first and second segments combined, beset with strong golden setae apically and internally; mentum quadrate, as broad as a stipes; gula well defined, slightly protuberant, almost twice as long as wide. Prothorax widest in front of middle, narrowing posteriorly; pronotum a little roughened on each side of median line in pigmented area near front margin, and along hind margin. Abdominal tergites 1 to 7 with dorsal ampullae finely asperate, with small shining areas, ampullae marked by two transverse folds and an anterior one marking off a narrowly fusiform transverse area (the shape is almost exactly as in Craighead's 1923 figure for the larva of Anoplodera nitens (Forster), pl.


Figure 26. Larva of Centrodera spurca. End of the abdomen in ventral view, showing the form of the ninth tergite with its single median tubercle.

XVII, fig. 5). Tergite 8 transversely wrinkled but without ampullae; tergite 9 irregularly wrinkled, median area before hind margin raised, somewhat triangularly tumid, with a single short mammillate tubercle at apex.

Legs about as long as labrum is wide, femur and tibiotarsus each twice as long as trochanter, unguiculus a little shorter than tibiotarsus; unguiculus pale in basal half, brown in apical half, with a strong seta arising laterally at apex of pale area and projecting beyond tip of segment. Eusternum somewhat triangular but with apex (cephalad) broadly rounded; mesosternum and metasternum each divided into two equal areas by a median transverse groove, surface fincly asperate; abdominal sternites 1 to 7 each similarly divided by transverse groove, surface finely asperate, front half of each division with transverse lines of low tubercles, 5 on each side of median line of abdomen; sternites 8 and 9 with transverse rugae or wrinkles. Spiracles suborbicular.

In Duffy's key to Lepturinae ( 1953, p. 67 ) the larva runs to couplet 2, and agrees with the first part of the first choice in having a terminal spine on the 9th abdominal segment, and a divided trons, but does not agree as to the remaining characters. In Craighead's key (1923, p. 82) it traces to numbered couplet 1, but will not run to Centrodera in the second half because the gula is almost twice as long as wide and the abdomen has only one caudal spine; neither will it run to couplet 2 .

## The Pupa of Centrodera spurca

The following scanty observations are based on the cast skin of the reared male mentioned in the section "Life History."

Pronotum with marginal line of setae, probably with two linear diseal groups, and seattered setae between them and marginal line. Metanotum with a group of about 35 setae on each side of median line; these are the longest and strongest setae on the pupa. Abdominal tergites with all setae long, slender, copper-colored as on rest of body. Abdominal tergites 1 to 5 each with two groups of about 14 slender setae on a tumid area on each side of median line, tergites 6 and 7 with about 12 setae in each group; tergite 8 with an undivided band of them, tergite 9 with 2 diseal setae and numerous apical setae on each side apically. Apex of 9 th abdominal tergite without urogomphi, but with two small seta-bearing tubercles, and a single median seta just beyond them. Femur with about 10 setae along outer face near apex; tarsus with a single seta near apex.

The larvae of ( $\because$ autumnata and ('. dayi are unknown, although the adults are common in at least parts of their ranges. The fact that there are no known rearings of either of these medium sized forest insects from trees, logs, or stumps suggests that the larvae may spend their lives in the soil;
possibly they feed on buried wood, or upon living roots, and almost certainly they pupate in the soil.

## A Partlal Life History of Centrodera spurca, with Notes on Other Species

Very little has been published on the life histories and habits of the species of Centrodera. In 1894 Hopkins (1894B, p. 150) cited the larvac of a species of cerambycid as causing extensive damage to the heartwood of both living and dead tulip trees [Liriodendron tulipifera] in West Virginia ${ }^{6}$. In 1896 (p. 245) he recorded having found a newly transformed adult in its pupal cell in the heartwood of a chestnut tree [Castanea sp.] and stated "This beetle was identified for me through the kindness of Mr. Howard, of the Division of Entomology, as Centrodera bicolor." This was an inadvertent error, as there is no such described species in the genus. His paper was republished in West Virginia with some changes in the text and the addition of a plate, in 1897 (pp. 143-152, pl. III), and the above sentence changed to read "This beetle was identified for me through the kindness of Dr. Howard, of the U. S. Division of Entomology, as Centrodera decolorata, Harr, by Mr. Linell."

In the next paragraph he recorded another example cut from a tulip $\log$, and wrote that the species was "one of the most destructive wood-boring insects that infest the wood of living trees" previonsly wounded by fire. In another part of the 1897 report (p. 81) he called it the Destructive Heartwood Borer, while on page 97 he wrote "Trees of all kinds in all sections of the State that have been in,jured by fire or other causes, sufficient to induce a diseased condition of the wood adjoining the wound, often have the heartwood literally ruined by the destructive heartwood borer. This pest extends its destructive depredations to the sound wood, which results in the final decay of all of the inner portion. This is quite a serious trouble and causes the loss of a large amount of timber." Footnote 4: "Centrodera decolonata [sic!'], Harr." [Refers to heartwood borer four lines above.|

If Hopkins correctly associated adults and damage by larvae, it is remarkable that the species has not gained subsequent attention. Craighead ( 1923, p. 85 ) repeated Hopkins' chestnut and tulip heartwood host records, but in his 1949 report did not mention the genus or the species.

Craighead (loc. cit.) also recorded the larvae of $C$. decolorata from old wet decaying oak logs (Quercus sp.) and a dead chestnut tree in Pennsylvania. He cited pupation from May to .July, in "a round cell of frass constructed before pupation. An adult was reared in early September."

Wickham (1897B, p. 170) mentioned that the adults of C. decolorata occur on beech, and this was repeated by Felt (1906, pp. 428, 456) who
6. Also in an 1894 paper in The Timberman, which reference I have not seen.
also recorded it as cut from butternut and gave a figure of the beetle. Blatchley (1910, p. 1048) gave beech and maple, as did Procter (1946, p. 177). Morris (1916, p. 20) recorded the species on or from a maple stump. Leng (1928, p. 437) cited larvae in oak, chestnut, and tulip poplar. Beaulne (1932, p. 199) listed the larvae as injurious to the following host plants: apple, beech, maple, oak, chestnut; and Chagnon (1936, p. 209) as occurring in walnut [Juglans cinerea] and beech [Fagus grandifolia].

Knull (1932, p. 63) reported finding a teneral adult of Centrodera picta Haldeman in its pupal cell in the decayed part of a living yellow birch [Betula lutea] in September; in 1946 (p. 175) he recorded the adults as frequenting "flowers of mountain maple (Acer spicatum)." Smith (1900, p. 291; 1910, p. 330) gave "rare on dry hickory;". Felt (1906, p. 715) repeated Smith's record. Leng and Davis (1924, p. 59) also cited hickory and stated that C. picta had been taken flying to light on Staten Island, New York.

The larval habits of the North African Apatophysis barbara Lucas were described by Peyerimhoff (1926, pp. 351-352). ITe found them tunneling in a dead specimen of Limoniastrum Guyonianum (Plumbaginaceae), a desert tree, and caged a section, partially burying it in dampened sand. The larval stage lasted for at least seven years! During the intense heat of the summer they seemed to remain quiescent in their galleries in the wood, but in winter when the sand was cool they tumneled out and round about in it, perhaps looking for additional food supplies. Pupation took place both in the sand and in the wood, and adults emerged in May and .June.

From what is now known, the larvae of C. spurca have some of the same habits. They commonly feed in rotting stumps and roots (and possibly on living roots) of several kinds of trees and shrubs; they wander freely through the soil, and pupate in the wood or in the soil as it suits them. Nothing is known of the larval stages of C. autumnata and C. dayi.

The first statement of a host plant for C. spurca, so far as I know, was by Garnett (1918, p. 212): "Breeds in Pseudotsuga taxifolia." I have been unable to trace the source for his record, which was repeated by Essig (1926, p. 452), Hardy (1926A, p. C28; 1926B, p. 5), Doane et al. (1936, p. 177) and Canova ( 1936 , p. 129). Later, on the basis of material collected by Mr. Lohbrunner, Hardy (1942, p. 10) was able to correct this.

In my field notebook for 1929 there is the following entry for April 25, at Salmon Arm, British Columbia: "1 Parapachyta spurca; this was found in the ground, \& had changed very recently, as it was quite soft, \& very white." Apparently I did not associate it with any rotting or other wood. There is a female in the collection of the University of British Columbia, labeled as taken in Victoria, B. C., Jamury 28, 1917, by W. D. [W. Downes];
judging by the date it probably was dug out of the ground. I have seen a male and a female in the collection of the Provincial Museum of Natural History at Victoria labeled "Saanich, B. C., 14.II.35. Ed Lohbrunner. Dug out of ground near oak trees \& Rosa nutkana." Hardy (1942, p. 10) wrote "Adults have been dug out of the ground in the vicinity of Garry oak trees among the roots of Rosa nutkana in February. Large larvae were found in gall-like swellings at the base of the rose bush but as I was unsuccessful in rearing them, proof as to their identity is lacking."

In a letter to me dated October 27, 1948, Mr. Hardy amplified this: "Although the host tree of C. spurca as I know it, is evidently Garry Oak, I have never been able to rear larvae found in the roots or base of trunk of these trees through to the adult; they have always died or disappeared in some way. I believe I mentioned in one of the B. C. proceedings that possible larvae and certainly the adults have been dug out of the ground at the base of the oaks in February and March, while I have several times taken large larvae presumed to be this species from burrows at the base of dying trees. This same type of larvae [sic!] has also been found in old roots of the wild rose growing near the oaks, so you will see that uncertainty is still rampant."

The statement by R. Hopping (? 1921, second page) that he had found Pachyta spurca breeding in six species of pine and some six species of shrubs in the Sierra of California, at altitudes of from 3000 to 4000 feet, is obviously a lapse of memory by the recording secretary, as to the genus and species concerned.

On May 16, 1954 , I was enlarging a small hillside vegetable garden at 427 Rose Avenue, Mill Valley, California, and dug into a bank containing a stump of scrub oak, Quercus Wislizeni var. frutescens. The green tree had been felled some four years earlier. A peculiar burrow-inhabiting predaceous carabid larva was found, so a large tin was nearly filled with big lumps and smaller bits of earth from the site, and the larva put into a hollow at the top. Tightly lidded, the tin was taken into the house with the expectation that I would add food and rear the carabid.

Unfortunately I became ill with pneumonia, and the tin was not opened again until October 11. By then there was no sign of the carabid larva, but in searching for it I broke up all the lumps of soil, and was amazed to find a freshly transformed male of $C$. spurca in one (figs. 27, 28). This must have been in its pupal cell, presumably as a mature larva, when I picked up the lump in May. At this time I suspected that the larva might have been working in the oak stump, then left it to pupate in the soil, as Craighead (1923, p. 85) recorded for Anthophilax and some other genera.

By happy coincidence, on May 17, 1954, the late Gordon Stace Smith obtained a teneral female of $C$. spurca, and a larva in association with it,


Figure 27. Recently transformed male of Centrodera spurca in its pupal cell in a lump of soil excavated from a bank; see text for details. (Photograph by E. L. Kessel.)


Figure 28. Close up of the teneral (entrodera spurea in its pupal cell. Note that the inner surface of the cell is unlined. (Photograph by E. L. Kessel.)
at Creston, British Columbia. In his letter of June 15 he wrote "Re Centrodera spurca: the Amelanchier roots where I took them were quite rotten, almost crumbling. Actually, the adult occupied only half itself [sic!] in the root, the other half in a sort of mud cell under the root. The larva was only an inch or so from the adult, but quite in the root. Now I have several times dug up larvae I believe the same, but could never before definitely associate them, though occasionally, adults have been so exposed. I assumed both were right in the soil, but probably in a fragment of rotten wood." There is a female in his collection, now at the University of British Columbia, labeled Creston, B.C., February 14, 1952, and "excavated from soil."

Another likely host may be mentioned. In the summer of 1931 my father found a larva feeding in the roots of a living Soopalallie (Shepherdia canadensis; Eleagnaceae) at Salmon Arm, British Columbia. On the basis of its size, and the known local cerambycid fauna, it had to be Tragosoma depsarius (Linnaeus) or Centrodera spurca. We failed to rear it, but since $T$. depsarius is known from conifers, I have little doubt that our larva was that of C. spurca.

The larval skin from the pupal cell of my reared Mill Valley specimen, with Mr. Stace Smith's larva, enabled me to identify an apparently mature larva found by my son Robin on January 24, 1954. It was dead, but in excellent condition, lying on the bottom of a small pool in Cascade Creek, Mill Valley. No doubt it had been washed by a freshet from its pupal cell in the stream bank.

On April 10, 1955, my son Thomas dug up a small pine tree planted as a seedling five years before; it was at the edge of a group of Coast Redwoods, Sequoia sempervirens, at our home in Mill Valley. In the process he uncovered a male of C. spurca and two larvae. One larva was in its pupal cell, and died there in late July without pupating. The other was free in the soil, 33 mm . long, and possibly immature; it is shown in fig. 24. All were in soil interlaced with small roots, including those of redwood, madroño (Arbutus Menziesii) and hazel (Corylus californicus), but no oak. We did not notice anything else in the soil, other than humus, on which the larvae could have fed. This, coupled with Hardy's records of oak and wild rose, and Stace Smith's of service berry, suggest that they may be general feeders, or that like the African Apatophysis barbara they may wander through the soil for some distance from their main food supply.

Since the above was written I have seen a female [USNM] which has the following label data "San Mateo Co. Cal., larva collected II.17.1935. larval host dead Madrone stump. Taken out of pupal cells on X.4.34. P. C. Ting Collector. Ase No. 81. Parapachyta spurca (Lec.) det. P.C. T." Mr. Ting tells me that the file of notes in which the original data were contained was destroyed in a flood at Reno, Nevada; so it is impossible to tell which of
the above year dates is correct. At any rate, he appears to have made the first definite association of larvae and adults.

The finding of two sizes of larvae and an adult at the same site in April, at Mill Valley ${ }^{\top}$, and an adult in its pupal cell in October, makes it fairly sure that the life cycle takes at least two years. Some mature larvae must form their pupal cells, pupate, and tranform into adults, in the fall. However, the fact that in the San Francisco Bay area of California the species is on the wing over a period of four months (table I) suggests that some larvae may not pupate until the spring. Adults of the other two species (tables II, III) are most numerous later in the year than is C. spurca, and presumably overwinter as larvae only; Linsley (1961, p. 9) remarks that "Species which are active in late spring, summer, and fall usually pupate shortly before emergence, remaining in the cell as adults for only a short time."

The pupal cell shown in figs. 27,28 is completely unlined, its inner surface appearing as if pressed and rubbed or tamped smooth by the larva when the soil was damp.

Where the females lay their eggs is unknown. I made several attempts to follow flying specimens at night, with the aid of a strong flashlight, but that is not easily done on a wooded hillside, and they always disappeared. On the basis of larval habitat it is likely that the eggs are laid in the soil, as are those of at least some species of the Old World genus Apatophysis, which Cressitt considered to be a subgenus of Centrodera. Certainly the males resemble species of the C. spurca group, but perhaps we should not expect the egg laying habits to coincide, because as Butovitch has remarked (1939, p. 225) the species of Apatophysis are desert-inhabiting forms in which the females show morphological adaptations similar to those of desert prionids: elongated abdomen, widely separated hind legs, shortened elytra and very long ovipositor.

There are no pulbished records as to the longevity of the adults of Centrodera. My only information is based on a female of C. spurca of unknown age, collected at light in Mill Valley, California, on June 20. She was kept in a jar containing some damp sand and sawdust, and lived until July 14 ; her only source of food was a very weak solution of honey.

## Flight Periods of the Adults of the Centrodera spurca Group

Centrodera spurca is a species of late spring and summer. Ninety-nine per cent of the 1061 specimens studied were taken during the months of May-August, inclusive, and 87 per cent of them in June and July. There are a few exceptional records; E. I. Schlinger took a female at Glendale,

[^14]Los Angeles County, California, March 21, 1947 [UCD], and E. A. Dodge found a female at Santa Cruz, Santa Cruz County on "III.17," which may have been March 17, or March, 1917. It is possible that both these specimens were found in the soil, and are not actual flight appearances, since one would expect males to be out before females. However, exceptional climatic conditions may bring out beetles which have pupated in exposed situations. For instance E. S. Ross mentioned to me on April 6, 1959, that he had recently dug up several adults of C. spurca in Mill Valley, Marin County, California, and that a specimen had come to light at his window "at least two weeks ago," i.e. during the last week of March. There had been an exceptionally warm spell during the second half of March that year.

Table I summarizes the dates of capture of the examples of $C$. spurca seen by me, arranged by geographic regions from north to south, with divisions east and west where the records permit. The main emergence is obviously in June and July, both on the coast and in the mountains, but it is interesting to compare the totals of males and females for each of the two months. It is surprising how many males are still around in August.

Following are the "First of season" records for specimens attracted to our (indoor) house lights at 427 Rose Avenue, Mill Valley : 1950 (May 11), 1951 (May 8), 1952 (May 6), 1953 (May 3), 1954 (May 3), 1955 (May 11), 1956 (May 14), 1957 (April 28), 1958 (May 13), 1959 (May 5). All these specimens were males. Of course it is uncertain that our lights attracted the actual first emergents of the area.

Another point brought out in table I has to do with northern distribution. Although C. spurca is common enough on southern Vancouver Island, British Columbia (of 39 specimens, my most northerly records are in about the same latitude for the inner and outer coasts, Nanaimo and Ucluelet respectively), and equally common in the southern interior of the mainland (Seton Lake to Creston), I have no records for the mainland west of the coast mountains. Neither is the species in Stace Smith's lists (1929, 1930) of the beetles from Copper Mountain, near Princeton and just east of the mountains. Yet the Vancouver area and the Lower Fraser Valley have had resident collectors for well over 60 years. I have not seen enough material from northwestern Washington to know how far south of British Columbia this state of affairs continues.

Centrodera autumnata is common during July, August and September, reaching its peak in August, by which time most C. spurca have disappeared. I took one male at Mill Valley on June 28, 1959, and have seen a male and a female from Ben Lomond dated June 3, 1946; this surprisingly early date is substantiated by a single male taken at light at Mill Valley on May 29, 1958. The first specimen for 1954 is dated July 11, and that for 1957, July
Table I. Captures of Centrodera spurca adults by months, regionally.

| C'entrodtra spurea LeConte | March |  | April |  | May |  | June |  | July |  | August |  | Sept. |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 0 | 아 | $0^{\circ}$ | $\bigcirc$ | $0^{*}$ | $\stackrel{+}{ }$ | $0^{7}$ | ¢ | $0^{7}$ | ¢ | $0^{*}$ | $\bigcirc$ | $\sigma^{*}$ | 안 |
| British Columbia: Vancouver Island | - | - | - | - | 2 | -- | 21 | 4 | 2 | 10 | - | - | - | - |
| British Columbia: mainland west of coast mountains | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| British Columbia: mainland east of coast mountains | - | - | - | - | 4 | 2 | 17 | 7 | 3 | 12 | - | 1 | - | - |
| Washington: west of Cascade mts. | - | - | 2 | - | 4 | - | 5 | 2 | 2 | 5 | 1 | - | - | - |
| Washington: east of Cascade mts. | - | - | - | - | 4 | 2 | 16 | 22 | 12 | 7 | - | - | - | - |
| Oregon: west of Cascade mts. | - | - | - | - | 5 | - | 19 | 8 | 14 | 9 | - | 2 | - | - |
| Oregon: east of Cascade mts. | - | - | - | - | 3 | 1 | 8 | 7 | 4 | 14 | - | - | - | - |
| Idaho | - | - | - | - | 4 | - | 7 | 4 | 14 | 11 | 3 | 1 | 1 | - |

Table I. (continued)

|  | March |  | April |  | May |  | .June |  | July |  | August |  | Sept. |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\sigma^{*}$ | $\bigcirc$ | $0^{\pi}$ | $\bigcirc$ | $0^{3}$ | $\%$ | $\sigma$ | $\because$ | $\sigma$ | $\bigcirc$ | $\sigma^{7}$ | ? | O' | $\bigcirc$ |
| California: coast, east to Trinity Co., and from north boundary south to Marin Co., inclusive | - | - | 1 | - | 22 | 2 | 28 | 14 | 9 | 10 | 1 | 4 | - | - |
| California: coast, Lan Franciseo and Contra Costa Co., south to San Diego Co. | - | 2 | $\underline{\square}$ | - | 8 | 2 | 48 | 19 | 75 | 55 | 19 | 3 | - | 1 |
| California: NE. mts.: ('ascades, east and south through Siskiyou, Modoc, Shasta, Tehama and Lassen counties | - | - | - | - | $\underline{ }$ | - | 51 | 15 | 43 | 36 | - | 1 | - | - |



Table II. Captures of adults of Centrodera autumnata by months, regionally.

Centrodera autumnata, new species

| May | June | July | August | Sept. |
| :---: | :---: | :---: | :---: | :---: |
| $0^{7}$ ( + | $0^{*} \quad$ ¢ | $\sigma^{*} \quad \circ$ | $0^{*} \quad \circ$ | $0^{7}$ |

California: Humboldt County,
south to south shore of

| Marin County | 1 | - | 2 | - | 16 | 1 | 94 | 10 | 14 | 1 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

California: San Francisco Co.
south to Monterey County $--\quad-\quad \begin{array}{llllllll}2 & 1 & 26 & 4 & 24 & 4 & 1 & 2\end{array}$
California: San Luis Obispo
Co. south to San Diego

| County |  | - | - | - | - | 2 | - | 4 | - | - | 1 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | TOTALS | 1 | - | 2 | 1 | 44 | 5 | 122 | 14 | 15 | 4 |

Table III. Captures of Centrodera dayi adults by months, regionally.

| June | July | August | Sept. |
| :---: | :---: | :---: | :---: |
| $0^{\pi}$ ¢ | $0^{\circ}$ ¢ | $0^{\pi} \quad$ ¢ | $0^{7} \quad 9$ |

Washington: west of Cascades $\quad-\quad-\quad-\quad-\quad-\quad-\quad$



Oregon: east of Cascades, including
Medford, Talent
$\begin{array}{llllllll}1 & - & 3 & 1 & 12 & 17 & - & -\end{array}$
California: Cascade mts., east and
south to Lassen Co.; also to
Yolo Co. on west side of
Central Valley $\quad-\quad-\quad-\quad 1 \quad 7 \quad 11 \quad-\quad-$

California: Sierra Nevada. Plumas
Co. south to Tuolumne Co. $\quad-\quad 1 \quad 2 \quad 2 \quad 4 \quad 4 \quad-\quad$ -

| TOTALS | 1 | 1 | 11 | 10 | 30 | 41 | - |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

4. These early emergences are probably due to the same causes as in $C$. spurca, q.v.

The records are summarized in table II. Note the surprising disparity in the numbers of females as compared to males in this species, in constrast with the totals for C. spurca and C. dayi in tables I and III. Of course this is not a true figure of the proportions of the sexes, but only of relative attraction to light, though it may indicate a difference in habitat in C. autumnata females.

As shown in table III, C. dayi appears to have a remarkably short flight period. Of the 94 specimens studied, from southern Washington to central California, all but two were collected in July and August, with by far the greatest number in August. Of course there are fewer collectors in the field during September than in the summer, but this fact hardly explains the complete lack of September records.

## Habits of the Adults of Centrodera spp.

Daytime retreats. The adults of C. spurca, C. autumnata and C. dayi are nocturnal; although fewer than half of those seen are documented as having been taken at light, I suspect that at least ninety per cent were collected in this manner. One is occasionally found in plain sight during the day, near an electric light which has been on all night, but they normally hide successfully.

To the best of my knowledge the only person to take specimens of $C$. spurca during the day on a number of occasions has been that outstanding collector, the late Gordon Stace Smith. In a letter to me of September 7, 1948, about finding them at Creston, British Columbia, he stated that the best way was to beat the overhanging branches of Douglas fir (Pseudotsuga Menziesii), but that he had beaten them also from cedar (Thuja plicata), aspen (Populus tremuloides), choke cherry (Prunus virginiana var. demissa) and willow (Salix sp.). One of the specimens in his collection [UBC] is labeled as from hazel (Corylus sp).

More unusual are two males and a female [WSU] labeled "Moscow Mt., Ida. May 1935. Ground squirrel burrow." Unless the female fell in while looking for an oviposition site, and the males followed her, this record is hard to explain. Possibly they all pupated in the soil adjacent to the rodent's tunnel, and emerged into it.

Attraction to Light. I suspect that all the western species of Centrodera are crepuscular or nocturnal, and know that at least five of them are attracted to light. The coarsely faceted eyes of the eastern species suggest that they too are nocturnal, and Professor J. N. Knull (in litt., 1962) states that C. sublineata LeConte comes to light, while Engelhardt (1942, p. 38) records a specimen so taken at Middletown, Virginia, April 13. Hatch
(1925, p. 579) lists C. decolorata as taken at light, and Leng and Davis (1924, p. 59) cited C. picta.

Centrodera spurca has several times been recorded as attracted to light. For instance Garnett (1918, p. 212) wrote "It flys [sic!] at night and is attracted to light." Hardy (1926A, p. C28; 1926B, p. 5) said "Taken only at 'light.' Occasional. Latter part of May to July." Doane et al. (1936, p. 176), ". . frequently flies to light." Moore (1937, p. 88), "Taken by the author at lights in San Diego in April and July." It is interesting to compare the ratios of males to females in collections, by species, as shown in the foregoing tables. This suggests either that females of C. autumnata are much less attracted to light than are the males (and are females of other species), or that they stay near the egg-laying sites while the males range widely.

My own experience with C. spurca and C. autumnata is that they are much attracted to light, especially of a rather low intensity. In season they appeared on the windows of, or entered, rooms in which there were at various times 1) one or more exposed regular 100 -watt electric light globes, or 2) only shaded reading lamps with similar globes, or 3) lights on the same walls as the windows and thus not directly visible from outside, or 4) two 20-watt fluorescent light tubes. They were also attracted to an outdoor light trap using a standard 300 -watt globe. These species and C. dayi have all been taken at single-mantle "Coleman" gasoline lanterns. I have had examples of both $C$. autumnata and $C$. spurca fly to the same "Coleman" lantern of an evening in places as widely separated as Mill Valley, Marin County (altitude about 625 feet; mid-July), and just below the top of Junipero Serra peak in the Santa Lucia mountains of Monterey County (altitude approximately 5800 feet; mid-August). Examples of both C. spurca and C. dayi from Oregon and California have been seen labeled as taken at black (ultra violet) light, and I have so taken C. spurca at Mill Valley, California, in June and July.

On the other hand, using a 500 -watt "Photoflood" globe in a metal reflector from 9 to 10 P.M. on August 25, 1950, I watched examples of $C$. autumnata on the trees by our house in Mill Valley. They were in all cases flying to and settling on the branches of living madroño (Arbutus Menziesii) trees, ten to fifteen feet above the ground; one landed on a spray of fruits and investigated it for some time, but did not appear to eat any of the berries. The beetles did not seem to be in any way disturbed by the bright light, and not one of them flew to it.

Mazkhin-Porshnyakov (1960) has proposed a most interesting theory of why insects fly to light at night. As he points out, "insects fly not only to a radial source of light rays, for instance, a lamp, but also to diffuse light reflected from a screen."

The following quotation is from his summary. "It is very probable that light attracts insects only because it is a sign of open space, or an absence of restraints. In nature open spaces are much better illuminated than closed ones and they attract insects because there are no obstacles to avoid. Thus they can orient themselves more easily in the carrying out of one or another of their vital functions. During their life insects constantly make use of brighter illumination as an indicator of open space (exit from cavities, from dense vegetation, etc.).
"Open space is characterized, above all, by an abundance of short-wave, generally ultraviolet rays. The source of these rays during the night appears to be the sky-an orienting source which leads to open space. The greater the quantity of short-wave rays (including ultraviolet rays) an artificial light contains, the more readily it attracts nocturnal insects. Such illumination is similar to, but brighter than, natural light at night."

Ability to Walk on Vertical Panes of Glass. There have been a number of papers written on the abilities of certain insects to hold onto or walk up very smooth surfaces. In the adephagous, silphoid, and some other groups of beetles it is not uncommon to find isolated or grouped specialized sucker-like hairs on the tarsi, especially on the fore tarsi, and often only in the males. Miall (1903, pp. 53-59) gives an interesting discussion of some of the problems involved in understanding how these suckers act.

One is surprised to find that the matter is still puzzling entomologists and seems not to be resolved. Curran (1958, p. 85), in considering the pulvilli of flies and how the insects land on ceilings, concludes "The contention that the puvilli are sticky is almost certainly mistaken. What is certain is that the pads act as suction cups, serving to anchor the fly firmly." The subject was fully discussed, with the same conclusions, by Kirby and Spence nearly 150 years ago.

Not having investigated the matter in detail, I wish merely to draw attention to the fact that both sexes of C'. spurca and of C. autumnata are able to land on and hold to a vertical window glass, from full flight. I do not know whether the hairs of the tarsal pads have suction cup tips, or exude an adhesive, but suspect the former type. I have seen a male $C$. spurca so "stuck" to a window pane by one foot, by his own doing, that he could not release himself, but could only slide slowly down the glass. One is tempted to explain this by the analogy of sliding a rubber suction cup on glass.

Adults on Flowers. No records of $C$. spurca or allies having been taken on flowers are known to me. In fact I do not recall flower records for any west-coast nocturnal Cerambycidae, though many of the diurnal species, especially in the Lepturini, are pollen feeders. It is thus interesting that
during the course of this study pollen has been found on examples of all three species of the C. spurca group.

Some males of C. autumnata have carried enough of it to obscure the surface of the prosternum, and the depression between the clypeus and the antennal bases. Pollen has been noted on the head (base of clypeus and near, genae, occiput, first three antennal segments, submentum-but not on the mouthparts, which are perhaps most easily cleaned), sides of prothorax, pro-, meso- and metasternum, fore and middle coxae, and the femora of all legs. The distribution suggests that the beetles may have been probing or feeding on floral parts, but not necessarily on pollen.

Mr. Robbin Thorp at the University of California, Berkeley, has been so kind as to examine samples of the pollen which he removed from the beetles. He reported that specimens of $C$. autumnata from Mill Valley, Marin County, California (mid-August) carry a common type found in several plant families. After eliminating groups not occurring in Marin County, and those not in bloom while the beetles were active, he suggests the following as probable sources of the pollen; my comments are in parentheses.

Fagaceae. Lithocarpus sp. (Tanbark oak, closely allied to Quercus. There is only one species, L. densiflorus Rehd.; it is common at 427 Rose Avenue, where the beetles were collected.)

Fagaceae. Castanopsis sp. (Chinquapin. A single species in the area, C. chrysophylla, but much less common than tanbark oak.)

Caprifoliaceae. Sambucus sp. (Elderberry. Two species in Mill Valley, $S$. callicarpa, red fruited, and $S$. coerulea, blue fruited. Neither species is known to occur close to the collecting site.)

A female of $\boldsymbol{C}$. dayi from Medford, Jackson County, Oregon, August 29, carries pollen similar to that on the C. autumnata males, as do a male and a female of C. spurca from Mount Hermon, Santa Cruz County, California, July 16. Both these latter have a good covering of pollen on the pro- and mesosternum and adjacent parts, and dorsally on the head.

A male of C. spurca from Johnsville, Plumas County, California, July 21, has a scattering of pollen which Mr. Thorp identifies as Pinus sp., probably lodgepole pine, $P$. contorta var. murrayana, on the pro-, mesoand metastermum and adjacent areas. Two other males and three females from the same place, taken on three different dates in July, also have Pinus sp. pollen. One female has a good deal, including on the femora, tibiae and pronotum. Four males and four females from Twain Harte, Tuolumne County, California, late June to late July, each show a little Pinus sp. pollen ventrally.

Since all western species of Centrodera are to the best my knowledge crepuscular or nocturnal, it was a surprise to read in Knull (1946, p. 175)
that in the eastern C. picta "Adults frequent flowers of mountain maple (Acer spicatum Lam.)." In a letter dated February 22, 1962, Professor Knull verified this statement, remarking that he had so taken them in southern Pennsylvania, and that he had collected isolated specimens by beating foliage. On the basis of such diurnal habits, it is a surprise to find that Leng and Davis (1924, p. 59) record examples of C. picta as having flown to light at Clove Valley, Staten Island, New York, June 7. Is it possible there is a sibling species involved? Certainly the specimens of $C$. picta I have examined differ from the rest of the species in the structure of the prosternum, and perhaps do not belong in Centrodera.

Attraction of Some Western Species to Baits. Currie (1904, p. 28) recorded having taken Pachyta spurca LeConte while "sugaring" for moths at Kaslo, Kootenay Lake, British Columbia, during the summer of 1903. He used a mixture of 3 pounds of sugar and 1 pound of molasses, boiled till the sugar was dissolved, then thinned with beer and a small glass of rum. Among specimens from Quamichan Lake, Vancouver Island, British Columbia (Hanham Collection, PMV) there is a male of C. spurca labeled "at sugar."

Mr. L. G. Gentner took the following specimens at Talent, Oregon: a male of C. spurca "In codling moth bait pan" on 11.V.1936 [CIS] and another on 19.VII. 1938 [LGG], a female "In bait pan" on 3.VII. 1941 [LGG] and another on 31.VII. 1941 [UCD]. Also a male [UCD] and a female [LGG] of C. dayi on 24.VII.1938, both "In c. moth bait pan." The bait was made of 1 quart of Fleischmann's Diamalt and 19 quarts of water, giving 5 gallons of solution, to which 2 cakes of Fleischmann's yeast were added, and the mixture allowed to ferment. It was placed in open sauce pans which were suspended in the upper third of the fruit trees (Gentner, in litt., 1962).

One female of C. dayi from Monroe, Benton County, Oregon, 23.VII. 1931 (N. P. Larson, OSU) is labeled "In moth trap." Judging by the condition of this specimen, and of a male taken 17 days earlier, both were collected from liquid bait traps.

Stridulation. Typical of the Cerambycinae, there is in C. spurca a longitudinal tumid dark area on each side of the median line of the prescutum, the two forming a pars stridens, the surface of which is uniformly covered with fine transverse ridges.

Each time the prothorax is moved backward and forward a ridge (plectrum) on the underside of its hind margin is drawn across these striated plates, producing a squeaking noise. It can be heard easily when live specimens of C. spurca and C. autumnata are held or restricted in their movements, and equally by moving the parts of a dead, relaxed specimen.

Examination of the pars stridens in the three species of the C. spurca
group has shown too much variation in its form to offer specific separations.
Copulation. On August 16, 1954 a male and a female of C. autumnata were taken as they came to light separately at Novato, Marin County, California. The next day they were released together; the male attempted copulation immediately, and the act was observed with the aid of a stereoscopic microscope.

The male mounted the back of the female from behind and took a position such that his head was almost at the basal one quarter of her elytra. Bending the tip of his abdomen down to contact hers, he extruded his parameres enough to catch against the tip of her fifth abdominal sternite, then inserted the tip of the aedeagus between this sternite and her eighth visible tergite (pygidium) and pulled upward.

At all times during the copulation the hairs of the parameres caught against and pushed down the rim of the fifth sternite, while the aedeagus pulled up on the pygidium. With these segments held apart, the intromittent organ was inserted into the tip of the ovipositor, which the female kept retracted except when she tried to prevent copulation, or terminated it by extending the ovipositor beyond the point to which the intromittent organ could reach.

These copulatory actions differ from any cited in Butovitsch's summary for the Cerambycidae.

Alexander (1962, p. 66) noted that the parameres of beetles have often been interpreted as pries; but on the basis of his observation of a mating in the carabid Pasimachus punctulatus Haldeman he is inclined (1959, p. 485) toward Jeannel's view that they are chiefly of use in producing tactile sensory effects upon the female. There is surely no doubt that this latter is true; but it is equally certain that at least in C. autumnata (and on the basis of similarities in structures, probably in many Cerambycidae), they are used not as true pries but as holders or pushers.

A pairing of $C$. spurca has also been observed. In this case the female was more receptive; after a quick push down with the parameres and pull upward with the tip of the aedeagus, the male extruded and inserted his intromittent organ, then retracted the parameres and aedeagus. The action up to this point was so fast that there was no chance for the parameres to be effective as tactile exciters, and they were not so used thereafter. The female remained quiescent; the intromittent organ was inserted almost up to the paired armatures (for a comparable example see the excellent fig. 8 on p. 27 of Jeannel's 1955 paper), at which point it became enlarged and somewhat bulbous. The apex of the aedeagus and the parameres barely extruded from the abdomen, and thus the tips of the abdomens of the copulating beetles were separated by between one and two millimeters, the length
of the everted intromittent organ between the paired armatures and the ostium at the apex of the aedeagus.

The male mounted the female so that his mandibles touched the tip of her scutellum. His front tarsi wrapped around her prothorax a little below the lateral tubercles, the claws holding at the median line just in front of her front coxae; his middle legs encircled her body, the tarsi closely in front of her hind femora, and his hind legs clasped her abdomen. The pair remained in copula for twelve minutes.

The positioning of the male with his mandibles at the female's scutellum may be significant. Michelsen (1958, p. 350) reported that in Rhagium bifasciatum Fabricius and R. mordax DeGeer the males "lick" the scutellar and adjacent areas of the females with their mouthparts, to calm them during courtship. In $R$. bifasciatum, only "licking" near the scutellum was effective, while in $R$. mordax any upper part of the elytra gave results. Males of $R$. bifasciatum never protrude the genital organs more than 1 millimeter, so that the abdominal tips of the sexes are close together during copulation; thus a male larger than the female would be forced to "lick" in front of the effective area, and fail to mate successfully. In R. mordax the male genital organs are protruded several millimeters, giving more latitude of movement, so that the size of the male relative to the female is less important..

No such attempt to quiet the female occurred in the pairing of Centrodera spurca reported above, though the male's mouthparts were adjacent to the scutellum of the female. No "licking" was observed in C. autumnata, but neither was it watched for. In C. spurca especially, there is such a range of sizes in both sexes that I doubt a "licking" or similar process is essential to successful matings.

## Dubious Records

Among the 1364 examples of C. spurca, C. autumnata and C. dayi personally seen ${ }^{8}$, two short series carried what surely must be erroneous locality labels. These were two specimens of $C$. spurca said to be from the Mackenzie River, Northwest Territories, Canada, and four of C. autumnata labeled Patagonia, Arizona. In addition two others are suspect. A single male of C. autumnata is labeled "Orinda, Cal." Contra Costa County, with an illegible year date only, and no collector's name. Of 209 specimens of C. autumnata seen, this is the only one from the east side of San Francisco Bay proper, an area which has had resident collectors for more than 75 years. Although the record seems distributionally probable, I prefer to

[^15]await fully documented specimens before accepting it. A female of $C$. spurca is labeled Salt Lake City, Utah; it has been included on the map (fig. 14), but is a long way from other known localities for the species.

A few dates of collection are puzzling, and may be the results of labeling from memory some time after the actual collecting. Such records are not used in the tabulations of captures.

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## PROCEEDINGS

OF THE

## CALIFORNIA ACADEMY OF SCIENCES

FOURTH SERIES

# G Dallas Hanna Anniversary Volume <br> Vol. XXXII, No. 8, pp. 219-289, 4 figs. <br> CONTRIBUTION TO THE BIOGEOGRAPHY OF COCOS ISLAND, INCLUDING A BIBLIOGRAPHY 

May 20, 1963

by

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## INTRODUCTION

The author's interest in Cocos Island was stimulated by an opportunity to collect mollusks on the island in 1932 , during the return of an expedition to the Galápagos Islands on G. Allan Hancock's motor cruiser Velero III. The results of a study of these mollusks are contained in two papers, one on marine species (Hertlein, 1932) and one dealing with non-marine and brackish-water species (Hanna and Mertlein, 1938).

The present paper presents information concerning the species of mollusks which I collected, including those reported on in various publications, and summarizes what is known about the relationships and the zoogeographical significance of this assemblage.

In addition to this, during the course of this study, information was accumulated concerning the occurrence and distribution of representatives of other phyla of organisms reported from Cocos Island. This information is included under each major category along with the names of authors and dates of pertinent references, which are included in the bibliography. However, no attempt has been made to include all the phyla or all the species reported from Cocos and scattered throughout the literature. I believe, however, that the biota here mentioned is representative of the island.

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Mr. William Old, Jr., American Museum of Natural History, New York City, kindly checked certain references in the libraries available to him. Mr. Robert I. Nesmith, Curator, Foul Anchor Archives, Rye, New York, furnished information concerning manuseripts and published literature concerning Cocos Island. Mr. William A. Coolidge, Cambridge, Massachusetts, generously lent me a copy of a rare paper dealing with an expedition to Cocos Island by his brother, Amory Coolidge. Dr. Bruce IIalstead, World Life Research Institute, Colton, California, and Mr. B. Joseph O'Neil, Boston Public Library, also furnished useful information.

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## GENERAL REMARKS

Cocos Island lies at $5^{\circ} 32^{\prime} 57^{\prime \prime}$ North Latitude and $86^{\circ} 59^{\prime} 17^{\prime \prime}$ West Longitude, about 500 kilometers ( 300 miles) west of Costa Rica and about 630 kilometers ( 350 miles) northeast of the Galápagos Islands. This island was known to mariners and cartographers at least as early as the first half
of the sixteenth century for it was first shown as "Ye de Coques" on a map by Nicholas Desliens, in 1541 (Anonymous, 1920, p. 15).

The name of this island appeared on many maps and in various publications during the following centuries. The abundance of fresh water, wood, pigs, sea fowl, fish, and coconuts, and the ease with which they could be obtained, made this small island a favorite stopping place of pirates, privateers, and whaling vessels (Colnett, 1798, p. 73, mentioned placing 2000 coconuts on board the Rattler when he stopped there in 1793). The names of various ships (see Hancock and Weston, 1960, pp. 300-302) carved in the rocks at Chatham Bay are reminders of these early visitors. Two bays offer anchorage for ships. Wafer Bay is the more attractive for visitors but


Fig. 1. Wafer Bay, Cocos Island, at the mouth of Arroyo del Genio. View showing sandy beach, dense vegetation, and a small house used by treasure hunters. (Photograph by John Garth, 1931.)

Chatham Bay, on the northeast side of the island, is more sheltered from the prevailing winds and offers more secure anchorage. In 1936, the government of Costa Rica issued stamps of several denominations on which an outline map of the island appears.

Politically, Cocos Island belongs to Costa Rica which country exercised sovereignty over it when, in 1888, ${ }^{1}$ August Gissler was nominated Governor of the island (see Anonymous, 1920, p. 23) with a concession to search for treasure. The circumference of Cocos is about 23.3 kilometers ( 13 nautical miles or 14.6 statute miles), and the land area comprises approximately 46.6 square kilometers. The highest point, located in the western portion of the

[^17]island, is reported to be 849.8 meters ( 2,788 feet) above sea level (see Anonymous, 1935, U.S. IIydrographic Office chart 823, South Pacific sheet 1; Anonymous, 1945, U.S. Hydrographic Office chart 1685, ed. 9). ${ }^{2}$ Much of the coast is abrupt, and in places towering cliffs reach a height of 182.88 meters ( 600 feet). Chubb (1933, p. 27) remarked on these high cliffs and stated: "It is clear that when the cliffs were being formed the island stood some two or three hundred feet higher above sea level than it does now, but that since then either it has subsided or the sea level has risen, with the result that the lower part of the cliffs is submerged and the lower reaches of the mature river valleys are flooded." He also remarked that at some places a shore-shelf a few feet above sea level is evidence of post-Pleistocene fall in the sea level.

The island is composed of volcanic agglomerates, tuffs, and chiefly of lava flows of labradorite-andesite and hornblende labradorite-andesite (Chubb, 1933, p. 29). It is situated upon the southwestwardly trending Cocos Ridge (Shumway, 1954) which in general lies about 1829 meters ( 1000 fathoms) below sea level. Chubb (1933, p. 30), concluded from a study of the rocks that "The Cocos Island analyses [of andesite] compare fairly closely with those of the Galapagos basalts, but their alumina and potash content is higher, and their lime content is lower. Except for their abnormally high alumina content they compare better with labradoriteandesites from Rapa and Tahiti." Macdonald (1949, p. 1588), however, believed that knowledge of the composition of the rocks on Cocos Island is not sufficient to justify placing it in the mid-Pacific petrographic province.

Sedimentary rocks have been mentioned [Pittier, 1899, p. 144; Chavarría Mora (in Pittier), p. 158; Thomas, 1960, p. 34] as occurring on the island but if present there, the details are vague.

Cocos Island, in general, lies within the path of the eastward flowing equatorial counter current. Occasionally, however, southward shifting of currents brings the island under the influence of currents sweeping westward from the mainland (see figures 3 and 4). The temperature of the air ranges between $20^{\circ} \mathrm{C}$. ( $68^{\circ} \mathrm{F}$.) and $33.3^{\circ} \mathrm{C}$. $\left(92^{\circ} \mathrm{F}\right.$.) (Stewart, 1912, p. 378), and the months of greatest rainfall are reported to be May, June, and July, although there is heavy rainfall throughout the year. The surface temperature of the sea water is reported to be about $26.7^{\circ} \mathrm{C} .\left(80^{\circ} \mathrm{F}\right.$.) but there is a mean annual variation of about $5^{\circ} \mathrm{C} .\left(10^{\circ} \mathrm{F}\right.$.).

This beautiful and picturesque island is densely covered with vegetation in which palms and cecropia trees are conspicuous. Abundant rainfall gives rise to numerous waterfalls which plunge over steep cliffs. Flocks of sea birds (terns, noddies, Frigate-birds, and boobies), Hying about the bays, and others perched in the trees, add to the attractiveness of the scene.

[^18]

Fig. 2. East side of Cocos Island, just south of Chatham Bay. View showing cliff, waterfall, and dense vegetation. (Photograph by Don Ollis, December 26, 1952.)

Any attempt to penetrate inland, however, is accomplished with difficulty because of the rough and irregular land surface which is covered by dense rain forest. Attempts to follow the bed of the stream emptying into Chatham Bay or the one in Arroyo del Genio (also cited as Canyon del Infierno on some maps) at Wafer Bay, is fraught with difficulty. The rocks in the stream and along the banks are very slick, and the stream bed is frequently interrupted by cliffs forcing the traveler to make a torturous detour. The presence of a particular fly, Leucomelina pica, and a species of ant, I'asmamia auropunctata, also add to the discomfort of such an adventure. One shipwrecked adventurer (Palliser, Brawner and Stachwick, 1932, p. 13t) described his attempt to cross the high ridge between Wafer Bay and Chatham Bay, a distance over water, by boat, of about 1.6 kilometers ( 1 mile). Ite lost his way in the dense jungle growth of trees, vines, tall sharp-edged grass, was drenched by frequent torrential rains, and after other harowing experiences, found his way back to Wafer Bay only after
several days had elapsed. Travel over the plateau-like top of the island is reported to be less difficult.

Cocos Island is best known from traditional accounts of treasure reputed to be buried there about 1819-1820, the value variously estimated at 60 to 100 million dollars. A large portion of this is supposed to have been placed there by a pirate, Benito Bonito (alias Bennett Graham) of the Relampago, who looted cities and ships along the coast of South America. Tradition has it that additional treasure was buried on the island by Captain William Thompson.

According to this latter story, a revolution in Peru, in 1820, led authorities in Lima to entrust for safe-keeping to Captain Thompson of the Mary Dear the "treasure of Lima," gold and jewels said to be valued at many millions of dollars. The vessel made its way to Cocos Island where the treasure was reputedly buried at Wafer Bay. The subsequent search with expenditure of much time, energy, and money has led to over 400 expeditions (Riesenberg, 1951, p. 5) of which at least 25 were well-equipped major expeditions. Captain August Gissler spent nearly 18 years searching for the treasure.

Although it has been rumored from time to time that these treasuretroves have been found, so far as is definitely substantiated, no one has found them, other than an occasional coin the source of which is unknown. A vast amount of literature has grown up based upon these fascinating legends of treasures and the search for them. Many references to this subject are contained in the bibliography.

For additional general information concerning Cocos Island see the following: Anonymous (1920; 1939b; 1945; 1951) ; Beebe (1926); Belcher (1843); Campbell (1932; 1934); Collenette (1926); Dampier (1729); Fraser (1943) ; Gueydon (1948); Hancock and Weston (1960); Lièvre (1893); Nesmith (1958); Pittier (1899); Rogers (1931); Rose (1926); Schmitt (1939a) ; Slevin (1931) ; Snodgrass and Heller (1902) ; Vancouver, 1798; Wafer [1699 (1903)].

## BIOGEOGRAPHY

An excellent summary of the zoogeography of the vertebrate fauna of Cocos Island was published by Schmidt (1930). The general consensus of most authors who have given careful consideration to this subject is that the island received its fauna and flora by transport over open water and that the endemic species have arisen because of geographic isolation.

The vertebrate fauna of Cocos Island consists of two lizards and seven land birds. Townsend reported a snake (not identified as to genus or species) from this island, but this record has not been substantiated by any subsequent collection from there. The lizards and three endemic land birds
differ from any other species, but their closest relatives live in Central America. There are no native mammals. A rat, Rattus norvegicus, is reported to have reached the island, undoubtedly from some of the many ships which have anchored there or from an occasional shipwreck. Pigs have been introduced, and evidence of their destructive influence is noticeable at many places. There are also reports of other domestic animals including cats, goats, deer, chickens, and even monkeys (Thomas, 1960, p. 34), introduced on the island intentionally or otherwise, and many of these appear to have become established as permanent members of the animal community.

The composition of the known invertebrate land and marine fauna is predominantly eastern Pacific in affinities. The evidence as to the origin of the sparse land snail fauna may be considered equivocal. Some authors consider their affinity to be with Indo-Pacific forms, others consider the relationship to be with American species. It is probable that some elements of the land snail fauna were derived from Central America, and some from Polynesia.

The most comprehensive study of the land plants of Cocos Island is by Stewart (1912). He reported that eight species, 8.69 per cent of 77 vascular plants, are endemic. Twenty-seven species also occur on the Galápagos Islands where the endemicity was reported to be 40.9 per cent. Stewart ( $1912, \mathrm{pp}, 381-383$ ) believed that the flora is that of an oceanic island, of more recent origin than that of the Galápagos Islands, and that its flora was derived chiefly from the mainland by chance agencies such as winds, ocean currents, and migratory birds. He, forthermore, concluded that there is no evidence to indicate that the island ever was comected by land with the mainland or with the Galápagos Islands.

Svenson (1935, p. 259) following Johnston (1931, p. 35), mentioned that the flora of Cocos Island consists of about 100 species of which about 10 are endemic, consisting overwhemingly of ferns, melanostomes, and orchids. He stated that with the exception of the ferns, virtually none of these species oceur in the Galapagos Islands.

More recently Vinton (1951), in discussing a possible explanation for the derivation of the ('alapagos fauna and flora, suggested a peninsula extending southwest from Costa Rica to within a hundred miles of the (talapagos Islands. He postulated that such a land area existed during Niocene time, and included the locality now occupied by Cocos Island (see his fig. 1). It was also his belief that such a land area would have deflected the currents at that time when an open seaway existed across Panama. He remarked on the recent origin of Cocos Island and suggested a probable Pleistocene age for it. He agreed in general with Stewart's opinion concerning derivation of the fauna and flora.

Schott (1931) publisher an exeellent diseussion concerning the shifting of oceanice currents, north and south. in the Panamic and northwestern


Fig. 3. Copy of illustration by Schott (1931, plate 20, figure 1) showing position of Cocos Island and the course of the equatorial countercurrent during AugustSeptember of a normal year.

South American region. He reported that this shift takes place about every seven years, and a decided displacement about every thirty-four years. The effect which this phenomenon produced upon the climatic and biological features in this region was described by Murphy (1936, pp. 102-108). Later Garth (1946) discussed the effect of this shifting of oceanic currents upon the composition of the brachyuran (crab) fauna of the Galápagos Islands. This same shifting of currents whereby Cocos Island is at times in the path of the Equatorial Countercurrent, and at other times under the influence of westwardly directed currents from off the mainland, can be invoked to explain the means of transportation by which the island received most of its invertebrate marine fauna.

The percentage of Indo-Pacific species in the invertebrate fauna of Cocos Island is small, except in the assemblage of corals and in those groups in which the species have an exceptionally wide distribution, such as the Holothurioidea. These species from the western Pacific may have reached the island by the agency of transpacific currents, directly, or conceivably by progressing eastward from one atoll to another or to truncated submarine islets (guyots) (see Ladd, 1960, pp. 143-145) which are known to exist in some places in the eastern Pacific.


Fig. 4. Copy of illustration by Schott (1931, plate 21, figure 3) showing position of Cocos Island and the course of the current westward from along the American mainland of Central America during March, 1891, a year of extreme displacement southward of the currents.

Very few species of invertebrates in the marine fauna of Cocos Island are identical with Caribbean or Atlantic forms but many closely related species occur in that region.

The following tabular summary indicating the distribution of the species of a few biologic categories (mostly those represented by a number of species), although based on lists which undoubtedly do not include all the species which may exist on the island, reveals the general interregional relationship of these groups. Additional collecting, especially in this and other tropical eastern Pacific islands where corals occur abundantly, may result in changes in the percentages of marine species shown in the various regions. I believe, however, that the general affinities of the fauna are revealed in this table. Additional remarks on the distribution and affinities of the phyla accompany the lists of species included under their respective categories in the following pages.

From the evidence of known distribution of the genera and species, I am inclined to agree with Stewart, Schmidt, and Vinton that the biota of Cocos Island was derived chiefly from the mainland, by the chance agencies of wind, ocean currents, hirds, or pelagie mammals.

Table 1. Number and general distribution of species of particular groups of animals reported from Cocos Island.

|  | Number <br> of <br> Species | Endemic on Cocos Island | Mainland and Panamic Region | Galápagos Islands | Indo- <br> Pacific | CaribbeanAtlantic |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Foraminifera | 17 |  | 14 | 13 |  | 1 Mediter- <br> ranean |
| Coelenterata |  |  |  |  |  |  |
| Hydrozoa | 5 |  | 5 | 3 |  | 1 |
| Anthozoa (corals) | 18 | 1 | 12 | 10 | 10 | 1 |
| Bryozoa | 20 |  | 18 | 20 | 1 | 2 |
| Echinodermata |  |  |  |  |  |  |
| Asteroidea | 6 |  | 4 | 5 |  |  |
| Ophiurioidea | 15 |  | 15 | 12 | 1 |  |
| Echinoidea | 13 | 1 | 12 | 10 | 1 |  |
| Holothurioidea | 11 |  | 11 | 6 | 8 | 2 |
| Mollusca |  |  |  |  |  |  |
| Marine and |  |  |  |  |  | Many related |
| Brackish-Water | 88 | 5 | 74 | 38 | 5 | species |
| Land snails | 9 | 7 |  |  | 1 or 2 |  |
| Annelida | 9 |  | 4 | 4 | 1 | 1 |
| Arthropoda <br> (Crustacea) |  |  |  |  |  |  |
| Brachyura | 33 |  | 30 | 23 | 3 | 2 |
| Anomura | 17 | 2 | 11 | 10 (or 11) | 4 | 1 |
| Myriopoda | 6 | 3 | 4 |  |  |  |
| Pisces | 59 | 5 | 38 | 20 | 16 |  |
| Reptilia <br> (lizards) | 2 | 2 | Related species |  |  |  |
| Aves |  |  |  |  |  |  |
| (land birds) | 7 | 3 | 4 |  |  |  |

ZOOLOGY
Phylum PROTOZOA
Class Sarcodina
Order Foraminifera
Ammodiscus pacificus Cushman and Valentine. Southern California to Panama; Galápagos Islands.

Dentalina filiformis d'Orbigny. Mainland; Galápagos Islands.
Dentaline cf. D. jugosa Williamson. Galápagos Islands. Monaco.
Eggerella advena Cushman. Cordova, Alaska, to Peru.
Haplophragmoides hancocki Cushman and McCulloch. Ketchikan, Alaska, to Peru; Galápagos Islands.
Lagena striatopunctata var. excentricitas Cushman and McCulloch. Galápagos Islands.
Nouria polymorphinoides Iteron-Allen and Earland. West Mexico to South America; Galápagos Islands.
Reophax agglutinatus Cushman. Mainland; Galápagos Islands.
Reophax excentricus Cushman. Mainland; Galápagos Islands.
Textularia articulata d'Orbigny. Southern California to Sechura Bay, Peru.
Textularia conicu d'Orbigny. Gulf of California to Colombia; Galápagos Islands.
Textskeria corrugata Heron-Allen and Earland. Gulf of California to Ecuador; Galápagos Islands.
Textularia panamensis Cushman. (ualf of California to Peru.
Textularia schencki Cushman and Valentine. Southern California to Central America; Galápagos Islands.
Trochammina charlottensis Cushman. San Francisco, California, to Colombia; Galápagos Islands.
Trochammina nitida H. B. Brady. Cordova, Alaska, to Sechura, Peru.
Vaginulina exilis Cushman and McCulloch. Galápagos Islands.
These 17 species of foraminifera were reported from Cocos Island by Cushman and McCulloch (1939;1950) and Lalicker and McCulloch (1940). Fourteen of these also occur on the mainland and 13 are reported from the Galápagos Islands.

## Phylum COELENTERATA

## Class HydrozoA

The following species were reported from Cocos Island by Fraser (1938; 1948).

Clytio cylindrica A. Agassiz. Colombia to Peru; Galápagos Islands.
Gonothyruec gracilis Sars. Costa Rica to Peru; Galápagos Islands.
IIalecium washingtoni Nutting. California to Peru.
Obelia commissuralis McCrady. Mexico to Panama ; Atlantic.
Thuriuriu orisioides Lamouroux. Mexico to Colombia; Galápagos Islands.
These 5 species all live on the mainland coast, and 3 have been reported from the Galapagos Islands. This class probably is represented on Cocos Island by more species than shown in the present list assembled from only a cursory seareh in papers published by Fraser.

## Class Anthozoa

## Order Pennatulacea

Family Pennatulidae
Leioptilus undulatus Verrill [Boone (1933, pp. 16, 57, pl. 19) reported Ptilosarcus gurneyi Gray (not P. gurneyi Gray, 1860), from Cocos Island. Deichmann (1941a, p. 13) later referred this record to Leioptilus undulatus]. Magdalena Bay, Baja California, to the north end of the Gulf of California and south to Panama.

Order Scleractinia
(Corals)
The following species have been reported from Cocos Island by Durham and Barnard (1952) and Durham (1962). These, with their geographic ranges follow:
Astrangia dentata Verrill (Durham, 1962, pp. 45, 46, 52). La Paz, Baja California, to Panama.
Astrangia hondaensis Durham and Barnard (1952, p. 73; Durham, 1962, pp. 44, 46). Questionably from Cocos Island and the Galápagos Islands. Balanophyllia scheeri Durham (1962, pp. 45, 46, 53). Known only from Cocos Island.
Cladocera debilis Milne Edwards and Haime (Durham and Barnard, 1952, p. 58 ; Durham, 1962, pp. 44, 46). Galápagos Islands; Atlantic.

Cycloseris mexicana Durham and Barnard (1952, p. 53 ; Durham, 1962, pp. 44, 46). Gulf of California to La Libertad, Ecuador ; Galápagos Islands. Endopachys vaughani Durham and Barnard (1952, p. 103; Durham, 1962, pp. 44, 46). Gulf of California; Galápagos Islands.
Leptoseris digitata Vaughan (Durham and Barnard, 1952, p. 36 ; Durham, 1962, pp. 44, 46). Questionably from Cocos Island; Gorgona Island, Colombia, to La Plata Island, Ecuador; Hawaiian Islands; Andaman Islands.
Pavona (Pavona) cf. P. (P.) explanulata Lamarck (Durham and Barnard, 1952, p. 42 ; Durham, 1962, pp. 44, 46). Clipperton Island; Indo-Pacific.
Pavona (Pavona) varians Verrill (Durham, 1962, pp. 45, 46, 50). Colombia; Hawaiian Islands; Great Barrier Reef; Red Sea.
Pavona (Polyastra) ponderosa Gardiner (Durham, 1962, pp. 45, 46, 50). Bonin Islands; Maldive Islands.
Pocillopora damicornis Linnaeus (Durham, 1962, pp. 45, 46, 48). Panama; Galápagos Islands; to Indian Ocean.
Pocillopora elegans Dana (Durham, 1962, p. 45, 46, 48). Gulf of Galifornia to the Galápagos Islands; Indo-Pacific.

Pocillopora meandrina Dana (Durham, 1962, pp. 45, 46, 48). Gulf of California: Indo-Pacific.
Pocillopora verrucosa Ellis and Solander (Durham, 1962, pp. 45, 46, 48). Gulf of California; Galápagos Islands; Clipperton Island; to Indian Ocean.
Porites excavata Verrill (Durham, 1962, pp. 45, 46, 51). Panama.
Psammocora profundacella Gardiner (Durham, 1962, pp. 45, 46, 49). Galápagos Islands; Fanning Island; Funafuti Island.
Psammocora (Stephanaria) stellata Verrill (Durham and Barnard, 1952, p. 30; Durham, 1962, pp. 44, 45, 46, 49). Gulf of California to La Libertad, Ecuador; Galápagos Islands; IIawaiian Islands; Fiji.
Tubastrea tenuilamellosa Milne Edwards and Haime (Durham, 1962, pp. $45,46,54)$. Gulf of California to Panama; Galápagos Islands.
Eighteen ${ }^{3}$ species of corals (three identifications doubtful) have been reported from Cocos Island and of these fourteen are reef-building (hermatypic) forms. One species is known only from Cocos Island. Twelve species (one identification doubtful) live along the eastern Pacific mainland or in the Panamic province and 10 species (one identification doubtful) live in the Galápagos Islands. Ten species (two identifications doubtful) also live in Indo-Pacific waters. Only one of the 18 species occurs in Atlantic waters.

## Phylum BRYOZOA

The following list of species of Bryozoa from Cocos Island, and their occurrence elsewhere, was generously furnished by Dr. John D. Soule.

These species are all from Allan Hancock Foundation sample number 328, Chatham Bay, Cocos Island, in 25.6 meters ( 14 fathoms), February 13, 1938. Three of these species, as indicated in the list, also were represented in Allan IIancock Foundation sample 330, Chatham Bay, Cocos Island, in 85.95 meters ( 47 fathoms), February 14, 1938.

A few species of Bryozoa from Cocos Island were mentioned by Osburn (1950; 1952).
Aplousina filum (Jullien), 1903. Previously reported from the Gulf of California; Cocos Island; Octavia Rocks, Colombia; Galápagos Islands. Cellaria veleronis Osburn, 1950. Originally reported from the Galápagos Islands. This is the first record of its occurrence from Cocos Island.
Chaperiella condylata (Canu and Bassler), 1930. Common in the Galápagos
Islands. It ranges from southern California to the Galápagos Islands. No prior record from Cocos Island.
Cleidochasma contracta (Waters), 1899. Previously reported from the
3. According to Dr. J. W, Durham (verbal communication, October 3, 1962), his record (1962, p. 51) of the occurrence of Porites californica Verrill from Cocos Island. is incorrect.

Galápagos Islands and the Gulf of California. No prior record from Cocos Island.
Colletosia radiata (Moll), 1803. Widely distributed from the cool temperate waters off Oregon to the Galápagos Islands. No prior record from Cocos Island.
Copidozoum tenuirostre (Hincks), 1880. Known from northern California to the Galápagos Islands. No prior record from Cocos Island. (Also present in sample 330.)
Crepidacantha poissoni (Audouin), 1826. Ranges from the Channel Islands, California, to the Galápagos Islands. No prior record from Cocos Island.
Crepidacantha setigera (Smitt), 1873. Previously reported from Cocos Island, Galápagos Islands and Florida.
Discoporella umbellata (Defrance), 1823. Common from Point Conception, California, to Point Santa Elena, Ecuador, including the Gulf of California, the coast of Costa Rica, and the Galápagos Islands.
Enantiosula manica Canu and Bassler, 1930. Reported from the Gulf of California, Cocos Island, and the Galápagos Islands. (Also present in sample 330.)
Holoporella brunnea (Hincks), 1884. Abundantly represented from off British Columbia to the Galápagos Islands. No prior record from Cocos Island. (Also present in sample 330.)
Micopora coriacea inarmata Soule, 1959. Common in the Gulf of California. Reported from the Galápagos Islands. No prior record from Cocos Island.
Microporella ciliate (Pallas), 1766. Common from the coast of Oregon to the Galápagos Islands. No prior record from Cocos Island.
Microporella marsupiata (Busk), 1860. Known from the Gulf of California and the Galápagos Islands. No prior record from Cocos Island.
Parellisina curvirostris (Hincks), 1862. World wide in tropical and temperate waters. No prior record from Cocos Island.
Reptadeonella violacea (Johnston), 1847. Previously reported from the Gulf of California, coast of Mexico, Cocos Island, and Galápagos Islands.
Reteporellina denticulata gracilis Osburn, 1952. Recorded previously from the Gulf of California, Cocos Island, and the Calápagos Islands.
Retevirgula areolata (Canu and Bassler), 1923. Ranges from southern California to the Galápagos Islands. Common at the Galápagos Islands. No prior record from Cocos Island.
Trypostega venusta (Norman), 1864. Previously reported from the Gulf of California, the coast of Mexico, Cocos Island, and the Galápagos Islands.
Tubulipora flexuosa (Pourtales), 1867. Previously reported from the Gulf of California and the Galápagos Islands. No prior record from Cocos Island.

Eighteen of the 20 species in this list live along the mainland in tropical eastern Pacific waters. All are known to live in the Galápagos Islands, 9 in California waters, 2 in the Caribbean area one of which occurs world-wide in tropical and temperate waters.

## Phylum BRACIIIOPODA

## Family Rhynchonellidae

Hispanirhynchia? craneana Dall [as Hemithyris craneana Dall, 1895, p. 717; 1920, p. 288; Hertlein and Grant, 1944, p. 60 as "Hispanirhynchia [?|" craneana].
This species was originally dredged off Cocos Island in 2149 meters ( 1,175 fathoms). It has not been reported elsewhere.

## Phylum ECILINODERMLATA

## Class Asteroidea

The following is a list of the species of Asteroidea from Cocos Island and their occurrence elsewhere. The records of species not previously re ported from this island were furnished by Mr. Fred Ziesenhenne.
Coronaster marchenus Ziesenhenne (1942, p. 212). Galápagos Islands.
Linckia columbiae Gray (Ziesenhenne, 1962, written communication). California to Peru; Galápagos Islands.
Narcissiu gracilis A. II. Clark (Ziesenhenne, 1962, written communication). Gulf of California; Galápagos Islands.
Oreaster occidentalis Verrill (H. L. Clark, 1940, p. 333). Mexico to Peru; Socorro and Clarion Islands, Revillagigedo Islands; Galápagos Islands.
Pauliella aenigma Ludwig (Ziesenhenne, 1937, p. 215). Gulf of California to Panama; Clarion Island, Revillagigedo Islands.
Tanaria obstipa Ziesenhenne (1942, p. 209). Galápagos Islands. Four of the 6 species of this class reported from Cocos Island also live along the mainland, 5 in the Galápagos Islands, and 2 in the Revillagigedo Tslands.

## Class Ophiurioidea

The following brittle stars, with their known ranges, have been reported from Cocos Island. Records of those not previously reported from this island were generously furnished by Fred Ziesenhenne.
Amphiodik violacea Lütken (A. II. Clark, 1939, p. 2). Los Coronados Islands, off west coast of Baja California, Mexico, to Colombia (Ziesenhenne, 1963 , written commumication).
Diopederma danianum Verrill (II. I. Clark, 1940, p. 343). Baja California to Panama.

Ophiacantha phragma Ziesenhenne (1940, p. 12). Southern California to Ecuador; Galápagos Islands.
Ophiactis savignyi Müller and Troschel (Ziesenhenne, 1962, written communication). Mainland; Galápagos Islands; Clipperton Island; worldwide in tropical waters.
Ophiactis simplex LeConte (Ziesenhenne, 1962, written communication). California to Peru; Galápagos Islands.
Ophiocoma aethiops Lütken (H. L. Clark, 1940, p. 341). Baja California to Panama; Galápagos Islands.
Ophiocoma alexandri Lyman (H. L. Clark, 1940, p. 341). Baja California to Panama; Galápagos Islands.
Ophioderma panamense Lütken (H. L. Clark, 1940, p. 342; Ziesenhenne, 1955, p. 193). San Pedro, California, to Paita, Peru; Guadalupe Island; Revillagigedo Islands; Galápagos Islands.
Ophioderma variegatum Lütken (H. L. Clark, 1940, p. 343 ; Ziesenhenne, 1955, p. 198). San Diego, California, to Panama; Revillagigedo Islands; Galápagos Islands.
Ophiomyxa panamensis Lütken and Mortensen (H. L. Clark, 1940, p. 336). Gulf of California to Panama; Calápagos Islands; Socorro Island, Revillagigedo Islands.
Ophionereis dictyota Ziesenhenne (1940, p. 30). Gulf of California, to Panama.
Ophionereis nuda Lütken and Mortensen (II. L. Clark, 1940, p. 340). Isabel Island, Mexico, to Panama; Galápagos Islands.
Ophiophragmus marginatus Lütken (Ziesenhenne, 1962, written communication). Mexico to Ecuador; Galápagos Islands.
Ophiophragmus paucispinus Nielsen (Ziesenhenne, 1962, written communication). Mexico to Costa Rica; Galápagos Islands.
Sigsbeia lineata Lütken and Mortensen (H. L. Clark, 1940, p. 336). Panama; Galápagos Islands.
Of the 15 brittle stars reported by H. L. Clark and by Ziesenhenne from Cocos Island, all also live in mainland waters, 12 in the Galápagos Islands, 3 in the Revillagigedo Islands, Mexico, and 1 in Indo-Pacific waters.

## Class Echinoidea

II. L. Clark $(1940 ; 1948)$ recorded the occurrence of 13 species of echinoids from Cocos Island. These, with their recorded geographic ranges follow.
Centrechinus (= Diadema) mexicana A. Agassiz (H. L. Clark, 1948, p). 235). Consag Rock, Gulf of California, to La Plata Island, Ecuador; Revillagigedo Islands; Galápagos Islands.

Centrocidaris doederleini A. Agassiz (H. L. Clark, 1948, p. 226). Galápagos Islands.
Clypeaster ochrus H. L. Clark (1947, p. 297). La Paz, Baja California, to Ecuador'; Galápagos Islands.
Clypeaster rotundus A. Agassiz (H. L. Clark, 1948, p. 296). Georges Island, Gulf of California, to Santa Elena Bay, Ecuador; Revillagigedo Islands; Galápagos Islands.
Clypeaster speciosus Verrill (H. L. Clark, 1940, p. 350). Magdalena Bay, Baja California, and the Gulf of California; Revillagigedo Islands; Calápagos Islands.
Echinometra van-brunti A. Agassiz (H. L. Clark, 1940, p. 349; 1948, p. 294). Angel de la Guardia Island, Gulf of California, to San Francisco Bay, Ecuador; Revillagigedo Islands; Galápagos Islands.
Encope cocosi H. L. Clark [1948, p. 330; Mortensen (Monogr. Echin., IV.2. Clypeastroida, p. 448, 1948, as Encope micropora cocosi)]. Known only from Cocos Island.
Eucidaris thoursii Valenciemnes (II. L. Clark, 1940, p. 347; 1948, p. 229). Santa Catalina Island, California; Guadalupe Island, Baja California, and the Gulf of California to La Plata Island, Ecuador; Revillagigedo Islands; Calápagos Islands.
Hesperocidaris panamensis A. Agassiz (H. L. Clark, 1948, pp. 226, 131). Off Galera Point, Ecuador; Galápagos Islands.
Lovenic cordiformis A. Agassiz (H. L. Clark, 1940, p. 352; 1948, p. 348). Santa Barbara, California, and the Gulf of California to Guayaquil, Ecuador; Revillagigedo Islands; Galápagos Islands. Hawaiian Islands (Ziesenhenne, 1937, p. 236).
Lytechinus pictus Verrill (H. L. Clark, 1940, p. 349). Monterey, California, to the Gulf of California.
3 eoma grandis Gray (II. L. Clark, 1948, p. 344). Angeles Channel, Gulf of California, to Port Utria, Colombia; Revillagigedo Islands; Galápagos Islands.
Plagiobrissus pacificus II. L. Clark (1948, p. 342). Gulf of California to Panama Bay and questionably from La Plata Island, Ecuador.
Of these 13 species, 1 is known only from Cocos Island. All the others
are known to occur also in the waters of the mainland of the Panamic
province. Six of these also occur in the Revillagigedo Islands and 10 occur
at the Cralápagos Islands. One has been reported from the Hawaiian Islands.

## Class Holothurioidea

Brandtothuria arenicola Semper. Gulf of California to Ecuador; Galápagos Islands; Revillagigedo Islands; West Indies. Almost circumtropical. Brandtotherim impetiens Forskàl. Cedros Island, Baja California, and Gulf
of California to Colombia; Galápagos Islands; Revillagigedo Islands; West Indies. Almost circumtropical.
Jaegerothuria inhabilis Selenka. Gulf of California to Ecuador; Galápagos Islands; Revillagigedo Islands; Hawaii to Australia.
Lessonothuria pardalis Selenka. Gulf of California to Colombia; Hawaii. Almost circumtropical but lacking in Atlantic and West Indies.
Ludwigothuria atra Jaeger. Galápagos Islands; Clipperton Island; Hawaii to Mozambique.
Ludwigothuria kefersteini Selenka. Mexico to Peru; Galápagos Islands; Revillagigedo Islands.
Microthele difficilis Semper. Gulf of California to Galápagos Islands; Clipperton Island; Australia; east coast of Africa to east coast of Pacific.
Psolus diomedeae Ludwig. Gulf of California to Ecuador; Galápagos Islands.
Selenkothuria theeli Deichmann. Gulf of California to Zorritos, Peru; Galápagos Islands; Revillagigedo Islands.
Semperothuria imitans Ludwig. Gulf of California to Panama; Galápagos Islands; Revillagigedo Islands; Samoa.
Theelothuria paraprinceps Deichmann. Gulf of California to Panama; Clarion Island, Revillagigedo Islands.
These holothurians were reported from Cocos Island by Deichmann (1941b; 1958). All occur in the Panamic region and all except three also live in western Pacific waters. The percentage of these species reported from both the eastern Pacific and western Pacific waters is much greater than that of most classes of invertebrates recorded from Cocos Island. However, many species in this group of animals, especially the Aspidochirota, are widely distributed (see Deichmann, 1958, pp. 253, 277).

## Phylum MOLLUSCA <br> Marine and Brackish-Water Mollusks

Class Pelecypoda
Arca (Anadara) reinharti Lowe [Rost, 1955, p. 227, as Anadara (Scapharca) reinharti.]
Cetoconcha scapha Dall (1902, p. 561). Off Cocos Island in 183 meters (100 fathoms).
Crenella divaricata d'Orbigny (Soot-Ryen, 1955, p. 130).
Isognomon (Melina) chemnitzianum d'Orbigny [Pilsbry and Vanatta, 1902, p. 559 (as Perna chemnitzianum d'Orb. (?) ; Dall, 1908, p. 437 (as Melina chemnitziana); Hertlein, 1932, p. 45 (as Pedalion chemnitzianum)].

Isognomon quadrangularis Reeve [von Martens, 1902b, p. 138 (as Perna quadrangularis); Pilsbry and Vanatta, 1902, p. 137 (as Perna quadrangularis); Biolley, 1907, p. 25 (as Perna quadrangularis)].
Lithophaga attemuata Deshayes (Bartsch and Rehder, 1939, p. 18).
Lithophaga (IIyoforceps) aristata Dillwyn (Soot-Ryen, 1955, p. 141; Tumer and Boss, 1962, p. 108).
Ostrea palmula Carpenter [von Martens, 1902b, p. 137 (as Ostrea ochracea Sowerby) ; Biolley, 1907 (as Ostrea ochracea) ; Hertlein, 1932, p. 45 (also cited as Ostrea callichroa IIanley )].
Pecten (Pecten) sericeus Hinds ( (irau, 1959, p. 142).
Pecten (Cyclopecten) cocosensis Dall (1908, p. 405) ; Hertlein (1935, p. 319. Original locality only and pl. 18, figs. 7 and 8) ; Keen (1958, p. 72); Grau (1959, p. 30) (Dall's record).
Pecten (Cyclopecten) exquisitus Grau (1959, p. 36).
Pecten (Oppenheimopecten) hancocki Grau (1959, p. 155).

## Class Cistropoda

(Marine and Brackish-Water Forms)
Acanthina brevidentata Wood [von Martens, 1902b, p. 137 (as DIonoceros brevidentata); Biolley, 1907, p. 21 (as Monoceros brevidentatum); Hertlein, 1932, p. 45|.
Acmaea (Nomatopelta) mesolenca Menke [von Martens, 1902b, p. 137 (as Acmaea striata Quoy and Gaimard) ; Pilsbry and Vanatta, 1902, p. 559 (as "Scarria" mesoleuca); Biolley, 1907, p. 26 (Record of Pilsbry and Vanatta (1902), also p. 24 (as Acmaea striata); Tomlin, 1928, p. 188 (as Collisella mesolenca); Hertlein, 1932, p. 45 (as Acmaea (Collisella) aeruginosa Middendorff); Hertlein, 1937, p. 306 (von Marten's record (1902b) of Acmaea striata cited)].
Acmaea strigatella Carpenter (Pilsbry and Vanatta, 1902, p. 559).
Bursa caelata Broderip [von Martens, 1902b, p, 137 (as Ranella caelata); Biolley, 1907, p. 21 (as Ranella caelata)].
('aclucifer cinis Reeve [von Martens, 1902b, p. 137 (as Pollia cinis); Pilsbry and Vanatta, 1902, p. 559 (as Tritonidea cinis); Biolley, 1907, p. 21 (as Polla cinis); Keen (1958, p. 398, as Caducifer thalia Pilsbry and Lowe).|
Cantharus (Gemmophos) gemmatus Reeve [Hertlein, 1932, p. 45 (as Cantharus gemmatus)|.
('antharus sangminolentus. 1)uclos [von Martens, 1902b, p. 137 (as "Pollia sanguinolenta 1)uclos $1832=$ huemustoma Cray, 1839"); Pilsbry and Vanatta, 1902, 1). 559 (as Tritonidea senguinolenta): Biolley, 1907, p. 21 (as Polliu sanguinolenta)].

Cerithium adustum Kiener (von Martens, 1902b, p. 137; Biolley, 1907, p. 22; Hertlein, 1932, p. 45.)

Cerithium maculosum Kiener (Pilsbry and Vanatta, 1902, p. 559; Dall, 1908, p. 437).
Conus brunneus Wood (von Martens, 1902b, p. 137; Biolley, 1907, p. 20; Tomlin, 1927, p. 155; Hanna and Strong, 1949, p. 269).
Conus dalli Stearns (Hertlein, 1932, p. 45 ; Hertlein, 1937, p. 306; Hanna and Strong, 1949, p. 305).
Conus gladiator Broderip (Calif. Acad. Sci. Coll., W. H. Ochsner collector, 1905).

Conus recurvus Broderip [Dall, 1910, p. 225 (as Conus scariphus Dall); Hanna and Strong, 1949, p. 280 (Conus scariphus in synon.)].
Conus tiaratus Broderip (Hertlein, 1932, p. 45; Hanna and Strong, 1949, p. 272).

Cymatium vestitum Hinds (Hertlein, 1932, p. 45).
Cypraea isabella mexicana Stearns [von Martens, 1902b, p. 137 (as Cypraea "wahrscheinlich" isabella Linnaeus) ; Biolley, 1907, p. 21 ("?"); Schilder and Schilder, 1938, pp. 176, 197 (as Cypraea controversa mexicana); Demond, 1957, p. 304 (as Cypraea (Luria) isabella)].
Cypraea moneta Linnaeus [Hertlein, 1932, p. 45; Hertlein, 1937, p. 307 ; Ingram, 1947a, pp. 58 (16), 74 (32); Ingram, 1947b, p. 147 (11); Ingram, 1948, p. 140 ; Ingram, 1951, p. 152 (28); Demond, 1957, p. 304 (as Cypraea (monetaria) moneta)」.
Cypraea rashleighana Melvill [Ingram, 1945, p. 106; 1947a, p. 76 (34); 1947b, p. 148 (12); 1951, p. 155 (31)].
Ellobium stagnalis d'Orbigny [Biolley, 1907, p. 19 (as Auricula (?) stagnalis); Hanna and Hertlein, 1938, p. 32 (as Auricula stagnalis)].
Fissurella virescens Sowerby (von Martens, 1902b, p. 137; Pilsbry and Vanatta, 1902, p. 559; Biolley, 1907, p. 23; Tomlin, 1928, p. 188; Hertlein, 1932, p. 45).
Harpa crenata Swainson (Hertlein, 1932, p. 45).
Hipponix grayanus Menke [Pilsbry and Vanatta, 1902, p. 559 (as Amalthea grayana) ; Biollev, 1907, p. 23 ; Hertlein, 1932, p. 45 "cf."].
Hipponix pilosus Deshayes [von Martens, 1902b, p. 137 (as Hipponix perhaps barbatus Quoy and Gaimard)].
Latirus tuberculatus Broderip (Dall, 1908, p. 436; Hertlein, 1932, p. 45).
Littorina aspersa Philippi [von Martens, 1902b, p. 137 (as Littorina aspera); Biolley, 1907, p. 23 (as Littorina aspersa); Hertlein, 1932, p. 45].
Littorina conspersa Philippi [von Martens, 1902b, p. 137; Biolley, 1907, p. 21; Dall, 1908, p. 437 (also, Malpelo Id.) ; Hertlein, 1932, p. 45].

Littorina modesta Philippi (Tomlin, 1927, p. 168). [Keen (1958, p. 282) pointed out that this species "has been cited from the Panamic province.
but it seems an indeterminate form with a type locality in Alaska."] MIarginella minor C. B. Adams (Bartsch and Rehder, 1939, p. 18).
Melampus tabogensis C. B. Adams [Dall, 1896, p. 452 (as Tralia panamensis C. B. Adams); Dall, 1900, p. 97 (as Melampus panamensis); von Martens, 1900 , p. 561 (Dall's record (1900) cited; von Martens, 1902b, p. 137 (as Melampus tabogensis) ; Dall, 1908, p. 436 (as Melampus panamensis) ; Morrison, 1946, p. 36)].
Melampus trilineatus C. B. Adams (Hanna and Hertlein, 1938, p. 134). Mitra fultoni E. A. Smith [(Calif. Acad. Sci. Coll., W. H. Ochsner collector, 1905; Sphon, 1961, pp. 34, 35)].
Mitra lens Wood [Dall, 1908, p. 436].
Mitra tristis Swainson (Stanford Univ. Coll.).
Mitrella ocellata Gmelin [Pilsbry and Vanatta, 1902, p. 559 (as Columbella cribraria Lamarck) ; Biolley, 1907, p. 26 (record of Pilsbry and Vanatta, (1902)].

Murex humilis Broderip (Dall, 1908, p. 436).
Nerita funiculata Menke [von Martens, 1902b, p. 137 (as Nerita bernhardi Recluz) ; Pilsbry and Vanatta, 1902, p. 559 (as Nerita fulgurans bernhardi Recluz) ; Biolley, 1907, p. 23 (as Nerita bernhardi); Hertlein, 1932, p. 45 (as Nerita bernhardi)].

Nerita ornata Sowerby [von Martens, 1902b, p. 137; Biolley, 1907, p. 23; Dall, 1908, p. 437 (as Nerita scubricosta Lamarek) ; Itertlein, 1932, p. 45 (as Nerita scabricosta var. ornata)].
Neritina pilsbryi Tryon [Biolley, 1907, p. 18 (as Neritina latissima Broderip var. globosa Broderip) ; Hertlein, 1902, p. 45].
Nitidella sertularium Orb.? (Tomlin, 1927, p. 162). [Record probably incorrect. A Patagonian species].
Olivella (Olivella) cocosensis Olsson (1956, p. 180; Keen, 1958, p. 424).
Phos cocosensis Dall (Dall, 1917, p. 578; Strong and Lowe, 1936, p. 310 ; Keen, 1958, p. 406.)
Planaxis planaxis Wood (Dall, 1908, p. 436).
Planaxis planicostatum Sowerby [von Martens, 1902b, p. 137 (as Planaxis planicostatus); Pilsbry and Vanatta, 1902, p. 559 (as Planaxis planicostatus); Biolley, 1907, p. 21 (as Planaxis planicostatus); Tomlin, 1927, p. 168; Hertlein, 1932, p. 45].
Polinices helicoides Gray [Tomlin, 1927, p. 170 (as Polinices glabella Reeve)].
Purpura patula pansa fould [von Martens, 1902b, p. 137 (as Purpara patula Limnacus); p. 140 (as "Purpura patula L. (pansa Conr.)"; Pilsbry and Vanatta, 1902, p. 559 (as Purpura patula); Biolley, 1907, p. 21 (as L'urpura patula) : Dall, 1908, p. 436 (as Thais patula); Tomlin,

1928, p. 163 (as Thais patula); Hertlein, 1932, p. 45 (as Thais patula)|. Pyrene labiosa Sowerby [Pilsbry and Vanatta, 1902, p. 559 (as Columbella labrosa); Biolley, 1907, p. 26 (as Columbella labrosa, record of Pilsbry and Vanatta)].
Siphonaria gigas Sowerby (Dall, 1896, p. 453; Dall, 1900, p. 97; von Martens, 1902b, p. 137 ; Pilsbry and Vanatta, 1902, p. 559; Biolley, 1907, p. 25 ; Dall, 1908, p. 436 ; Dall, 1909, p. 205 ; Hertlein, 1932, p. 45).

Siphonaria gigas var. characteristica Reeve [Tomlin, 1927, p. 15t (as Siphonaria characteristica); Hertlein, 1932, p. 45.]
Tegula cooksoni E. A. Smith (Tomlin, 1928, p. 187; also Calif. Acad. Sci. Coll., W. H. Ochsner collector, 1905).
Tegula maculostriata C. B. Adams [Pilsbry and Vanatta, 1902, p. 559 (as Chlorostoma maculostriatum C. B. Adams) ; Biolley, 1907, p. 26 (record of Pilsbry and Vanatta cited)]. [The type locality of T. maculostriata is Jamaica. The specimens so identified by Pilsbry and Vanatta from Cocos Island resemble the illustration of the type specimen published by Clench and Turner (Occasional Papers on Mollusks, Department of Mollusks, Museum of Comparative Zoölogy at Marvard College, Vol. 1, No. 15, p. 305, pl. 39, fig. 13). The spire is higher and the scupture coarser than that of T. cooksoni E. A. Smith].
Tegula gallina multifilosa Stearms [Pilsbry and Vanatta, 1902, p. 559 (as Chlorostoma gallinum multifilosum) ; Biolley, 1907, p. 26 (as Chlorostoma gallinum multifilosum, record of Pilsbry and Vanatta cited)]. [Record from Cocos Island doubtful. Not known with certainty south of Baja California].
Thais columellaris Lamarck [ron Martens, 1902b, p. 137 (as Purpuru columellaris); Pilsbry and Vanatta, 1902, p. 559 (as Purpura columellaris); Biolley, 1907, p. 21 (as Purpurt columellaris); Dall, 1908, p. 437; Hertlein, 1932, p. 45)].
Thais haemastoma biserialis Blainville [Hertlein, 1932, p. 45 (as Thais biserialis)].
Thais (Vasula) melones Duclos [von Martens, 1902b, p. 137 (as Purpura melo); Pilsbry and Vanatta, 1902, p. 559 (as Purpura melones): Biolley, 1907, p. 21 (as Purpura melones); Dall, 1908, p. 436 (as Thais melones); Hertlein, 1932, p. 45 (as Thais crassa Blainville)].
Thais speciosa Valenciennes (Calif. Acad. Sci. Coll., W. II. Ochsner, collector, 1905).
Thais triangularis Blainville (Calif. Acad. Sci. Coll., W. H. Ochsner, collector, 1905).
Trivia pacifica Gray (Tomlin, 1927, p. 166.)
Vermetus sp. (von Martens, 1902b, p. 137; Biolley, 1907, p. 25).

## (Land Forms)

Habroconus (C'ocosconus) hopkinsi Dall (Baker, 1941, p. 225).
IIabroconus (Pseudoguppya) pacificus Pfeiffer (Baker, 1941, p. 226).
Hubroconus (Cocoslens) pallidus H. B. Baker (1941, p. 224).
Leptinaria biolleyi von Martens (Hanna and Hertlein, 1938, p. 128).
Nesopupa (Cocopupa) cocosensis Dall (Hanna and Hertlein, 1938, p. 129). Ochrodermella biolleyi von Martens (Hanna and ITertlein, 1938, p. 127). Ochrodermella cumingiana Pfeiffer (Hanna and Hertlein, 1938, p. 125). Opeas gracile Hutton (Hanna and Hertlein, 1938, p. 130). Succinea globispira von Martens (Hanna and Hertlein, 1938, p. 129).

The land snails from Cocos Island have been discussed in a paper by Hamna and Hertlein (1938) who have summarized the literature pertaining to them. Baker (1941, pp. 223-226) later made changes in the nomenclature of some of the species.

Of the 9 species reported from Cocos Island, Opeas gracile Hutton is widely distributed over the Indo-Pacific region and evidently is an introduced species. It also is possible that the species of Leptinaria may have arrived on the island adventitionsly. The other 7 species, known only from Cocos Island, belong to the genera IIabroconus, Nesopupa, Ochrodermella, and Succinea. Kobelt (1899) and Hanna and ILertlein (1938) suggested Indo-Pacific affinities of the endemic species of these genera on Cocos Island. Germain (1934, p. 153), remarked on the small number of species, the absence of Bulimulus, and the fact that Ochrodermella also occurs in the Caroline Islands. Baker (1941, p. 352) believes that the affinities of the land snails from Cocos Island are with species on the American mainland. It appears probable that some elements of the land snail fauna were derived from the eastern Pacific and others from Polynesia.

For additional information concerning these land snails see Ancey (1903) ; Baker (1945) ; Biolley (1907; 1908-1909) ; Dall (1896; 1900) ; Gude (1903); von Martens (1890-1901; 1898; 1902a); Pilsbry and Cooke (1920).

## Order Pteropoda

Limacina inflata d'Orbigny (IToward, 1952, p. 13).
('reseus virgula Rang (Howard, 1952, p. 13).
Dincrie quadridentata parve Howard (1952, p. 13).
('acolina longirostris constricta IIoward (1952, p. 13).

## Class Amphineura

Acanthochitona himediniformis Sowerby.
('hiton stokesi): Biolley, 1907, p. 24 (as Chiton (Radsia) stokesi); Dall, Chiton (('hiton) stokesii Broderip) Pilsbry and Vanatta, 1902, p. 559 (as

1908, p. 436 (as Chiton stokesii); Tomlin, 1927, p. 154 (as Chiton stokesii) ; Leloup, 1956, p. 246.]
Chiton (Radsia) goodallii Broderip [von Martens, 1902b, p. 137 (as Chiton (Radsia) goodalli); Boone, 1933, p. 24 (as Chiton (Chiton) goodallii), p. 201 (as Chiton goodallii)].

Placiphorella blainvillei Broderip (Dall, 1908, p. 357 ; Dall, 1909, p. 246).

## Class Cephalopoda

Abraliopsis hoylei Pfeffer (Robson, 1948, p. 118).
Argonauta expansa Dall (Robson, 1932, p. 197, in synonymy of Argonauta cornuta Conrad, 1854, p. 332. Not Argonauta cornutus Bose, Hist. Nat. des Coquilles, vol. 3, p. 262, AN X[1802]).
Helicocranchia beebei Robson (1948, p. 130).
Liocranchia reinhardti Steenstrup (Robson, 1948, p. 128).
Melanoteuthis beebei Robson (1932, p. 103).
Octopus (Octopus) pusillus Gould [Dall, 1909, p. 194 (as Polypus pusillus); Robson, 1929, p. 150].
Octopodoteuthis nielseni Robson (1948, p. 120).
Onykia (Teleoteuthis, Auctt.) sp. (Robson, 1948, p. 121).
Polypus januarii Hoyle (Dall, 1909, p. 194). [Locality records from the Pacific doubtful according to Robson, 1932, pp. 235, 240. Type locality northeast Brazil].
Pyroteuthis giardi Fischer (Robson, 1948, p. 118).
(?) Sthenoteuthis sp. (Rhynchoteuthis stage) (Robson, 1948, p. 125).
Symplectoteuthis oulaniensis Lesson (Dall, 1909, p. 195; Berry, 1912, p. 304: Robson, 1948, p. 127).
Taonidium pacificum Robson (1948, p. 130).
One of the earliest references in which the occurrence of marine mollusks at Cocos Island is mentioned is that by Colnett (1798, p. 71) who stated "Shell-fish, were scarce, though we collected some very large limpets, of a new kind, and a few dead conches. The latter were seen in great numbers on the beach, and mostly inhabited by the Diogenes crab." It seems possible that the large limpets mentioned by Colnett might be referable to Siphonaria gigas Sowerby or S. gigas characteristica Reeve which occur abundantly at some places on this Island.

The identification of some of the species in the present paper, based upon records taken from the literature, may be doubtful, but the general composition of the assemblage is in harmony with other island mollusean faunas (except that of Clipperton Island) in the eastern Pacific. Further collecting on Cocos Island would undoubtedly yield additional species. I believe, however, that the general composition represented by the present list is representative of the marine molluscan fauna of this Island.

The present list contains 88 species and subspecies ( 3 species identified only as to gemus, not included in this number) arranged as follows: Pelecypoda 12, Gastropoda 57, Pteropoda 4, Amphineura 4, Cephalopoda 11. Of the total only 4 species, 3 pelecypods and 2 cephalopods, described from or near Cocos Island, have not been reported elsewhere. All but 14 species have been reported occurring on or near the mainland. At least 38 species listed here also have been reported from the Galápagos Islands and at least 33 species occur in the Gulf of California. Two gastropods, belonging to the genus Cypraea, and 3 cephalopods, also have been reported from Indo-Pacific waters.

The 4 species of pteropods reported from Cocos Island by Howard (1952, p. 13) also occur at other localities in the eastern Pacific.

The marine molluscan fauna of Cocos Island contrasts decidedly with that of Clipperton Island where nearly 50 per cent of the species are IndoPacific forms or have affinities with species in the central or western Pacific (sce Tertlein and Emerson, 1953; 1957).

## Phylum ANNELIDA

Chlocia entypa Chamberlin (Hartman, 1939a, p. 3). Southern California to Panama.
Chloeia viridis Schmarda (Hartman, 1940, pp. 190, 205. Also cited from Cocos Island as C. euglochis Ehlers by Treadwell, 1928, p. 450). Gulf of California to Panama and the Galápagos Islands; West Indies.
Eusigalion spinosum Hartman (1939b, pp. 10, 17, 59). Farallon Islands, California, to Cocos Island, and the Cialápagos Islands.
Lepidonotus furcillatus Ehlers (Hartman, 1939b, p. 16). Cited from Cocos Island on page 16 but on page 2 cited from Wreck Bay, Chatham Island, Galápagos Islands.
Neime cirratulus hirsutus Treadwell (1928, p. 479, as Spio hirsuta); Hartman (1959, p. 390). Known only from Cocos Island.
Notopygos crinita Grube (Treadwell, 1928, p. 450). St. Helena Island.
Perinereis helleri Grube (Cited from Cocos Island as Neanthes obscura Treadwell, 1928, p. 472). Philippine Islands.
Psammolyce spinosa Hartman (1939b, pp. 10, 17, 74). Clarion Island, Revillagigedo Islands, Mexico.
Sthenelais fusca Johnson (Hartman, 19391, pp. 10, 17, 61). Washington to Panama and the (ialápagos Islands.
A few species of this group have been reported from Cocos Island by Treadwell (1928) and Hartman (1939a, 1939b, 1940). All except two of these have also been reported from mainland waters. The nomenclature followed here is that of Itartman (1959).

# Phylum ARTHROPODA 

Class Crustacea
Subclass Copepoda
Gloiopotes ornatus Wilson.
Pennella instructa Wilson.
These two species, parasites on a sailfish, were reported from off Chatham Bay, Cocos Island by Schmitt (1939b, p. 27).

## Subelass Cirripedia

Conchoderma, "very probably C. virgatum (Spengler)" (Schmitt, 1939b, p. 27). Attached to a copepod, Pennella instructa Wilson (with sucker fish, Echeneis remora Limnaeus), taken from a sailfish from off Chatham Bay, Cocos Island.
Tetraclita squamosa Bruguière [von Martens, 1902b, p. 138, (as Tetraelita (type. error) porosa Gmelin)]. World-wide in tropical and subtropical seas (see Pilsbry, 1916, U. S. Nat. Mus., Bull. 93, p. 249).
Tetraclita squamosa milleporosa Pilsbry (Hertlein, 1932, p. 45). Originally described from Albemarle Island, Galápagos Islands (Pilsbry, 1916, U. S. Nat. Mus., Bull. 93, p. 257).

## Subelass Malacostraca <br> Order Amphipoda

Podoceropsis dubia Shoemaker (1942, p. 32, fig. 12). Originally described from Chatham Bay, Cocos Island.
Talorchestia fritzi Stebbing (1903, p. 928). Originally described from Cocos Island.

## Order Decapoda

## Brachyura

Dr. John Garth furnished the following list of species of spider crabs from Cocos Island:

## Family Majidae

Euprognatha bifida Rathbun. Mainland.
Euprognatha granulata Faxon. Mainland; Galápagos Islands.
Herbstia tumida (Stimpson). Mainland.
Inachoides laevis Stimpson. Mainland.
Lissı aurivilliusi Rathbun. Mainland; Galápagos Islands.
Lissa tuberosa Rathbun. Mainland.

Microphrys branchialis Rathbun. Mainland.
Microphrys triangulatus Lockington. Mainland; Galápagos Islands.
Mithrax (Mithrax) spinipes (Bell). Mainland; Galápagos Islands.
Podochela hemphilli (Lockington). Mainland.
Sphenocarcinus agassizi Rathbun. Mainland; Galápagos Islands.
Stenocionops ǒ،ata (Bell). Mainland; (ialápagos Islands.
Stenorhynchus debitis Smith. Mainland; Galápagos Islands.
Teleophrys cristulipes (Stimpson). Mainland; Galápagos Islands.

## Family Parthenopidae

Thyrolambrus glasselli Garth (formerly known as T. erosus Rathbun). Mainland.
According to Dr. Garth, all these species also occur on the mainland and none is found in the Indo-Pacific. He stated: "The only semi-endemics among the brachyurans that I recall are Euprognatha granulata Faxon, shared with the Galápagos Islands, and Portunus (Achelous) brevimanus (Faxon) (family Portunidae), shared with the Revillagigedo Islands."

The following records of Brachyuran crabs from Cocos Island, with their general distribution, are taken from Boone, Rathbun, and others.

## Family Majidae

Mithrax (Mithraculus) denticulatus Bell. Mainland; Galápagos Islands. Paradasygius depressus Bell (Carth, 1958, p. 81). Mainland.

## Family Parthenopidae

Parthenope (Platylambrus) exilipes Rathbun. Mainland; Galápagos Islands.

## Family Portunidae

Portunus (Achelous) brevimanus Faxon. Cocos Island, type locality; Revillagigedo Tslands.

## Family Xanthidae

Carpilodes cinctimanus White. Galápagos Islands. [According to Rathbun (U. S. Nat. Mus., Bull. 152, p. 242, 1930), Liomera cocosana Boone, type locality, Cocos Island, is a synonym of C'. cinctimamus].
Eriphia squamate Stimpson. Mainland; Galápagos Islands. [According to Garth (Allan Mancock Pacific Expeditions, Vol. 5, No. 10, p. 486, 1946) Boone's record (1927) of Eriphia granulosa A. Milne Edwards from Cocos Island is referable to $E$. squamata].

Leptodius cooksoni Miers. Galápagos Islands; Clarion Island, Revillagigedo Islands. [According to Glassell (Trans. San Diego Soc. Nat. Hist., vol. 7, no. 38, p. 453, 1934), Boone's record (1927) of Xanthodius lobatus A. Milne Edwards, a female from Cocos Island, is based on a young specimen of Leptodius cooksoni].
Micropanope polita Rathbun [1902, p. 281 (as Xanthias politus)]. Gulf of California; mainland; Galápagos Islands.
Ozius tenuidactylus Lockington [Boone (1927, p. 225) as Ozius agassizii A. Milne Edwards, a species now believed to be a synonym of Ozius tenuidactylus Lockington (see Glassell, Trans. San Diego Soc. Nat. Hist., vol. 8, no. 14, p. 104, 1935, as Ozius tenuiductylos)]. Mainland; Galápagos Islands.
Ozius verreauxii de Saussure. Mainland; Galápagos Islands.
Trapezia cymodoce ferruginea Latreille. Mainland; Galápagos Islands; Indo-Pacific.

## Family Grapsidae

Grapsus grapsus Linnaeus. Mainland (east and west coasts); Galápagos Islands. [According to Dr. Garth (written communication), Boone's record (1927) of Pachygrapsus crassipes Randall from Cocos Island, was based upon a young specimen of Grapsus grapsus].
Pachygrapsus transversus Gibbes. Mainland (east and west coasts); Galápagos Islands.
Plagusia immaculata Lamarck. Mainland; Calápagos Islands; Indo-Pacific [Also recorded from Cocos Island by Garth (Allan Ilancock Pacific Expeditions, vol. 5, no. 10, p. 512, 1946)].
Planes cyanea Dana. 60 miles south of Cocos Island; mainland; Galápagos Islands; Indo-Pacific. [According to Chace (Proc. U. S. Nat. Mus., vol. 101, no. 3272, p. 70 et seq., 1950), records of Planes minutus Linnaeus (such as that of Boone, 1927) from the eastern Pacific are referable to $P$. cyanea].

## Family Gecarcinidae

Cardiosoma crassum Smith (Schmitt, 1939b, p. 27). A land crab. San José, Baja California, Mexico, to the mouth of the Tumbes River, Peru.

## Family Ocypodidae

Uca panamensis Stimpson. Mainland; Galápagos Islands. [According to Crane (Zoologica, New York Zool. Soc., vol. 26, pp. 205, and 178, 1941, respectively), Boone's record of Uca galapagensis Rathbun, based upon a female from Cocos Island, is now referable to $U$. panamensis, and her
record of $U$. galapagensis, a male, from the Galápagos Islands, is referable to $U$. macrodactyla Milne Edwards and Lucas].

## Family Calappidae

Calappa convexa de Saussure. Mainland; Galápagos Islands.

## Anomura

Miss Janet Haig furnished the following list (supplemented by three species by Boone, 1932) of Anomuran crabs from Cocos Island with their oceurrences elsewhere.

## Family Coenobitidae

Coenobita compressus II. Milne Edwards. Mainland; Galápagos; Indo. Pacific.

Family Paguridae

Pagurus californiensis Benedict (Boone, 1932, p. 9). Mainland; Galápagos Islands.
Calcinus explorator Boone (1932, p. 22; Chace, 1962, p. 624). Galápagos Islands.
Pylopagurus hirtimanus Faxon. Galápagos Islands.
Pylopagurus longimanus Faxon. Known only from Cocos Island.

## Family Porcellanidae

Petrolisthes cocoensis ILaig (1960, p. 117). Cocos Island, probably endemic. Petrolisthes edwardsii de Saussure. Mainland.
Petrolisthes marginatus Stimpson. Mainland.
Petrolisthes ortmanni Nobili. Mainland.
Petrolisthes tonsorius. Haig. Mainland.

## Family Hippidae

IIippa denticulatifrons Miers (Boone, 1932, p. 58). Galápagos Islands; Indo-Pacific.
'To these may be added the following Macruran forms:

## F'amily Palaemonidae

Brachycerpus biunguiculatus Lucas (Itolthuis, 1952, pp. 6, 7). Gulf of Califormia to Colombia; Last and West Americas; Galápagos Islands; Mediterranean: Indo-Pacific.
Macrobranchium americamum Bate (Holthuis, 1952, pp. 130, 131, 132. Also cited from Cocos Island as . II. jamaicense IIerbst by Beebe, 1926, p. 435,
and by Boone, 1930, pp. 20, 146). Baja California to Peru; Galápagos Islands.
Macrobranchium hancocki Holthuis (1952, pp. 112, 113. Also cited from Cocos Island as M. olfersii Wiegmann by Beebe, 1926, p. 435, and Boone, 1930, pp. 20, 143). Costa Rica to Colombia; Galápagos Islands.
Palaemon (Palaemon) ritteri Holmes, Holthuis (1952, pp. 175, 176, 177). San Diego, California, to Paita, Peru; Galápagos Islands.

## Family Palinuridae

Panulirus gracilis Streets (Holthuis and Villalobos, 1961, p. 254). Gulf of California to Paita, Peru; ?Galápagos Islands.
Panulirus penicillatus Olivier (Chace, 1962, p. 617). Galápagos Islands; Socorro Island, Revillagigedo Islands; Hawaiian Islands; Tuamotu Islands; Red Sea to South Africa.
From an inspection of the ranges of the species in the foregoing lists, it is obvious that the affinities of the species are with those of the mainland and the Galápagos Islands.

Fifty species of brachyuran, anomuran and macruran (shrimp-like) crustaceans are here listed from Cocos Island but additional species are known to occur there. Of the 50 species, two are endemic, 41 occur on the mainland, 33 (or 34 ) at the Galápagos Islands, seven in Indo-Pacific waters and three (or four) in Atlantic waters.

Authors who have published papers which include crabs and shrimps occurring at Cocos Island include: Boone (1927; 1930a; 1930b; 1932); Chace (1962) ; Faxon (1893; 1895, list pp. 257-258) ; Garth (1946; 1958) ; Haig (1960); Holthuis (1952); Holthuis and Villalobos (1961); Rathbun (1902; 1930) ; Schmitt (1939b).

## Class Myriopoda

Newportia rogersi Pocock. Mainland.
Otocryptops melanostoma Newport. Mainland.
Otostigmus scabricauda Humbert and Saussure. Mainland.
Epinannolene pittieri Brölemann. Cocos Island only.
Leptodesmus folium Brölemann. Cocos Island only.
Orthomorpha coarctata Saussure. Cocos Island only.
Rhinocricus (Eurhinocricus) biolleyi Brölemann. Mainland.
Seven species of Myriopoda have been reported from Cocos Island by Brölemann (1903; 1905). Of these, 3 chilopods and 1 diplopod also occur on the mainland, and 3 diplopods are reported only from Cocos Island.

## Class Insecta

A few members of this class from Cocos Island noticed in the literature are mentioned here.
Arrhinotermes oceanicus Wasmann (1902, p. 139). A termite.
Eutermes sp. (prope ripperti Rambur) (Wasmann, 1902, p. 139). A termite.
Kalotermes (Neotermes) larseni Light (1935, p. 239). A termite. Known
only from Cocos Island. Said to be related to Neotermes castaneus Burmeister which occurs in the American tropics.
Leucotermes insularis Wasmann (1902, pp. 139, 140). A termite.
Historis odius Fabricius. Cited as IIistrio probably odius by Williams, (1911, p. 296). II istrio orion Fabricius, now believed to be a synonym, also was reported from Cocos Island by Beebe (1926, p. 436). This butterfly ranges throughout the American tropics.
Herse cingulata Fabricius [Williams, 1911, p. 317 (as Phlegathontius cingulata) ]. This hawk-moth is wide spread in the American tropics and also occurs in the Galápagos Islands.
Leucomelina pica Maequart (Coquillett, 1901, p. 375). This little fly is abundant on Cocos Island at least at certain times in the vear. It was originally described from Brazil and the American tropics.
Cicada sp. (Ifeidemann, 1901, p. 370). One species of cicada has been reported from Cocos Island.
Odynerus (Pachodynerus) nasidens Latreille (Williams, 1926, p. 349). Williams reported this wasp from Cocos Island.
Popilius lenzi Kuwert (1897, p. 301; van Doesburg, 1953, p. 203). This beetle was described from Cocos Island. Its affinities are with species on the mainland.
Collenette (1926, p. 234) mentioned collecting a "longicorn beetle" and "lady-birds" on Cocos Island. He also mentioned (p. 231) seeing an insect there resmbling Agrautis vanillae Limnaeus (a widely distributed species) from the Galápagos Islands.

## Order Hymenoptera

Atta cophalotes Linnaeus* (Forel, 1908, p. 40; Emery, 1919, p. 40).
Aztect emmue Forel* (1908, p. 62; Emery, 1919, p. 40).
Brachymyrmex longicomis Forel*" (1909, p. 64; Emery, 1919, p. 40).
('amponotus (Mymothrix) abdominalis stercorerius Forel* (1908, p. 71; Emery, 1919, p. 40).
Camponotus (Mymobrachys) biolleyi Forel [Forel, 1902, p. 177 (as Camponotus biolloyi): Wheeler, 1919, pp. 301, 305; Emery, 1919, p. 40)].
(amponotus (Myrmobrachys) blandus F. Smith* [Forel, 1908, p. 72; Emery, 1919, p. 40 , as ('umponotus (Myrmocamelus) blandus $\rceil$.

Camponotus (Myrmaphaenus) cocosensis Wheeler (1919, pp. 301, 305; 1933, p. 61).

Cryptocerus cristatus Emery (1919, p. 40).
Cyphomyrmex rimosus slavini Forel* (Forel, 1908, p. 43; Emery, 1919, p. 40).

Eciton (Labidus) crassicornis F. Smith (Emery, 1919, p. 40).
Euponera (Trachymesopus) stigma Fabricius (Wheeler, 1919, pp. 301, 302; Emery, 1919, p. 40).
Odontomachus haematodes Linnaeus* (Forel, 1908, p. 35; Emery, 1919, p. 40).

Odontomachus haematodes insularis Guérin (Wheeler, 1919, pp. 301, 303).
Pheidole biconstricta bicolor Emery (1919, p. 40).
Pheidole punctatissima Mayr (Emery, 1919, p. 40).
Pheidole subarmata Mayr* (Forel, 1908, p. 52; Emery, 1919, p. 40).
Prenolepis (vividula) guatemalensis cocoënsis Forel [Forel, 1902, p. 178 (as Prenolepis guatemalensis var. cocoensis); Wheeler, 1919, pp. 301, 305 ; Emery, 1919, p. 40, as Prenolepis (Nylanderia) guatemalensis var. cocoënsis].
Pseudomyrma belti Emery, var. (1919, p. 40).
Solenopsis geminata Forel* (1908, p. 45; Emery, 1919, p. 40).
Solenopsis succinea Emery (1919, p. 40).
Tetramorium guineënse Fabricius (Wheeler, 1919, pp. 301, 303; Emery, 1919, p. 40).
Wasmannia auropunctata Roger (Wheeler, 1919, pp. 301, 30t; Emery, 1919, p. 40).
Wasmannia auropunctata var. rugosa Forel* (1908, p. 45; Emery, 1919, p. 40).

The foregoing includes the combined lists of species and subspecies of ants reported from Cocos Island by Forel (1902; 1908), by Wheeler (1919; 1933) and by Emery (1919).

Forel (1908) suggested that 10 species (those in the list indicated by the symbol*) of the ant fauna of Cocos Island evidently arrived there with cultivated plants. Emery (1919) discussed the ant fauna and remarked on the preponderance of Central American forms. Apparently he favored the theory that some of these insects reached the island by way of a land bridge connected with the mainland during late Tertiary time.

Wheeler (1919, p. 301) remarked on seven species (which he listed) as follows: "With the exception of the tropicopolitan 'tramp', Tetramorium guineënse, of Old World origin, none of the forms is known to occur in the Galápagos Islands and all are neotropical or have strongly neotropical affinities." Further (p.302), "It is evident that the Cocos ants are decidedly. tropical whereas those of the Galápagos are mainly such as belong to sulb-
tropical or temperate regions or at any rate to the cooler or subalpine regions in the New World tropics."

## Class Arachnida

Argyroepeira nigriventris Keyserling. Reported from Cocos Island by Banks (1902, p. 61) and by Heller (1902, p. 78). It has also been reported from the Galápagos Islands, Central America, Colombia, Brazil, and the West Indies.

## Phylum CHORDATA

Class Reptilia
Anolis townsendi Stejneger
Sphaerodactylus pacificus Stejneger
Only two species of lizards have been described from Cocos Island, both by Stejneger ( 1900 , p. $163 ; 1903$, p. 3). Sphaerodactylus pacificus has been compared by herpetologists with $S$. lineolatus Lichtenstein which ranges from Central America to Colombia (Stejneger, 1903, p. 4; Barbour, 1921, p. 236, pl. 1, fig. 3, pl. 13, figs. 1-4).

For additional information on this group see Heller (1903); Taylor (1956).

## Class Pisces

Fowler (1938, pp. 248-261) published lists of the fishes known to occur at Cocos Island. He recorded 72 species from or in the general vicinity of this island. Briggs (1961, pp. 552-554) reported 16 of 53 ( 30 per cent) species of transpacific shore fishes at Cocos Island. This would be 22.2 per cent of the 72 species reported from the island by Fowler. More recently Briggs (written communication April 3, 1962) mentioned a total of 59 shore fishes "of which sixteen are trans-pacific, thirty-eight are American, and five are endemic."

A freshwater guppy, Cotylopus cocoensis ITeller and Snodgrass (1903, p. 211, pl. 11), described from streams at Chatham Bay, Cocos Island, was said to be allied to Nicydium salvini Grant from Panama.

Other workers who have contributed information concerning fishes from Cocos Island include: Beehe (1926, pp. 228, 435); Beebe and Tee-Van [1941a; 1941b (sharks, rays, mantas, chimacras)]; Fowler (1932); Halstead and Bunker (1953) ; Halstead and Schall (1956) ; Heller and Snodgrass (1903) ; Heere (1936) ; Klansewitz (1958) ; Myers (1941); Myers and Wade (19+1); Nichols and Breeder (1928) ; Schmitt and Schultz (1940); Seale (1940): Snodgrass and Heller (1905).

Class Aves<br>(Land Birds)

Butorides virescens maculatus Boddaert. (Green heron). [Gifford, 1913, p. 65 (as Butorides virescens); Sludd, 1962, written communication (as Butorides virescens maculatus)]. Mainland and Galápagos Islands.
Dendroica petechia aureola Gould. (Yellow warbler). Reported from Cocos Island as Dendroica aureola Gould by Townsend (1895, p. 122) and as Dendroeca petechia by Gifford (1919, p. 216) ; Beebe, 1926, p. 435 (as Dendroica petechia aureola) ; Sludd, [1962, written communication (as Dendroica petechia aureola)]. Mainland.
Hirundo rustica erythrogaster Boddaert. (Barn swallow). (Gifford, 1919, p. 205). Mainland.

Nesococcyx ferrugineus Gould. (Cocos Island Cuckoo). [Gould, 1843, p. 105 (as Coccyzus ferrugineus); Gifford, 1919, p. 195 (as Coccyzus ferrugineus) ; Beebe, 1926, p. 435 (as Coccyzus ferrugineus) ; Sludd, 1962 [written communication (as Nesococcyx ferrugineus)]. Known only from Cocos Island.
Nesotriccus ridgwayi Townsend. (Ridgway's flycatcher). (Townsend, 1895, p. 124; Gifford, 1919, p. 200 ; Beebe, 1926, p. 435). Known only from Cocos Island.
Pandion haliaëtus Linnaeus. (Osprey). (Gifford, 1919, p. 193). Mainland. Pinaroloxias inornata Gould. (Cocos Island finch). [Gould, 1843, p. 104 (as Cactornis inornata) ; Townsend, 1895, p. 123 (as Cocornis agassizi); Richmond, 1902, pp. 247-248 (discussion of the type locality and synonymy of Pinaroloxias inornata); Gifford, 1919, p. 242 (as Pinaroloxias inornata); Beebe, 1926, p. 435 (as Cocornis agassizi); Swarth, 1931, pp. 268-271; Lack, 1945 , pp. 19, 126, 129, and 1953, pp. 67, 72; Bowman (1961, pp. 20, 92, 94, 100, 104, 109, 113, 115, 129, 159, 161, 168, 177, 204, $207-216,218,220,225,231,234,289$, pls. 7, 12, 16, 20)]. Known only from Cocos Island.
This list of 7 species and subspecies of land birds from Cocos Island with their occurrence elsewhere, was compiled from the literature supplemented by information received from Dr. Paul Sludd. Of the 7, 3 are known only from this island. Wallace in 1876 (p. 60), remarked on the interesting occurrence of "Coccyzus" [Nesococcyx] on this island.

Gifford (1919) discussed the land birds of Cocos Island and additional remarks concerning members of this group may be found in papers by Beck (1907) ; Murphy (1936) ; Rothchild (1902) ; Townsend (1895) ; see also Carriker (1910) and Eisenmann (1955).

Sea birds from Cocos Island have been discussed by Snodgrass and Heller (1902; 1903) ; by Gifford (1913), whose account includes references to other authors; and by Murphy (1936, p. 319).

## BOTANY

The flora of Cocos Island has attracted the attention of several botanists. A comprehensive report by Stewart (1912) recorded 77 species of vascular plants, 20 of which are ferns. Only 8 of them ( 8.69 per cent), are endemic. Twenty-seven of these species, 11 of them ferns, also occur in the Galápagos Islands where the endemicity is reported to be 40.9 per cent

Stewart concluded from his studies that the flora of Cocos Island was that of an oceanic island, younger than that of the Galápagos Islands, and that there was no evidence to support the theory that the island was ever comnected by land with either the mainland or the Galápagos Islands. He believed that the flora reached the island chiefly from the mainland fortuitously through the agencies of winds, ocean currents, and migratory birds.

Svenson (1935, p. 259), referring to Johnston (1931, p. 35), stated that the vegetation of Cocos Island consists of about 100 species, of which about 10 are endemic, "overwhelmingly of ferns, melanostomes, and orchids." He mentioned that there is no change in the flora to a height of at least 457 meters ( 1500 feet). He also stated that except for ferns, virtually none of the species also occur on the Galapagos Islands.

Cook (1939) described a mountain palm, Rooseveltia frankliniana, from Cocos Island. It was said to be rather closely related to Plectis oweniana Cook from Guatemala. Cook believed that the coconut palms observed on Cocos Island as early as 1699 by Wafer, were introduced there.

Various components of the Cocos Island flora have been discussed by authors in several papers including: Bartram (1933. Mosses; see also list by Stewart, 1912, p. 395) ; Clark (1953, Hepaticae) ; Cook (1910; 1939; 1940, Palms) ; Cooke and Bonar (1961, Fungi) ; Howe (1934, Hepaticae) ; Pittier (1899) ; Rose (1892) ; Stewart (1911, pp. 230, 233-235. He remarked on the origin of the Galápagos flora and gave occasional reference to Cocos Island) ; Svenson (1935, includes various authors in his bibliography).

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# THE GOOSE LAKE FRAGMENTS 

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## Introduction

The Goose Lake meteorite was discovered in Modoc County, California, by three hunters in the fall of 1938, removed from the site in May, 1939, and brought to San Francisco, where it was exhibited at the Golden Gate International Exposition. After the close of the fair it was shipped to the Smithsonian Institution where it is now on display in the United States National Museum.

The original site of the fall was re-examined in 1960, when a large meteoritic fragment field was discovered in and around the impact point. These fragments have raised several new questions to add to those already associated with this remarkable meteorite. This paper is the first report on the distribution, morphology, and metallurgy of these particles, and some speculations on their relationships to the cavities and low terminal velocity of the main mass.
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## Background Studies

The Goose Lake meteorite is unique among most of the existing meteorites, principally because of its peculiar cavities, the origin and significance of which have been controversial for a number of years. Several of these are clearly shown in figure 1.

A typical cavity in this iron is 11 centimeters deep, 5 centimeters in diameter at the aperture, with a slightly larger diameter at the bottom of the hole. Width to depth ratios range from 0.25 to 1.10 . In one case, a hole forms a tumnel completely through the mass. Around the edges of the cavities, there is an overhanging lip of deformed metal with serrated radial grooves extending back a short distance. These overturned edges are not apparently related to the origin of the cavities but may be due to some thermal action during flight through the atmosphere.

Three possibilities have been considered by Itenderson and Perry (1958a) to account for such cavity formation during flight:


Figure 1. The Goose Lake meteorite, showing its cavities and two typical over-turned-rim formations. This photograph was made soon after arrival at Mills College, Oakland, California, and before exhibition at Treasure Island.

1. Burned out minerals. Troilite and carbon inclusions occur in rounded masses in iron meteorites, often an inch or more in diameter, but none have been found approaching the dimensions of the cavities. The melting temperatures of troilite and schreibersite are close to $1000^{\circ} \mathrm{C}$. but the microstructure of slices cut through a cavity does not indicate that temperatures this high were ever reached.
2. The energy trap. If a small crevice or hole pre-existed, particles striking this depression would erode the sides, thus deepening the hole since they would not be deflected from the surface. If such a condition existed on the leading edge or forward face of the meteorite when the stagnation temperatures and adiabatic pressures were the highest, the rim of the holes would certainly heat just as rapidly and erode away leaving a shallow depression, instead of a deep hole.
3. Wave action within a cavity. It might be assumed that during the ablation period, spallation of the surfaces would free small particles which would be caught in a pre-existing hole and enlarge them by repeated impacts around the interior. This is analogous to the holes formed in solid rock on river bottoms, where stones are rolled around by the water currents forming deep circular holes. It is hard to visualize how such a mechanism could remove the volume of metal required in the short time available during its fall.

There is ample evidence that the cavities are not due to weathering, principally because the cavities are uniformly distributed over the surface which would not be the case had the iron rested on the ground long enough for oxidation on the under side to erode away large masses. Furthermore, the Modoc Plateau is semi-arid, with an annual rainfall of about 12 inches, approximately half of which falls as snow.

Henderson and Perry (1958a) concluded that the cavities existed before the iron entered the atmosphere and further that "this meteorite is not much smaller now than when it formed in some primordial body; that no large piece broke off during flight and that this is probably not a portion of the metallic core of the planetlike body where it was formed."

All the evidence available indicates that the iron landed gently. When found, about half the mass protruded above the surface of the ground, just as though it had been dumped from a truck. Measurements of the crater depth made in 1961 showed that the distance from the surface to bedrock was about 9 inches. There are no discernible impact scars on the iron, even though it fell on hard basaltic rock. The sand and detritus are so thin in this area that one can easily scrape away the surface material by hand, exposing the bedrock underneath.

Linsley (1939), who was present at the time it was recovered, reported: "There was no evidence of shattered rocks indicating a recent fall and
there were no skid marks to show that the meteorite had swept along the surface and come to rest where it was found. There was only a slight depression in which it rested, which appeared to be due in part to wind erosion as the air currents had eddied about it. A marmot seeking a bombproof shelter had made a home under it."

Something acted like a cushion at the end of its flight, and here it is tempting to suggest that it fell in winter into a deep snow bank. The total depth of accumulated snow for Modoc County is estimated to be 50 inches, but it should be noted that the deep snows do not occur in flat denuded windblown areas. Snow banks deep enough to cushion such a mass can accumulate only in the lee of canyons or in heavily wooded regions.

The cavities may be related to its slow descent as suggested by Cornish in Henderson and Perry (1958a), "The large cavity which made an opening through this iron probably would give the body considerable spin during its fall. This spin would generate enough lift to reduce the velocity of the fall." If an effect of this kind is possible, there is still the question of explaining the absence of intense ablation heating, for there are no evidences of either a fusion crust on the surface, or granulation of the Neumann lines which extend almost unbroken to the very edge.

## Meteoritic Fragiaents

At the time the Goose Lake meteorite was discovered, the concept that molten droplets of iron from a glowing meteor would settle to the earth and could be recovered from the soil was not widely recognized, although Spencer (1933) had reported evidence of metallic rain of meteoric origin in the Henbury Craters in Australia. At that time ablation heating and the re-entry problems associated with missiles and satellites was not yet a serious scientific problem.

Professor Leonard (1940), who was present at the time the Goose Lake metcorite was removed, reported, "Although further and more conclusive evidence of the impact as well as other meteorites, were diligently searched for in the neighborhood, none was found." Ninninger (1956), another member of the recovery party apparently did not use the magnetic cane which he says had "been an essential part of our field equipment since 1933."

Since 1939, a great deal of work has been done on recovering meteoritic particles from the soil, both in Arizona around the Canyon Diablo Crater and at the site of the great Sikhote-Alin fall in 1947 in eastern Siberia. Krinov (1960) and his colleagues recovered large numbers of meteoritic particles of this fall which were seattered over an area of several square miles. Small globular droplets of nickel-iron ranging in size from 8 microns to 0.10 millimeters in diameter were found seattered over a very wide area.

These are true ablation products, blown off the melting surface of large masses during flight, and which subsequently condensed in little spheres. Their original microstructure and composition are not identical with the main masses because their temperatures were at least $1500^{\circ} \mathrm{C}$. in an oxidizing atmosphere. Krinov calls these ablation products "meteoric dust." Besides the little droplets, they also found a great many fragmentation particles, ranging in size from tiny flakes to pieces weighing several pounds. Polished sections of these pieces showed that they retain both the microstructure and composition of the main body. These fragments are not ablation products, but are produced by mechanical forces set up by shock waves in the main mass during its flight. He calls these fragments "meteoritic dust," and from his descriptions they are apparently identical to the particles which Ninninger found around the Canyon Diablo Crater in Arizona and which he calls "sluglets." The Canyon Diablo is estimated to have fallen some 50,000 years ago, a sufficiently long time so that one would intuitively assume that tiny fragments of the nickel-iron would either be completely rusted away, or would be so dispersed by weathering that recovery would be very unlikely. Yet, in Ninninger's words, ". . . the idea that all small particles resulting from disintegration of large meteorites would undergo immediate oxidation was seriously in error."

An important difference between the Goose Lake and other fragment producing falls is that there is no evidence that its impact velocity was high. The Sikhote-Alin was seen to break up during flight and its fragments were found scattered over several square miles. The impact velocity of the Canyon Diablo was sufficient to produce complete fragmentation accompanied by an explosion which excavated a hole in the ground 570 feet deep and 4000 feet across. While the main mass of the Coose Lake weighs a little more than a ton, there is no evidence of any fragmentation of the main body or crater formation at the place where it was found. It has been suggested that it landed some distance away and bounced, coming to rest where it was found. In this paper, the place where it was found will be called the "impact site" as the simplest description of its terminal location.

## First Goose Lake Expedition, 1960

In the light of the work done on recovering meteoritic particles during the last two decades, it seemed odd that no particles had been reported from the site of the Goose Lake fall. Inquiry showed, however, that no magnetie survey had been made, and as far as known, no one visited the site between 1939 and 1960 , except stockmen and hunters who would not have been interested by a pole marker in the midst of a barren rock strewn area.

In 1960, the California Academy of Sciences approved a preliminary
survey of the site, and in June of that year, the author and his son carried out the first magnetic survey of the Goose Lake impact site.

Aside from the coordinates of the site given by Leonard (1956), the only clue to its location on current Forest Service maps is an excavated reservoir designated by a sign reading "Meteorite Stock Tank," which is


Figure 2. Photograph of the Goose Lake meteorite in situ at the time of discovery, October 13, 1938.
almost half a mile south of the actual site. When the meteorite was removed from the small crater in which it rested, the recovery party marked the spot with a pole picturesquely described by Leonard, ". . . as a rude monument or marker, hewn from the trunk of a nearby sapling."

With the able assistance of the U. S. Forest Service in Alturas, we found this same pole intact and still erect, together with other small poles lying about on the ground which were apparently used in hoisting the heavy mass onto the wagon. From pictures made at the time of discovery and before the iron had been moved, we were able to identify the same trees on the horizon, even though they were somewhat taller than 21 years ago. One very tall tree showing on the original print is now missing, but we found it lying on the ground, its stump corresponding to its original location.

Figure 2 shows a print of the Goose Lake meteorite before it was moved at the time of discovery, October 13, 1938, and figure 3 is a picture taken from about the same position in June, 1960, showing the pole marking the impact site, and the same trees in the background.

Within a matter of minutes from the time we started searching the area with a hand-held magnet, it was clear that meteoritic particles lay


Figure 3. Photograph of the impact site of the Goose Lake meteorite, made in June, 1960 .
about in great profusion. These were bottled, labeled, and returned to the Academy for further study.

## Second Goose Lake Expedition, 1961

The success of the first survey in recovering meteoritic fragments prompted plans for a second survey of the field with more people. The second Academy-sponsored expedition in September, 1961, included representatives of the U. S. Geological Survey, the California State Division of Mines, and the California Academy of Sciences. A much more thorough search of the area was conducted, including partial excavation at the impact point to determine the extent of bed-rock deformation. Many more specimens were recovered, including large oxide fragments lying quite exposed at some distance from the site.

## Magnetic Recovery Methods

During the course of the first survey, no excavations were made, partly because we wanted the evidence perfectly clear that particles of nickel-iron and oxide were lying within a few millimeters of the surface of the ground. A handful of soil was scraped from the ground and poured over the end of a large conical magnet and during this operation magnetic particles in the soil were drawn to and held by the magnet. Some of the material is magnetite, but this was readily separated from the nickel-iron by shaking the magnet, the weaker magnetite falling off while the nickel-iron fragments adhered as tightly as an iron nail. (The small magnetite particles must be quite impure, because of their weak magnetism.) This method has the disadvantage that meteoritic oxide particles may not be recovered, because they are less magnetic and may be lost.

Similar methods were used during the second expedition, but this time the small magnet was replaced by a much larger double-pole magnet which was provided with a long handle so it could be carried and lowered over a given place. On this occasion, also, magnetic samplings of the soil were bagged, marked, and returned to the Academy for analysis.

When the distribution of the large black massive-oxide fragments was found to extend well beyond the limits of a few feet from the impact point, areas of about 10 feet square were paced off at likely distances and azimuths. Then a visual search was made by going over this area on hands and knees, looking for the distinctive sheen of the oxide fragments. After this visual search, a second scanning was made with a hand-held magnet. The material from each plot was then bagged and labeled.

A more thorough search was conducted later on these samplings by mounting the same magnet with the pole pieces facing down on a drill press
stand, spreading a small amount of the field material on a shallow aluminum pan, and moving the pan around underneath the magnet. It was possible to readily adjust the height of the magnet pole so that the magnetite particles would not be drawn up as were the meteoritic particles. A thin aluminum plate held to the magnet by a spring, was placed so as to extend over both pole pieces, and each time a nickel-iron particle was separated, a distinct ping could be heard as it struck the plate. When all the particles had been removed, the magnet was inverted bringing the aluminum plate on the top with all the particles clustered around the two poles. Then, detaching the spring, the plate could then be lifted vertically and the particles scooped into bottles. This method keeps the pole pieces clean, and allows all the particles from one sample to be collected with no contamination from previous sampling.

A photograph of the separator is shown in figure 4. This is a somewhat simplified version of the automatic magnetic sampler used by Rhinehart (1958) in his magnetic survey for meteoritic particles from the Canyon Diablo area.


Figure 4. Photograph of the magnetic separator used to sort out the nickel-iron fragments from the soil.

Figure 5. Typical massive oxide fragments found lying on the surface of the ground, and concentrated in a small area approximately 250 feet south of the impact site. The largest piece measures about 3 centimeters in length.

After separating the particles, they were cleaned with a fine brass wire brush, the heavy crusts and adhering soils removed with a dental scaler. This latter operation must be done under a low power microscope.

After cleaning in this manner, some of the particles were mounted in 1-inch diameter lucite blocks, ground down with course emery paper until an appropriate area for study had appeared and finished with 600 -grit paper. They were then carefully washed with water to remove any remaining grits, and polished on a wheel with a felt lap saturated with AB alumina polishing compound. The polishing was carried on until a good specular finish was obtained with few scratch marks or comet tails. Since the lucite is so much softer than the iron, it polishes away faster making the surfaces slightly convex, especially at the edges where the nap of the polishing cloth cuts away the interface between the iron and lucite. For this reason, the Neumam lines which extend to the edges are not quite in the same vertical plane as those in the center. All ctching was done with Nital. Alternate polishing and etching was followed until the lines were clear.

## Morphologiy of the (ioose Lake F'ragments

1. The nickel-iron particles. The shape and appearance of eight fragments of the nickel-iron found during the first expedition in 1960 are shown in figures 6 and 7. Their dimensions are indicated by seales and their in-


Figure 6. Typical nickel-iron fragments before cleaning. These were found within a radius of 10 feet from the impact site. The scale shown along the lower margin indicates millimeters. The weights of the fragments given in grams are $0.148,0.162,0.183$, and 0.122 respectively.

Figure: 7. Typical nickel-iron fragments which have been cleaned with a soft wire brush. The scale shown along the lower margin indicates millimeters. The weights of the fragments given in grams are $0.383,0.250,0.525$, and 0.217 respectively.
dividual weights are given in each caption. Those in figure 6 are just as they were removed from the magnetic separator, those in figure 7 have been cleaned with a soft wire brush.

The color of the nickel-iron particles before cleaning is a light brown or mahogany shade, identical with the soil. It is very difficult to distinguish these by visual inspection from similarly shaped particles of rock. They do not exhibit the characteristic brick red of freshly oxidized iron. When cleaned, however, they look very much like many of the large iron meteorites which exhibit the typical dull dark-grey sheen.

One feature common to almost all the nickel-iron particles is that they are flattened. A rough estimate gives the average thickness to length ratio of about $1 / 10$. These dimensions were measured by placing each particle between the jaws of a micrometer, so that the thickness figure includes any protuberance or nodule. Some of the fragments excavated at the crater during the second expedition measured 0.1 centimeter thick and 1.0 centimeter long. The nickel-iron fragments from below the surface show a greater size range than those found on the surface. There is a marked similarity between the shape of these flattened particles and the Algoma, which Farrington (1915) calls a peltoid or shield shape, even though the dimensions differ by a factor of at least 50 .

These pictures of the Goose Lake fragments should be compared to Ninninger's sluglets from Canyon Diablo. The hook shape is common to both and the tiny hole in the lower right hand specimen in figure 7 is very much like the holes in some of the sluglets. The protuberances have the same general appearance. The dimensions of the sluglets are about the same as those just described from Goose Lake.

One of the smallest individual nickel-iron specimens of the Sikhote-Alin shown by Krinov has the same weight as that of the lower right specimen in figure 6, and shows much the same surface topography. The Goose Lake fragments, even after cleaning, do not appear to be as shiny and smooth as those of the Sikhote-Alin.
2. The massive oxide fragments. The shape and appearance of the Goose Lake metcoritic oxide fragments is entirely different from the nickeliron fragments. A few of these oxide fragments are shown in figure 5, photographed soon after they were found. These are most easily recovered by simply scanning the ground visually for their distinctly black sheen. There are no other rocks in the vicinity which have quite the same color. They are all magnetic, intermediate between magnetite and the nickel-iron, and hence can be immediately checked in the field for meteoritic origin. The fine powdery soil which was so adherent to the nickel-iron had apparently been blown or washed from these fragments, leaving the surfaces
quite clean. No large pieces of the oxide were recovered from the pit excavated at the impact site. However, there were many tiny oxide fragments mixed with the nickel-iron fragments, not only on the surface but below as well. Those found mixed with the soil did not have the characteristic black sheen of the surface specimens, since they were covered with the lightbrown soil. However, they can often be recognized from their shape.

All the oxide fragments recovered show sharp fracture planes, including the very smallest. The larger specimens taper toward the edges, giving an elliptical cross-section. The sloping edges are not smooth, however, but reveal steps formed by the lamellae planes.

The shapes of the ends of these oxide fragments suggest a block puzzle. Of all these pieces of the oxide, only two were found which fitted togethe:just as though they had recently been broken. As shown in figure 8, it is obvious that they were originally one piece. These large pieces are quite homogeneous, are very hard and cannot be broken by hand. By contrast, the thin oxide flakes can be pinched in two with the fingers.


Figure 8. Two pieces of massive oxide which fit together perfectly. It is not known how close together these lay. The larger weighs 8.19 grams, the smaller 3.70 grams. The scale indicates a length of 1 centimeter.

Figure 9. Circular raised rim of hydrous iron oxide on one of the massive oxide fragments. Weight 2.08 grams. The number (9) shown directly above the scale is the figure number and is not related to the scale. The scale indicates a length of 1 centimeter.

In the interstices of the lamellae, tiny deposits of salts and soil can be seen under the microscope. The salts appear white when dry, green when wet, can be removed easily with a pointed scaler.

One specimen of the oxide shows a small circular raised rim of brown hydrous iron oxide, shown in figure 9. It has been suggested that this
might also be the remains of an impact crater when the original metal was in a near molten state. This example should be compared with a similar structure found on one of the Canyon Diablo oxide fragments as given by Buddhue (1957).

The oxide fragments collected from the surface of the ground only, appear to increase in size from the crater or impact point out to about 250

Table 1
Weights of the massive oxide fragments found on the surface of the ground by the second expedition to the Goose Lake site.

| Specimen No. | Azimuth from Crater <br> (degrees) | Distance from Crater (feet) | Weight (grams) |
| :---: | :---: | :---: | :---: |
| 1 | 170 | 125 | 5.44 |
| 2 | " | " | 2.75 |
| 3 | " | " | 3.61 |
| 4 | " | " | 1.00 |
| 5 | " | " | 1.00 |
| 1 | 180 | 150 | 2.61 |
| 2 | " | " | 1.17 |
| 3 | " | " | 1.11 |
| 4 | " | " | 0.75 |
| 5 | " | " | 0.62 |
| 6 | " | " | 0.48 |
| 7 | " | " | 0.36 |
| 8 | " | " | 0.25 |
| 9 | " | " | 0.24 |
| 10 | " | " | 0.19 |
| 1 | 170 | 200 | 10.85 |
| 2 | " | " | 2.18 |
| 3 | " | " | 2.08 |
| 4 | " | " | 1.28 |
| 5 | " | " | 0.91 |
| 6 | " | " | 0.26 |
| 7 | " | " | 0.21 |
| 8 | " | " | 0.18 |
| 9 | " | " | 0.15 |
| 10 | " | " | 0.11 |
| 1 | 174 | 250 | 13.31 |
| 2 | " | " | 12.34 |
| 3 | ، | " | 11.45 |
| 4 | " | " | 8.20 |
| 5 | " | " | 6.91 |
| 6 | " | " | 4.32 |
| 7 | " | " | 4.16 |
| 8 | " | " | 3.70 |
| 9 | " | " | 2.69 |
| 10 | " | " | 3.24 |

feet to the south and then terminate. There are also many small ones mixed with these large pieces. The east and west distribution is roughly 20 feet on either side. It should be emphasized that the terrain slopes gently to the south, so that the natural drainage is in the same direction as the principal distribution of the surface oxide fragments. The prevailing wind however, is at right angles to this, i.e., from the west.

The individual weights of the large oxide fragments collected from the four principal concentration areas to the south of the crater are given in table 1. These were found only on the surface, during the second expedition and may or may not represent the true aerial distribution. This list includes only the ten largest specimens from each area, but does not include any of the nickel-iron particles.

An effort was made to estimate the total number of nickel-iron individuals and their weight distribution, but this was not satisfactory. It is a simple matter to weigh and count the larger specimens, but as they get smaller and smaller, their individual weights are more and more affected by the thin oxide layer covering all the nickel-iron fragments. Besides this, the amoint of adhering soil and salts on each particle contributes more and more to their weights.

A few of the larger nickel-iron fragments weighed about 0.200 grams, but most weighed much less than this. When the weights approached 20 milligrams, the uncertainties mentioned above introduced very large errors. We have not estimated how many of the smallest sizes were recovered, but the number is certainly in the thousands.

During the course of both expeditions, it was anticipated that ablation products in the form of spherical particles would be found. There are some tiny, nearly spherical particles, but under the microscope they are seen to have a crystalline form suggesting magnetite. The fact that we found no true ablation products adds further evidence to confirm Itenderson's theory that this iron fell through the atmosphere at a low velocity.

## Metallurgy of the Fragments

A number of the nickel-iron particles were examined under the microscope to determine their internal structure and composition. These are shown in figures 10 through 15 , with some description of each. In all cases examined, Neumann lines appeared. Since these lines appear only in kamacite, it can be stated that all the nickel-iron particles recovered and examined are kamacite. A few thin threads of taenite were found traversing the fragment. The Goose Lake iron is a coarse octahedrite, and if all the nickel-iron fragments are kamacite, then there is no question that they are


Figure 10. Undistorted Neumann lines near the center of a nickel-iron fragment. The number (10) shown directly above the scale is the figure number and is not related to the scale. The scale indicates a length of 10 microns.
not fragments of the parent body, i.e., the particles were not removed either during flight, or mechanically by shock when it landed. However, no nickel-iron particles have been found and examined which are greater than the widest kamacite bands in the main mass, so if some mechanism could selectively remore fragments like those we discovered, this would support the possibility that the main mass is the parent body.

It is generally agreed that Neumann lines disappear at temperatures above approximately $400^{\circ} \mathrm{C}$, and since every nickel-iron fragment shows these lines clearly, it seems evident that they were never heated above this temperature and hence cannot very well be ablation products. If they were not formed this way, then they must have been broken from a larger body mechanically. Since there is no evidence that the main mass suffered a severe shock on impact, we must conclude that the particles existed before entry and were carried down through the atmosphere in the cavities or in the wake of main mass.

In all specimens the nickel-iron particles show evidence of mechanical strain or mechanical shock in the displacement and bending of the Neumann lines. Many show the lines extending undistorted to the edge of one side,
while at the other side of the specimen the lines are bent and twisted and in some cases completely granulated. The appearance of cross sections of these particles suggests that they were projectiles at one time and that they struck something hard. Their impact velocity was not sufficient to raise their temperatures above $400^{\circ} \mathrm{C}$, but was high enough to cause deformation at the leading edge.

One case in particuiar shown in figure 16 is that of an elongated fragment which apparently suffered a head-on collision, bending completely back on itself, in exactly the same way as a nail driven through a thin board backed with an iron plate. One Neumann line could be followed all the way around the end until it was nearly parallel to itself going in the opposite direction. As in some of the other examples, the small end of this specimen was apparently the leading edge, since all lines were obliterated at the tip. At the other end, the lines appear in their normal undisturbed form. This little spike was apparently traveling like an arrow when it collided with a solid surface just hard enough to double it back.

The hypothesis that an extraterrestial shock effect can be observed in meteoritic iron is not new. From analyses of the deformation structure in


Figure 11. The same specimen as shown in figure 10 , taken near one edge, showing deformation of the lines. The scale shown in the upper part of the figure indicates a length of 1 millimeter.
kamacite, Maringer and Manning (1962) tentatively conclude that a relatively slow impact velocity between a large and a small body in space could produce this kind of deformation. The gross forms as well as the internal evidence of the Goose Lake fragments apparently confirm this suggestion.

One slice of the Goose Lake meteorite was available for making comparisons between its internal structure and that of the fragments. There are some likenesses, but the long clean curving Neumann lines at the edge of this slice have not been found among the nickel-iron fragments. In this slice, there are many well formed rhabdite inclusions mixed with the kamacite, but none have been found in the Goose Lake particles. Likewise, no troilite inclusions have been found, although they are found in the main mass. This may not be unusual, however, because the troilite inclusions are roughly the same size as the fragments, and since this mineral is non-magnetic, it may not have been recovered from the soil by our techniques.

A few of the larger massive oxide fragments were ground and polished, one of which is shown in figure 17. Etching was unnecessary to reveal either the laminar structure, or the rhabdite inclusions. This characteristic laminar form is almost identical to that of the massive oxide from Canyon Diablo as can be seen in a similar specimen shown by Buddhue. Likewise, the rhabdite crystals in the oxides appear identical to those found in the Canyon Diablo as shown in figure 18.

## The Origin of the Goose Lake Fragments

The principal conclusion of these preliminary studies of the Goose Lake fragments centers around the question of whether the particles we discovered were once a part of the main body.

Since well developed Neumann lines have been found in all nickel-iron particles so far examined, it is clear that they are not ablation products. If they had been torn away mechanically from the surface of the main body, either by violent vibrations during flight or by the shock of impact with the ground, evidence of surface spallation should show on the surface of the iron. None has been found.

Since taenite melts at a lower temperature than kamacite, Henderson (1956a) has suggested that at the leading edge of the main mass where the layers show some thermal deformation, ablation heating could loosen or at least weaken the bonds between the taenite and kamacite plates. Then the shearing action of the atmosphere during deceleration might tear off some of the kamacite plates. If this occurred, it seems reasonable that some of these particles of kamacite would be caught in the turbulent wake, or in the cavities and be carried to the ground. There remains the question of how this process could produce so many particles, and whether the heating time required to weaken the bonds would also obliterate the Neumann lines


Figure 12. Leading edge of a nickel-iron fragment showing three undistorted Neumann lines completely granulated toward the edge. The number (12) shown directly above the scale is the figure number and is not related to the scale. The scale indicates a length of 100 microns.

Figure 13. The same specimen as shown in figure 12, taken from the opposite side of the fragment. Note that the lines extend completely undisturbed to the edge. These same lines connect with the three of figure 12. The number (13) shown directly above the scale is the figure number and is not related to the scale. The scale indicates a length of 100 microns.
in the kamacite plates. The outer surface of the main mass does not show that such a phenomenon took place, but it is conceivable that subsequent heating and pressure smoothed the leading edge where the fractures took place. While this concept has some attractive features, it does not appear to explain the occurrence of the fragments as simply as the following account.

Another alternative which seems more attractive, is that the fragments pre-existed and accompanied the main mass when it was captured by the gravitational field of the earth. If this third concept is tenable, then some hypothesis is required to account for the high concentration of particles so close to the point where the meteorite was found.

While we have no direct information on this point, it is tempting to suggest that they were transported through the atmosphere in the cavities. After reaching the ground, weathering on the top and gravity on the bottom removed the nickel-iron particles from the holes, scattering them in the immediate vicinity of the impact point. The highest concentration was actually in the bottom of the pit, directly under the place where it fell. So far as we know, no one at the time of discovery thought to make a thorough examination of those cavities facing upward to see if any of the fragments were lying in the bottom.

It is quite certain that we have not recovered all the material at the site, but the total volume of all we have found, including the large oxide fragments could easily fit into the cavities, with room to spare. Cavity transportation of the fragments would account for their concentration around the impact point.

If we assume that the main mass of the Goose Lake meteorite had passed through swarms of tiny particles such as we have discovered, it seems reasonable to suppose that during the thousands of years it was orbiting through the solar system, there would have been hundreds of collisions, say


Figure 14. Lateral displacement in Neumann lines. The number (14) shown directly above the scale is the figure number and is not related to the scale. The scale indicates a length of 1 millimeter.
one a year. Further, if the orbits of the particles and of the main mass are nearly identical so that the collisions made soft impacts, then there would be no spallation of the surface of the main mass nor fusion of the particles owing to heating by their sudden loss of kinetic energy. We will assume that the impact velocity is just sufficient to partly deform the particles which we have described. This would explain the deformation of the Neumann lines on the leading edge of the particle, leaving those on the trailing edge intact.


Figure 15. Large bend in a nickel-iron fragment, showing an inclusion of taenite bent in a jagged Z-shape. The number (15) shown directly above the scale is the figure number and is not related to the scale. The scale indicates a length of 1 millimeter.

Now, if the magnetic and gravitational forces between the main mass and these particles is sufficient, those which have collided in this manner will adhere to the main mass and be carried along with it, until it begins to encounter atmospheric drag as it approaches the earth. At this time, those particles which are on the outside will be swept away by the violent turbulence of the air stream and will fall to the earth over very widely scattered areas. Those others, however, which enter the apertures and collide with the bottoms of the cavities will be protected from the streaming atmosphere and will remain in their protected holes until arriving at the surface of the earth.

The oxide fragments present another puzzling problem. Had these not been found, we would have concluded that the large numbers of small nickel-iron particles on the surface show further evidence that the Goose Lake fall is of recent origin. Furthermore, if our preliminary conclusions are correct, that these nickel-iron fragments are not a part of the main mass,
we have suggested a method by which they could have been transported from the orbit of the main mass to the ground.

The thick oxide fragments, however, indicate that they have been subjected to oxidation processes for a very long time. Their thicknesses are not greatly different from the massive oxidation fragments from the Canyon Diablo. It is not clear how pieces of this meteoritic oxide ranging in size from a few milligrams to 13 grams could still be clustered on the surface of the ground so close to the impact point for even a fraction of the time required to form this thick stable oxide. This area is wind whipped by violent storms characteristic of the high Sierras, especially in winter. These winds would certainly scatter particles like these over wide areas in a fraction of the time presumably required to form these thick laminar oxide layers.

It is possible, of course, that we are dealing with more than one fall. In this case, there should be evidence of a fall nearby and many more of these fragments throughout Modoc County.

However, if no more oxide fragments are discovered, and if the Goose Lake meteorite did fall within the last fifty years or so, then we must conclude that the oxide fragments were transported in a manner similar to that of the nickel-iron fragments, i.e, in the wake of the main body or in its cavities. The origin of pre-entry massive oxide meteoritic fragments requires further study.


Figure 16. Hook-shaped nickel-iron fragment. Individual lines can be followed all the way around the bend. The number (16) shown directly above the scale is the figure number and is not related to the scale. The scale indicates a length of 1 millimeter.

Figure 17. Flat side and edge of massive oxide fragment revealing laminar structure. The number (17) shown directly above the scale is the figure number and is not related to the scale. The scale indicates a length of 1 centimeter.

Figure 18. Rhabdite crystal in one of the massive oxide fragments. No etching. The number (18) shown directly above the scale is the figure number and is not related to the scale. The scale indicates a length of 100 microns.

## Sumimary of the Evidence

Two types of meteoritic particles have been discovered at the site where the Goose Lake meteorite was found; nickel-iron fragments of kamacite whose weights are in tenths of grams and massive laminar oxide fragments weighing up to 13 grams. The former are concentrated close to the assumed impact point, the latter distributed out to distances of approximately 300 feet.

The appearance of Neumann lines in the nickel-iron fragments indicates that they were never heated above about $400^{\circ} \mathrm{C}$. The bending and twisting of the lines shows that they were deformed while cold.

The massive laminar oxide fragments, showing rhabdite inclusions, are identical to those found at Canyon Diablo.

## Conclusion

Evidence that the Neumann lines in the nickel-iron fragments are dissimilar to those in the Goose Lake meteorite indicates that their origin is independent of this mass of iron, that they were swept up by the meteorite during its long life in orbit around the solar system. Only those fragments which found their way into the cavities were recovered, any others were blown off by the air stream during its final flight. Cavity transportation explains their abundance at the impact site, as well as protection against aerodynamic heating. Deformation of the nickel-iron fragments occurred when they collided with the main mass in space.

The massive laminar oxide fragments suggest a second meteorite fall in the same vicinity as old as Canyon Diablo.

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The author wishes to express his appreciation to the California Academy of Sciences for its support in this work, especially in view of the fact that all published data on the Goose Lake meteorite up to the time of the first expedition were silent on the subject of fragments. A number of people were most helpful in the early stages of this work before the problem had been fairly defined. Dr. Max Hey of the British Museum and Dr. E. M. Shoemaker of the Geological Survey made valuable suggestions as well as providing me with specimens of other meteorites for comparison studies. Special mention should be made of the voluminous correspondence and personal discussions with E. P. Henderson of the Smithsonian Institution. He very kindly made available a slice of the main mass, together with permission to polish and etch it in the same way as the fragments.

For some 12 years, the author has been fortunate in having the advice and counsel of Dr. G Dallas Hanna in problems relating to optical materials,
eclipse instrumentation, and in meteoritics. His enthusiastic and youthful outlook has been an inspiration, and it was largely through his encouragement that the first formal proposal was submitted to go in search of the Goose Lake fragments.

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## PROCEEDINGS

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# RELATIONSHIPS OF THE PERCOID FISH PENT ACEROS RICHARDSONI SMITH, WITH DESCRIPTION OF A SPECIMEN FROM THE COAST OF CALIFORNIA 

by

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A specimen of the percoid fish Pentaceros richardsoni Smith ${ }^{1}$ was collected March 10, 1960, off Pigeon Point, San Mateo County, California. This capture extends the recorded range of this species more than 400 miles southward on the Pacific coast of North America and adds to the known fauna of California the western Pacific family Pentacerotidae.

The specimen (fig. 1), California Academy of Sciences no. 26759, measures 252 mm . in standard length and 305 mm . in total length. It was collected by the drag boat Henrietta Paladini in California Department of Fish and Game Block 481 ( $37^{\circ} 15^{\prime} \mathrm{N} ., 122^{\circ} 55^{\prime} \mathrm{W}$.) in one of three tows made at depths of 265,255 , and 220 fathoms.

Other fishes taken in these tows were the pleuronectids Eopsetta jordani (Lockington), Parophrys vetulus Girard, Microstomus pacificus (Lockington), and Glyptocephalus zachirus Lockington; the scorpaenids Sebastodes

[^19]

Figure 1. Pelagic armorhead, Pentaceros richardsoni Smith, CAS 26759, standard length 252 mm ., collected March 10, 1960, off Pigeon Point, San Mateo County, California. Photograph by W. I. Follett.
paucispinis (Ayres), S. goodei Eigenmann and Eigenmann, and Sebastolobus alascamus Bean; and the anoplopomatid Anoplopoma fimbria (Pallas).

## Distribution

Pentaceros richardsoni has been recorded but once from South Africa, its type-locality (Smith, 1849), and twice from New Zealand (Hutton, 1890; McCulloch and Phillipps, 1923). Certain evidence suggests that its center of abundance is in the vicinity of southern Japan: a number of specimens have been taken south of Tokyo (Abe, 1957; Tomiyama and Abe, 1958), and a fishery for this species is conducted about 50 nautical miles northeast of Hachijō Island, off central Honshu (Tokiharu Abe, personal communication, November 21, 1961). Probably, the specimens recorded from the North Pacific Ocean (Welander, Johnson, and Hajny, 1957) and off British Columbia (Neave, 1959; Clemens and Wilby, 1961) and Oregon (Wagner and Bond, 1962), and our specimen from central California, were transported far to the east of the center of abundance of this species by the North Pacific current system (Kuroshio, Kuroshio Extension, North Pacific Current, and California Current; see Sverdrup, Johnson, and Fleming, 1946, pp. 719-724; chart 7).

## Synonymy

Pentaceros richardsonii Smith, 1849, p. [3] (listed in index to plates). Günther, 1859, p. 212 (reference; diagnosis; distribution; holotype in British Museum). Bleeker, 1876, p. 270 (type-species, by original designation, of Pseudopentaceros, new genus). Hutton, 1890, p. 277 (specimens, from New Zealand, in Canterbury Museum). Gill, 1893a, p. 116 (synonym of Pseudopentaceros richardsonii; reference). GilChrist, 1902, p. 108 (references). Waite, 1907, p. 19 (reference). Thompson, 1916, p. 134 (synonymy).
Pentaceros richardsoni Smith, 1849, pp. [51]-[52] (original description; type-locality, "near to Cape Point," South Africa, "in very deep water"); pl. 21. Bleeker, 1860, p. 52 (listed, Cape of Good Hope). Hutton, 1904, p. 41 (reference). Jordan, 1907, p. 236 (specific name only; type of Gilchristia, new genus; record). McCulloch, 1915, p. 144 (type of Pseudopentaceros Gill [sic], which = Gilchristia Jordan and, possibly, Quinquarius Jordan; references). Jordan, 1919, p. 382 (orthotype of Pseudopentaceros Bleeker, which "replaces" Gilchristia Jordan).
Pseudopentaceros richardsonii. Gıl, 1893a, p. 116 (Pentaceros richardsonii a synonym; listed, New Zealand). Waite, 1907, p. 19 (listed, New Zealand; reference). Phillipps, 1927, p. 13 (listed, New Zealand).
Histiopterus richardsoni. Jordan, 1920, p. 524 (orthotype [sic] of Gilchristia Jordan ${ }^{2}$, a synonym of Pseudopentaceros Bleeker).

Pseudopentaceros richardsoni. Hutton, 1904, p. 41 (listed, New Zealand). McCulloch and Phillipps, 1923, p. 18 (references; description of 70mm . specimen from Nelson, New Zealand) ; pl. 4, fig. 1. Barnard, 1927, pp. 621-622 (references; description; distribution) ; 1937, pp. 56, 57 (comparisons; counts; reference). Suith, 1951, pp. 873-875 (distribution; references; comparisons) ; 1961, p. 242 (references; diagnosis; distribution) ; pl. 35, fig. 622. Welander, Joinnson, and Hajny, 1957, p. 244 ("boar fish") ; p. 245 (reference; counts ; measurements ; description; comparisons; taxonomic notes; specimens from North Pacific, $45^{\circ} 49^{\prime} \mathrm{N} ., 160^{\circ} 03^{\prime} \mathrm{W}$. , to $\left.51^{\circ} 00^{\prime} \mathrm{N} ., 150^{\circ} 00^{\prime} \mathrm{W}.\right)$ Abe, 1957 , pp. $35-39$, 71-73 ("kusakari-tsubodai"; references; description; counts; measurements; comparisons; specimens from southern part of Bōsō Peninsula (probably), from Hachijō Island, and off Amatsu, Japan); fig. 1. Toniyama and Abe, 1958, p. 165 ("kusakari-tsubodai"; diagnosis; "fairly palatable"; distribution; specimens from Hachijōo Island and off Amatsu; col. fig.). Neave, 1959, p. 384 ("boar fish"; reference; specimen from $50^{\circ} \mathrm{N} ., 145^{\circ} \mathrm{W}$., off British Columbia). Clemens and Wilby, 1961, p. 42
2. Jordan (1920, p. 524) wrote "orthotype Histiopterus richardsoni Gilchrist"-surely a lapsus calami for Pentaceros ichardsoni Smith (see Jordan, 1919, p. 382).
(characters in key) ; p. 219 ("boarfish"; description; records; distribution) ; fig. 126. Wagner and Bond, 1962, pp. 71-72 (references; counts; measurements; distinguishing characters; age; specimens from Oregon coast, between Umpqua and Alsea rivers, in $80-90$ to 110 fathoms); fig. 1 ; fig. 2 (head).
Griffinetta nelsonensis Whitley and Phillipps, 1939, p. 233 (new genus and species, based on young specimen (total length 70 mm .) from Nelson, New Zealand, described as Pseudopentaceros richardsoni by McCulloch and Phillipps, 1923, p. 18).
In view of the extensive changes that occur with age in this family (McCulloch, 1915, pp. 145-146, pl. 26; Waite, 1923, p. 143; Smith, 1951, pp. 874-875), we follow McCulloch and Phillipps (1923, p. 18) in referring their young specimen from Nelson, New Zealand, to Pentaceros richardsoni. Whitley and Phillipps (1939, p. 233) referred this specimen to a distinct genus and species, Griffinetta nelsonensis, but expressed no basis for such distinction.

## Description

We confine our discussion to those respects in which our observations differ from, or supplement, the excellent description of this species by Abe (1957).

Counts and measurements are expressed as by Hubbs and Lagler (1958). Principal caudal rays consist of all branched rays plus the upper and the lower adjacent unbranched ray; all other unbranched caudal rays are regarded as procurrent rays. Predorsal bones (called auxiliary interneurals by Starks, 1904 , p. 613) are the median bones (rayless pterygiophores) that are anterior to the dorsal pterygiophores (see Smith and Bailey, 1961, p. 345 ). Counts of the caudal rays, predorsal bones, and vertebrae were determined from a radiograph.

Counts: Dorsal rays XIV,9. Anal rays IV,8. Caudal rays: principal 17 (9 upper, 8 lower) ; procurrent 11 ( 6 upper, 5 lower). Pectoral rays 19 on each side (first two and last two unbranched). Pelvic rays I, 5 on each side. Scales (left side): 68 lateral-line pores, 14 rows above lateral line, 42 rows below lateral line. Scales (right side): 69 lateral-line pores, 14 rows above lateral line, 41 rows below lateral line. Cheek scales: horizontal rows 7 on each side; vertical rows 13 on each side. Predorsal bones 2. Branchiostegal rays $4+3$ on each side. Vertebrae 25 (precaudal 12; caudal 13, including wrostylar vertebra).
fill rakers (counts include all rudiments: count of lower limb includes raker in angle of arch):

|  | Anterior |  | Posterior |  |
| :--- | :---: | :---: | :---: | :---: |
|  | Left | Right | Left | Right |
| 1st arch $\ldots \ldots \ldots \ldots$ | $7+17$ | $7+17$ | $3+15$ | $4+15$ |
| 2nd arch $\ldots \ldots \ldots \ldots$ | $3+15$ | $3+15$ | $2+12$ | $2+12$ |
| 3rd arch $\ldots \ldots \ldots \ldots$ | $2+12$ | $2+13$ | $1+11$ | $1+11$ |
| 4th arch $\ldots \ldots \ldots \ldots$ | $1+11$ | $1+11$ | $0+7$ | $0+7$ |

Measurements. These are given in hundredths of standard length ( 252 mm .) . Body depth: fifth dorsal spine to pelvic spine 40 ; fourteenth dorsal spine to first anal spine 30 ; posterior end of dorsal base to posterior end of anal base 15. Least depth of caudal peduncle 9. Body thickness: greatest 16 ; between outer margins of pelvic origins 10 .

Snout to dorsal origin 39. Dorsal base 53; spinous-dorsal base 40 ; softdorsal base 13. Posterior end of soft-dorsal base to base of middle caudal ray 15. Snout to pectoral origin 33. Snout to pelvic origin 45. Pelvic origin to anal origin 29. Snout to anal origin 72. Anal base 17; spinousanal base 7; soft-anal base 10. Length of caudal peduncle (posterior end of anal base to base of middle caudal ray) 16 .

Head: length 33 ; depth 30 ; width 16 ; postorbital length 13 . Snout length 12. Suborbital width 1 . Cheek: height 9 ; length 15 . Orbit to angle of preopercle 12. Interorbital width (least bony) 11. Orbit: horizontal diameter 9; vertical diameter 8. Upper-jaw length 10. Mandible length 13. Gape width 7.

Dorsal-fin supports. The two predorsal bones and the first proximal pterygiophore are shaped somewhat like the number " 7 ." The first and second proximal pterygiophores are ankylosed, but they are distinguishable from each other by their lateral keels (as we have confirmed by dissection). Thus distinguished, the first and second pterygiophores support each one dorsal spine. The first predorsal bone extends downward in front of the first neural spine; the second predorsal bone, between the first and second neural spines. The first and second pterygiophores extend downward between the second and third neural spines; the third and fourth pterygiophores, between the third and fourth neural spines. The fifth pterygiophore extends downward between the fourth and fifth neural spines. (Radiographs reveal the same arrangement in the three other specimens of Pentaceros richardsoni that we have examined (see table 1) and in a specimen of Quinquarius $(=$ Pentaceros) japonicus (Stanford University no. 18191) 184 mm . in standard length.)

Dorsal spines. The dorsal spines are heteracanth. Because of their bilateral asymmetry, they fit closely together when depressed into the


Figure 2. Locking mechanism of dorsal spines of Pentaceros richardsoni, CAS 26759. Spines erect. Radiograph by W. I. Follett.


Figure 3. Locking mechanism of dorsal spines of Pentaceros richardsoni, CAS 26759. Spines partly depressed, indicating the manner in which the serrate lobe engages the face of the preceding spine. Radiograph by W. I. Follett.
dorsal groove. (Jordan, 1907, p. 235, perhaps inadvertently, noted as a familial character "dorsal . . . spines . . . not depressible in a groove.") As in one of the specimens recorded by Abe (1957, p. 72), the first, third, fifth, and successive odd-numbered spines incline to the right and the second, fourth, sixth, and successive even-numbered spines incline to the left. (In two other specimens recorded by Abe (1957, pp. 36, 71) the oddnumbered spines inclined to the left and the even-numbered spines inclined to the right.) The spines are longitudinally ridged. The ridges are more conspicuous on the left side of the odd-numbered spines and on the right side of the even-numbered spines.

The third to sixth spines, immediately distal to the articulation, are each expanded into a vertical, laterally compressed anterior lobe (see figs. 2-4). (A lobe is faintly indicated on the second and the seventh spines, but is not discernible on any of the others.) The front edge of the lobe is bluntly serrate. The serrae are marginal protrusions of smooth ridges that extend obliquely around the front edge of the lobe (see fig. 4). The lobe of the third and fifth spines is at the left of the interradial membrane; that of the fourth and sixth spines is at the right.


Figure 4. Fourth dorsal spine of Pentaceros richardsoni, CAS 26759. a. Lateral view, left side. b. Anterior view. c. Lateral view, right side. Photographs by W. I. Follett.

These lobate spines, which resemble those in Pentaceros capensis Cuvier in Cuvier and Valenciennes, 1829, and those in Pentaceros japonicus Döderlein in Steindachner and Döderlein, 1884, function as a locking
mechanism. This mechanism is similar to that in $P$. capensis as described by Smith (1951, p. 878).

Anal spines. The anal spines are heteracanth. The first and third spines incline to the left; the second and fourth, to the right. (In two specimens recorded by Abe, 1957, p. 72, the second spine inclined to the right.) The spines are longitudinally ridged. The ridges are more conspicuous on the right side of the first and third spines and on the left side of the second and fourth spines.

The third spine, immediately distal to its articulation, is expanded into a vertical, laterally compressed anterior lobe, the edge of which bears five blunt serrae. There is a slight anterior lobe on the second spinc, but none is discernible on the first or fourth. These lobes are elements of a locking mechanism.

Pelvic spines. Longitudinal ridges similar to those on the dorsal and anal spines extend along both sides of the pelvic spines (and along the basal portion of the lower side of the pelvie soft-rays).

Branchiostegal membranes. The inner fold of the right branchiostegal membrane overlaps that of the left. This asymmetry is contrary to the rule that, in fishes with overlapping branchiostegal membranes, the left membrane generally overlaps the right (see Hubbs and Hubbs, 1945, p. 279; Crossman, 1960, p. 368).

Variability in the asymmetry of the branchiostegal membranes may be common in this species. Three specimens with the right branchiostegal membrane overlapping the left, and four with the left overlapping the right, were recorded by Abe (1957, pp. 38, 71, 72, 73). In the $254-\mathrm{mm}$. specimen preserved by Welander, Johnson, and Hajny (1957, p. 245), the right branchiostegal membrane overlaps the left; in their $240-\mathrm{mm}$. specimen, the left overlaps the right. In a $257-\mathrm{mm}$. specimen collected by Richard C. Johnson, August 15, 1958, in the North Pacific Ocean, $49^{\circ} 43^{\prime}$ N., $146^{\circ} 10^{\prime} \mathrm{W}$., the left branchiostegal membrane overlaps the right.

## Association of Bilateral Asymmetries in Seven Spechiens

The bilateral asymmetries of the dorsal spines, anal spines, and branchiostegal membranes in Pentaceros richardsoni are variously associated with one another. The combinations of these characters in the four specimens examined by us and in three specimens recorded by Abe (1957) are shown in table 1.

Table 1. Bilateral asymmetries in seven specimens of Pentaceros richardsoni.

| Specimen | Side of spine expanded into an anterior lobe |  |  |  | Overlapping branchiostegal membrane |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Odd-numbered spines |  | Even-numbered spines |  |  |
|  | Dorsal | Anal | Dorsal | Anal |  |
| CAS 26759 | Left | Right | Right | Left | Right |
| Abe '57-125 | Right | Right | Left | Left | Leit |
| Abe (Masuda) | Right | Right | Left | Left | Left |
| Abe 10552 | Left | Right | Right | Left | Right |
| UW 11468 ${ }^{1}$ | Right | Right | Left | Right | Left |
| UW 11469 ${ }^{2}$ | Left | Left | Right | Left | Right |
| UW 15515 ${ }^{3}$ | Left | Right | Right | Left | Left |

1. Welander, Johnson, and Hajny (1957, p. 245), 240-mm. specimen.
2. Welander, Johnson, and Hajny (1957, p. 245), 254-mm. specimen.
3. Specimen collected in a surface gill net by Richard C. Johnson, August 25, 1958, in the North Pacific Ocean, $49^{\circ} 43^{\prime} \mathrm{N}$., $146^{\circ} 10^{\circ} \mathrm{W}$., water temperature $11.8^{\circ} \mathrm{C}$.

Dentition. The teeth on the premaxillaries and dentaries are in a band. They are small, conical, and slightly curved-those of the outer row irregularly enlarged. There are 24 small, scarcely curved teeth on the head of the vomer. No teeth are present on the shaft of the vomer or on the palatines or tongue. The teeth of the upper and lower pharyngeals are similar in shape to the enlarged teeth of the premaxillaries and dentaries, but are somewhat larger. (The lower pharyngeals are not coalesced.)

Caudal skeleton. Characters revealed by a radiograph of our specimen indicate that the caudal skeleton of Pentaceros richardsoni resembles the most primitive perciform type as defined by Gosline (1961). In the following discussion, the terminology follows that of Gosline (1961), except as noted.

Epurals. There are three epurals, similar in shape and size. Their rounded anterior (lower) ends lie above uroneural 1, the anterior end of epural 1 extending slightly ahead of uroneural 1, to a point above the neural process of the penultimate (12th) vertebra.

Uroneurals. There appear to be two uroneurals. Uroneural 1 is similar in shape to that figured by Gosline (1961, fig. 1). The presence of uroneural 2 is suggested by a projection above the dorsal margin of hypural 6 (the uppermost hypural) and by a faint line extending obliquely downward and forward from that projection.

Urostyle. There is a single urostylar ossification.

Hypurals. The sutures separating all six hypurals are distinct. The hypural spine (defined by Merriman, 1940, p. 63) is well developed.

Hemal arches. The hemal arch of the antepenultimate vertebra, as well as that of the penultimate vertebra, is autogenous (separate from the centrum).

Caudal rays. There are 17 principal caudal rays ( 9 upper, 8 lower) and 11 procurrent rays ( 6 upper, 5 lower), their articulation with the epurals, hypurals, and hemal spines, respectively, appearing to be as follows:

Epurals 1 and 2 support each one procurrent ray; epural 3 supports four procurrent rays.

Hypural 6 supports one unbranched ray (the uppermost principal ray); hypural 5 , six branched rays; hypurals 5 and 4 together, one branched ray; hypural 4, one branched ray (the lowermost ray of the upper lobe); hypural 3 , one branched ray (the uppermost ray of the lower lobe) ; hypural 2, four branched rays; and hypural 1, two branched rays (including the lowermost branched ray of the lower lobe).

The hemal spine of the penultimate vertebra supports the lowermost (unbranched) principal ray and three procurrent rays. The hemal spine of the antepenultimate vertebra supports two procurrent rays.

## Generic Position

We find no characters that justify the distinction of Pseudopentaceros Bleeker, 1876, from Pentaceros Cuvier in Cuvier and Valenciennes, 1829.

When Bleeker (1876, p. 270) erected the genus Pseudopentaceros (typespecies, Pentaceros richardsoni), he diagnosed it as having small teeth on maxillaries and vomer, 14 dorsal spines, 4 anal spines, and no crests or prominent osseous tubercles on the upper surface of the head. He diagnosed the genus Pentaceros Cuvier and Valenciennes (type-species, Pentaceros capensis) as having small teeth on maxillaries and vomer, 12 dorsal spines, 5 anal spines, and crests or prominent osseous tubercles on the upper surface of the head (Bleeker, 1876, p. 269).

The supposed distinction based on 14 dorsal spines and 4 anal spines in Pseudopentaceros in contrast with 12 dorsal spines and 5 anal spines in Pentaceros is dispelled by the following material:

1) A specimen of Pentaceros capensis with 4 anal spines (Fowler, 1935, pp. 393-39t and fig. 26, as Quinquarius capensis). (Fowler's scale counts negate the possibility considered by Barnard, 1937, p. 57 , that this specimen might represent Pentaceros richardsoni.)
2) A specimen of Pentaceros capensis with 13 dorsal spines (Barnard, 1937, p. 56, as Quinquarius capensis).
3) A specimen of Pentaceros richardsoni with 13 dorsal spines (Clemens and Wilby, 1961, p. 219, and fig. 126, as Pseudopentaceros richardsoni).

The presence or absence of cephalic crests or osseous tubercles appears of doubtful significance. This distinction was proposed by Bleeker on the basis of a juvenile of one form and an adult of the other, and apparently without knowledge that these structures are known only in juveniles. (See McCulloch, 1915, pp. 145-146, pl. 26; Waite, 1923, p. 143; Smith, 1951, pp. 874-875.)

In the following summary of noteworthy similarities of the two forms, the characters of Pentaceros richardsoni are based on our specimen, 305 mm . in total length, and those of $P$. capensis are based on the description by Smith (1951, as Quinquarius capensis) of a specimen 320 mm . in total length.

Bones of the head exposed, bearing rugulose ridges. Lips and chin villous. Dorsal spines heteracanth, longitudinally ridged on alternate sides; on the ridged side, a serrate anterior lobe near the base of the third, fourth, and fifth spines, functioning as an element of a locking mechanism. Anal spines heteracanth, longitudinally ridged on alternate sides; on the ridged side, a serrate anterior lobe near the base of the third spine, functioning as an element of a locking mechanism. Teeth on head of vomer ${ }^{3}$, none on palatines or tongue. Lower pharyngeals not coalesced. Preorbital, circumorbitals, preopercle, and ventral surface of mandible, with large sensory pores roofed by membrane. Six large pores across the chin. Lateral line arching toward base of fourth dorsal spine, thence roughly parallel to dorsal base, curving down to caudal peduncle, and thence extending horizontally to caudal base. Scales of throat, breast, cheeks, belly, and nape scutelike, slightly or not at all imbricate. Vertebrae $12+13=25$. (The vertebral count of $12+12$ noted by Welander, Johnson, and ILajny (1957, p. 245) in two specimens of Pentaceros richardsoni must have excluded the urostylar vertebra. We have X-rayed these two specimens and we find that each has a vertebral count of $12+13$, including the urostylar vertebra. Smith (1951, p. 877) noted the number of vertebrae in his specimen of Pentaceros capensis as $13+12$. His demarcation between precaudal and caudal vertebrae may be different from ours, since his radiograph (ibid., pl. 18) shows 13 vertebrae that we regard as caudal, and seems to show 12 vertebrae that we regard as precaudal. We therefore believe that both forms have the vertebrae, according to our method of counting, $12+13=$ 25.)

Smith (1951, p. 874) stated that if only the adult stadia of Pseudopentaceros and Quinquarius ( = Pentaceros) were compared, "one might al-

[^20]most be justified in uniting them." But he distinguished them on the following basis (ibid., p. 876) :

Pseudopentaceros
Scales in more than 70 series Exposed bones of head without marked sensory pores In juveniles:

No horns above eye
Pelvics not very widely separated
Depth of body less than half length

Quinquarius ( $=$ Pentaceros)
Scales in fewer than 60 series Exposed bones of head with large sensory pores
In juveniles:
Horns above eye
Pelvies widely separated
Depth of body more than half length

The difference in scale counts does not impress us as of generic significance.

In our specimen of Pentaceros richardsoni, the exposed bones of the head have large sensory pores. The presence of such pores in this species has been noted also by Welander, Johnson, and Hajny (1957, p. 245) and Abe (1957, p. 37 ).

The presence or absence of horns above the eye in juveniles may not be a reliable character in this family. In another species of this family, these structures, which had been considered characteristic of the young of that species, were absent in one young specimen (Barnard, 1927, p. 621).

The distance between pelvies has not been determined for juveniles of Pentaceros richurdsoni. (In the four adults that we have examined (see table 1), this distance ranges from 2.5 to 3.3 in length of head.)

The difference between a body depth of 2.3 in a juvenile of Pentaceros richardsoni (McCulloch and Phillipps, 1923, p. 18) and a body depth of 1.8 in juveniles of $P$. capensis of comparable size (Smith, 1951, p. 881) does not impress us as of generic significance.

We therefore concur with Welander, Johnson, and Hajny (1957, p. 245) in regarding Pseudopentaceros Bleeker, 1876, as a subjective synonym of Pentaceros Cuvier in Cuvier and Valenciennes, 1829.

## Specific Distinction

A lower number of dorsal soft-rays and a higher number of scales distinguish Pentaceros richardsoni from $P$. capensis, as well as from $P$. japonicus Döderlein in Steindacher and Döderlein, 1884, and from $P$. hendecacanthus McCulloch, 1915; a lower number of dorsal soft-rays distinguishes $P$. richardsoni from $P$. decacanthus Günther, 1859 (based on a dried specimen less than two inches long). See table 2.
(The data in table 2 suggest that $P$. japonicus and $P$. hendecacanthus, and possibly even $P$. decacanthus, may not be specifically distinct from P. capensis.)
Table 2. Counts of five species of Pentaceros.

|  | richardsoni1 <br> (15 specimens) | $\begin{gathered} \text { capensis }{ }^{2} \\ (5 \text { specimens }) \end{gathered}$ | decacanthus ${ }^{3}$ <br> (1 specimen) | $\begin{gathered} \text { japonicus } \\ \text { (4 specimens) } \end{gathered}$ | hendecacanthus ${ }^{5}$ (8 specimens) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Dorsal | XIII or XIV, 8 to 10 | XII or XIII,12 | X,13 | XI or XII,13 or 14 | XI,13 to 15 |
| Anal | IV, 7 to 9 | IV to VI, 7 or 8 | IV,8 | IV or V,9 or 10 | IV,10 or 11 |
| Pectorals ....................... | 17 to 19 | 16 | -....... | 16 or 17 | 17 |
| Pelvics | I,5 | I,5 | I,5 | I,5 | I,5 |
| Caudal | $9+8$ | $9+8$ | . .... | $9+8$ | $9+8$ |
| Gill rakers ................... | 6 to $8+17$ or 18 | 5 or $6+16$ or 17 |  | $7+17$ | -....... |
| Lateral-line pores ......... | 64 to 78 | 50 | ....... | 46 to 49 | 45 to 47 |
| Scale rows: |  |  |  |  |  |
| Above lateral line....... | 12 to 14 | 7 | ........ | 9 | 10 |
| Below lateral line....... | 41 to 46 | 27 or 28 | ....... | 31 or 32 | 33 |
| Predorsal | 14 or 15 | 10 | $\ldots$ | 10 | 9 |
| Cheek: |  |  |  |  |  |
| Horizontal | 7 to 9 | 5 | ....... | 5 or 6 | 5 |
| Vertical ................. | 12 to 14 | 10 | ........ | 9 or 10 | 9 |
| Branchiostegals | $4+3$ | 7 | 7 | $4+3$ | ........ |
| Vertebrae ....................... | $12+13=25$ | $12+13=25$ | -....... | $11+14=25$ | ........ |

1. Data from four specimens examined by us (see table 1) and from Smith (1849), McCulloch and Phillipps (1923), Abe (1957), and Clemens and Wilby
1961). Cuvier and Valencienne (1820) and Smith (1951)
2. Data from Günther (1859).
3. Data from a specimen examined by us (Stanford University no. $18191,154 \mathrm{~mm}$. in standard length, collected March 17, 1952, by A. Ishizuka at Kozu, Sagami Bay, Japan) and from Steindachner and Döderlein (1884) and Abe (1957).
[^21]
## Nomenclature

Generic nane. The generic name Pentaceros Cuvier in Cuvier and Valenciennes (1829, p. 30) is valid. For some time it has been thought to be preoccupied either by Pentaceros Schulze (1760, p. 50) or by Pentaceros Schröter (1782, p. 58), but it is evident that under the present rules neither of those earlier names is nomenclaturally available.

For a name to be available, the International Code of Zoological Nomenclature requires that its author must have consistently applied the principles of binominal nomenclature in the work in which the name is published (International Commission on Zoological Nomenclature, 1961, Art. 11c). Binominal nomenclature is the system under which each species receives a name consisting of two words, of which the first is the generic name and the second is the specific name (ibid., Glossary, p. 148).

Schulze (1760) did not consistently, if at all, apply the principles of binominal nomenclature (see Clark, 1908, p. 517; Springer, 1909, p. 183; Bather, 1909, p. 40; and Jordan and Richardson, 1909, p. 192). It cannot be demonstrated that the names used by Schulze are even names of genera or species. Pentaceros Schulze ( 1760 , p. 50 ) is a descriptive term applied to a group of starfishes of indeterminate rank. It includes two subgroups, also of indeterminate rank, the planae (plural) and the gibbae (plural). Jordan and Evermann (1917, p. 126) remarked that "obviously this is not scientific nomenclature," and Fisher (1908, p. 91) stated that "there is no evidence that Schulze knew anything about binomial nomenclature, for he does not conform to the Linnaean system . . ."

Any doubt regarding the nomenclatural status of Pentaceros Schulze, 1760, has now been eliminated by Opinion 636, which placed Schulze, 1760 (misspelled "Schultze"), on the Official Index of Rejected and Invalid Works in Zoological Nomenclature, on the ground that the author did not apply the principles of binominal nomenclature (International Commission on Zoological Nomenclature, 1962, p. 263).

Schröter (1782), the next author to use the name Pentaceros, did not consistently apply the principles of binominal nomenclature. In his only mention of Pentaceros (ibid., p. 58), he merely cited the polynominal term that had been applied to the "five-horned star" by the pre-Linnaean author Linck:
"Fig. III. ist auf der Seite des Rückens vorgestellt, und kommt vor im Link [sic] de stellis mar. tab. III. fig. 3. auf der Rückenseite, und Tab. II. fig. 3. auf der Seite der Mündung. S. 21. 22. stehet er unter dem Geschlecht Pentaceros, der fünfhörnige Stern, und heisst Pentaceros gibbus turritus pluribus velut turricutis munitus. Die Seepastete Rumph holländ. p. 39. Beym Linné ist er ed. XII. p. 1100. Gen. 298, sp. 7. Asterias nodosa oder Asterias stellatu, radiis convexis longitudinaliter elevatis muricatis. . . ."

We concur with Fisher (1908, p. 93), who stated, "Schröter, in 1782 (Musei Gottwaldiani Testaceorum, Stellarum marinum, etc., Nürnberg, 58), used Pentaceros, but he is not a consistent binomialist, and his 'generic' names are not tenable."

Since Pentaceros Cuvier in Cuvier and Valenciennes is not preoccupied, the name Quinquarius Jordan, 1907, which was proposed "to replace Pentaceros Cuv. \& Val., regarded as preoccupied" (Jordan, 1920, p. 524), is relegated to synonymy.

The name Pentaceros Cuvier in Cuvier and Valenciennes has been used in the primary zoological literature within the past fifty years (Thompson, 1916, p. 134), and is therefore not to be considered a forgotten name (nomen oblitum); see International Commission on Zoological Nomenclature (1961, Art. 23b).

Family name. The oldest available family-group name based on the nominal genus Pentaceros is Pentacerotinae (correction by Gill, 1893b, p. 134, of Pentaceratina Günther, 1859, p. 212). The name Pentacerotinae fulfils the requirements of availability of family-group names (International Commission on Zoological Nomenclature, 1961, Art. 11e) : it was based on the name then valid for a contained genus (Pentaceros) and it was a noun in the nominative plural; it was clearly used to denote a suprageneric taxon (it was designated "group" but was used in the sense of subfamily), and was not merely employed as a plural noun or adjective referring to the members of a genus. The subfamily name Pentacerotinae, so used, makes available the family name Pentacerotidae Günther, 1859 (see International Commission on Zoological Nomenclature, 1961, Arts. 29, 36). The name Pentacerotidae, which has priority over the name Histiopteridae Jordan ( 1905, p. 398, and footnote to p. 585), is the valid name of this family. (Under the present rules, the valid name of a family is the oldest available name applied to it. See International Commission on Zoological Nomenclature, 1961, Art. 23.)

The correct form of the family name based on Pentaceros is Pentacerotidae, not Pentaceridae or Pentaceratidae. The genitive singular of Pentaceros, an adjectival form (used as a noun) based on -ceras, is Pentacerotos, from which is derived the family name Pentacerotidae (L. W. Grensted, classical adviser to the International Commission on Zoological Nomenclature, in litt., February 9, 1962).

Family-group names based on Pentaceros have been used by a number of authors: the family name Pentacerotidae, by Bleeker (1860, p. 52, correction by Gill, 1885, p. 210, of Pentacerotoidei), by Gill (1893a, pp. 105, $116 ; 1893 b$, p. 134), by Jordan and Evermann (1902, p. 351), by Hutton (1904, p. 41), by Jordan (1905, p. 333), by Smith and Pope (1906, p. 479), and by Jordan and Richardson (1909, p. 192) ; the subfamily name Penta-
cerotinae, by Günther (1859, p. 212, correction by Gill, 1893b, p. 134, of Pentaceratina), by Bleeker (1876, pp. 269, 287, correction by Gill, 1893b, of Pentacerotiformes), by Boulenger (1910, p. 660), and by Thompson (1916, p. 134, correction of Pentaceratinae).

Specific name. The specific name of this fish was spelled in two ways in the original publication (Smith, 1849) : richardsonii in the index to the plates, and richardsoni in the text and on plate 21.

If a name is spelled in more than one way in the original publication, the spelling adopted by the first reviser is to be accepted as the correct original spelling (International Commission on Zoological Nomenclature, 1961, Art. 32b). An author, to be a first reviser, must cite the names in question, make it clear that he believes them to represent the same taxon, and choose one as the name of that taxon (ibid., Art. 24a(i)).

Since we have found no publication, other than the original description, in which both original spellings of this specific name were cited, we conclude that neither spelling has been adopted by a "first reviser."

The Code recommends that a specific name based on a modern personal name that is neither Latin nor latinized nor of Greek origin should end in -i rather than -ii (ibid., Appendix D, Recommendation 16). As first revisers, we therefore choose the spelling richardsoni in preference to the spelling richardsonii for the specific name of this fish.

## Common Name

We propose the common name "pelagic armorhead" for Pentaceros richardsoni.

Although the name "boarfish" has been applied to this and other species of the Pentacerotidae by a number of ichthyologists (see, for example, Günther (1880, p. 388), Tenison-Woods (1883, p. 183), Waite (1898, p. 33; 1911, p. 216; 1921, p. 117), Roughley (1916, pp. 9, 127), Phillipps (1927, p. 13), McCann (1953, p. 12), Welander, Johnson, and Hajny (1957, p. 244), Smith (1961, p. 242), and Clemens and Wilby (1961, p. 219)), we believe that "boarfish" should be restricted to the species of the Caproidae. Such a restriction appears justified on the following grounds:

1) Capros (the name of the type-genus of the family Caproidae) itself means "boar." The vernacular "aper," meaning "wild boar," was applied to the fish currently known as Capros aper (Linnaeus, 1758) more than 400 years ago (Boussuet, 1558, p. 28) -and more than 300 years before "boarfish" was applied to any species of the Pentacerotidae.
2) Use of the name "boarfish" for Capros aper and other species of the Caproidae is deeply ingrained in the literature of the past century (see Yarrell, 1859, p. 258; Couch, 1869, p. 142; Buckland, 1880, p. 77; Günther, 1880, p. 449; Tenison-Woods, 1883, p. 183; Gill, 1885, p. 209;

Jordan and Evermann, 1898, p. 1663; Jordan and Fowler, 1902, p. 521; Aflalo, 1904, pp. 129, 137; Jordan, 1905, p. 398; Boulenger, 1910, p. 666; Meek, 1916, p. 305; Barnard, 1925, p. 380; Norman, 1931, p. 378; Gregory, 1933, p. 272; Munro, 1938, p. 77, and 1955, p. 89; Jenkins, 1950, p. 81; Berry, 1959; Food and Agriculture Organization, 1960, p. 99; Myers, 1960, pp. 89, 96; Herald, 1961, p. 160).
3) The name "boarfish" has been adopted for species of the Caproidae by the American Fisheries Society Committee on Names of Fishes (1960, p. 24).

No English name other than "boarfish" has been widely used for species of the Pentacerotidae ${ }^{t}$. It seems desirable therefore to apply a new common name to those species. Our choice of such a name, "armorhead," is based on the rough, bony plates of the head-a conspicuous and unique character.

The attributive "pelagic" in the proposed name, "pelagic armorhead," refers to the occurrence of Pentaceros richardsoni far offshore.

## Summary

1) A specimen of Pentaceros richardsoni Smith from the coast of California is described, with meristic and morphometric data and notes on the dorsal-fin supports, the locking mechanism of the dorsal and anal spines, and the osteology of the caudal region. The bilateral asymmetries of the dorsal spines, anal spines, and branchiostegal membranes of seven specimens of this species are shown to be variously associated.
2) Distributional notes and an annotated synonymy of Pentaceros richardsoni are provided.
3) Pseudopentaceros Bleeker, 1876 (type species, Pentaceros richardsoni) is shown to be a subjective synonym of Pentaceros Cuvier in Cuvier and Valenciennes, 1829 (type species, Pentaceros capensis).
4) The specific distinction of Pentaceros richardsoni from $P$. capensis Cuvier in Cuvier and Valenciennes, $P$. decacanthus Günther, $P$. japonicus Döderlein in Steindachner and Döderlein, and P. hendecacanthus McCulloch is confirmed. Pentaceros japonicus and $P$. hendecacanthus, and possibly even $P$. decacanthus, are regarded as questionably distinct from $P$. capensis.
5) The generic name Pentaceros Cuvier in Cuvier and Valenciennes, 1829, thought to be preoccupied either by Pentaceros Schulze, 1760, or by Pentaceros Schröter, 1782, is shown to be valid. Quinquarius Jordan, 1907, proposed to replace Pentaceros Cuvier in Cuvier and Valenciennes, is relegated to synonymy. The family name Pentacerotidae Guinther, 1859, which has priority over Histiopteridae Jordan, 1905, is shown to be valid.
6) Of the two original spellings, richardsoni is adopted as the correct

[^22]original spelling in preference to richardsonii for the name of this species.
7) The common name "pelagic armorhead" is proposed for Pentaceros richardsoni.

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CONTRIBUTIONS TO THE PETROGRAPHY
of the
GALÁPAGOS, COCOS, MALPELO, CEDROS, SAN BENITO, TRES MARÍAS, AND WHITE FRIARS ISLANDS

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## Introduction

For a period of several years, between 1905 and 1932, the California Academy of Sciences conducted extensive scientific expeditions to the Galápagos, Cocos, Malpelo, Cedros, San Benito, Tres Marías, and White Friars islands.

During the course of studies of these eastern Pacific Ocean islands, numerous volcanic rocks were collected by Washington Itenry Ochsner from the Galápagos Islands (including Abingdon, Albemarle, Barrington, Bindloe, Charles, Chatham, Gardner, IIood, Indefatigable, Jervis, South Seymour and Tower islands) ; from Cocos, Malpelo, Tres Marías and White Friars islands by C. B. Perkins, Leo G. Hertlein, and G Dallas Hanna; and metamorphic and plutonic rocks from Cedros, San Benito and Tres Marías islands, by G Dallas Hanna. The volcanic rocks that were collected on these islands range in composition from basalt to rhyolite. Those lavas on the Galápagos Archipelego and Cocos Island are principally basaltic in composition, although a few are of andesitic composition (Richardson, 1933, p. 46). One lava from Cocos Island is a latite, and several collected from María Madre of the Tres Marías islands are rhyolitic in composition. Glaucophane schists were collected on Cedros and San Benito islands and several plutonic rock types were collected on María Madre Island.

Special thanks are due to Dr. Leo G. Hertlein for his encouragement and suggestions during the course of this investigation, and especially to Dr. G Dallas Hanna who made available the rock specimens and suggested that a petrographic study be made of them.

## Galápagos Islands

Location and General Ceology. The Galápagos Islands are on the equator about 650 miles west of Ecuador. They form an archipelago con-


Figure 1. Map of the Galápagos Archipelago showing the major islands and the localities where rock specimens were collected.
sisting of 13 islands and many islets and projecting rock masses. The islands, except for minor amounts of sedimentary beds, are wholly of volcanic origin and contain at least 2000 cones and craters (Darwin, p. 110-131, 1891). This is a very conservative estimate for it has been shown that there are at least 2500 cones and craters alone on Albemarle Island (Banfield et al., 1956, p. 222) which is the largest island in the archipelago. Some of the volcanoes have erupted during the last hundred years (Sapper, 1917, p. 95). In addition to the many craters, there are lava flows and deposits of tuffs and tuff-breccias.

Petrography. Most of the crystalline rocks that make up the Galápagos Islands are basaltic in composition, and porphyritic with phenocrysts of basic plagioclase set in a microcrystalline groundmass. Olivine is not common, but when it is present it is more readily visible in lavas collected on Chatham, Charles, Gardner, Hood, Jervis, and Indefatigable islands.

Abingdon Island (Pinta; Geraldino). Two specimens of basalt were collected on Abingdon Island, the northernmost island in the archipelago.

Specimen no. 88 is typical of a great mass which forms an extensive flow that covers much of the island. Specimen no. 90 is from a more recent flow, and is less extensive in its occurrence than specimen no. 88 over which it lies.

Specimen no. 88 is a dark, porphyritic, vesicular rock containing phenocrysts of plagioclase up to one-half inch across enclosed in a fine-grained groundmass of feldspar laths, grains of colorless pyroxene and black opaque glass. The feldspar phenocrysts are subhedral in shape, and show welldeveloped zoning and twinning. They are unaltered and have a composition in the range of intermediate labradorite $\left(\mathrm{An}_{50}\right)$. The groundmass feldspar is in irregular laths and is seldom more than .2 mm . in length. They, too, are fresh, twinned and have a composition slightly more sodic than the feldspar phenocrysts. The augite is fresh and occurs in subhedral colorless grains. The principal constituent of the groundmass is dark, opaque basaltic glass which derives its dark color in part from small dust-like particles of magnetite. Specimen no. 90 is not porphyritic, but shows a welldeveloped hyaloophitic texture in thin-section. It is a fine-grained rock and under the microscope one can see laths of feldspar and grains of augite enclosed in a dark glassy groundmass. The feldspar laths are small and not more than .7 mm . in length, but reasonably accurate determinations indicate a composition in the range of intermediate labradorite $\left(\mathrm{An}_{45-50}\right)$. This mineral constitutes about 35 per cent of the rock. The augite is colorless and is in twimned, subhedral grains that constitute about 10 per cent of the rock. The remainder of the rock is dark basaltic glass.

Bindloe Island (Marchena; Torres). Of the three rock specimens collected on Bindloe Island, only one, no. 86, was available for study. This specimen was collected from a lava flow well exposed along the west coast of the island which appears to consist largely of pyroclastic deposits with a few narrow, smooth-surfaced lava flows.

Specimen no. 86 is basalt. It is porphyritic, slightly vesicular, and contains phenocrysts of feldspar up to one-half inch across enclosed in a finegrained, medium-gray colored groundmass.

The feldspar phenocrysts are euhedral to subhedral in shape, unaltered and constitute from 15-20 per cent of the rock. This mineral shows zoning, a combination of twinning, and a composition in the range of intermediate labradorite $\left(\mathrm{An}_{50}\right)$. The groundmass feldspar is in irregular-shaped laths that range up to .6 mm . in length. The laths are fresh and constitute as much as $45-50$ per cent of the rock. They are twinned, but not zoned, and have a composition slightly more sodic than the feldspar phenocrysts, and are in the range of $A n_{45}$ to $A n_{50}$. The augite is in angular grains which are seldom more than .2 mm . across. The mineral is slightly pleochroic in pale pinkish to pale greenish colors, unaltered, and is untwinned and unzoned.


Figure 2. Map of the Pacific Ocean off the west coast of Central America showing the location of Cocos, Malpelo, Cedros, San Benito, Tres Marias and White Friars islands.

It constitutes about 35 per cent of the rock. Magnetite which occurs in irregular grains, scattered among the other minerals, constitutes about 5 per cent of the rock.

Tower Island (Genovesa, Ewres). Only one specimen was collected on Tower Island, and this is a basalt from one of several prominent lava flows well exposed in Darwin Bay. The basalt from Darwin Bay, is moderately vesicular and porphyritic, with phenocrusts of feldspar up to one-quarter inch across set in a fine-grained, dense, gray groundmass.

The feldspar phenocrysts are euhedral and subhedral in shape, and show well developed zoning and twinning. They are in the composition range of intermediate labadonite $\mathrm{An}_{50-55 .}$. The crystals are slightly altered and contain small, dark, angular and irregular shaped inclusions. The groundmass feldspar occurs in poorly developed lath-shaped crystals. They are fresh and range in composition from $\mathrm{An}_{45}$ to $\mathrm{An}_{50}$.

Augite occurs as euhedral phenocrysts and as anhedral grains in the groundmass. This mineral is common, fresh and lacks zoning and twinning.

Olivine occurs sparingly as euhedral grains in the groundmass. It is colorless where unaltered, but commonly shows alteration to golden brown iddingsite.

Jeryis Island (Rábida). Four rock samples were collected on Jervis Island, and only one of these, a lava, was collected from loose boulders which occur on the north side of the island.

The rock specimen no. 38, collected from Jervis Island is an olivine basalt. It is porphyritic and contains phenocrysts of olivine and feldspar, both as much as one-quarter inch across, set in a medium-grained gray groundmass. In thin section the rock has a xenomorphic-granular texture, yet with phenocrysts of olivine and feldspar set in a granular groundmass composed of the same minerals plus augite and a small amount of glass.

The plagioclase in the phenocrysts and in the groundmass appear to be identical in all respects except in size, of which the phenocrysts are as much as one-quarter inch across and the groundmass grains rarely more than 3 mm . across. The feldspar is fresh and constitutes between 25 and 30 per cent of the rock. The crystals are twinned and a few of the phenocrysts show zoning. Inclusions of dark glass are common and appear to be concentrated along the margins of the crystals where they are elongated and arranged in rows parallel to cleavage and twimning planes. The feldspar is intermediate labradorite, $\mathrm{An}_{50-5,5}$.

Augite is pale greenish in color, and occurs as anhedral crystals as much as .5 mm . across. This mineral, too, has dark glass inclusions, but in lesser amounts than the feldspar. The augite is fresh and constitutes about 50 per cent of the rock.

Olivine is in colorless anhedral crystals that show zones of yellow which are due to limonite and not the result of alteration to iddingsite.

South Seymour Island (Baltra). Three specimens were collected on South Seymour Island, and only two of these, nos. 27256 and 32, were available for study.

Specimen no. 27256 is fossiliferous limestone from one of beach terraces near the southern part of the island (no. 2 of Ochsner), and specimen no. 32 is from a lava flow that rests upon the fossiliferous terrace deposits, also in the southern part of the island.

Specimen no. 27256 should properly be called a fossiliferous tuffaceous sandstone. It contains white fossil shell fragments and dark brown, dark red and buff colored volcanic rock fragments enclosed in a medium-gray, fine-grained, dense groundmass.

Under the microscope one can see rounded grains of orange-red pumice containing phenocrysts of plagioclase, $\mathrm{An}_{50}$, rounded grains of plagioclase, $\mathrm{An}_{45-50}$, olivine altered almost wholly to orange-red iddingsite, and white shell fragments all enclosed in a murky matrix of secondary calcite.

Specimen no. 32 is andesite. It is a fine-grained, weakly prophyritic. medium- to dark-gray colored rock. Phenocrysts of plagioclase are uncommon, and range in size from .6 to 1.0 mm . The crystals are lath-shaped, fresh, and show simple albite and carlsbad twinning. They are in the composition range of $\mathrm{An}_{3,5}$ to $\mathrm{An}_{40}$. The groundmass plagioclase occurs as microlites which are less than .5 mm . in length. They are abundant and constitute about 30 per cent of this rock. The microlites of plagioclase have the same range in composition as the plagioclase phenocrysts. Augite is also very common, and it occurs in two distinct sizes: as small anhedral grains less than .1 mm . in diameter scattered throughout the rock and as larger subhedral grains up to .5 mm . across. The smaller grains are nearly colorless and the larger grains show pale pinkish and greenish pleochroic colors. All of the augite is fresh and untwinned. Magnetite is common and constitutes about 10 per cent of the rock.

Indefatigable Island (Santa Cruz; Bolivia; Norfolk; Porter; Valdéz: Chavez; San Clemente). Five specimens were collected on Indefatigable Island. Of these specimens, no. 28, was the only specimen available for study. It is a dense, fine-grained, dark gray, slightly vesicular olivine basalt. Under the microscope, the olivine basalt has a diabasic-intergranular texture. Plagioclase, which constitutes approximately 40 per cent of the rock, occurs in lath-shaped crystals that range up to 1.0 mm . in length. It is twinned, fresh and has a composition of $\mathrm{An}_{50}$. Augite occurs in large irregular-shaped crystals and constitutes approximately 45 per cent of the rock. It is weakly pleochroic in shades of pale purple and light green. Olivine is colorless when fresh, but golden-yellow when altered to iddingsite. It occurs in subhedral-shaped grains and constitutes about 15 per cent of the rock. Both magnetite and ilmenite are present. Magnetite is in angular and rounded grains whereas the ilmenite is in small skeletal crystals, usually enclosed in the feldspar.

Albenarle Island (Isabela; Santa Gertrudis). Eleven specimens were collected on Albemarle Island. Specimens numbered 44, 47, 48, 51, 52, and 54 are volcanic rocks, and of these specimens only nos. $48,49,50$, and 52 were available for study. Specimen no. 48 is basalt. It is non-vesicular, porphyritic, and contains phenocrysts of feldspar and angite up to oneeighth inch in length enclosed in a dense, fine-grained, medium-gray colored groundmass. The phenocrystic feldspar, in the composition range of $A n_{\overline{5}}$ to $\mathrm{An}_{60}$, occurs as anhedral and subhedral shaped grains. They are completely twinned, but not zoned or altered. Augite occurs as small granular inclusions in the larger feldspar phenocrysts. The groundmass feldspar, whose composition is approximately $\mathrm{An}_{50}$, occurs as irregular-shaped laths that are slightly more sodic than the feldspar phenocrysts. The groundmass feldspar constitutes about 25 per cent of the rock. Augite, although ocur-
ring as phenocrysts and in the groundmass too, is more abundant in the groundmass. It is pale-greenish in color and shows twinning but no zoning. The phenocrysts are euhedral in shape, whereas the groundmass grains are subhedral and anhedral in shape. Few of the phenocrysts of augite are rimmed with dust-like particles of magnetite, and a few of the grains in the groundmass are almost completely clouded by magnetite.

Specimen no. 49 is a crystal-lithic-vitric tuff. It contains pyroclasts of plagioclase, porphyritic basalt and andesite, and pumice set in a groundmass of fine-grained, partly altered glass. The feldspar pyroclasts are subhedral and anhedral in shape, and range in composition from $\mathrm{An}_{40}$ to $\mathrm{An}_{50}$. The larger grains contain bleb-shaped inclusions of pale-yellowish glass, arranged parallel to twinning planes. The larger grains are unaltered, but a few of the smaller feldspar grains have a narrow rim of pale-yellowish opal. Augite pyroclasts are colorless, and are rimmed by yellowish nontronite. The lithic pyroclasts consisting essentially of andesite and basalt, are rounded and also rimmed by opaline silica. The pumice pyroclasts are rounded and contain a few crystals of potash feldspar (sanidine) as well as some yellowish colored nontronite. A small amount of secondary calcite is present.

Specimen no. 50 is tuff-breccia. It consists of angular and rounded, dark-gray pumice fragments up to one-half inch across enclosed in a medium- to fine-grained, grayish- and greenish-brown matrix of partly altered volcanic ash.

Specimen no. 52 is a porphyritic basalt from Tagus cove. It contains phenocrysts of plagioclase and augite up to one-quarter inch across enclosed in a fine-grained, dense, dark-gray, vesicular groundmass. The plagioclase phenocrysts are in the composition range of $\mathrm{An}_{55}$ to $\mathrm{An}_{60}$, and occur in subhedral and anhedral grains that are well twinned and show zoning. Inclusions of dark glass are present, and especially noticeable at the interior of the feldspar grain where they are arranged in elongated clots parallel to the twinning planes. The groundmass feldspar occurs in microlites that constitute about 30 per cent of the rock. They are twinned and range in composition from $\mathrm{An}_{50}$ to $\mathrm{An}_{55}$. Augite occurs as euhedral phenocrysts and as anhedral grains scattered among the feldspar microlites. The angite is fresh, though in places it is stained yellowish-orange by limonite. It constitutes about 30 per cent of the rock. The remainder of the rock is dark basaltic glass.

Barrington Island (Santa Fé). Three specimens were collected on Barrington Island; and only one of these (no. 73), a specimen of olivine basalt, was available for study. It is said to be characteristic of the lava flows in the northern part of the island. This olivine basalt is a fine-grained, slightly vesicular rock containing phenocrysts of olivine and plagioclase set


Figure 3. Olivine basalt from Barrington Island, Galápagos Achipelago. Phenocrysts of olivine are rimmed by yellow iddingsite and are enclosed in a groundmass composed of plagioclase laths $\left(\mathrm{An}_{60}\right)$ and granular augite. Plain light. $\times 30$.
in a groundmass of feldspar laths and augite grains. The plagioclase phenocrysts are labradorite $\left(\mathrm{An}_{60}\right)$ and occur as slightly rounded, twinned, unzoned crystals as much as .2 mm . across. The feldspar phenocrysts are fresh and constitute about 5 per cent of the rock. The groundmass feldspar occurs in lath-shaped crystals not more than .5 mm . in length. They are fresh, twinned, not zoned and are in the composition range of $\mathrm{An}_{45}$ to $\mathrm{An}_{50}$.

Olivine occurs as subhedral and anhedral grains up to .2 mm . in diameter. They are colorless and slightly altered to golden-yellow iddingsite. Olivine also makes up part of the groundmass where it occurs in rounded grains scattered among the feldspar laths. It constitutes approximately 20 per cent of the rock. Augite occurs in irregular-shaped crystals that include small laths of feldspar. It is weakly pleochroic from pale pinkish-purple to pale greenish, and constitutes about 40 per cent of the rock.

Chatham Island (San Cristóbal; Dassigney; Grande). Five rock specimens were collected on Chatham Island. Only one of these specimens,


Figure 4. Olivine basalt from Chatham Island, Galápagos Archipelago. Phenocrysts of olivine enclosed in a groundmass of plagioclase ( $\mathrm{An} n_{50}$ ) and augite. Plain light. $\times 30$.
no. 43 , an olivine basalt collected at the terminus of a lava flow south of Sappho Cove, was available for study. The olivine basalt from Sappho Cove is a fine-grained, finely-vesicular, medium-gray porphyritic rock which contains phenocrysts of augite and plagioclase enclosed in an intergranular groundmass of feldspar laths and grains of augite and olivine. The feldspar phenocrysts, intermediate labradorite $\mathrm{An}_{55}-\mathrm{An}_{60}$, occur in subhedral and anhedral crystals up to .5 mm . across. They are fresh, well-twinned and constitute about 10 per cent of the rock. The groundmass plagioclase $\left(A n_{50}\right)$ is slightly more sodic than the feldspar phenocrysts, and occurs as lath-shaped crystals partly enclosed in the augite and partly forming a mesh structure which is infilled by smaller augite crystals. The groundmass feldspar constitutes about 50 per cent of the rock. The augite occurs in colorless and pale-purplish, irregular-shaped crestals that measure as much as .6 mm . across. This mineral is unaltered and constitutes between 35 and 40 per cent of the rock. Olivine is in euhedral to subhedral grains. It is colorless where fresh, but is altered in part to golden-yellow iddingsite,
especially around the margins of the crystals. Olivine constitutes between 10 and 15 per cent of the rock.

Charles Island (Santa María; Floreana). Eight rock specimens were collected on Charles Island. Two of these specimens numbered 59 and 63 , were available for study. Specimen no. 59 was collected from an exposure on Cormorant Bay and is a crystal-vitric-lithic tuff. In hand specimen this rock is dark, greenish-black to black in color and contains angular pyroclasts set in a fine-grained, dense matrix of dark-brown colored glass.

Under the microscope one can see angular pyroclasts of colorless augite and irregular grains of basic andesine $\mathrm{An}_{45}$, and rounded pyroclasts of slightly vesicular, amygdaloidal, and vitrophyric glass. These pyroclasts of glass constitute a bulk of the rock. They are yellow in color, with the interior part being canary-yellow and the rims a golden-yellow. The amygdules are ovoid in shape and more or less completely filled with secondary calcite. Augite and andesine are the crystalline constituents in the glassy prroclasts. The augite is colorless and is in angular crystals. The andesine ( $A n_{40}$ to $\mathrm{An}_{45}$ ) occurs in lath-shaped as well as in irregular-shaped crystals. The matrix is a glass. It is grayish in color and contains finely divided magnetic as well as microlitic laths of andesine and angular grains of colorless angite.

This tuff is similar in many respects to the tuffs found on Albemarle Island, excepting the tuff from Cormorant Bay on Charles Island contains very small amounts of lithic material such as pyroclasts of andesite and basalt. Specimen no. 63 is said to be representative of a lava flow which reached the ocean at Black Beach Road (Ochsner, unpublished manuscript). The rock is basaltic in composition. It is porphyritic and contains phenocrysts of plagioclase and prroxene set in a sub-ophitic groundmass of plagioclase microlites and intergranular augite.

The plagioclase phenocrysts $\left(A n_{\overline{\overline{5}}}\right.$ to $\left.A n_{60}\right)$ occur in subhedral and anhedral grains. They are completely twinned, zoned and show a slight amount of alteration. The larger phenocrysts, up to .5 mm . across, contain numerous inclusions of glass, augite, and alteration products of the pyroxene, all localized more toward the interior of the crystal and oriented parallel to the twinning planes. The plagioclase phenocrysts constitute about 25 per cent of the rock.

The plagioclase in the groundmass has the composition of $\mathrm{An}_{5 \overline{5}}$ and occurs in subhedral and irregular-shaped crystals up to .4 mm . in length. They are twinned, but not altered, and constitute about 30 per cent of the rock. The pyroxene is hypersthene which occurs in slightly colored euhedral grains that exhibit weak pleochroic colors. Many of the larger crystals of hypersthene have a rim of iddingsite; the smaller grains are almost completely altered to iddingsite.

Small amounts of magnetite and colorless glass are present in the rock.

Hood Island (Española). Three rock specimens were collected on Hood Island. Specimen no. 65 is from a lava flow exposed in the cliff southwest of Cardner Bay, and specimen no. 69 from a lava flow exposed due west of Gardner Bay. Specimen no. 65 is olivine basalt. It is porphyritic and contains phenocrysts of olivine and plagioclase set in a dense, finegrained, dark-gray groundmass composed of plagioclase microlites and grains of augite. The plagioclase phenocrysts are in rounded, zoned crystals that range in composition from $\mathrm{An}_{45}$ to $\mathrm{An}_{55}$. They contain numerous inclusions of very small crystals of apatite and augite which tend to be concentrated in the outer zone of the phenocrysts. The plagioclase microlites are slightly more sodic than the phenocrysts and have a composition of approximately $\mathrm{An}_{45}$.

Augite is in small, colorless, subhedral and anhedral grains. It is very common and constitutes about 25 per cent of the rock. Olivine occurs as anhedral crystals, of which many of them have been altered in part to iddingsite. Olivine constitutes about 20 per cent of the rocks. Specimen no. 69 , too, is olivine basalt, and is similar in many respects to specimen no. 65 , excepting the augite which in specimen no. 69 is pale purplish in color, indicates the presence of titanium in more than normal amounts.

## Cocos Island

Cocos Island, governed by Costa Rica, is located on latitude $5^{\circ} 32^{\prime} \mathrm{N}$. . about 650 miles west of Cape Corrientes, Colombia. It is a volcanic island approximately 4 miles long and slightly more than 2 miles wide, with a maximum elevation of 1932 feet* above sea level. Six rock specimens were collected on Cocos Island by W. H. Ochsner in 1905, and by Dr. Leo G. Hertlein, California Academy of Sciences, February, 1932. Specimen nos. $14-1$ and 17 are basalt, no. $12-1$ is latite, no. $13-1$ is tuff-breccia, and no. $18-1$ is andesite (oligophyre).

Specimen no. $14-1$ is basalt. It is a dense, fine-grained, medium-gray, slightly porphyritic rock containing phenocrysts of plagioclase and hypersthene enclosed in a sub-ophitic groundmass of plagioclase laths and microlites and intergranular hypersthene. The plagioclase phenocrysts are anhedral in shape and are in the composition range of $\mathrm{An}_{5 \overline{5}}$ to $\mathrm{An}_{60}$. Both zoning and twinning are common, and a few of the crystals are partly altered. The larger phenocrysts contain many inelusions of glass, hypersthene, and its alteration products. The inclusions tend to be localized more at the central portion of the crostal and in a few crystals they are oriented somewhat parailel to the twinning planes. The plagioclase phenocrysts constitute about 25 per cent of the rock. The groundmass plagioclase

[^23]

Figure 5. Oligophyre from Cocos Island. The euhedral phenocryst of olivine which has been altered entirely to iddingsite, is enclosed in a trachytic groundmass of oligoclase laths and grains of olivine. Plain light. $\times 30$.
occurs in microlites and subhedral, irregular-shaped laths, of which the latter are no more than .4 mm . in length. The laths are twinned, but not altered and are slightly more sodic than the phenocrysts. The groundmass feldspar constitutes about 30 per cent of the rock. Hypersthene occurs in euhedral crystals, of which a majority are phenocrysts. The large hypersthene crystals have a narrow rim of yellow iddingsite, whereas, the smallgrains of hypersthene are altered largely to yellowish-orange iddingsite. Minor accessory materials include colorless glass and grains of black magnitite. Specimen no. 16, olivine basalt, is porphyritic and contains phenocrysts of olivine and plagioclase set in a groundmass of plagioclase laths and grains of augite.

The plagioclase phenocrysts are subhedral to euhedral and exhibit well developed twinning and zoning. Their composition is in the range of $A n_{50}$ to $A n_{55}$ and most of the alteration is at the interior of the crystals where they are more calcic. The groundmass plagioclase occurs in irregular, lath-shaped crystals. Because of their small size their composition is difficult to determine, but it is in the range of $\mathrm{An}_{45}-\mathrm{An}_{50}$. The olivine is in
euhedral-shaped crystals which are altered largely to iddingsite, especially around the margins of the crystals. Augite is present in small colorless grains. Secondary materials include iddingsite, limonite, and sericite. A small amount of dark glass occurs interstitially between the feldspar laths.

Specimen no. 17 is also an olivine basalt. It has a porphyritic texture and contains phenocrysts of plagioclase and hypersthene enclosed in a finegrained groundmass of feldspar laths and grains of olivine and hypersthene.

The plagioclase phenocrests are in anhedral and subhedral-shaped cerystals and are in the composition range of $\mathrm{An}_{4,5}$ to $\mathrm{An}_{515}$. They are completely twinned, zoned, and remarkably fresh. The groundmass plagioclase is in small, lath-shaped errystals and is in the composition range of $\mathrm{An}_{40}$ to $\mathrm{An}_{45}$. They are twinned, unaltered and show no zoning.

Hypersthene occurs in euhedral-shaped crystals that show faint pleochroism, and are rarely twinned. Olivine is in euhedral-shaped erystals that show almost complete alteration to yellowish-orange iddingsite.

Specimen no. 12-1 from Cocos Island is latite. It is slightly vesicular, purplish-gray in color, and porphyritic with phenocrests of plagioclase set in a fine-grained groundmass. The plagioclase phenocrysts occur as euhedral and subhedral grains of which some are skeletal and contain inclusions of magnetite and glass. Their composition is oligoclase, in the range of $\mathrm{An}_{20}$ to $\mathrm{An}_{25}$. The crystals are zoned and complexly twinned and constitute about 10 per cent of the rock. The plagioclase in the groundmass is slightly more sodic than the phenocrysts and have an An content of about 20 per cent. The grains are anhedral and show slight alteration, twinning, and zoning. They are very abundant and constitute about 80 per cent of the rock. The pyroxene is diopsidic-augite and it occurs in pale, rellowishgreen anhedral grains. It makes up about 5 per cent of the rock. Magnetite occurs in irregular-shaped grains which are commonly surrounded by yellow limonite.
specimen no. 13-1 is a lapilli-tuff-breceia. This rock is well consolidated and consists of angular and rounded fragments of dark-gray and brownish vesiculated glass, lithic material, and mineral grains set in a fine-grained ashy matrix. The vesiculated glass fragments range up to three-eighths of an inch across. They are relatively unaltered, and contain very few phenocrysts, but refractive index determinations made on the glass indicate an andesitic composition. In addition to the vesiculated glass fragment, the rock contains also dark pyroclasts of vitrophyre which have phenocrysts of intermediate andesine, $\left(\mathrm{An}_{45}\right)$ enclosed in a dark glass. The lithic fragments are of three trpes: hormblende andesite, andesite, and basalt. The hormblende andesite contains strongly pleochroic, needle-shaped erystals of hormblende and fresh andesine $\left(\mathrm{An}_{40-45}\right)$. The andesite is composed of andesine phenocrysts $\left(\mathrm{An}_{45-50}\right)$, set in a groundmass of small andesine


Figure 6. Olivine basalt from Cocos Island. Phenocrysts of plagioclase (An $\mathrm{A}_{4}$ to $\mathrm{An}_{\mathrm{an}}$ ) and olivine enclosed in a fine-granied groundmass of feldspar laths and grains of olivine and hypersthene. Plain light. $\times 30$.
grains and colorless diopsidicaugite. The basalt pyroclasts, on the other hand, are much darker in color than either of the andesite pyroclasts and contains phenocrysts of labradorite ( $\mathrm{An}_{60-65}$ ), enclosed in a fine-grained groundmass of plagioclase microlites and small, anhedral grains of augite. Olivine, too, is present in the basalt and this mineral is in small, anhedral grains which are altered largely to iddingsite. Mineral pyroclasts include euhedral grains of plagioclase in the composition range of $\mathrm{An}_{40}$ to $\mathrm{An}_{45}$, subhedral, fiesh and colorless grains of hypersthene, rounded and corroded grains of brown hornblende, and a few rounded grains of quartz.

Specimen no. $18-1$ is by far the most interesting rock collected on Cocos Island. The rock is called an oligophyre for want of a better name. It is fine-grained, buff-colored, and has a poorly defined flow banding. Under the microscope one can see that the rock is weakly porphyritic. It is composed largely of oligoclase. The phenocrysts of oligoclase are anhedral and are in the composition range of $\mathrm{An}_{30}$ to $\mathrm{An}_{35}$. The groundmass oligoclase $\left(\mathrm{An}_{20-25}\right)$ is in lath-shaped grains that are arranged in zones around the
oligoclase phenocrysts. Diopsidic-augite is present in colorless, subhedral grains. Biotite is in dark brown, strongly pleochroic, anhedral grains. Both of these ferromagnesian minerals are present in about equal amounts. Magnetite occurs in cubic-shaped grains. Secondary minerals include limonite, which is probably derived either from the biotite or from the small amount of prrite that is present in the rock.

## Malpelo Island

Malpelo Island is on latitude $3^{\circ} 59^{\prime} \mathrm{N}$., and lies about 250 nautical miles westerly from Buenaventura, Colombia. It is a territory of the Republic of Colombia and was known as early as 1530. The island is of volcanic origin and is approximately one and one-half miles long, one-half mile wide, and has a maximum elevation of 854 feet above sea level. Very little has been written regarding the geology of Malpelo Island, and only a limited amount is known about the rocks that are exposed there. McConnell (1943) gives an excellent description of the fresh lava and phosphatized rocks that were collected by Comandante Eduardo Fallon of the Colombian Navy in December, 1940 (Murphy, 1941, p. 57).

Two rock specimens were collected by C. B. Perkins, herpetologist, San Diego Zoo, in December, 1931, and the following comments are based upon a study of these specimens. One is pyroxene andesite and the other is phosphate rock.

The pyroxene andesite is greenish-gray in color, dense, and fine-grained. Under the microscope the rock is holocrystalline, microporphyritic, and has a pilotaxitic texture. The plagioclase phenocrysts are fractured, twinned, slightly altered, and range in composition from $\mathrm{An}_{35}$ to $\mathrm{An}_{40}$. The plagioclase that comprises a bulk of the groundmass is in microlites whose composition based upon limited determination is in the range of $\mathrm{An}_{20}$ to $\mathrm{An}_{25}$. The plagioclase phenocrysts and groundmass microlites combined constitute about 50 per cent of the rock. The pyroxene, diopsidic-augite, occurs in colorless, anhedral grains usually no more than .05 mm . across, and occasionally in larger grains up to .1 mm . across. It constitutes about 20 per cent of the rock. Chloritic material is present, especially in close association with the plagioclase phenocrysts and the larger pyroxene grains. It is grass-green in color, moderately pleochroic, and locally stained brown by limonite. Both quartz and chalcedony are present, but as secondary minerals, and in small amounts. Scattered uniformly throughout the rock are black, slightly angular, needlelike crystals. They are opaque and could possibly be ilmenite. The phosphate rock is dark brownish-black, mottled, and fine- to medium-grained. Under the microscope it is dark brown in color with scattered irregular, colorless areas, composed of quartz and chalcedony. Calcite is present in narrow, curved veinlets.

Because of the lack of relict mineral grains in the phosphate rock, it is exceedingly difficult to determine whether it was originally a pyroclastic or flow rock. One could speculate, on the basis of lack of crystalline constituents, that the original rock was a vitric-crystal tuff in which the crystalline constituents were titanium and iron-bearing minerals, or titaniferous magnitite.

## Cedros Island

Cedros (Cerros) Island is situated just outside of Sebastian Vizeaino Bay, on the west side of Baja California, midway between San Diego and Cape San Lucas. The island is elongated in a north-south direction, and measures about 22 miles long and 7 miles wide. The highest peak is Cedros Mountain whose elevation is 3950 feet. Very little is known about the geology of the island, but from observers (Hanna, 1925, p. 268) who have visited the island we learn that it is composed largely of cherts, sandstones, schists, and serpentine, all similar in many respects to the Franciscan rocks (upper Jurassic) that are exposed so well in the San Francisco Bay area. In addition there are Miocene and Pliocene sedimentary rocks on the eastern side of the island and some volcanic rocks of presumably Tertiary age at the southwest corner of the island.

Two rock specimens were collected on Cedros Island: Specimen no. 7 is tuff-breceia and specimen no. 9 is glaucophanized volcanic rock.

Specimen no. 7 tuff-breccia, is orange red in color, somewhat friable, and contains partly altered pumice fragments, pyroclasts of basalt, and grains of augite, altered olivine, biotite, hornblende, and plagioclase ( $A n_{50}$ ), all enclosed in a matrix of partly devitrified, brownish colored glass. The basalt pyroclasts are of two types, one which is composed wholly of a felted mat of plagioclase $\left(\mathrm{An}_{50}\right)$ laths, and the other which contains plagioclase microlites $\left(\mathrm{An}_{\overline{50-5} 5}\right)$ set in a dark brownish glass which constitutes at least 50 per cent of the rock.

Specimen no. 9, glaucophanized volcanic rock, the first of two metamorphic rocks to be mentioned in this paper, is a dense, fine-grained bluish gray rock. Distinct foliation is lacking and the rock has a cataclastic texture. Glaucophane is common and contributes largely to the bluish coloration imported to the rock. It occurs in ragged and irregular-shaped grains that are strongly pleochroic with $X=$ pale greenish-colorless, $y=$ lavender blue, $\mathrm{z}=$ blue. The glancophane appears to have formed in part from a colorless pyroxene, and it is altered locally to a fibrous mineral of low birefringence. Tremolite is very abundant and constitutes at least 45 per cent of the rock. It occurs in small, lath-shaped crystals and fibrous needles. usually arranged in angular and subangular clots.

Both calcite and aragonite are present. The calacite is colorless and is
in veins, whereas the aragonite, which, too, is colorless, is present as discrete grains forming a mineral phase in the rock. A pyroxene of diopsidic-augite composition occurs as rounded grains that have altered in part to glaucophane and to pale-green chlorite. Quartz is not abundant, but this mineral is present as small rounded grains seattered irregularly throughout the rock.

Because of the lack of distinct foliation, the irregular distribution of the glaucophane and tremolite, and the presence of relict pyroxene, it is believed that the glaucophane rock was derived from a basic voleanic rock.

## Sin Benito Islands

The San Benito Islands are about 18 miles west of Cedros Island. There are three islands in the group. West San Benito (the largest), Middle San Benito (smallest), and East San Benito (next largest); all lie close together in an east west line. West and middle San Benito are composed largely of Franciscan chert, and East San Benito, the most rugged of the three islands, contains schist and marble in addition to chert (Hanna, 1924, pp. 373-374) (Van West, 1959, pp. 8-13). Only one specimen was available from San Benito Islands for study, and it is a glaucophane schist, collected on East San Benito Island.

The glaucophane schist is a medium-to-fine-grained, grayish-blue rock that shows well developed foliation. Under the microscope one can see wispy muscovite plates curved around earlier formed grains of glaucophane and plagioclase. Glaucophane occurs in irregular-shaped to xenoblastic crystals that show distinct pleochroism: = colorless, $\mathrm{y}=$ purplish blue, $z=$ ultramarine blue. The crystals appear broken as though they had developed early and were fractured and disrupted during shearing stages of metamorphism. Plagioclase ( $\Lambda n_{\mathfrak{r}_{j-10}}$ ) occurs as rounded and angular grains, usually closely associated with quartz which, too, is in rounded grains. The quartz shows undulatory extinction. Muscovite is present as wispy-shred-like aggregates of small plates. It apparently developed late. Van West (1958, pp. 535-37) deseribes glatcophane sehists from San Benito Islands similar to that mentioned immediately above and states that this is ". . . a common variety among the glaucophane schists formed on East San Benito Island."

## Tres Maríls Islands

The Tres Marías Islands, consisting of Maria Madre, Maria Magdalena, and Maria Cleofas, lie about 55 miles oft the west coast of Mexico, west of San Blas, Nayarit, hetween latitudes $21^{\circ}$ and $22^{\circ}$ N., and longitudes $106^{\circ}$ and $107^{\circ} \mathrm{W}$. (see fig. 2. 2 ).

Much has been written of the paleontology of these islands as a result
of expeditions by the California Academy of Sciences. However a few remarks about some of the rocks collected in 1925 by G D. Hanna and E. K. Jordon. and other rocks collected and reported upon by Hertlein and Emerson (1959, p. 4) will help to explain further the geology of these islands.

All of the rock specimens were collected on María Madre Island which. according to Hanna (1926, p. 69) is stated as consisting ". . . of granite, chiefly, with a rim of diorite around the edges." It is apparently from this granitic core and dioritic rim that the specimens of biotite granite and hornblende-quartz diorite porphyry were collected. The biotite granite (CAS-35) is a medium-grained, light-colored rock which is speckled by biotite and hornblende. Under the microscope the rock has a hypidiomorphicgranular texture, the texture common to most plutonic rocks of this composition. Both orthoclase and plagioclase feldspars are present and where they occur adjacent to another a myrmeketic border has developed on the orthoclase. The orthoclase is in anhedral grains which constitute about 40 per cent of the rock. It is fresh for the most part and contains a small amount of sericite along fractures. Plagioclase, in the composition range of $\mathrm{An}_{10}$ to $\mathrm{An}_{15}$, occurs in subhedral and anhedral grains which, too, contain some sericite. Zoning is absent, but the twinning in the plagioclase is complex. This mineral constitutes about 20 per cent of the rock. Quartz is in rounded, slightly fractured grains. It constitutes about 10 per cent of the rock. Biotite is present in strongly, pleochroic, dark greenish-brown subhedral grains. This mineral has been altered locally to deep-green chlorite and contains small inclusions of zircon and apatite. Hornblende is in short prismatic crystals. It is fresh, grass-green in color, and too contains inclusions of apatite and zircon.

CAS-39, the hornblende-quartz diorite porphyry, is considerably darker colored than the biotite granite. It has a distinct porphyritic texture and contains phenocrysts of plagioclase, quartz, and hornblende enclosed in fine, granular groundmass of the same materials.

The plagioclase phenocrysts are subhedral in shape and range up to . 4 mm . in size. They are zoned and complexly twinned and range in composition from core to rim, from $\mathrm{An}_{30}$ to $\mathrm{An}_{25}$. Alteration is present, principally to sericite and calcite, with the cores being more highly altered than the rims. This mineral constitutes about 40 per cent of the rock. The groundmass feldspar is in small lath-shaped crystals that average less than .5 mm . in length. They range in composition from $\mathrm{An}_{20}-\mathrm{An}_{25}$, show slight alteration to sericite, and locally form diabasic intergrowths with the quartz. The groundmass plagioclase constitutes about 20 per cent of the rock. Quartz occurs as angular phenocrysts up to .4 mm . across and as rounded grains in the groundmass. It constitutes about 10 per cent of the rock. The horn-
blende is in pale-green crystals that have a moth-eaten appearance. It is weakly pleochroic, contains inclusions of apatite and magnetite, and constitutes about 5 per cent of the rock. A small amount of deep-green biotite is present. It is strongly pleochroic in shades of green and brown, and contains inclusions of apatite and magnetite. Several specimens of rhyolite (CAS-37 and 38) were collected as float in the first main canyon southwest of the village on María Madre Island. The rhyolite is a fine-grained, dense rock and ranges in color from purplish-gray to gray. It shows flow banding and contains white, rounded phenocrysts and small cavities of which the latter now contain small, well-formed quartz crystals. The rock is porphyritic and contains altered phenocrysts of plagioclase and green biotite enclosed in a fine-grained groundmass which shows a micrographic structure. The plagioclase phenocrysts are subhedral in shape, show simple twinning, and are in the composition range of $\mathrm{An}_{15}$ to $\mathrm{An} n_{20}$. Alteration of the plagioclase is principally to sericite and calcite. The phenocrysts constitute about 10 per cent of the rock. The groundmass feldspar is orthoclase and is in anhedral, untwimned, slightly altered grains. It forms microscopic intergrowths with quartz and constitutes about 50 per cent of the rock. Excepting for a few seattered ragged-appearing, green-colored phenocrysts of biotite, quartz comprises the remainder of the rock. It occurs both as distinct anhedral grains and in micrographic intergrowths with the groundmass feldspar. In the same canyon where the rhyolite was collected and upstream from the contact between the Pliocene sedimentary rocks and the underlying granite, a specimen (CAS no. 36) of rhyolite granophyre was collected from an outcrop of this rock. The granophyre resembles the rhyolite in hand specimen. It lacks the flow banding which is so characteristic of the rhyolite, but does show phenocrysts of feldspar and has a dull gray color. The texture of the rock is granophyric and porphyritic, and the rock contains rounded phenocrysts of plagioclase and quartz set in a granophyric intergrowth of quartz and orthoclase. The plagioclase, though slightly altered is in the composition range of $\mathrm{An}_{19}$ to $\mathrm{An}_{15}$. It is subhedral in shape and measures up to .3 mm . in size. The groundmass feldspar, orthoclase is less altered than the phenocrystic, and constitutes about 45 per cent of the rock. Quartz occurs sparingly as rounded phenocrysts. However, it is more abundant in the groundmass where it is much coarser grained when intergrown with the orthoclase. The quartz constitutes about 40 per cent of the rock. The biotite is green, strongly pleochroic, and occurs in sponge-like crystals with irregular outlines.

Specimen CAS-40 is fossiliferous siltstone and was obtained from a large boulder in the first main canyon southwest of the village on Maria Madre Island. The siltstone is fine-grained and contains rounded and angular grains of quartz and shell fragments, and fossil foraminifera in a matrix consisting of calcite and chalcedonic silica. C. C. Chureh (written
communication, January, 1963) kindly examined the siltstone and identified the following genera:

Peneroplis sp.
Bolivina sp.
Bulimina sp. similar to B. ovata
Frondicularia sp.
Globigerina sp.
These fossils indicate late Tertiary (possibly Pliocene) age for the siltstone.

## White Friars Islands (Morro de Papanoa)

During the course of later excursions off the west coast of Mexico by the California Academy of Sciences, several rock specimens were collected by Dr. Leo $G$. Hertlein from a group of small islands which lie some 5 to 6 miles south of Zihuatenejo, State of Guerrero. These islands are referred to as the White Friars and are said to resemble members of that monastic order in a kneeling position.


Figure 7. Phosphate rock from the White Friars Islands. Veins of white metavariscite in collophane. Plain light. $\times 30$.

Most of the rock specimens collected by Dr. Hertlein are highly phosphatized volcanic rock, but one (CAS-42) is reasonably unaltered and is identified as hormblende andesite. The andesite is porphyritic and contains plagioclase phenocrysts set in a granular matrix of feldspar, hornblende, volcanic glass, and minor quartz. The plagioclase phenocrests are subhedral, twimned, and zoned; a few are bent. Those phenocrysts that show the best zoning are euhedral in shape. Many of the phenocrystic plagioclases are of a pale, pinkish-brown color. These colored feldspar crystals have a composition in the range of $\mathrm{An}_{311}$ to $\mathrm{An}_{355}$. The remaining, non-colored plagioclase phenocrysts are in a composition range of $\mathrm{An}_{45}$ to $\mathrm{An}_{5 \times 11}$. The phenocrystic plagioclase constitutes about 45 per cent of the rock. The groundmass plagioclase is in subhedral and anhedral grains which show twinning, but lack zoning. They are relatively unaltered, range in composition from $\mathrm{An}_{35}$ to $\mathrm{An}_{40}$, and constitute about 40 per cent of the rock.

Hornblende occurs as pale-green, weakly pleochroic, prismatic and skeletal crystals. Biotite is in irregular pleochroic crystals. The hormblende and biotite constitute less than 10 per cent of the rock. The quartz present in this rock is scarce, and occurs in rounded grains that show wary extinction and contain tiny prismatic crystals of zirion. Both apatite and magnetite are present. The apatite occurs as needle-like inclusions in the plagioclase and the magnetite usually in close proximity to the biotite and hornblende. A dark, brown-colored volcanic glass occurs in irregular areas scattered irregularly throughout the rock.

Phosphate Rock. Several samples of phosphate rock were available for study and they appear to be the same in all respects. Specimen no. CAS-44 is the largest and offers the greatest opportunities for detailed petrologic and mineralogic study. It is relatively smooth, dense, and light brownish-gray to beige in color. Cut surfaces show irregularly distributed open voids as well as a well developed colloform banding which in some cases conforms to the outline of the void. Under the microscope the colloform banding shows up fairly well and one can see that the rock consists principally of two distinct materials: (1) a pale-buff to brown-colored, weakly birefringent isotropic mineral whose refractive index and structure indicate collophane and (2) a crystalline, colorless mineral which has moderate to strong birefringence, moderate axial angle, optically positive and an extinction of $Z^{\prime} \wedge C=27^{\circ}$. This latter mineral is metavariscite in which a small amount of iron isomorphously replaces some of the aluminum. The metavariscite occurs as small prismatic crystals and in crusts that show a radial-fibrous structure.

The phosphate rock from the White Friars resembles in many respects the phosphate rock found on Mapelo Island, yet they differ somewhat in their mineralogical content. The phosphate rock on Malpelo consists largely
of phosphosiderite and strengite (McComell, 1943, p. 713) whereas that on the White Friars Islands is collophane and metavariscite.

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# PROCEEDINGS 



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# STUDIES ON THE ATLANTIC AMERICAN PIPEFISHES WITH DESCRIPTIONS OF NEW SPECIES 

By

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The Atlantic American Syngnathid fauna seems to be in the process of evolving many new forms. Some of the divergencies from the parent stock are as yet so slight that a sizable collection of comparative material is often required to distinguish these trends. In part this has been responsible for some of the confusion in the classification within this group. The material herein presented is an attempt to clarify some of the problems.

The descriptions of four new forms in this paper as well as the resurrection of two old names brings the known Atlantic American pipefishes to a total of 29 forms representing 25 species. In the following list, the common names with asterisks appear for the first time. Those without asterisks are from the American Fisheries Society Checklist of Common and Scientific Names (second edition, 1960):

| Opossum Pipefish | Oostethus lineatus (Valenciennes, 1856) |
| :--- | :--- |
| Whitenose Pipefish | Corythoichthys albirostris Heckel, 1853 |
| Crested Pipefish | Corythoichthys brachycephalus (Poey, 1867) |
| *Deepwater Pipefish | Corythoichthys profundus, new species |
| Northern Pipefish | Syngnathus fuscus fuscus Storer, 1839 |
| *Relict Northern Pipefish | Syngnathus fuscus affinis Günther, 1870 |

Gulf Pipefish
Sargassum Pipefish
*Chesapeake Dusky Pipefish
Dusky Pipefish
*Key Dusky Pipefish
*Bermuda Dusky Pipefish
*Caribbean Pipefish
*Pivothead Pipefish
Chain Pipefish
Bull Pipefish
*Southern Pipefish
Shortfin Pipefish
*Ocellated Pipefish
Pugnose Pipefish
*Dwarf Pipefish
*Freshwater Pipefish
*Finless Pipefish
*Lost Pipefish
*Deep-bellied Pipefish
Banded Pipefish
Fringed Pipefish
Insular Pipefish
*Seahorse Pipefish

Syngnathus scovelli (Evermann and Kendall, 1895)

Syngnathus pelagicus Linnaeus, 1758
Syngnathus floridae hubbsi, new subspecies
Syngnathus floridae floridae (Jordan and Gilbert, 1884)
Syngnathus floridae mckayi (Swain and Meek, 1884)

Syngnathus floridae nesiotes Herald, 1942
Syngnathus rousseau Kaup, 1856
Syngnathus fistulatus Peters, 1868
Syngnathus louisianae Günther, 1870
Syngnathus springeri Herald, 1942
Syngnathus folletti Herald, 1942
Syngnathus elucens Poey, 1867
Syngnathus randalli, new species
Syngnathus dunckeri Metzelaar, 1919
Syngnathus hildebrandi, new species
Pseudophallus mindii (Meek and Hildebrand, 1923)

Penetopteryx nanus (Rosen, 1911)
Ichthyocampus pareneei Herald, 1950
Leptonotus blainvilleanus (Eydoux and Gervais, 1837)

Micrognathus vittatus (Kaup, 1856)
Micrognathus (Anarchopterus) crinigerus (Bean and Dressell, 1884)
Micrognathus (Anarchopterus) crinitus (Jenyns, 1842)

Amphelikturus dendriticus (Barbour, 1906)

Since the primary purpose of this paper is to describe new forms that will be treated in more detail in a forthcoming volume of the Sears Foundation, Fishes of the Western North Atlantic, a key will not be published herein. However, during this interim period, a mimeographed key, modified from Herald, 1942, will be available upon request from the author.

Deepwater Pipefish, Corythoichthys profundus Herald, new species.
Holotype. USNM 198096, male 198.5 mm . standard length ( 204 mm . total length) ; Silver Bay Station 3466: About 90 miles slightly south of due east from Melbourne, Florida (Lat. $27^{\circ} 56^{\prime}$ N.; Long. $79^{\circ} 05^{\prime} \mathrm{W}$. ); 100 fathoms; 6foot tumbler dredge; October 25, 1961.

Diagnosis. Dorsal fin rays 27 ; pectoral 14-14; anal 3; caudal 10; dorsal
fin covering $1 / 2$ trunk ring and $51 / 2$ tail rings; trunk rings 18 ; tail rings 38 ; head 21.8 mm .; snout 12.6 mm .; dorsal fin base 16.0 mm .; pectoral base 2.2 mm .; pectoral length 3.6 mm .; head-in-standard length 9.12 ; snout-in-head 1.73; dorsal fin-base-in head 1.36; pectoral base-in-pectoral length 1.63 ; brood pouch covering 20 tail rings; eggs in anterior section only, starting at second tail ring and extending for an additional 9 rings; eggs arranged 1 layer in thickness and maximum of 6 rows in width with an approximate total of 131; brood pouch closure of open type with flaps not meeting in center (see Herald, 1959); brood pouch protecting plates slightly developed. Body ridges of Corythoichthys type.

Description. All ridges of head and body strongly accentuated showing minute crenulations when viewed under low-power microscope. Median snout ridge extends over posterior half of snout ending between eyes. Anterior orbital projection accentuated; superior orbital ridge begins above center of eye and extends posteriorly for about one eye diameter. Opercular ridge extends over anterior fourth of opercle; single supra-opercular ridge is half length of opercle. Median head crest trilobed with small additional projection just behind eyes. Pectoral cover plate with both superior and inferior ridges. Color overall light tan with small flecks of black pigment when viewed under scope. Small blackish pigment spots in web between individual rays of caudal fin. Dorsal fin with pigment spots along base of rays and extending out for short distance on individual rays. Pectoral and anal fins colorless.

Discussion. The combination of characters: (a) ring counts, (b) dorsal count, (c) position of dorsal fin, (d) head-in-standard length, and (e) snout-inhead values serve to segregate Corythoichthys profundus from all other Atlantic American pipefishes. Corythoichthys profundus comes from a greater depth than that at which other pipefishes are found (100 fathoms: 600 feet).

The head of Corythoichthys profundus has the typical appearance of the Indo-Pacific group of Corythoichthys, all of which have long snouts but lack protective plates along the sides of the brood pouch. Corythoichthys profundus does have pouch protecting plates, although only slightly developed. This has been one of the main features used to separate the Atlantic species (subgenus Corythoichthys) and the Pacific species (subgenus Bhanotichthys), so that now the validity of the subgenera becomes questionable.

Habitat data. The detailed data carefully recorded in the log of Silver Bay (Station 3466) show that the type of Corythoichthys profundus was taken in a 55 -minute drag over coral and sand bottom. During this time the 6 -foot tumbler dredge traveled a distance of about 4 knots all on a flat bottom of 100 fathom depth. Surface water temperature was $78^{\circ} \mathrm{F}$.; bottom temperature was not recorded; and air temperature was $75^{\circ} \mathrm{F}$. Fifteen pounds of material was found in the dredge, of which two pounds was inert calcareous bottom material and 13 pounds consisted of animals of 17 kinds: 5 crinoids, 15 sand dollars, 100 miscel-
laneous crabs, 50 hermit crabs, 5 Sconsia sp., 2 Fusinus sp., 25 Murex calliati, 1 cat-shark egg case, 7 Kathetostoma cubana, 1 wrasse, 2 Antigonia capros, 3 Trichopsetta ventralis, 3 Achirus inscriptus, 10 Syacium sp., 15 other flatfish, 1 Prionodes phoebe, and 1 pipefish (the type described above).

Dwarf Pipefish, Syngnathus hildebrandi Herald, new species.
Syngnathus elucens Longley and Hildebrand, 1941, Carnegie Inst. Wash., Tortugas Lab., vol. 34, pp. 61 (holotype doubtfully identified as $S$. elucens).

Holotype. USNM 117251, female 86.5 mm . standard length; Tortugas, Florida; W. H. Longley.

Paratypes. USNM 73235, female 72.5 mm .; Fish Hawk Station 7165; Pepperfish Key, SW. Florida (Lat. $29^{\circ} 13.25^{\prime}$ N.; Long. $83^{\circ} 32.5^{\prime}$ W.) ; $7^{1 / 1}$ fathoms, rocky bottom; oyster dredge; November 21, 1901.

USNM 73239, two females 61.5 and 52.5 mm .; Fish Hawk Station 7216: St. Martin's Reef, West Florida (Lat. $28^{\circ} 26.5^{\prime}$ N.; Long. $83^{\circ} 08^{\prime}$ W.) ; 10 fathoms, sandy-grassy bottom; oyster dredge; January 15, 1902.

USNM 109826, female approximately 67 mm . (tail broken) ; Fish Hawk Station 7217: St. Martin's Reef, West Florida (Lat. $28^{\circ} 27^{\prime}$ N.; Long. $83^{\circ} 13^{\prime}$ W.) ; 11 fathoms, rocky-sandy bottom; oyster dredge; January 15, 1902.

USNM 134312, female 59 mm .; Fish Hawk Station 7220: St. Martin's Reef, West Florida (Lat. $28^{\circ} 34^{\prime} 30^{\prime \prime}$ N.; Long. $83^{\circ} 15^{\prime} 45^{\prime \prime}$ W.) ; $7^{1 / 2}$ fathoms; oyster dredge; January 15, 1902.

Diagnosis. Dorsal fin rays 19-21; pectoral 10-12; anal 2; caudal 10; dorsal fin covering 0 to $1 / 2$ trunk ring and $4^{1 / 2}$ to 5 tail rings; trunk rings 17 ; tail rings 33-34; head-in-standard length 9.5-10.7; snout-in-head 2.53-2.87; dorsal base-in-head 0.97-1.22; length of brood pouch unknown; color light tan; cirri sometimes present on head and body; very similar in appearance to Syngnathus dunckeri. Body ridges typical for genus Syngnathus.

Discussion. Syngnathus hildebrandi has a small anal fin which instantly serves to segregate it from Syngnathus dunckeri, with which it would otherwise be easily confused. In ring counts it is similar to Syngnathus elucens, but its much shorter head will separate it from that species (head-in-standard length $9.5-10.7$ for $S$. hildebrandi versus 7.08-8.13 for S. elucens). Syngnathus hildebrandi also has fewer dorsal fin rays than other Atlantic American pipefishes with the same lateral ridge pattern. It may be noted that there are four additional species with a different lateral ridge pattern, i.e., three of Micrognathus and one of Amphelikturus, that also have low dorsal fin counts in the 16-22 range.

Named hildebrandi in honor of the late Dr. Samuel F. Hildebrand who recognized that the holotype was somewhat different from other previously known American pipefishes.

## The Floridae Complex

Along the Atlantic coast of North America from Chesapeake Bay to Panama there lives in many shallow areas a grass-inhabiting pipefish which has been variously called Syngnathus floridae and Syngnathus mckayi. This population complex presents an interesting study in that it must have had a continuous shoreline distribution during earlier geological periods, although the present distribution is discontinuous. In the Caribbean the insular member of this complex is Syngnathus rousseau.

One population is now restricted to the region between Chesapeake Bay and Seabrooks Beach, South Carolina. This isolated form has previously been known as Syngnathus floridae, but herein is given a new name (Syngnathus floridae hubbsi). From South Carolina to Biscayne Bay on the southeast Florida coast there is a break in distribution in which no member of the floridae complex is known to occur. At Biscayne Bay the floridae-type pipefishes are very different from those of the Chesapeake-South Carolina area. This Biscayne Bay member of the complex (Syngnathus floridae mckayi) is found from the Miami area south along the keys to Tortugas. Another population (Syngnathus $f$. floridae) is found along the west coast of Florida from Cape Sable (SW. Florida) to Corpus Christi, Texas. From the coastline distances involved, it would be suspected that the Chesapeake S. f. hubbsi and the southern Florida S. f. mckayi would be most closely related. Surprisingly, this is not the case, for it is the west Florida to Texas component that shows the closest relationship with S.f. hubbsi. This similarity is most striking when pipefishes from the Pensacola to Corpus Christi area are compared with the Chesapeake group. It is suspected that these last two populations were continuous at an earlier time by means of a wide seaway or canal which geologists tell us formerly existed across the north-central section of Florida.

It may be noted that Ginsburg (1937) has shown a similar relationship for the common Atlantic American seahorse, Hippocampus erectus (sometimes called $H$. hudsonius), in which the populations north and west of Florida are considered to be the same whereas those found in southern Florida and Cuba are assigned to a separate subspecies.

Between southern Texas and Panama only a few specimens of S. floridae are known, undoubtedly because of limited collecting. At Panama records indicate a sizable population which meristically is more closely related to the Florida keys' S. f. mckayi than it is to the adjacent S.f. floridae. This may be a natural result either of temperature or of ocean current patterns moving through the Cayman Sea northeastward through the Straits of Florida. When more material is available it is probable that the Panamanian population can stand as a separate subspecies, and this is probably also true of the Syngnathus floridae group on the west coast of Florida. In fact, the writer at one time had these written up in this manner, but has withheld such until the case is stronger.

In the Caribbean, the inshore weed habitat of Syngnathus floridae is taken over by the closely related but less abundant Syngnathus rousseau. Specimens of the former have not been collected in grassy habitats within the insular area although the two species have been taken together in Panama. Even in this locality it is not easy to separate them since most of the meristic characters are similar with the exception of the tail ring count (32-34 for S. rousseau and 3537 for $S$. floridae). Were it not for the fact that they have been collected at the same place, they would otherwise have to be considered as mutual subspecies rather than full species. Unfortunately this tail ring separation breaks down in the Caribbean so that the many small floating pipefishes found at sea are often impossible to assign exactly to one species or the other.

Although there is a large $S$. floridae population of dwarf forms in Bermuda (S.f.nesiotes), only four S. floridae specimens have been collected in the intervening Bahamas. Indications are, however, that some grassy shallow areas in the Bahamas do support a modest $S$. floridae population, for example, Little Bahama Bank. Detailed analyses of the various S. floridae groups will be presented later; for the present the Chesapeake Bay population will be recognized under a new name, described as follows:

Chesapeake Dusky Pipefish, Syngnathus floridae hubbsi Herald, new subspecies.
Holotype. USNM 91321, gravid male 177 mm . standard length; Lower York River, Virginia; Wm. C. Schroeder, July 8-12, 1921.

Paratypes. USNM 133053, 33 specimens including 6 males and 27 females and subadults (44-172 mm.) : same data as holotype.

Other specimens examined. (Total 133, excluding types; mostly in USNM) ; Maryland: Crisfield (4); Plum Point (1); Virginia: Cape Charles City (33); Lewisetta (2); Lower Rappahannock River (49); Buckroe Beach (5); Mouth of Hampton Creek (4); Norfolk (3); Cape Henry (1); North Carolina: Beaufort (28); Cape Lookout (2); Wilmington (1).

Diagnosis. Dorsal fin rays $27-31$; pectoral $14-15$; anal 3 ; caudal 10; dorsal fin covering $1 / 2-2$ trunk rings and $5-6^{1 / 2}$ tail rings, usually $1+6$; trunk rings 16-18, usually $17-18$; tail rings $31-34$; head-in-standard length $5.2-6.8$, usually $5.4-5.9$; dorsal-in-head 1.35-1.85, usually $1.45-1.7$; snout-in-head $1.6-$ 1.88 ; brood pouch covering 18-21 tail rings; brood pouch closure of inverted type, i.e., contacting brood pouch folds turning inwardly dorsad; eggs averaging 0.9 mm . in diameter and arranged 1 or 2 layers in depth and 3 or 4 rows in width on each side of pouch; protecting plates of pouch moderately developed; largest female 206 mm .; largest male 180 mm .; smallest sexually mature male 103 mm .; adult females slightly V-bellied.

Discussion and comparison. Syngnathus floridae hubbsi has been recognized since 1882 when Jordan and Gilbert stated in their original description of the Pensacola types of Syngnathus floridae: "In our paper on the Fishes of Beaufort Harbor (Proc. U. S. Nat. Mus., 1878, 368), we have recorded a 'Siphostoma fuscum' from that locality. The specimens referred to under that name belong to Siphostoma louisianae chiefly; among them are examples of the present species."

Although at the time of his 1942 paper the writer considered the Chesapeake Bay population as distinct from that existing in Florida, Texas, Panama, and Bermuda, it was nevertheless felt that there was reason to suspect that some of the type material of Syngnathus floridae from Pensacola had been mixed with males of the Chesapeake form. Consequently the use of names in the 1942 publication is different from that in this paper. The change is due to the additional material which has become available since that time and to the conclusion that the Chesapeake Bay form, although recognized, had never actually been described.

In the region in which Syngnathus floridae hubbsi occurs, it can be segregated from the other two species which are present ( $S$. fuscus and S. louisianae) by the head-in-standard length value ( $S$. f. hubbsi $5.4-5.9$ vs $6.3-9.5$ for others) ; also by the number of rays in the dorsal fin (S. f. hubbsi 28-31 vs 32-41 for others) ; and by the position of the dorsal fin on trunk and tail (S. f. hubbsi usually $1+6$ vs $3-5+4-6$ for others). From the members of the floridae complex, the mature males of S.f. hubbsi can be separated without difficulty on the number of rings covered by the brood pouch (S.f. hubbsi 18-21 vs 12-17 for others). Although geographically the females of $S$. $f$. hubbsi can be segregated from the other subspecies of S. floridae on the basis of locality data, there are nevertheless many females of $S$. $f$. hubbsi which cannot be segregated from the other subspecies of $S$. floridae on meristic characters. This is especially true of the type subspecies, $S$. $f$. floridae. One who is thoroughly familiar with the two subspecies can sometimes segregate typical females by means of their general appearance, but as yet there are no objective criteria which can be applied despite a considerable amount of time that has been expended on the problem.

Named hubbsi in honor of Dr. Carl L. Hubbs whose helpful interest in the S. floridae complex has been of considerable aid.

## Lectotypes

Since the original descriptions of two of the $S$. floridae complex were based on series material without designation of holotype, it is advisable to select lectotypes as follows:

Syngnathus floridae floridae (Jordan and Gilbert, 1884). Siphostoma floridae Jordan and Gilbert, 1884, Proc. U. S. Nat. Mus., vol. 5, p. 263.

Lectotype (herein designated). MCZ 35958, originally from USNM

30826; 148 mm . gravid male with brood pouch covering $171 / 2$ tail rings; Pensacola, Florida; Silas Stearns and David Starr Jordan.

Syntypes. USNM 30826, six females 121-155 mm.; same data as lectotype above.

Syngnathus floridae mckayi (Swain and Meek, 1884). Siphostoma mckayi Swain and Meek, 1884, Proc. U. S. Nat. Mus., vol. 7, p. 239.

Lectotype (herein designated). SNHM 1894; 138.5 mm . gravid male with brood pouch covering 13 tail rings; Key West, Florida; David Starr Jordan; December, 1884.

Syntypes. SNHM 1894, three females, 170, 178, and 211 mm ; same data as lectotype; USNM 34989, two females, 158 and 163 mm .; same data as lectotype.

Relict Northern Pipefish, Syngnathus fuscus affinis Günther, 1870.
Syngnathus affinis Günther, 1870, Cat. Fishes, Brit. Mus., vol. 8, p. 163; holotype 145.5 mm . male from "Louisiana"; Brit. Mus. 1854.7.32.

Other material examined. USNM $132675 ; 174 \mathrm{~mm}$. male and 117 mm . female from Corpus Christi Pass, Oct. 14, 1926, J. C. Pierson; CNHM 40309; two females, 206 mm . and 218 mm ., from Corpus Christi, C. T. Reed.

Diagnosis. Dorsal fin rays $36-39$; dorsal covering $4-5$ trunk rings and 4-5 tail rings; pectoral $14-16$; anal 3; caudal 10; trunk rings 18-19; tail rings 33-36; head-in-standard length 8.55-9.8; snout-in-head 2.06-2.36; females flatbellied as is characteristic of Syngnathus fuscus in the southern portion of the range (South Carolina to Florida). Brood pouch covering 121/2 to 15 tail rings.

Discussion. Since the time of the original description of Syngnathus affinis, no specimens have been known which could definitely be assigned to this species. At the time of his 1942 paper, the writer thought that the holotype of S. affinis was a specimen of S. fuscus from an erroneous locality. However the four specimens indicated above demonstrate that there is a relict $S$. fuscus population in the Corpus Christi area. Although the characters of these specimens are slightly different from those of the type of S. affinis, their variation is not sufficiently great to prohibit their being assigned to subspecific status under that name. The holotype of Syngnathus affinis was re-examined for the writer by the late Mr. V. Tchernavin.

Further study and more material will be needed to determine the relationship of this relict flat-bellied population to the similar flat-bellied group of S. fuscus from South Carolina to Florida.

## Bull Pipefish, Syngnathus springeri Herald, 1942

At the time the writer described this short-nosed, long-trunked cousin of Syngnathus louisianae, only four specimens were known. Since then, largely
because of the extensive exploratory work of the U. S. Fish and Wildlife Service ships, Silver Bay, Oregon, Pelican, Combat, and Gill, a representative group of specimens has become available. It now appears that Syngnathus springeri is truly different in habitat from the other American pipefishes. Although moderately abundant, it generally does not occur in the intertidal and other very shallow water, but prefers slightly deeper water from 10 to 70 fathoms, and it may occur as much as 100 miles offshore. In the young stages it may be a floater and be picked up by dipnet under the night light (eight localities) or eaten by tuna (one locality). The species apparently has a higher reproductive potential than most other pipefishes: one male, 274 mm ., had 1,390 eggs in the $161 / 2$-ring brood pouch. The range, based on the 65 specimens and 48 localities examined either directly by the writer or from data sent to him, now extends from Cape Lookout and Morehead City, North Carolina, to Pensacola, Florida. It occurs in the Bahamas (four localities) where its relative, Syngnathus louisianae, does not occur; but it is missing at Bermuda where the latter is found. It has been taken in the same offshore haul with Syngnathus louisianae ( 30 miles south of Pensacola, 70 fathoms), but this latter species, by contrast, is found as well in very shallow water. These two species are the largest in the Atlantic American Syngnathid fauna, with the short-snouted $S$. springeri reaching 355 mm ., and the long-snouted S. louisianae, 326 mm . Syngnathus springeri also has the distinction of having the largest number of trunk rings-23-24, usually 23, as contrasted with the next highest number for S. louisianae-19-21, usually 20.

## Insular Pipefish, Micrognathus (Anarchopterus) crinitus (Jenyns, 1842).

Pipefishes previously assigned to Micrognathus (Anarchopterus) crinigerus have upon re-analysis been found to represent two species whose appearances are identical, but whose meristic characters allow quick separation on the following data:

|  | No. Specimens | Dorsal Rays | Pectoral Rays | Trunk Rings | Tail Rings |
| :---: | :---: | :---: | :---: | :---: | :---: |
| M. crinitus | 28 | 18-20 | 10-11 | 17-18 | 32-35 |
| M. crinigerus | 86 | 16-18 | 8-9 | 14-16 | 37-39 |

Micrognathus crinitus has been taken at Tortugas, Florida, and between Vieques and Culebra islands, Puerto Rico; other records are from the Bahamas: Royal Island, New Providence Island, and Little Bahama Bank. Records for five additional Bahaman localities are contained in the collections of the Academy of Natural Sciences of Philadelphia, and will be reported by Dr. James Böhlke. Surprisingly, only one specimen of Micrognathus crinigerus has been taken in the Bahamas, and yet it is not an uncommon species along many sections of the Florida coastline from Biscayne Bay southward as well as on the entire west coast of Florida. On the other hand, Micrognathus crinitus is strictly
insular in habitat, at least insofar as the Caribbean is concerned. A total of 28 specimens including the type are known (January, 1965).

The late Mr. V. Tchernavin of the British Museum re-examined the type of Syngnathus crinitus for the author, and in spite of the fact that it was collected at a considerable distance from the Caribbean, i.e., Bahia Blanca, northern Patagonia, its characters are sufficiently close to those of the North American specimens that the latter can be assigned to $M$. crinitus.

The subgenus Anarchopterus of Micrognathus has only the two species mentioned above. This subgenus is characterized by smooth body ridges and absence of the anal fin. By contrast, the subgenus Micrognathus is characterized by sharp body ridges, and the presence of the anal fin. It has one Atlantic species, M. vittatus, and eight species in the Pacific.

Banded Pipefish, Micrognathus vittatus (Kaup, 1856) versus
Micrognathus ensenadae (Silvester, 1916).
There are two color variations of the banded pipefish. If these were to be recognized as separate species, the above two names would be applicable. The two forms are not separable on the basis of meristic data; however, some of the writer's colleagues feel that they are separable on ecological data and should thus be accorded specific rank. Hence a re-examination of the approximately 42 known specimens has been made. These specimens came from 25 localities ranging from Bermuda and the Bahamas southward through the Florida keys to Cuba, Jamaica, Haiti, Puerto Rico, Arcas Cay ( 75 miles off Campeche), Venezuela, and Brazil. Obviously, with this distribution the banded pipefish is primarily insular in habitat. On the basis of color, the specimens available separate into a group of 31 with the vittatus pattern and 11 with the ensenadae pattern. It is interesting to note that the ensenadae pattern is duplicated in the smaller but not closely related Micrognathus nitidus of the Pacific.

The typical vittatus coloration is usually rather dark, variable, and nondescript; there may be 3-5 dark bands around the trunk and 8-9 around the tail. These bands are more distinct on the upper surface, often fading ventrally. By contrast, the ensenadae pattern is quite spectacular with a series of rich brown bands around the head and body. These are about a ring or more in width. The head has a variable mottled pattern with the first distinct band just ahead of the pectoral fins, followed by 6 bands on the trunk and 13-16 on the tail. Between the brown rings is a much lighter color ranging from yellow to off-white. Although the type of Corythoichthys ensenadae is lost, Silvester did publish an excellent color plate two years after his original description (Carnegie Inst. Wash., Publ. 252, Dept. Mar. Biol., vol. 12, p. 21, fig. 3, 1918). The type of Corythoichthys vittatus Kaup is in good condition at the Paris Museum (no. 602 ), where it was examined by the writer.

The range in size of the 11 M . ensenadae specimens is from 54 mm . to 116 mm ., whereas that of the 31 M . vittatus specimens is from 52 mm . to 140 mm . Unfortunately, there are no really small specimens, hence the size at which the patterns first appear cannot be determined. Not one of the patterns is truly intermediate between $M$. vittatus and $M$. ensenadae although there is an occasional indication that intermediates might occur in some individuals of $M$. vittatus. Micrognathus vittatus-ensenadae appears to be a solitary species, as demonstrated by the collection records, most of which consist of single individuals. In four cases, two specimens were taken at the same time, and from Bermuda there is one collection of five individuals which might, however, be an accumulation of specimens. From Albrolhos Islands, Brazil, there are two specimens, both 92.5 mm ., one of which exhibits the M. ensenadae pattern and the other the $M$. vittatus pattern. This is the only time that both color patterns were taken at the same site, apparently at the same time. In the Bahamas the two color patterns have been taken at closely adjacent localities.

My colleagues, Drs. James Böhlke and Richard Robins, have postulated that the $M$. ensenadae type is always found in the area of sea fans and gorgonian corals, whereas the $M$. vittatus type is characteristically found in grassy areas.

In summation, Micrognathus vittatus and Micrognathus ensenadae must be considered as one from the standpoint of anatomy, but from the standpoint of coloration they are definitely two distinct varieties which as yet have no intergrades. More material will be required to make the final determination whether we are dealing with two full species, subspecies or color variants.

While this manuscript was in page proof, a strange new Venezuelan pipefish was received from Dr. John Randall. Fortunately it was possible to add its description to this paper.

## Ocellated Pipefish, Syngnathus randalli, new species.

Holotype. USNM 198903; female 93.5 mm . standard length $(95.3 \mathrm{~mm}$. total length) ; South side of Isla Venados, about 28 kilometers WSW of Cumaná, Venezuela; mangroves sparse on rocky shore; bottom, Porites furcata; depth 1 to 2 feet; visibility 20 ft .; temperature $22.5^{\circ} \mathrm{C}$. ( $72.5^{\circ} \mathrm{F}$.) ; ichthyocide station; January 27, 1965 ; John E. Randall.

Diagnosis. Dorsal fin rays 24 ; pectoral 13-14; anal ABSENT; caudal 10; dorsal fin covering $1 / 2$ trunk ring and $4 \frac{1}{2}$ tail rings; trunk rings 17 ; tail rings 32 ; snout 3.9 mm .; head 9.4 mm .; trunk 31 mm .; tail 53.1 mm .; dorsal fin base 8.3 mm .; pectoral base 1.3 mm .; pectoral length 1.5 mm .; head-instandard length 9.84; snout-in-head 2.41; head-in-dorsal fin base 0.88 ; brood pouch details unknown; lateral trunk ridge of typical Syngnathuts type, i.e., interrupted at anal ring and not continued with lateral tail ridge; belly slightly

V-shaped. Color brown with regular series of round to oval spots on trunk giving way to band markings on tail.

Description: Median snout ridge smooth, slightly raised, beginning at interorbital area and extending forward, three-quarters length of snout. Superior ocular ridge extends posteriorly from center top of orbit for about one eye diameter. Supraopercular ridge present, in posterior position; midopercular ridge short, equal to one-quarter length of opercle. Pectoral cover plate with single ridge in inferior position. Nuchal ridge slightly raised, trilobed. Body ridges distinct, rounded, not sharp. Intermediate plates between rings fairly large, about equal in plate width to distance between plates.

Color pattern quite startling and from Dr. Randall's Field Notes: "Color when fresh, coarse network of greenish brown, enclosing dark-edged spots of light yellowish gray; posteriorly the ground color is light yellowish gray and the reticulatum gives way to interconnected spots along side and ultimately to discrete bars; upper part of snout light greenish yellow, the lower part reddish brown; cheek area olive brown with [four] dark edged light yellow lines (most of which are diagonal) ; dorsal fin pale; caudal fin dusky yellow; iris red with spoke-like lines of pale yellow." Some appear to continue outward onto throat (five), behind eye (one), and above eye (one).

With preservation, greens and yellows gradually disappear leaving dark brown ground color punctuated with regularly arranged series of light spots, each bordered by a thin dark line. All seven intermedial plates between each trunk ring covered by individual dark-ringed light spots; one on upper surface, two on each side surface, and two on belly. Center of each trunk ring with additional six spots: one at lateral trunk ridge; one at upper trunk ridge extending onto dorsal surface of trunk, and one at lower trunk ridge extending onto abdomen. This middle series of spots begins coalescing at anal fin area, giving rise on tail to complete dark bands between each ring.

Other specimens. USNM 164831, 2 juveniles, 31.3 and 32 mm . standard length; Haiti; William Beebe. These are referred questionably to Syngnathus randalli, but are not paratyped. Although both lack the anal fin and have nearly identical meristic counts when compared with the holotype, the head-instandard length values are quite different: 9.84 for Syngnathus randalli and 7.35-7.45 for the Haitian specimens. In addition, the head profiles of the Haitian and Venezuelan specimens are more dissimilar than would be expected if they were size variables of the same species.

Discussion. Syngnathus randalli is best described as a short-nosed cousin of Syngnathus elucens, but it also differs from S. elucens in that it lacks the anal fin. Absence of the anal is important because the only other Atlantic American pipefish with the same lateral ridge pattern that also lacks the anal
fin is Syngnathus dunckeri. However, this latter species has a much shorter snout (snout-in-head $2.5-3.4$ for $S$. dunckeri versus 2.41 for S. randalli), and also the dorsal fin of $S$. dunckeri covers 6 or 7 rings rather than 5 rings and is located entirely on the tail.

Named in honor of Dr. John E. Randall whose extensive underwater ecological studies have made him a leader in the new approach to ichthyology.

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# THE PINNIPED POPULATION OF AÑO NUEVO ISLAND, CALIFORNIA 

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#### Abstract

A 3-year study on Año Nuevo Island, California, showed that this area was regularly used by four species of pinnipeds, the Steller sea lion (Eumetopias jubata), the California sea lion (Zalophus californianus), the northern elephant seal (Mirounga angustirostris), and the harbor seal (Phoca vitulina). Steller sea lions were found there throughout the year although a minimum population, consisting of several hundred cows and young, occurred in late winter and early spring. In late April the first large males arrived. Maximum numbers of about 100 bulls were present by the end of May. Bachelors also began arriving in late April and reached maximum numbers by late June. There was a great increase in the number of females in late May and early June as the harems formed. By the end of June the female population was about 1,100 . An estimated 1,000 pups were born in June and early July. The bulls and bachelors began to leave in the latter part of July at which time the harems broke up. They were essentially all gone by late August or early September. In midwinter another exodus of many of the females and young occurred.

Male California sea lions were present in numbers except from early June to late July when the species was essentially absent from the island. No females were noted here. Approximately $80 \%$ of the males present were adults. There were two population peaks, one in mid-May and the other around September 1. The latter peak was the higher and was found to double each year.

Elephant seals were present throughout the year; breeding occurred from late December to early March. Greatest numbers were noted in early May and during


#### Abstract

October and early November. The spring peak was the higher of the two. Total numbers recorded on May 7, 1961, May 15, 1962, May 8, 1963, and May 7, 1964 were $86,157,450$, and 483, respectively. These figures indicated a marked annual increase in numbers. Bulls were present only in midwinter and midsummer. In spring and autumn the population consisted almost entirely of immature animals. There was a resident population of about 100 harbor seals in the vicinity of Año Nuevo Island.


## Introduction

In May, 1961, we began a study of the pinniped population on Año Nuevo Island which is one-half mile off the central California coast approximately 40 miles south of San Francisco. It was originally anticipated that observations would be concerned almost exclusively with the Steller sea lion (Eumetopias jubata) since the island has long been known to have one of the largest rookeries of these animals south of Alaska. However, it was soon discovered that it was also used regularly by three other species of pinnipeds, the California sea lion (Zalophus californianus), the elephant seal (Mirounga angustirostris), and the harbor seal (Phoca vitulina). A fifth species, the northern fur seal (Callorhinus ursinus), was also recorded here.

Between May 25, 1961, and May 7, 1964, 60 visits were made to the island primarily for the purpose of observing seasonal changes in its pinniped population and composition as well as to conduct behavioral studies on the several species concerned. There were a few occasions, however, when unfavorable conditions or disturbances made it impossible to secure accurate counts. Additional trips were made for other purposes at which times incidental population data were occasionally secured. All crossings of the half-mile channel separating Año Nuevo Island from the adjacent mainland were made in a 14 foot fiberglass boat with an outboard motor. As the result of unfavorable weather for considerable periods of time between October until April more days were spent on the island in summer than in winter (tables 1 to 3 ).

Counts were made with the aid of binoculars and were usually checked later against extensive photographs which were made on each visit. On-the-spot counts were frequently made from the top of the lighthouse which affords a view of most of the areas occupied by pinnipeds as well as by careful approach to each of the rookery or hauling-out areas. Effort was made to determine the sex and age composition for each species whenever possible.

## History of the Sea Lions in Central California

For the past century the specific composition of the sea lion population along the central California coast has presented many confusing aspects. This is an area where the ranges of two genera, Zalophus and Eumetopias, overlap. The breeding range of the northern Steller sea lion (Eumetopias jubata) extends from Japan northward to the Bering Sea, then down the coast of North America

Table 1. Total Steller sea lion population on Año Nuevo Island from May, 1961, to May, 1964.

| Date | Number | Date | Number |
| :---: | :---: | :---: | :---: |
| 1961 |  | 1963 |  |
| May 25 | 1,500 | April 13 | 268 |
| June 27 | 1,934 | April 19 | 286 |
| July 13 | 1,586 | April 21 | 305 |
| July 28 | 1,596 | April 22 | 300 |
| August 11 | 1,632 | April 25 | 315 |
| September 7 | 1,395 | April 29 | 524 |
| September 23 | 1,712 | May 8 | 350 |
| 1962 |  | May 23 | 672 |
| February 24 | 225 | May 27 | 418 |
| March 24 | 451 | May 29 | 428 |
| May 15 | 193 | June 4 | 1,045 |
| June 5 | 839 | June 6 | 954 |
| July 3 | 1,822 | June 11 | 1,166 |
| July 16 | 2,226 | July 12 | 2,395 |
| August 4 | 1,255 | July 23 | 1,981 |
| August 18 | 2,629 | July 30 | 2,625 |
| September 1 | 2,207 | August 19 | 1,605 |
| September 21 | 2,009 | August 23 | 1,509 |
| October 24 | 1,188 | August 30 | 1,510 |
| November 26 | 940 | September 6 | 1,070 |
| December 20 | 1,543 | September 13 | 1,186 |
| December 29 | 1,220 | September 27 | 1,602 |
| 1963 |  | October 12 | 1,449 |
| January 9 | 927 | October 25 | 1,140 |
| January 19 | 690 | November 13 | 1,093 |
| February 15 | 624 | December 28 | 815 |
| February 16 | 603 | 196 |  |
| February 17 | 583 | January 8 | 445 |
| March 2 | 212 | March 30 | 244 |
| March 3 | 240 | May 7 | 477 |

from Alaska to the Channel Islands off southern California (Scheffer, 1958). The California sea lion, Zalophus californianus, is represented by three separate breeding populations: Z. c. wollebaeki in the Galapagos Islands, Z. c. japonicus in the Sea of Japan, and Z.c.californianus extending from the west coast of northern Mexico northward to the Channel Islands off southern California. The
distribution of Eumetopias and Zalophus outside of the breeding season, plus periodic decimation of large numbers of these animals by man in the past, has been responsible for much of the confusion apparent in the literature.

Rowley (1929) refers to some of the presumed errors and inconsistencies of early observers like Scammon (1874) and H. W. Elliott (1875). As Rowley points out, Captain Scammon's measurements and descriptions obviously indicate that he confused Eumetopias and Zalophus in the area where the two species overlap. Elliott (sup.cit.) reported both Eumetopias and Zalophus around San Francisco and the Farallon Islands, 25 miles to the west, yet indicated that in numbers Zalophus greatly predominated. Rowley implied that these early observers were in error and that Zalophus regularly came only as far north as Monterey. Bonnot (1928), however, who was also an authority on this group, stated that "In the past, the California sea lion was fairly abundant and probably maintained rookeries as far north as the Farallons. They have been recorded as far north as Puget Sound."

Sea lions of both species periodically were hunted and killed for their oil and hides from around 1860 until the early part of the present century (Rowley, op. cit.; Bonnot, 1951). This resulted in the elimination of certain breeding rookeries, including that at Seal Rocks, San Francisco, where Steller sea lions formerly bred, and a general reduction in the total number of sea lions of both kinds along the coast of California and Baja California. It also makes it difficult to ascertain the distribution and relative numbers of the two species of sea lions in this region prior to their disturbance by man.

In 1927 the California Department of Fish and Game, at the instigation of fishermen who believed that pinnipeds were increasing and endangering commercial interest, made a census of the sea lions along the coast between the Mexican border and the Oregon state line. This and subsequent censuses in 1928, 1930, 1936, 1938, 1946, and 1947 were conducted primarily by the late Paul Bonnot (Bonnot, 1928a, 1928b, 1931, 1937; Bonnot, Clark, and Hatton, 1938; Bonnot and Ripley, 1948). The results of these censuses are summarized in the last-cited publication. These counts were made in June or July, the breeding season for both species concerned. Pups, in most instances were not included. The northernmost point any California sea lions were noted was Pt . Reyes where nine were seen in 1936. Proceeding geographically southward, 6 were seen on the Farallon Islands in 1927, 28 in 1930, 25 in 1936, and 90 in 1938. None was noted during these years at Purissima Rock which is several miles south of Half Moon Bay. In 1936, 200 were counted on Año Nuevo Island. This was the first time this species was recorded here. No observations were made between Año Nuevo Island and the Monterey County coast because of the lack of either suitable hauling-out areas or rookeries.

The Steller sea lion counts over these areas at the same time were much greater, especially since Año Nuevo constitutes what is believed to be one of the

Table 2. California sea lion population on Año Nuevo Island from May, 1961, to May, 1964.

| Date | Number | Date | Number |
| :---: | :---: | :---: | :---: |
| 1961 |  | 1963 |  |
| May 25 | 1,500 | March 3 | 186 |
| June 27 | 1 | April 13 | 1,289 |
| July 13 | 5 | April 19 | 1,254 |
| July 28 | 319 | April 21 | 1,146 |
| August 11 | 1,700 | April 22 | 1,966 |
| September 7 | 3,243 | April 25 | 1,488 |
| September 23 | 1,827 | April 29 | 1,345 |
| 1962 |  | May 8 | 2,000 |
| February 24 | 95 | May 23 | 1,183 |
| March 24 | 1,050 | May 27 | 1,258 |
| May 15 | 2,400 | May 29 | 1,090 |
| June 5 | 800 | June 4 | 482 |
| July 3 | 2 | June 6 | 309 |
| July 16 | 10 | June 11 | 185 |
| July 25 | 400 | July 12 | 15 |
| July 30 | 2,000 | July 23 | 198 |
| August 4 | 2,205 | July 30 | 3,203 |
| August 18 | 3,555 | August 3 | 4,650 |
| September 1 | 6,597 | August 19 | 10,275 |
| September 21 | 3,914 | August 23 | 5,874 |
| October 24 | 2,350 | August 30 | 13,367 |
| November 26 | 2,763 | September 13 | 8,173 |
| December 20 | 3,360 | September 27 | 8,119 |
| December 29 | 3,253 | October 12 | 4,000 |
| 1963 |  | October 25 | 5,251 |
| January 9 | 818 | November 13 | 6,285 |
| January 19 | 1,102 | December 28 | 2,899 |
| February 15 | 503 | 19 |  |
| February 16 | 298 | January 8 | 250 |
| February 17 | 232 | March 30 | 915 |
| March 2 | 417 | May 7 | 3,428 |

largest breeding rookeries for this species south of Alaska. At Pt. Reyes 45 Steller sea lions were counted in 1936, 6 in 1938, and 2 in 1947. On Farallon Islands the number was 700 in 1927, 540 in 1928, 900 in 1930, 500 in 1936, 357 in 1938, and 750 in 1947. At Purissima the count was 150 in 1927, 42 in 1928, 4 in 1936,

2 in 1938, and 50 in 1947. The population on Año Nuevo was 1,500 in 1927, 1,500 in 1928, 2,500 in 1930, 1,000 in 1936, 2,000 in 1938, and 2,050 in 1947.

A census was taken along the California coast in 1958 and again in 1960 and 1961 by the Department of Fish and Game (Ripley, Cox, and Baxter, 1962). Pups were included in these censuses but no segregation was made as to species. During these 3 years aerial counts showed the Año Nuevo population to be 1,170, 1,350, and 2,342, respectively. Smaller aggregations, possibly breeding, were noted on the Farallon Islands and occasionally small groups were found hauled out at Pt. Reyes and Purissima. The latter animals were no doubt nonbreeding individuals. Earlier observations in 1920 by Evermann (1921), and in 1924 by Evermann and Hanna (1925), showed that in those years the Steller sea lion population was around 2,000 on Año Nuevo Island and no California sea lions were observed there.

The numbers of California sea lions recorded were small and sporadic for the years in which the censuses were made and seemed to lend support to Rowley's (1929) conclusions that Scammon, Elliott, and other early observers confused the two species.

Probably the first real clue to the reason for this seeming confusion was presented by Fry (1939) who made a population study of sea lions for the California Division of Fish and Game in March of that year on some of the Channel Islands. The purpose was to determine the numbers of these animals along the the California coast outside of the breeding season when they are rather widely dispersed and many individuals may be overlooked. Despite this the March count showed the number of California sea lions to be twice that obtained during the census the previous summer. Fry (op.cit.) also noted that between the Channel Islands and San Francisco fewer Steller sea lions were seen than during the previous summer. He concluded that the increase in the number of California sea lions was probably the result of an influx of animals from Baja California. This, he stated, "could have been caused by the activities of a dog-food manufacturer who has been using sea lions from Lower California as a meat supply. The creatures may possibly have decided that their old haunts were no longer healthy, but is seems more likely that the migration is a regular annual event."

With regard to the decrease in the number of Steller sea lions in March over the previous summer's population (Fry op. cit.) suggests: "If California sea lions show a northward migration, it seems within reason that the Stellers would show a corresponding movement."

Bartholomew and Hubbs (1952) published an account of winter observations on pinnipeds made late in January and early in February, 1950, on Guadalupe, the San Benito, and Cedros islands off the northwest coast of Baja California. The California sea lion populations on both Guadalupe and Cedros islands were small (less than 200 and 340, respectively). On the San Benitos they were extremely high, 9,714 individuals being recorded. Most interesting, however, is

Table 3. Elephant seal population on Año Nuevo Island from March, 1961, to May, 1964.

| Date | Number | Date | Number |
| :---: | :---: | :---: | :---: |
| 1961 |  | 1963 |  |
| March 11 | 24 | March 3 | 54 |
| May 7 | 86 | April 13 | 243 |
| May 25 | 53 | April 19 | 276 |
| June 27 | 18 | April 21 | 276 |
| July 13 | 15 | April 22 | 325 |
| July 28 | 8 | April 25 | 333 |
| August 11 | 11 | April 29 | 429 |
| September 7 | 6 | May 8 | 450 |
| September 23 | 50 | May 23 | 400 |
| November 19 | 51 | May 27 | 200 |
| 1962 |  | May 29 | 125 |
| February 24 | 36 | June 4 | 107 |
| March 24 | 55 | June 6 | 95 |
| May 15 | 157 | June 11 | 54 |
| June 5 | 60 | July 12 | 29 |
| July 3 | 26 | July 23 | 26 |
| July 16 | 18 | July 30 | 23 |
| August 4 | 9 | August 19 | 18 |
| August 18 | 8 | August 23 | 25 |
| September 1 | 20 | August 30 | 25 |
| September 21 | 37 | September 6 | 30 |
| October 24 | 125 | September 13 | 58 |
| November 26 | 134 | September 27 | 75 |
| December 20 | 73 | October 12 | 100 |
| December 29 | 51 | October 25 | 146 |
| 1963 |  | November 13 | 107 |
| January 9 | 31 | December 28 | 47 |
| January 19 | 56 | 196 |  |
| February 15 | 76 | January 4 | 45 |
| February 16 | 70 | March 30 | 112 |
| February 17 | 71 | May 7 | 483 |
| March 2 | 52 |  |  |

the fact that most of these animals were less than 3 years old and the majority were yearlings. These writers state (op. cit.): "Of the 9,714 sea lions which we counted on the San Benitos, only 11 were identified as adult males." They concluded, as did Fry (op. cit.) that there was a northward postbreeding move-
ment of California sea lions from Baja California. They indicated that this northward migration was essentially confined to adult males. They further state (op. cit.) regarding adult male California sea lions as follows: "That they may migrate northward as far as California seems possible. A very high proportion of adult males has been observed in nonbreeding aggregations in that state. Thus on April 22, 1950, Bartholomew estimated that fully $80 \%$ of the 956 sea lions on a sandy beach on San Nicolas Island were adult males. The overwintering population of sea lions on a beach in Monterey County south of Point Sur, with numbers estimated by Hubbs as high as 1,800 and by others still higher, consists largely of adult males of this species, with a few Steller sea lions."

Bartholomew and Boolootian (1960) made a study of the summering and wintering populations of pinnipeds on the Channel Islands off southern California so that comparisons could be made with data obtained since 1927 when the first comprehensive census was made by the California Department of Fish and Game. The Steller sea lion population, which reached a peak of about 2,000 animals in that area in 1938, was found to be almost completely replaced by California sea lions by 1958. Only 50 individuals of the former species were recorded the latter year and no bulls were noted in winter. The increase in California sea lions was logarithmic. The nonbreeding population for the Channel Islands was between 9,000 and 10,000 in 1959 and the breeding population that year was more than 13,000. In 1927 the total count for this species for the entire state of California was only 915 in summer. Furthermore, the winter population of California sea lion bulls in 1958 was greater than the summer population. This tended to confirm the theory that there is a northward movement of California sea lion bulls in winter and possibly a southward movement of cows and immatures. The absence of Steller sea lion bulls in winter also indicates the possibility of a northward movement of adult males of this species after the breeding season.

The data from our studies confirm the suggestions made by Fry (1939), Bartholomew and Hubbs (1952), and Bartholomew and Boolootian (1960) concerning a postbreeding northward migration of male California sea lions, and also support the idea that there is a similar northward postbreeding migration on the part of male Steller sea lions in central California. Seasonal movements of Steller sea lions have been noted in British Columbia by Pike and Maxwell (1958) and in Alaska by Kenyon and Rice (1961).

## Año Nuevo Island

The island (fig. 1) is irregular in shape with its main axis in a northwestsoutheast direction. It has a land mass of slightly less than 12 acres but an ad-

[^24] Photograph by John Gorman, April 7, 1961.



Figure 2. Map of Año Nuevo Island. The areas most frequently used by pinnipeds are referred to by number.
ditional 4 acres is provided by adjacent rocks and reefs. These areas were computed at low tide level. The greatest length along the main axis from water line to water line is about 1,300 feet and the greatest width 850 feet. At its narrowest point it is 36 feet. On its seaward side, from the northwestern end to the south end, there are numerous slabs of rock rising out of the water and separated from the main mass of the island. Some of these lie 450 feet from the island. The larger of these rocks, whose exposed surfaces are 300 to 400 feet long, are used extensively by Steller sea lions. For convenience and quick reference, numbers were given to parts of the island and to those rocks that were utilized to a significant extent by pinnipeds (fig. 2).

The island is composed of layered beds of Miocene cherty shale which generally slope down toward the southwest. The most extensive reefs and exposed slabs of shale are on the seaward side. There are two fairly extensive sandy beaches, one on either side of the southeastern half of the island, each over 300 feet in length. The main mass of the island above the beaches and reefs is covered with sand on which a number of kinds of plants grow. The movement of large numbers of sea lions has essentially eliminated vegetation over the southeastern half of the island, but these animals, even when abundant along the shoreline, rarely come onto the top of the northwestern part of the island. Here I)istichlis spicata, Lupimus arboreus, Eriophyllum staechadifolium, Cakile maritima, Oenothera cheiranthifolia, Amsinckia spectabilis, Franseria bipinnatifida, Chenopodium californica, Spergularia macrotheca, and Echeveria farinosa are among the most common plants found.

For a history of the island and its former utilization as a lighthouse station


Figure 3. A Steller sea lion harem in area 7. The bull (slightly right of center) is surrounded by cows with pups in the foreground. Photograph by Robert T. Orr, July 9, 1964.
by the United States Coast Guard, see Orr and Poulter (1962). Although Año Nuevo Island is the most important area for pinnipeds in central California, certain supplemental data obtained from other localities in this region, including the Farallon Islands, Pt. Reyes in Marin County, Seal Rocks off San Francisco, and coastal San Mateo County, are included here.

## Steller Sea Lion

Areas occupied. In general the Steller sea lions showed preference for the large, outlying rocks off the northwest end of Año Nuevo Island. Those rocks, designated as 11 and 12 , were found to have some of these sea lions on them throughout the year. On only one occasion, December 20, 1962, was rock 11 unoccupied. On this day, however, it was completely awash because of very large swells. Two of the three largest aggregations of breeding sea lions occupied these rocks during the summer months. The other most utilized rock was 10, which, because of its partial division by a surge channel, was designated as 10 E (east) and 10 W (west). Rock 14 was utilized as a hauling-out area through-


Figure 4. The total Steller sea lion population on Año Nuevo Island from May 25, 1961, to May 7, 1964.
out most of the year by a small number of Steller sea lions but it was of considerably greater importance to California sea lions and harbor seals. A few harems of Steller sea lions were noted here in the breeding season. Areas 1 and 2 were used to a large extent by bachelors or nonbreeding animals during the breeding season, and to a limited extent by a few females and young during other times of the year when the California sea lion population was low. Area 7 contained an active breeding rookery with 11 harems in the summer of 1961. This is the only breeding group recorded on the main island, either in 1961 or 1962. In 1962 area 7 was occupied by a number of solitary bulls, but no females were present. In 1963 and 1964, however, both area 7 (fig. 3) and area 9 contained breeding groups. Toward the end of the breeding season the smaller rocks around the periphery of reef 7 , including 6 a, were frequently used as haulingout areas for cows, pups, and even subadults and occasionally bulls. Solitary bulls were frequently seen on area 8 from late May to early July; and during most of the breeding season some females and pups were found on 9a.

The large sandy beach on the eastern side of the island was not used by Steller sea lions although the sandy beach on the west side (no. 3) was occasionally occupied by bachelors at the height of the breeding season. It appeared that they were forced to occupy it then because the more favorable situations were preempted by the breeding bulls who were rather intolerant of the bachelors from early May until the middle of July.

Breeding population. Although there was marked seasonal fluctuation in
the total number of Steller sea lions occupying Año Nuevo Island (fig. 4, table 1), as well as changes in the sex and age composition throughout the year, there appears to have been relatively little change in the number of animals breeding here for at least the past 42 years. Evermann (1921), in his report on the Año Nuevo Steller sea lion rookery as of June 27 and 28, 1920, estimated the total population as "between 1,500 and 2,000 , with the probability that 2,000 is more nearly correct." His total pup count for the reefs and island was "not more than 100 " with another 106 dead or dying pups recorded on the beaches and floating in the water. Counts made on June 22 and 29, 1924, by Evermann and Hanna (1925) again resulted in an estimate of approximately 2,000 animals of all ages. Of this number 954 were adults. Another 150 were estimated to have been overlooked. This would indicate a total adult population of about 1,100 animals. Mention is made of the absence of subadult males and females at this time. Such nonbreeding animals may have been disturbed by human beings, as the island was then being used as a lighthouse station, and nonbreeding animals are easily flushed into the water in contrast to those on breeding rookeries.

These figures are not too different from those obtained by us during the breeding seasons of 1961, 1962, and 1963. On May 25, 1961, a total of 1,500 adults or subadults, including yearlings, was estimated to be present. No separation by age and sex was attempted, but this was just prior to the birth of the first pups. On June 27, 1961, the total population was estimated to be $1,934$. On July 3, 1962, the adult and subadult population was estimated to be about 1,500, consisting of approximately 100 bulls, 275 bachelors and subadults, and 1,125 adult females. In addition 750 pups were counted. On July 12, 1963, the Steller sea lion population consisted of about 100 bulls, 266 bachelors and subadults, 1,444 cows, and 585 pups. The pup count was too low because of poor visibility.

The various censuses taken by the California Department of Fish and Game from 1927 to 1961 tend to substantiate the relative uniformity of the breeding population. The summary given by Ripley, Cox, and Baxter (1962) shows a range in numbers counted from 1,200 to 2,500 . However, the time, as previously noted, varied from June to July and no effort was made to distinguish species. Furthermore, some counts were made on the ground and others by means of aerial photography.

Bulls. Adults bulls spend a relatively short time on the island. They first arrive in the latter part of April, reach maximum numbers by the first of June, begin to leave late in July, and are mostly gone by the middle of August. On April 25, 1963, 10 bulls or large subadult males were observed on the island. Approximately 2 weeks later (May 8) 52 large males were present. Fortyseven were counted on May 7, 1964. Twenty-two of these were bulls and all except one, which was sleeping on beach 3 with a group of California sea lions,
were established on rookery areas. Twelve were associated with cows and yearlings. The remaining 27 males were in bachelor groups. By the last week in May in 1961, 1962, and 1963, approximately 100 harem bulls were present.

By July 28, 1961, the harems had largely broken up and a marked decline in the number of bulls was apparent. In area 7 only two lone bulls were seen on rocks that had contained 10 bulls, 120 cows, and 100 pups 15 days earlier. Aggregations composed of females, pups, subadults, and several bulls were seen on some of the larger islets. On August 4, 1962, and August 11, 1961, only a few bulls were seen in the island area and on August 18, 1962, only one large bull was seen among the 2,427 Steller sea lions counted. The August population consisted almost entirely of adult females, pups, yearlings, and subadults.

Females. Evermann and Hanna (1925) reported that the lighthouse keeper on Año Nuevo Island informed them that some sea lions (presumably Eumetopias jubata) are present on the island throughout the year. They suggest that "it is possible that the young males and females haul out there after the breeding season is over."

At no time during this study was the island devoid of adult female Steller sea lions, although there were marked seasonal changes in numbers. Maximum numbers were recorded from shortly after the beginning of the breeding period in early June, through September, and minimum numbers in late winter and spring.

On May 15, 1962, the total population for this species consisted of about 200 individuals of which less than 100 were females. On this date some bulls were noted. The arrival of large numbers of females followed the arrivals of the bulls. On June 5, 1962, 558 adult females were counted and the number reached 1,125 on July 3, 1962. The reason for the small number on June 5 of that year is not understood. Some of the females present had young by this date. Furthermore, the presence of harbor seals, elephant seals, and California sea lions indicated that the island had not recently been disturbed by human activities. The previous year, on June 27, the total adult female population was 1.023 .

From September until early May the composition of the Steller sea lion herd consists entirely of adult females, young of the year, and a few animals judged to be between 1 and 2 years old. There was a marked decline each year in midwinter in the number of animals present (table 1).

Little is known about the movements of cows or young in winter and spring when the Año Nuevo population shows a marked decline. Some evidence indicates, however, that it may be largely local, perhaps confined to the central California area. During these seasons some females and immatures are usually to be found on Seal Rocks and Pt. Reyes. The following numbers of Steller sea lions, thought to be females and immatures, were observed on Seal Rocks on each of the following dates: January 27, 1962, 10; March 3, 1962, 19;


Figure 5. Adult and immature male California sea lions on beach 3. Some may also be seen on the edge of area 19 (upper left) next to the abandoned Coast Guard houses and on area 2 (extreme upper right). A few elephant seals are on the upper beach just below the houses. Photograph by Robert T. Orr, November 13, 1963.

May 26, 1962, 12土; February 14, 1963, 45; February 16, 1963, 5. A visit to Pt. Reyes on April 15, 1962, showed 10 females and immatures hauled out with a group of 90 California sea lion bulls. We were not able to visit the Farallon Islands where sea lions are present throughout most of the year, but it is probable that a considerable number of Steller females and immatures haul out there.

Bachelors. Nonbreeding males begin to appear on the island at about the same time as the bulls. The first individuals were noted by the latter part of April. On May 8, 1964, 25 bachelors (males not sufficiently old to secure a harem) were present. On June 5, 1962, when 101 bulls were counted, 154 bachelors were recorded. On June 27, 1961, about 200 bachelors and bulls without harems were observed on one beach alone. Others were scattered along the shore, on reefs, and in the water. Two hundred and sixty-four bachelors were counted on July 3, 1962. In 1961, 1962, and 1963, the maximum bachelor and yearling population during the breeding season was between 275 and 300 individuals. By the middle of July there appeared to have been a decline in the number of these nonbreeding sea lions.

Evidence that a northward migration starts about mid-July was obtained


Figure 6. California sea lions hauled out on areas 19, 3, and 2 of Año Nuevo Island. Photograph by Robert T. Orr, August 30, 1963.
on July 20, 1961, when one of us (Orr) visited Pt. Reyes, approximately 70 miles northwest of Año Nuevo Island. On this occasion 32 large Steller sea lions, believed to be subadult males or young bulls, were seen hauled out on exposed rocks in the water or on ledges at the base of a cliff. Since Año Nuevo Island is the only known breeding rookery along the central California coast it was suspected that these animals were recent arrivals from there. Nineteen bull California sea lions, also believed to be recent migrants from southern California or northern Baja California, were intermingled with the larger Stellers. A visit to Año Nuevo Island 8 days later revealed a marked decline in both the number of bachelor and bull Steller sea lions and a corresponding increase in male California sea lions. The departure of all of the bachelors was not complete until early September. Not one of this age group was seen on September 7, 1961, while on September 1, 1962, a few remained.

Young. On May 25, 1961, two dead pups were found on one of the sandy beaches but no living young were seen. The pups, which had died very
recently, were thought to have been born prematurely. On June 14, 1961, numerous young were observed. In 1962 no young were present on May 22, but on June 5 there were 18 newborn young. By July 3 the number had increased greatly and 750 were counted. This was considered a very conservative figure since the pups are difficult to count and many are overlooked, especially on the outermost reefs, when they are lying on the far side of adult sea lions. It is probable that the actual figure was closer to 1,000 . At the peak of the breeding season in 1961, 1962, and 1963, the total number of adult females was estimated to be approximately 1,100 , and probably most of these bore young.

There was a high pup mortality during the first month following birth. Likewise, in midwinter the number of young showed a marked decline. The latter, however, appeared to be correlated with the disappearance of many of the females. It was thought that either many of the young and their mothers left the island or else both spent more time at sea, thus leaving the island relatively depopulated. However, some young were always to be found there throughout the winter and spring months.

A small percentage of yearlings was present during the breeding season and some were observed until the following January at which time they were 19 or 20 months of age. Mathisen, Baade, and Lopp (1962) estimated that yearlings constituted about 15 per cent of the Steller sea lion population on Chernabura Island, Alaska, in the summer. This is much higher than we observed on Año Nuevo Island.

## California Sea Lion

Areas occupied. Members of this species, unlike the larger Steller sea lions, show preference for sandy beaches or inner reefs and rocks. The greatest numbers of California sea lions were found on the southern part of Año Nuevo Island because of the presence there of these habitats. The area most frequently used for hauling out throughout much of the year was the sandy, seaward beach designated as 3 (fig. 5). This beach is approximately 350 feet long and slopes gently back 50 to 75 feet to the base of the bluff marking the edge of the main body of the island. The few individuals present in midsummer could be found here. This was also true during the population low of late winter and early spring. On September 27, 1963, when the population was high, 2,125 California sea lions and 75 elephant seals were counted on this beach. The greatest number seen here was on May 7, 1964, when 2,700 California sea lions and 483 elephant seals were recorded. Since the area of this beach is only 0.56 acre, an average of about 7 square feet was available for each of the 3,183 animals.

During the population peak in late summer and early autumn area 19, comprising the top of the south end of the island, was frequently utilized as a resting area by the majority of the California sea lions present (fig. 6). For


Figure 7. Seasonal fluctuation and annual increase in the California sea lion population on Año Nuevo Island from May 25, 1961 to May 7, 1964.
example, on August 30, 1963, about 9,000 individuals were observed here. The total count for the island on this day was slightly more than 13,000. On September 13, 1963, when the total count for this species for the island was approximately 8,000 , about 5,000 were on area 19. At other times of the year area 19 was rarely used. Beach 17 on the leeward side of the island was another hauling-out area found to be important when the population was high or when the animals had been disturbed elsewhere. It is 0.95 acre in extent and, unlike the seaward beaches, consists of coarse gravel, shells, and rocks in addition to sand.

In late August and September 1963, over 1,000 individuals were recorded here on several occasions.

Areas 1, 2, 3a, $6 \mathrm{a}, 9,9 \mathrm{a}, 14,15,16$, and 18 were also frequently used by California sea lions. Rocks designated as 4,5 , and 6 were of little significance because of their small size. Less frequently used as hauling-out areas by members of this species were areas $7,10 \mathrm{E}, 10 \mathrm{~W}, 11$, and 12 . These provided the major breeding areas for Steller sea lions. Area 11 was also occupied throughout the year by Steller sea lions. Only on rare occasions did California sea lions haul out here. Their essential absence from this rock, however, was attributed to its exposed seaward position rather than to the presence of the larger Steller sea lions (Orr, 1965).

Seasonal and annual changes in numbers. As noted previously, there is little information available on the presence of this species in central California. Several aerial photographs of Año Nuevo Island taken in 1953 and made available to us by the United States Coast Guard reveal the presence of about 1,000 California sea lions on beach 3. From our present knowledge of the habits of these animals we judge that the pictures were taken sometime during the winter season.

Two of the most interesting discoveries made during this study were the marked seasonal changes that occurred in the numbers of California sea lions on Año Nuevo Island and the great increase in the population each successive year. There were two population peaks during each year, one just prior to the middle of May and the other about the first of September (fig. 7, table 2). The September peak, however, was by far the higher. Both population highs were of rather brief duration. Following the spring peak there was a steady decline in numbers until the latter part of June when practically no California sea lions were present. They reappeared in the latter part of July and within 5 or 6 weeks reached maximum numbers. By October 1 the population declined to about one-half that present in early September and then gradually leveled off until the first of the year at which time a second low of 1,000 or less was found. Around April 1 there was an increase in numbers again which culminated in the spring peak. The population during the September peak in 1962 was essentially twice that of 1961 , and that of September 1963 was twice that of 1962 (fig. 7, table 2). This is even greater than the rate of increase recorded from the Channel Islands by Bartholomew and Boolootian (1960).

The absence of California sea lions throughout most of June and July in Central California was correlated with the breeding season for this species and we presume these animals migrated south to rookeries on the islands off southern California and the west coast of Baja California. A possible explanation to account for the fall and spring peaks at Año Nuevo Island is that many sea lions migrating to and from nonbreeding areas north of central California rest at the island for a while en route. This might be an especially important


Figure 8. Immature elephant seals on beach 3. Male California sea lions may be seen in the distance near the water's edge. Photograph by Richard Jennings, early May, 1963.
resting place in late August and September after the rigors of the reproductive season farther south.

Sex and age composition. In no instance during the 3 years of this study was the total California sea lion population found to consist of less than 80 per cent adult males. The others were immatures ranging from subadults down to individuals that were thought to be yearlings. Every individual in this immature class whose sex could be determined proved to be a male. This was also true of all young California sea lions found dead on the island.

These observations substantiate the suggestion made by Bartholomew and Hubbs (1952) that adult male California sea lions move north to California after the breeding season. These authors found males of this species essentially absent in winter from the islands where they breed along the west coast of Baja California. They also comment on the fact that on April 22, 1950, fully 80 per cent of the 956 California sea lions on San Nicolas Island off the coast of southern California were adult males.

## Northern Elephant Seal

Areas occupied. The history of the development of the elephant seal colony on Año Nuevo Island has already been described (Radford, Orr, and Hubbs, 1964). Elephant seals were most often seen on beach 3 where they


Figure 9. A young bull elephant seal in process of molt in summer on Año Nuevo Island. Photograph by Robert T. Orr, July 9, 1964.
tended to stay on the upper dry sandy parts. This is in contrast to California sea lions which were usually found closer to the water's edge (fig. 8). This habitat preference by members of this species is thought to be associated with their habit of throwing dry sand over the body with the front flippers.

Beach 3a was also used occasionally by a few immature animals. Rarely single individuals were seen on top of the island in area 19 . Small numbers of immatures were sometimes noted on beach 17 in spring and fall. This area, however, was regularly used by solitary bulls during the breeding season. These large males might also be found anywhere about the periphery of the island from late December until early March.

All breeding activity was confined to beaches 3 and 17 . Cows and pups were not noted elsewhere. Although most of the young were observed on beach 3, three were born on beach 17 in January, 1963, and 16 during the 1964 breeding season.

Males. Large males, ranging in age from old bulls to subadults or bachelors, were regularly observed from December until March and again during July and August. A few large subadults were seen at other times. Each


Figure 10. An elephant seal bull with a harem of cows and pups on beach 3. Photograph by Richard Jennings in late January, 1963.
year the population appeared to increase over that of the preceding year. Four large males were recorded on July 28, 1961, 6 on February 24, 1962, 8 on July 16, 1962, 23 on December 29, 1962, 22 on July 23, 1963, and 20 on December 28, 1963. Even though this paper relates primarily to observations made up to May 7, 1964, 30 big males were counted on July 9, 1964. The large males all appeared to undergo a molt in summer (fig. 9).

Females. Adult females are present during the reproductive season which is from the latter part of December until March (fig. 10). Not one was observed during July and August. Their presence in spring and fall was questionable and difficult to ascertain because of the large number of immatures of both sexes that were present then.

Pups. The young are born in January and February. Each winter during this study the number of births increased. Twenty-three were recorded in 1962, 32 in 1963, and 60 in 1964. These young began leaving by the end of May and by midsummer were mostly gone, although a few were noted later. Since metal flipper bands were attached to 12 of the 23 pups born in the winter of 1962 and to all but one or two in 1963 and 1964, it was easy to determine the presence or absence of the young subsequently. Some information was obtained regarding the movements of these animals. One male, tagged as a pup on Año Nuevo Island on March 28, 1962, was observed by Dr. David Regnery and


Figure 11. Seasonal fluctuation and the annual increase in the elephant seal population on Año Nuevo Island from May 7, 1961 to May 7, 1964.

Theodore C. Pinney on South Farallon Island on September 20, 21, and 22, 1962. In late May, 1964, three of five elephant seals seen by the same observers on South Farallon bore Año Nuevo Island tags. The Farallon Islands are approximately 55 miles northwest of Año Nuevo Island. A male elephant seal that had been tagged as a pup on Año Nuevo Island on February 17, 1962, was found dying on a beach $5^{1 / 2}$ miles south of Cape Sebastian, Oregon, by Dan Snook on May 30, 1964, and reported to the Oregon Fish and Game Commission. The distance between these two localities is nearly 400 miles.

Immatures. The majority of elephant seals on Año Nuevo Island come under this category, here used to include animals ranging from about 6 months of age up to, but not including, subadults. Males classified as subadult were those with a fairly well developed, yet not markedly, pendulous proboscis and which lacked the gray and pink coloration on the thickened epidermal shield of the chest and neck. With the females age grouping was more difficult so relative size alone was relied upon.

Because the young are born in January and February, the influx of immature elephant seals which began in early September and reached a peak in October (table 3) was composed of animals over 6 months of age. No adults or subadults were noted until late in November when the immature population began to decline. A few immatures were still present in January, but none was recorded in February. In March immatures again appeared on the island. This influx continued through April, with the greatest number of individuals for the year being recorded about the beginning of the second week of May (fig. 11). Maximum numbers recorded for 4 years are as follows: 86 on May 7, 1961 (Radford, Orr, and Hubbs, 1964, table 1), 157 in 1962, 450 on May 8, 1963, and 483 on May 7, 1964. On only one of these dates were any individuals other than immatures and young of the year noted. This was on May 15, 1962, when two subadult males were seen. Bartholomew and Hubbs (1960) noted a complete absence of adults in April on Guadalupe Island.

After the middle of May the number of immatures declined, and by July they were mostly replaced by large males. The number of males exceeded the number of females during the spring peak but in late September and October the sexes were present in about equal numbers.

## Harbor Seal

Areas occupied. The harbor seal, unlike the Steller sea lion, the California sea lion, and the elephant seal, is a shoreline, bay, and estuarine species. In the Año Nuevo area it is not limited to the island but is also found along the adjacent rocky mainland. There appeared to be a movement of individuals between these two areas which are separated by only one-half mile of shallow water.

On Año Nuevo Island harbor seals were observed in the vicinity of the northern and northeastern parts. During low tide area 13 was a favorite resting place. Here they were scattered on rocks that were underwater at high tide and with the incoming tide they floated or swam off. Some would remain in the protected cove formed by rocks $11,12,13,14$, and 15 , while others frequently moved onto a ledge on the south end of 14 (fig. 12). A number of individuals could usually be observed in the water east of both 14 and the northern part of 17 during high tide.

On the mainland the principal hauling-out areas at low tide were offshore rocks about one-quarter of a mile north of Año Nuevo Point and a large offshore rock about 300 yards east of the point in Año Nuevo Bay. At high tide most of the seals appeared to stay in the water between the point and the island or in the Año Nuevo Bay just east of the point.

Population. The maximum number of harbor seals in the area extending from the northwestern part of Año Nuevo Bay to the end of the reefs about 1


Figure 12. Three harbor seals on a ledge near the water's edge on reef 14. Photograph by Robert T. Orr, July 23, 1963.
mile north of Año Nuevo Point and out to the island itself was estimated to be about 100 . The greatest number counted at low tide was 86 on July 23, 1963. Not all potential hauling-out areas were examined at this time and some individuals may have been overlooked in the water.

There was no indication, locally, of any migratory movement on the part of harbor seals; consequently the population showed only minor fluctuations throughout the year. Since the young are born in this region from late March through May, somewhat greater numbers were noted in June and July.

Northern Fur Seal
On July 27, 1962, James H. Miller observed a fur seal periodically occupying a rock in area 18. The following day one of us (Poulter) photographed it with a 24 -inch telephoto lens. Pictures were sent to Dr. Victor B. Scheffer and Dr. Carl L. Hubbs, both of whom are familiar with fur seals. Each wrote that without doubt is was a northern fur seal (Callorhinus ursinus) ; Dr. Scheffer further concluded from the appearance of the animal that it was a male "at least five years old and probably much older."

Through the courtesy of Mr. Raymond Bandar we also examined a skull from a northern fur seal that washed ashore on Waddell Beach in the spring of 1959. This locality is about 3 miles southeast of Año Nuevo Island.

On March 30, 1964, we found the remains of a newborn northern fur seal on beach 17. The skin, vertebral column, and shoulder girdles were all that remained, but this was sufficient for identification. It was suspected that gulls had attacked the carcass. We do not know whether this seasonally early birth occurred on this beach or at sea.

Northern fur seals regularly winter in small numbers off the California coast but these are mostly females (Taylor, Fujinaga, and Wilkie, 1955). Since many of the females are pregnant, an occasional birth prior to the northward migration to the Pribilof Island rookeries does not seem too unusual. Much more surprising is the presence of the adult male in the midsummer of 1962. Males recorded along the California coast have been young and were not found in midsummer.

## Acknowledgments

Many persons visited Año Nuevo Island with one or both of us during the course of this project. To these persons we wish to express our sincere thanks for numerous valuable suggestions. We are indebted to the California Division of Beaches and Parks for permission to make these studies on property under its administration. Personnel of that Division in Sacramento, as well as in the Half Moon Bay office, were extremely generous in providing maps, photographs, and other valuable data bearing on the region; frequently one or more staff members accompanied us on our visits.

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# BREEDING CHARACTERISTICS OF YELLOWBILLED CUCKOOS IN ARIZONA 

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The yellow-billed cuckoo is widely distributed throughout the United States, southern Canada, and northern Mexico. The nominate race, Coccyzus a. americanus, is found in the most suitable habitat and is one of the commonest eastern birds. There are no striking distributional gaps. Nevertheless, in eastern North America this species has received only casual attention and the only account of its life history consists of various remnant materials gathered by Bent (1940). The western subspecies, Coccyzus a. occidentalis, at best a weakly defined race, is more scattered, occurring only in certain relatively humid regions in the West, especially along river bottoms in the southerly parts of its range. In California some of the habits of this race have been reported by Shelton (1911) who described a population nesting along a slough in Sonoma County in northern California, and Jay (1911) and Hanna (1937) who reported characteristics of populations in Los Angeles and Riverside counties in southern California.

In Arizona the only accounts are Bendire's (1895) report of a number of nests along Rillito Creek near Tucson, and Brandt's (1951) comments on the status of the species in the San Pedro Valley near Hereford.

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[^26]tern typed all field notes taken on recorder tape; her rapid and accurate execution of this task greatly facilitated this research. In addition, we are grateful for her help in preparing the manuscript. Mr. J. T. Howell, California Academy of Sciences, supplied the plant indentifications.

## Local Environment

The observations upon which this account are based were made along the San Pedro River, Cochise County, Arizona, 4 miles downstream from Fairbank, Arizona ( $31^{\circ} 43^{\prime} \mathrm{N} ., 110^{\circ} 11^{\prime} \mathrm{W}$. ) at an elevation of 4,100 feet, and along Sonoita Creek, Santa Cruz County, Arizona, southwest of Patagonia, Arizona ( $31^{\circ} 33^{\prime}$ N., $110^{\circ} 45^{\prime}$ W.) at 3,800 feet. A brief visit was made to the Patagonia area in mid-June, 1963, and an intensive investigation was made during the first 3 weeks of August, 1963, at both localities.

Brief additional observations were made at the Arizona-California border in mid-June, 1964, near Laguna Dam on the Colorado River.

Physical environment. These two Arizona locations were of considerably different physiognomy. At Patagonia a small stream, Sonoita Creek, cuts through a narrow mountain valley. On either side of the river bottom, never more than a half-mile wide and eventually narrowing to a gorge, rocky outcrops and steep slopes give way to the arid jagged terrain of the Santa Rita and Patagonia mountains. Sonoita Creek floods with seasonal rain, but the underlying rock basin forces water to the surface to maintain a permanent water flow beginning about 2 miles below Patagonia. Upstream the flow is subterranean except during the rainy season, and it is emergent only for a few hours after storms.

The San Pedro River has, by contrast, a broad river bottom, in some places over a mile wide. It centers in a sloping valley many miles wide. The drainage, from a considerable area, maintains a permanent flow. During the rainy season the shallow sandy river is over 100 feet wide in places.

These two areas, approximately 50 miles apart, share a similar climate. By late June or early July thunderstorms originating in the nearby mountains sweep across the intermountain plains, creating intermittent flood conditions in streambeds. The rivers often rise under sunny skies, the result of runoff from heavy rainfall elsewhere in the watershed. In consequence the summer climate during the yellow-billed cuckoo's stay is regularly quite humid. Only a few yards away from the river, however, the terrain becomes very dry, and the humidity drops sharply shortly after a storm passes.

Biological environment. No attempt is made here to describe the faunal of these two localities. Swarth (1929) has surveyed the vertebrate fauna of the Patagonia area.

Broad-topped tall cottonwoods (Populus fremontii) line the stream edge and scatter across the stream bottom of Sonoita Creek. Tree willows (Salix
gooddingii) edge the creek and their roots, together with occasional large rock outcroppings, fix the stream meander. Additional willows occur irregularly in the stream bottom and along lateral tributaries of sufficient drainage. These willows often rise from several main trunks and may be as tall as 40 feet. Under the cottonwoods is a ragged cattle-grazed understory of elderberries (Sambucus glauca), walnuts (Juglans major), and mulberries (Morus microphylla). In gravelly bars in the actual river bottom, arrowwood (Celtis reticulata) occurs in dense stands, a favored nesting place of the yellow-breasted chat (Icteria virens). Four miles below Patagonia the river bottom widens, and in this flat the ash (Fraxinus pennsylvanica) is exceeded in abundance only by the tree willows. At the edge of this creek mesquite (Prosopis juliflora) flourishes, shaded in places by tall cottonwoods. As mesquite extends from the river bottom, individual bushes are smaller and more widely scattered. They extend, however, well up on the rocky slopes before giving way to mesic vegetation such as ocotillo, century plant (Agave sp.), and Opuntia.

The woody vegetation along the San Pedro River resembles that at Patagonia. Cottonwoods, tree willow, and mesquite occupy comparable habitats. However, in the broad river bottom the Eurasian tamarisk (Tamarix pentan$d r a)$, absent at Sonoita Creek, is a prominent feature of the broad river plain. The Juglans, Sambucus, Morus, Celtis, and Fraxinus species, so characteristic of the Sonoita Creek locality, were not found on the San Pedro below Fairbank.

One of the most important floral features of both areas was Condalia lycioides, a spiny shrub scattered amongst the understory of the often continuous stands of mesquite and spottily but regularly distributed amongst the river bottom vegetation. A caterpillar hosted by this plant was an important food of the yellow-billed cuckoo at both study areas in the summer of 1963.

## Demeanor and Hunting Behavior

Cuckoos observed during the breeding season in August were not as vocal as most breeding songbirds. Possibly these birds become more vocal with the onset of July rains. In June they were practically silent. At that time we each spent over 30 daylight hours encamped and actively searching an area occupied by cuckoos. Yet we each heard but a single "kowlp" call. A 4-mile stretch of creek bottom was covered, listening carefully for 20 - to 30 -minute periods, without hearing a cuckoo. But when we played a recorded yellowbilled cuckoo call, we were at once able to locate an adult bird which had apparently been lurking nearby. Subsequent use of this technique produced two additional birds in less than 2 hours in the same area that had been so carefully worked earlier. These observations point out the inadequacy of attempting to determine presence or absence, much less abundance at this season, by observation or listening-post techniques. A more casual observer,
spending 3 hours in the field in a morning, could expect to hear less than one call a week at this season and in this area.

Skulkiness. During the course of the fieldwork in August, it gradually occurred to us that cuckoos were deliberately avoiding movement in our presence, especially nesting individuals. Continued observation confirmed this matter. When foraging undisturbed by the human observer, cuckoos would move about in the willow and ash vegetation with no apparent predilection to any particular level. High posts in cottonwoods were largely avoided. But when a bird was surprised or approached incautiously, it often retreated to a high post in the leafy lobes of cottonwood vegetation, holding this post for a remarkable period of time without additional movement. On some occasions the initial flight would take the cuckoo into the deep willow or mesquite understory, especially in areas lacking cottonwoods.

The positioning of these skulky birds was usually the same, backside to the observer. The back was arched, the body held low, the head turned slightly, watching the intruder. This performance, with the cryptically colored back oriented to the witness, the white front shaded, was a regular response to the observer. Once a bird in a willow was circled and during the periods when this bird was in view, its position relative to the observer was the same.

During these occasions when the human intruder was holding the attention of the cuckoos, they would not feed but simply devoted their time to watching and to evasive retreat. Only after repeated association with a bird, or in areas such as much used picnic grounds, would the cuckoo ignore the observer to carry out more routine activities.

Hunting behavior. Occasionally we were able to follow a bird without apparently disrupting its normal feeding routine for 2 hours or more. At first impression these birds seemed to have time to spare, being mainly concerned with scratching the head or other minor comfort movements, with much leisure time left over. For nonincubating birds this may indeed have been the case. However, it soon became apparent that what we were witnessing was the hunting mode of this bird. They are, in fact, no less alert to potential food reserves than a sparrow hawk sitting quietly on a wire over a field. Many of the actions of the hunting cuckoo are indeed quite hawklike. Much time is spent quietly waiting for the prey to reveal itself by movement.

Such a preying stratagem is suited only to predation upon large items, i.e., items with a unit intake value approximately equivalent to the amount of food which could be obtained by active search in an equivalent amount of time minus the extra energy required for active versus passive prey search. The items taken were indeed quite large, consisting, so far as we could indentify them, of large moth larvae and katydids. Apparently numerous smaller insects, many perhaps belonging to the same groups as those of the larger prey items selected, were being ignored.

An account of the relatively slow feeding tempo of a hunting cuckoo on August 6 for 35 foraging minutes, spoken to a tape recorder, was as follows:
(1) At 0943 it hopped through a tree willow at the 15 -foot level, then
(2) flew 60 feet to another tree willow 20 feet up, changed its perch three times,
(3) flew 40 feet to another tree willow, 10 inches from the outer limbs, and 20 feet up, took a new perch 10 feet higher in the same tree, again changed perches at this level, capered along a bare limb with tail cocked, stopped at this spot, then moved 5 feet across the open heart of the tree, to take a new post,
(4) flew across an opening to an ash, 18 feet up, and almost at once
(5) flew on 100 feet to the outer limbs of a cottonwood 45 feet up, moved 30 feet across the crown to a new post in the same tree, gave a "kowlp" call, and disappeared at 1018.

It thus changed posts 13 times in 35 minutes, with the feeding circuit including five trees, one of them only momentarily. No prey was taken during this period.

## Vocalizations

"Kowlp" calls and spatial relationships. This characteristic call is the species identification tag, often the field observer's only indication of the presence of this species. It has been variously described as "an uncouth guttural sound or note, resembling the syllables kowe, kowe, kowe, kowe, kowe! beginning slowly, but ending so rapidly, that the notes seem to run into each other, and vice versa. . ." (Wilson and Bonaparte, 1878), and as resembling a rapid pulling of corks from a bottle (Hanna, 1937). We have already mentioned the almost complete absence of this or any other call by cuckoos at Patagonia in June prior to the actual breeding season. In August these calls were considerably more prevalent.

On several occasions "kowlp" calls were answered by "kowlp" calls from other individuals. In these instances when the calling bird was observed, it faced toward the other calling individual and sometimes flew off in the direction of it.

Each pair clearly ranged over several acres and it was impossible to follow any individual long enough to effectively determine its spatial relationship to its neighbors. The response to recorded calls varied from individual to individual. The observer with the recorder was approached only occasionally. Then the bird moved in with a swooping flight, tail and wings spread, and flight slowed as the bird moved past the observer and instrument to a distance beyond. Frequently the responding bird either called back at the recording or simply moved into the vicinity of the playback device, remaining silent and perched at a high lookout post.

On August 11 at 1610 a cuckoo was heard giving repeated "knocker" calls (see below) at the mouth of a dry gulch entering the San Pedro River. This bird was perched in the top of a 40 -foot willow on the bank of the San Pedro. Moments later another cuckoo flew into the adjoining willow only 15 yards
from the bird giving the "knocking" call. Shortly the original bird again gave the "knocker" call. Almost at once the second bird gave a full "kowlp" call, then flew over and supplanted the original bird, almost landing on top of him. During the supplanting performance there was no obvious plumage or postural display. The supplanted bird flew off downstream. The supplanting bird found a small prey item near the top of this tree where the original bird had been, secured it, and ate it almost at once. This individual was followed as it hunted in the treetops here for the next 28 minutes. During this time it gave one additional "kowlp" call at 1635 . At 1640 it flew 75 yards upstream, to within 40 yards of its nest, giving a full "kowlp" call as it landed. This and other similar field observations suggest that the "kowlp" call is associated with the species spacing mechanism.

Since birds had probably been on these areas for 2 months, it is perhaps not surprising that no clear territorial situation was determinable. If territoriality is characteristic of this species, the wide range of each pair, covering many acres, and their secretive and elusive habits will make the description of the spatial characteristics of pairs a formidable task.

On numerous occasions birds gave "kowlp" calls after a flight, immediately upon landing. On August 7 below Patagonia, at 0901, we heard a complete "kowlp" call. It was possible to visually surround the tree from which this bird called as we approached. Presently, the bird flew out of this willow, directly overhead, with labored wingbeat and in full song. This vocalization approximated the usual "kowlp" call, but the delivery was more deliberate. While it was not the typical two-parted "kowlp" call, it was obviously composed of the same notes. On no other occasion did I hear this peculiar assemblage of notes. This bird landed within sight high in a cottonwood, went through a considerable series of preening movements, and hopped to a high open perch and at once gave a full and more characteristic "kowlp" call.

On all occasions when a bird was observed giving a "kowlp" call, there was never any indication of an extension of the chest or throat.

During August we heard over 200 "kowlp" calls. Since none was ever heard beyond 150-200 yards, this was the carrying limit of this call to our ears. "Kowlp" calls were given most frequently in the early morning hours before 0700. However, additional calls were given from time to time throughout the day.

It is possible that the "kowlp" call may have a mating function as well. On June 17, 1964, along the Colorado River, what was probably a male cuckoo flew into a willow tree directly over our heads, 40 minutes before sunset. Moments later he flew to an upper position in the tree willows 50 meters from the river and gave two complete "kowlp" songs. A female joined him in the dense upper branches of this willow tree. This female took what seemed to be the preflight intention movement (fig. 1c), but exaggerated, so that her tail pointed
straight up. The male flew down, hovered over her with legs dangling, landed on her back, and either attempted to or did mate with her. This all took place quite quickly and the male at once flew off. The female remained in the vicinity for awhile, then flew off in a different direction. Some minutes later the male gave the "kowlp" call again, and was apparently rejoined by the female.

At this season (June 17-18) along the Colorado it was apparent that nesting was not yet under way, for we saw several pairs moving about as a pair, often separated by 50 meters or more, but occasionally coming together. Territorial boundaries seemed to be in a state of flux, but with the general spatial features already established. The frequent songs ("kowlp" calls) suggested that this population was at a stage approaching that of the southern Arizona populations we had observed on August 1 the year before. One pair was frequently observed in a tree willow overhanging the river, a site to which they repeatedly returned. Perhaps this was the potential nest site, but on June 18 there was no trace of a nest in this dense vegetation.

On these occasions when two birds were under observation for a considerable period of time only one bird of the pair was ever noted to give the "kowlp" call. It seems probable, therefore, that the "kowlp" call is limited to the male.

The loudness and ringing character of this call is probably adapted to the large territory size of this species. Little attention seems to have been paid to the volume characteristics of territorial proclamation. Increased volume should be characteristic of sizable territories, the natural sound environment playing a modifying role. This may be one reason why early morning song is so characteristic, for it is a time of environmental stillness, generally windless. Selection for lowered volume in territorial proclamation calls would come from factors of energy conservation and reduction in the number of territorial boundary encounters.

At the Colorado River area this call seemed much more variable than in the Patagonia or San Pedro areas. Here this call was often not as prolonged and sometimes terminated with but a single or two or three ringing notes. Since this population was decidedly more dense, it is possible that the more varied vocal repertoire was related to this aspect of the population.
"KNOCKER" CALL. This call, a harsh rattled call, was quite different in character from the clear "kowlp" call. Often repeated once initiated, this call consists of a series of notes blended together; each quickly follows the other to form an integrated call which sounds somewhat like a mechanical door knocker allowed to drop freely against a striker plate. Unlike the "kowlp" call, this call appeared to be limited to social situations; when we heard it we could be sure that the mate was nearby. The volume was considerably less than for the "kowlp" call and we rarely were able to hear it beyond 40 meters. A very variable call, it seemed less ritualized than the "kowlp" call, yet it was usually quite identifiable as this particular vocalization. This call is given by both mem-
bers of the pair, often several calls to the sequence, again in contrast to the "kowlp" call which was seldom repeated as frequently as once every 10 minutes. The communicatory significance of this call was never well understood by us, but the most frequent response of a bird hearing it was to return the call and fly off in the direction of it if it were not already in the presence of the mate. In close proximity return calls were regularly given. Yet we should not create the impression that these birds chatter back and forth with this call in the normal course of activity. Normally they are silent. Occasionally they give the "kowlp" call, and when disturbed or in other unidentified special circumstances the members of a pair may vocalize with a "knocker" call.
"Coo" call. On several occasions during August a soft many-noted cooing call was heard. These resonant sequences of cooing were repeated several times per minute, often for an hour or more. Cooing birds held high to the treetops, usually at exposed posts in dead snags 40 feet or more above the ground. Sometimes these cooing birds would range widely to the surrounding slopes several hundred yards from the river bottom, taking posts on bare oak limbs. All the while these individuals were incredibly exposed by comparison with the usually secretive demeanor of the birds in the river bottom. Moreover they did not attempt to shelter the white breast, which was sometimes visible 100 yards or more in the slanting morning light. Exposure was indeed typical of this behavior, and cooing birds moved openly along the river bottom, venturing freely into areas occupied by other birds. Occasionally other cuckoos would approach, to give the "kowlp" call once or twice, then back off. These cooing performances were persistent, with activity located in certain broad areas for days. We saw this performance from only three birds, out of a total population of more than 30 taken under observation. One possible explanation, based upon the persistence of the behavior, the response of other birds, the openness suggesting advertisement, and the visual component described below, is that this display is a function of unmated males.

Accompanying this call, with every note of each series of coos, the gular area is remarkably inflated, filling to about the size and shape of a golf ball (fig. 1). The sac is inflated and collapsed with each note. The bill is not opened, but the head falls lower and lower with each successive coo.

The number of cooing notes per sequence varied from individual to individual. A typical observation was as follows: "During the past 28 minutes, starting at 0903 (August 7, 1963) the bird has given 4 to 6 series of these coo notes per minute. The number of notes in each series does not vary to any great extent. The following count is the total notes per series for a sample run: 7, 9, 8, 6, 8, 10, 9, 11, 9, 7, 5, 9, 9, 7, 6, 6." Each sequence takes from 3 to 7 seconds to deliver and the pause between sequences was from 7 to 10 seconds.

In June of 1964 along the Colorado River we heard this call repeatedly, coming from at least three different birds. At that time the birds in that area


Figure 1. Postures of the yellow-billed cuckoo. The upper left shows a "coo"-calling cuckoo with throat sac inflated, the upper right the same bird at the end of a series of "coo" notes. The lower left is the flight intention movement (but see text) and the lower right is a hunting and alert (to man) posture. Drawings by Bob L. Olson.
moved about in pairs, apparently defending large territories together. The observation of coition and the frequency of "kowlp" calls suggested that nesting was imminent but not yet under way. The context of these "coo" calls was less apparent in this region since we were unable to extend observations over a sufficient period to evaluate the status of individual birds. However, these observations seem to offer additional evidence that these calls are characteristic of prebreeding behavior.

Scream. On August 18 we attempted to net the birds at a nest with nestlings. In spite of the presence of a mist net near the nest, the female at once returned to brood the young and was secured in a fold in the net when it left the nest. As one of us was climbing to within about 12 feet of the netted bird, it ceased its struggles and began to scream continuous loud, harsh, rasping cries. Almost at once the male dashed through a gap in the crown, struck the net full force, and was captured. This call as never heard on other occasions in the natural situation. These individuals gave this call in captivity on other occasions when attempts were made to grab them inside a cage.
"Mew" call. A unique mewing sound accompanied the distraction performance of these birds under certain circumstances (see Incubation, below). Like the scream, this call is reserved strictly for predation situations.

Calls of the young. Some of the vocalizations of the young are described below under Development of the Young. It is interesting to note that in the young there is an additional unique vocalization which has apparently evolved in the context of potential predation.

## Incubation

Data on the incubation period were obtained at nest 2. This nest was located on August 6, 1963, at 0904. It contained one cold egg. No bird was on or close to the nest. The egg was marked. On August 8 at 1025 a bird was on the nest incubating two eggs. The new egg was noticeably smaller and more evenly colored than the first. It was also marked. Daily visits on the following days confirmed that the clutch was complete at two eggs. On August 17 at 1045 the nest contained one egg and one freshly hatched young. The following morning at 1030 the second egg had hatched.

An approximate determination of the incubation period is possible based upon these data. Since the eggs hatched on separate days, incubation must have started on separate days, assuming the incubation period of both eggs was the same. The earliest incubation could have started would be the morning of August 6 for the first egg and August 7 for the second. It could have been a day later for both. This would make the incubation between 10 and 11 days. Perhaps the first egg was laid on August 5 and incubated during the nights of August 5-6 and August 6-7, with the second egg being laid the morning of August 7 and continuous incubation starting at that time. This would still leave the incubation period at 10 or 11 days.

With this incubation period as a basis, it is possible to fairly accurately estimate the timing of the start of the other nests. Nest 1 contained two young and one egg on August 13 at 1030. One of these young gaped freely when the nest was jiggled, the other kept its head down. Probably they had hatched on separate days, one on August 12 and one the morning of August 13. The third young had hatched when the nest was checked at 1255 on August 14. Presumably, then, the final egg was laid August 3 and the others on August 1 and July 29, if laying on separate days is assumed.

Nest 3 had one egg and one young when it was discovered on August 12. This egg never hatched. The eyes of the young bird opened the following day, which would make it about 3 days old when first discovered, putting hatching at August 9 and the incubation start at July 30 for this egg.

It is revealing to review historical statements concerning the incubation period of the cuckoo. The duration is currently quoted in most references as 14 days for both the yellow-billed and black-billed cuckoos. This erroneous
figure has been repeated in scores of state bird compendia and other references. The first reference to the incubation period of the yellow-billed cuckoo was by Bendire (1895): "Incubation, I think, lasts about 14 days. . . ." This qualified statement was enlarged upon by Burns (1915) who did not cite his source but indicated that all the sources of his information were "reliable." He gave the incubation period for the yellow-billed and black-billed cuckoos as 14 days, without qualification. It is apparent that later workers have derived their figures from this source or from one another.

The incubation period of the black-billed cuckoo was determined in 1943 by Spencer as 11 days. It thus seems likely that the incubation period of both North American cuckoos is 10 or 11 days.

Behavior at the nest. The only persistent pattern to the incubation position was that the bird never faced the heart of the tree, but always oriented at least generally away from the trunk. The long tail poses a considerable concealment problem during incubation. Held horizontally it would hang over the side of the nest, and often it is held in such a position. On other occasions the bird aligned the tail along the nest limb, but this apparently does not exceed chance. This was true at both nest 1 and nest 2 . The posture of the bird at nest 2 differed from nest 1 . The incubating bird at nest 2 would often sit with the tail cocked at a $45^{\circ}$ angle with the neck and bill pointing up at the same angle. Perhaps this was simply an alert position induced by close approach to this low nest.

Incubating birds did not sit especially close. On August 10 we raised a pole with a mirror to the 32 -foot-high nest 1 . The bird, sitting on well-incubated eggs, flushed when the pole was 2 feet away. At this same nest on August 14, with three newly hatched young, the adult bird did not flush when one of us climbed to within 5 feet of the nest. Instead, it stood at the edge of the nest, back to the hot midday sun, wings spread, sheltering the nest. It made no move to depart until a gesture was made to approach closer. At the more strongly supported nest 2 no such approach was tolerated at any stage of the nesting cycle.

Shading the young was noted again on August 13 at 1400. The day was hot and this crown nest was shaded from the sun only by a thin sprig of willow leaves. The heat was intense. An adult stood at the edge of this nest, back to the sun, wings cupped and partially spread, but flew off when the nest was approached to within 15 feet. By the time the nest was reached, the unprotected young, pinfeathered bird was panting, mouth continuously open.

Distraction elements. A distraction display was noted at nest 1 on August 10 when we put off an incubating bird. When the bird flushed it dropped through the open undercanopy of the tree willow in which the nest was located. The wings were held high over the back, sharply cocked at the carpal joint, and opened, so that the copper red of the primaries and secondaries flashed. It
alighted first on a heavy trunk in the upper canopy 18 feet from the ground, then immediately continued its downward flutter, landing again on the trunk of the adjacent tree willow, now with the wings held more fully to the side. The tail was half fanned, the dorsal aspect oriented towards us. This away-facing posture was held, so that we could view the upper side of the wings and the dorsal side of the tail. The entire effect was one of a greater show of the coppery-red plumage in the wings than could have been presented in any other manner. The limb on which it now perched was nearly on the ground. It cocked its head towards us, then moved off into the deeper streamside vegetation. A few moments later we heard a modified "kowlp" call less than 50 yards away. On other occasions these same birds remained in the adjacent trees giving repeated "knocker" calls.

On August 16 the distraction attempts at nest 1 were more vigorous. The bird dropped almost vertically through the upper stay of the host willow's vegetation, all the while holding the wings forward and fanned. The tail was spread wide, and for the first time the bird gave an audible sound to accompany the performance, a whining "mew" interspersed with "knocker" calls. Now the mate appeared, flashing its wings. This second bird gave a modified "kowlp" call. On subsequent visits this mewing call always accompanied the distraction display.

The birds at nest 2 never performed this sort of distraction. On August 8 the bird flew directly away in a wavering flight when flushed, only 2 or 3 feet from the ground. The following day it left when we were 12 yards away. As it departed it dropped low, remaining no more than $31 / 2$ feet above the level clear ground under the mesquite canopy. The flight was slightly erratic, the tail flashed considerable white, and the red in the wings was more noticeable than in ordinary flight. On this and other occasions the departure flight was slowed. Once, a bird leaving this nest actually soared for 8 or 10 feet in much the manner and posture of a sailing nighthawk. On other occasions the wingbeat was deliberate, the deep strokes could easily be counted, and at least once were alternate.

At nest 3 the performance closely resembled that at nest 1 . Like nest 1 this nest was in the crown of a sizable tree willow. These birds displayed with the wings and tail, and were very vocal with "knocker" and occasionally "kowlp" calls. On August 12, while we were examining their young, one of the birds flew from perch to perch in the nearby trees giving repeated "knocker" calls at approximately 10 -second intervals.

Distraction seems, therefore, to be adjusted to the environmental situation. Under the closed canopy of the nest tree at nest 1 , a slowed flight directly away from the nest would have been meaningless to a ground-traveling predator. At nest 2 this might have induced pursuit.

The distraction elements noted were, then: (1) display of bright plumage
features, including the coppery red of the wings and the white in the tail, (2) sound production, including a special mewing call heard only in this context, frequent "knocker" calls, and occasional "kowlp" calls, and (3) slowed locomotion away from the nest.

The distraction elements noted may be broadly categorized as auditory and visual. Auditory distraction was noted where a close canopy limited the opportunity for effective visual displays.

The visual distraction display includes the following elements: (1) the distracting bird drops almost vertically from the nest position, (2) it moves away from the vicinity of the nest at the same time, (3) spreading the wings and tail, and (4) accompanying this visual performance with a mewing call.

During auditory distraction this mewing call is not utilized. Instead, the bird may (1) emit "knocker" calls at intervals much more frequently than would ordinarily be produced, along with (2) a similarly accelerated pace of "kowlp" calls, while (3) circling the potential predator out of sight, but not moving away.

While yellow-billed cuckoos in most areas nest in fairly deep vegetation, they are often at the edge of openings. This is particularly true of western yellowbilled cuckoos which may nest in deep riparian vegetation, but are often close enough to openings over watercourses to permit an injury-feigning arena. In the case of the nests reported here, this adaptability to the particular local situation was prominent. In the case of nests 1 and 3 , which were in deep-willow vegetation, the response tended toward auditory distraction. Nest 2, in a comparatively open area, lacked auditory distraction altogether. At nest 1 the open understory of the tree was the visual distraction arena. This again emphasizes the latitude of the response in closely adapting to the immediate situation. The distraction at this site could not be elicited simply by open space and a clear view ahead: the tree canopy precluded this visual stimulus.

## Development of the Young

Abbreviated incubation is followed by a similarly rapid nestling development. The eyes open 3 days after hatching. On the 6th or 7 th day the feather sheaths are methodically pulled off by the nestlings and the whole appearance of the bird changes from a quilled, dark-skinned lump, to a feathered bird with brown back and white breast. The tail is still stumpy and takes several days to grow out, but after the 8th day these birds can easily move away from the nest and, if forced, will fly to another perch. They are not easily caught.

Sound production. By the time the young are a day old they begin to make a persistent buzzing call which remains in the vocal repertoire until fledging. This call becomes louder during the 2nd and 3rd days, but thereafter its intensity no longer increases noticeably. Basically a series of very closely
spaced clicks, these calls follow one upon the other. When there is more than one bird in the nest the effect is a continuous insect-like buzz.

In captive young this buzzing is continuous during agitation. With artifical brooding, i.e., a warm covering, the buzzing becomes less frequent and each burst is less prolonged, until the sound fades away. This sound accompanies begging. Nevertheless, it is not necessarily an amplification of the begging response, since it is also continued when the young are satiated and not begging. Nestling black-billed cuckoos from Ithaca, New York, made a very similar sound, but louder and crisper. There we thought this sound resembled and perhaps mimicked the solitary paper wasps which make a similar buzz before exiting their homes. The sound is well adapted to predation situations, since it is continuous, permitting few location cues, and is faint, audible at only 4 or 5 feet.

Predator responses. In their first days the young show no awareness of potential predation by a human intruder. When the eyes open this at once changes. On August 16 the two older young at nest 1, now aged 4 and 5 days, hunched down when we appeared a yard away. Their eyes were wide open, but they remained motionless. At the same time the 2-day-old birds at this nest betrayed their silence and stillness, rising high and begging vigorously and noisily when the nest branch was disturbed. The same thing happened the following day. Lack of uniformity of action is obviously one of the prices paid for the advantage derived from asynchronous hatching.

By the time the young are a week old the alert posture of the adults, with tail up and wings down, is attempted by nestlings, and they may try to scramble away. From their 3rd day the young clutch at the lining or framing material of the nest when they are picked up and it is difficult to remove them without damaging the nest. The young at nest 3, about 7 days old on August 17, performed the wings down, tail up, posture and gave a hard rasping squawk. It was 2 feet distal to the nest on a large, deeply furrowed willow limb. When we started to pick it up, it dug its claws deeply into the fissures of the willow bark and hung on tightly with its toenails.

There was no opportunity to follow nestling development more than a day beyond the sheath-breaking stage in the field. From the fully feathered phase there is surely a considerable period of additional wing and tail feather development. At this stage the young weigh only about 20 grams, and they will reach 50 at maturity. But the spurt in 17 days from the start of incubation to freedom from the nest is one of the shortest for any bird, precocial or altricial. Predation might be a selective pressure favoring a rapid development, but there was no evidence of unusual predation factors in either area, and a more likely explanation is discussed below under Food.

## Food

From June 12-16, 1963, the river bottom at Sonoita Creek was populated with cuckoos. At that season they were secretive (see Vocalizations: "kowlp" call), but the breeding population had apparently arrived. No observations on feeding behavior were made then and it was possible to evaluate only in general the availability of cuckoo food items.

In August the longer observation period and the breeding activity of cuckoos permitted direct observation of feeding behavior and an attempt was made to determine food items taken.

Food habits of cuckoos. The American cuckoo species seem to specialize on insects of fairly sizable proportion available locally in abundance. In North America at times other than the breeding season, a comparatively wide variety of insect and fruit species may be taken. Among the insect prey of the cuckoo are several species not usually selected by other insectivorous birds. For example, Audubon (1849) illustrates the yellow-billed cuckoo holding a swallowtail butterfly (Papilio turnus), and Dawn (1955) noted a black-billed cuckoo taking an adult monarch butterfly (Anosia plexipus), during the period of fall migration, then returning to attempt to capture another individual of the same species. An examination of a large series of stomachs revealed an entire tree frog in one (Beal, 1897), and Clay (1929) saw one hunt down a tree frog on the ground and swallow it. Lizards occasionally enter the dietary. Swarth (1929) found a whole lizard in a yellow-billed cuckoo stomach and we have seen one take a sizable Sceloporus lizard in central California. Reptiles are staple fare for many tropical cuckoos, so these observations are, perhaps, not surprising.

But by far the most regular and characteristic category of food items of cuckoos consists of caterpillars. These the cuckoo takes regardless of whether they are smooth, hairy, or spiny. In the eastern United States where massive outbreaks of certain tent-building caterpillars are periodic, it has frequently been suggested that cuckoos are especially abundant during these irruptions (Clay, 1929; Forbush, 1927; many others). Presumably cuckoos are recruited to areas of high caterpillar density during outbreaks such as these, suggesting a relatively nomadic phase during the period of spring arrival. In western river bottoms there may be a similar dependence upon a small number of caterpillar species during the breeding season.

Food in southern California. Cottonwood and willow bottoms along permanent freshwater courses are the habitat of the yellow-billed cuckoo in southern California (Jay, 1911; Hanna, 1937). Along the Santa Ana River and its tributaries near Riverside, Hanna (1937) found 30 nests over a period of years, with egg dates extending from May 29 to July 10.

During the first 11 days of June, 1963, we intensively worked the riverbottom areas along this river in the area where Hanna had been so successful in locating nests. Eugene Cardiff (personal communication) had heard cuckoos
in this area in recent years. But in 1963 we were unable to locate a cuckoo. Available habitat for cuckoos along the Santa Ana River has been greatly reduced owing to increasing urbanization and water-use changes. However, considerable stretches of seemingly favorable habitat remain, and most of the associated species mentioned by Hanna (op.cit.) are still to be found. Since the cuckoo is notably erratic in local abundance, no firm conclusions concerning its status here can be made. During this period of field investigation we were struck by the abundance of a spiny caterpillar (Hemileuca sp.). This caterpillar reaches a length of approximately 40 mm . before descending to the ground to pupate. In its early stages of development it is colonial and obvious. It feeds upon the cottonwood (Populus sp.), and several species of willow (Salix sp.) which flourish along the permanent sections of this stream. During June these caterpillars mature. The last instar is solitary and the coloration becomes lighter, making them comparatively cryptically colored. It seems possible that the June and July breeding season of the cuckoo, so clearly established by Hanna's large series of nests, may be timed to this caterpillar species here. Most other species in this area, insectivorous and seed eating, complete their breeding cycle considerably earlier.

## Nests

The three Arizona nests upon which this account is based were examined entire, then turned upside down and taken apart. Since there was practically no intertwining of components, nests came apart piece by piece in about the order of original construction. While these nests were basically similar to those described above and to one another, several differences indicate a certain versatility adapted to the nest site and to available materials.

Anchoring. Versatile adaptation of the nest to its site was well illustrated by nest 3 . This nest was centered in the uppermost and outermost branches of a 35 -foot tree willow at the fork of a 1 -inch branch. The first material laid down was a series of 51 dead willow twiglets close to the fork. The nest was not centered over this start, however, but was 65 mm . more distal. It seems that in order to properly secure the nest this preliminary anchor was constructed. By comparison, the anchoring and framing materials of nest 2 were indistinguishable. This nest was also placed in a fork, but the broader branches were larger and the nest was nearly centered over the fork. The anchoring material of nest 1 could not be examined. In removing it from its treetop position 32 feet over a stream this material pulled away.

The anchoring branchlets and the framing materials of all nests were all either mesquite or willow twiglets except for one tamarisk branchlet in nest 3. In nest 3 the first 51 twiglets were measured (table 1). The uniform diameter and fairly uniform length of these twiglets is probably not simply a reflection of the size twig which is easily broken off since there were a few which were

Table 1. Consecutive measurements in millimeters of the first 50 willow twigs laid down in cuckoo nest number 3.

| No. | Diam. | Len. | No. | Diam. | Len. | No. | Diam. | Len. | No. | Diam. | Len. |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 1. | 1.8 | 110 | 14. | 1.9 | 190 | 27. | 1.8 | 100 | 39. | 3.4 | 110 |
| 2. | 2.1 | 130 | 15. | 2.5 | 140 | 28. | 2.3 | 240 | 40. | 2.8 | 100 |
| 3. | 1.5 | 90 | 16. | 2.3 | 170 | 29. | 2.0 | 90 | 41. | 2.1 | 170 |
| 4. | 1.9 | 170 | 17. | 2.1 | 130 | 30. | 2.3 | 200 | 42. | 2.3 | 90 |
| 5. | 2.2 | 110 | 18. | 2.4 | 160 | 31. | 1.9 | 60 | 43. | 2.2 | 130 |
| 6. | 2.0 | 190 | 19. | 2.1 | 150 | 32. | .8 | 140 | 44. | 2.1 | 120 |
| 7. | 2.1 | 110 | 20. | 1.3 | 80 | (Tamarisk | Branch) | 45. | 2.5 | 140 |  |
| 8. | 1.5 | 90 | 21. | 1.9 | 120 | 33. | 2.2 | 190 | 46. | 2.6 | 140 |
| 9. | 1.7 | 120 | 22. | 2.9 | 180 | 34. | 2.3 | 160 | 47. | 1.8 | 70 |
| 10. | 1.7 | 150 | 23. | 1.0 | 50 | 35. | 1.8 | 110 | 48. | 2.4 | 280 |
| 11. | 1.8 | 130 | 24. | 1.9 | 100 | 36. | 1.9 | 150 | 49. | 1.5 | 90 |
| 12. | 1.8 | 110 | 25. | 2.0 | 100 | 37. | 2.7 | 270 | 50. | 1.9 | 70 |
| 13. | 2.1 | 100 | 26. | 2.2 | 160 | 38. | 2.5 | 270 | 51. | 1.8 | 180 |

considerably larger. In Ohio, Clay (1929) observed a yellow-billed cuckoo breaking off twigs for nesting material with the bill.

These anchoring branchlets are laid across one another in a random pattern, some extending well to the side of the main nest as supporting outrigging extending over the hosting limbs. All of the branchlets used in nest 3 were terminal tips. The majority were placed with the butt end outward. The outermost anchoring branchlets and the outermost framing pieces above them which did not cross under the center of the nest were the longest. Several of these long branchlets were curved, the contour of the curve forming the outline of the nest.

When I attempted to make a similar structure I had considerable difficulty at the start in keeping it from dropping through the crotch of the nest site. This was a lesser problem if branched twiglets were used, and the most complete nest, number 3, was examined with this in mind. Of the 51 twiglets listed in table 1, 9 of the first 10,6 of the second 10 , and 5 of the third and fourth 10 's, and 4 of the final 10, were branched. Branch 32, of a different material, was not included in this tally. Evidently cuckoos resolved the problem of having the initial structure collapse some time ago, and tend to use branched twiglets when starting their nest.

The first item laid down in nest 1 was a bunch of three $90-\mathrm{mm}$. willow leaves. This nest, unlike nests 2 and 3, was placed on the top of a limb. A leafy start would, of course, only be possible at such a site. Above these three willow leaves were four cottonwood leaves, then a nest frame of willow branchlets much like nest 3 . These leaves appear to have come from the tents of a hairy caterpillar whiched flourished in the river-bottom cottonwoods during June, 1963. These communal caterpillars, under the protection of web tents, eat both sides
of the surface flesh of cottonwood leaves, leaving the vein structure of the leaf intact. It was four of these leaves that followed the willow leaves into nest 1. Their presence in this nest confirms the presence of cuckoos about these tents. It may also suggest that actual nest construction was initiated, at least in a preliminary way, by late June or early July. They may have been placed in the nest along with the willow leaves when nest-site selection was under way and the actual process of nest construction had not yet started. However, some of these leaves persisted into August, and could have been obtained then.

Framing. Above the anchoring material in nest 3 there were 92 additional willow twigs. As with the anchoring pieces, the butt ends are most frequently pointed outward. These pieces are on an average shorter than the anchoring members and only a few spikes stick out from the nest to give it its pincushion appearance.

In nest 2 the anchoring material and the framing stuff were indistinguishable. In this nest these parts were all mesquite, the species of the host tree, in spite of an abundance of nearby willows. Perhaps this is more a concession to concealment than necessity. These larger branches conformed neatly to the host tree, hiding the nest much more effectively than if it had been made of willows. These twigs were of much greater diameter than the willow twigs used in nests 1 and 3 . There were 137 of these mesquite twigs below the lining cup.

Throughout the anchoring and framing portion of the nest, there seems to be no indication of weaving. However, the twigs do seem to be poked into place at the higher levels, and the precise order of insertion was difficult to determine.

Lining the nest. Above the frame the construction materials change abruptly to lining items. In nest 3 the material from the lining was about 6 mm . thick and consisted of strips of bark, leaves, and a great number of small twigs from the river cedar. A count of this latter material did not seem very useful since it was probably gathered in mouthfuls rather than as individual items. There were several hundred individual twiglets of this material and several larger much branched pieces. The whole of this material could have been gathered very quickly near the nest tree.

In addition there were 7 pieces of stripped bark in this nest, to 260 mm . in length and 15 mm . wide. The rest of these pieces were less than half as large. Two of these straps were wrapped over a framing willow twig and pushed back into the cup material. This was the only evidence of any weaving in any of the three nests examined.

Additional material in this nest included eight small separate willow leaves, a single small cottonwood leaf, and four mesquite leaves which had broken apart to a considerable extent. It seems likely that the mesquite leaves which Brandt (1951) found in his nest fell apart on drying rather than being stripped as he suggests.

The lining of nests 1 and 2 was similar but the area of these nests near Patagonia lacked the tamarisk material. We did not find this plant at Patagonia. The 6 mm . lining of nest 1 started with a flat mat of 6 willow leaves. These may have been placed fresh, since they were matted quite flat. These leaves were oriented so that the long axis of the leaves followed the long axis of the nest. Above these leaves there were additional mesquite leaves (entire compound leaf) and a number of cottonwood bark strips. These could have been obtained easily from almost any nearby cottonwood tree since almost all of these trees had a number of large dead branches with bark stripping away.

The lining of nest 2 was more than twice as deep as in the other two nests. This lining was clearly stratified. As in nest 1, broad leaves start the lining, in this case 17 caterpillar-eaten cottonwood leaves. Above these followed a mixture of broken mesquite leaves, 9 willow leaves, 11 additional pieces of mesquite twigs all about 50 mm . in length, a branchlet of ash seeds, and a small packet of unidentified capsular seeds. Finally, there was a lining of several strips of bark, more than a dozen rootlets, and two oak leaves.

All of the lining above the cottonwood leaves seems to have been added after the first egg was laid since my notes indicate that on the day the nest was discovered, August 6 , it was lined with three cottonwood leaves, and it was only by the grace of these three leaves that the egg was not visible from below.

Overall features of nests. The greatest overall dimensions of these nests were as follows: The frame of nest 1 was not measured. The cup was 102 by 275 mm . Nest 2 had a frame $275 \times 360 \mathrm{~mm}$. with a cup $84 \times 112 \mathrm{~mm}$. Nest 3 was $290 \times 365 \mathrm{~mm}$. and had a cup $115 \times 140 \mathrm{~mm}$. These dimensions emphasize the oblong and somewhat unsymmetrical appearance of the nest. From the nest cup the brooding bird overhangs the cup but only the tail exceeds the frame. The frame material effectively breaks up the outline of the bird which would otherwise, in a nest of more modest dimension, be silhouetted against the background.

Behavior of adults relative to the nest. That this may indeed be a very adaptive structure is illustrated by an experience with the adults of nest 1. After the eggs hatched in this nest, the nest was shifted to a lower position in the tree in order to facilitate netting the adults at a later date. The entire nest was placed on a rimmed wooden platform slightly larger than the anchoring branchlet lengths. The sitting bird could thus not see through the nest to the ground. On August 16 at 1545, when I approached the tree to check the progress of the nest, a stiff wind was blowing, the promise of an oncoming thunderstorm. The major trunks of the tree, including the displaced nest, were swaying considerably. I was anxious to flush the bird so it would not be startled and perhaps injure the young. So when I reached the branching trunk 8 feet below the bird, I banged the trunk and shook it. The bird was unperturbed, and remained on the nest, with the tail hanging over the edge of the platform. It finally flushed when

I was only 4 feet below and in sight. On other occasions these birds would leave when we were over 20 feet away. The advantage of the open nature of the framing material is demonstrated by this experience. It allows a careful watch of movement below the nest and at the same time conceals the brooding bird.

Nest building. Our arrival on August 3 was probably too late to witness nest construction activity. However, on August 4 at 1545, following our 5 hours of intermittent rain, Clark Ross observed a cuckoo, probably one of the nest 1 birds, in the top of a mesquite tree along a nearby tributary creek. First it flew into a mesquite tree and gave the "kowlp" call. It then picked off a short dead leaf from a mesquite tree, dropped this item, did the same with another leaf, and finally selected a larger dead leaf and flew off with it to the base of a nearby hill. This would be in the direction of nest 1 , which contained three eggs at that time, with incubation just under way. There are several possible interpretations of this observation. It is possible (1) that nest improvements continue after incubation has started, (2) that the continuing rain stimulated an attempt to dry or improve the nest lining, (3) that the nest building tendency had not completely subsided in spite of the recent completion of the nest, or (4) that the nest material gathering movements were a displacement activity resulting from some social encounter not sensed by the observer.

Incomplete nests and their interpretation. The entire lining of the nest seems to be omitted on certain occasions, while at other times it is less complete (Hanna, 1937). Since the lining phase of nest construction is a distinct step, its omission may reflect an inherited trait, perhaps favored in areas of high predation or moderate climate during incubation.

## Migration

In Arizona the yellow-billed cuckoo is strictly a summer resident. The winter quarters for this population are unknown, but probably include the jungles of South America where the species winters, from Venezuela to Argentina (A.O.U. Checklist, 1957).

Spring arrival. For a bird as unobtrusive as the cuckoo, migratory schedules are best established by workers who are in the field continuously through the spring and after the breeding season. In 1927 Swarth (1929) was in the vicinity of the Patagonia study area from May 10. He first observed yellowbilled cuckoos at Patagonia on May 25 and "others were seen and heard several times during the next few days, and it seemed evident that they were just arriving from the south."

Other evidence suggests that cuckoos are on the move later than June 1, however. At Sycamore Canyon, Arizona, Miller (1950) observed what he interpreted as a migratory wave on June 30, 1945. He had been encamped at that locality 2 days before this species was observed. They were quite vocal for a day or two, then none were seen.

At some western localities these cuckoos apparently occupy upland country prior to actual breeding, invading riparian woodland only when it is time to breed. In Sonoma County, California, Shelton (1911) states that "this bird keeps to the higher land, among the oaks and other timber, for a period of two or three weeks before retiring to the willow bottoms to breed." And in southern California Baumgardt (1951) watched a yellow-billed cuckoo eating caterpillars on manzanita in the San Bernardino Mountains at 5,000 feet on June 2, 1950. This is a habitat completely different from the lowland riparian habitat occupied by the species during the breeding season. In the Cape Region of Baja California the species has been reported in the mountains in midsummer. This may be the retreat of this species prior to its arrival in lower riparian situations to breed later in the summer (Brewster, 1902). But other workers have subsequently searched these mountain areas without obtaining evidence of cuckoo breeding populations (Van Rossen, 1945).

Fall departure. Swarth (1929) continued fieldwork through the period of fall migration. He notes: "During the last week in August cuckoos were seen in fair abundance about Patagonia, and in lesser numbers somewhat later, the last on September 11." I have examined five specimens taken by his group at that time, now in the collection of the California Academy of Sciences. A specimen taken in the Huachuca Mountains, Arizona, August 31, was an adult as were two birds taken at Patagonia on September 5 and 9. Two additional specimens taken at Patagonia on August 31 and September 11 were juveniles, easily identified by the less strikingly patterned tail feathers. It would appear from this scant evidence that the adults do not precede the departure of the young by any considerable degree.

## Discussion

Limiting factors, biological. The overall picture which this study produced was one of cuckoos breeding at a density considerably below that which the apparent food supply would permit. It is possible that food, in fact, is not a factor limiting the abundance of this species, but in Arizona we found no evidence of other environmental population-limiting mechanisms.

In considering the food supply with respect to the cuckoo population, three possibilities become evident. First is that breeding densities and spatial distribution of breeding pairs are adapted to the average or lowest year of food abundance. In 1963 the caterpillar which formed the major part of the diet of the young might have been unusually abundant. At the San Pedro River location there were, in fact, fewer caterpillars than along Sonoita Creek. Nevertheless, even there they seemed to be superabundant.

Second, what seems to be a superabundant food supply may be basically marginal to begin with. The caterpillar of the Condalia bush which is the main item taken to the young, is a relatively small prey item for the cuckoo, and
they are taken one at a time. Since each caterpillar it treated before feeding to the young or before being eaten by the adults, the labor involved in flying out to a Condalia bush, obtaining a caterpillar, and returning to the nest, would be considerable. Thus, it may be that several of the breeding adaptations of the yellow-billed cuckoo in Arizona are adaptations to time limitations with respect to this caterpillar.

A third possibility is that the spatial distribution characteristic of the yellow-billed cuckoo is adapted to other regions of quite different nutritive characteristic. There is some evidence to support the contention that gene flow from other areas is significant. The western race of the yellow-billed cuckoo is poorly defined and additional races from either Mexico or other regions have not been suggested. In other parts of North America the spatial requirement for successful breeding is probably greater. If the relatively small populations in Arizona are swamped by gene flow from these cuckoo populations, the yellow-billed cuckoos of Arizona might have no opportunity to evolve spacing mechanisms locally adapted to a particularly favorable food resource. It seems reasonable, therefore, to suggest that the density regulation mechanism of the Arizona populations may, in fact, reflect the requirements of the species population center in the eastern United States.

Limiting factors, physical. Possibly the location of nest sites is restricted to river bottoms because of humidity requirements for successful hatching and rearing of the young, regardless of the proximity of food. In the San Pedro River locality there are numerous stock ponds which have large cottonwoods and willows about them. Some of these ponds have permanent water. Near Saint David, Arizona, yellow-billed cuckoos were seen about these ponds in mid-August. While no nests were found, it seems likely that the species breeds there. Except for these ponds, no cuckoos were seen other than in the immediate vicinity of river bottoms. Along Sonoita Creek no cuckoos were noted above the region of permanent water. These observations suggest that permanent water or some environmental factor closely correlated with it are a basic requirement for the yellow-billed cuckoo. At the San Pedro River locality the Condalia shrub and its caterpillar extended several hundred yards beyond the river bottom. Cuckoos flew out to these areas to feed, but nests were apparently all located along the river bottom. The denser cover in the river bottom would not seem to be the sole factor dictating this choice since nest 2 at Sonoita Creek was in a mesquite tree, a few yards from the river bottom. Mesquite is the predominant shrub in the area for a considerable distance beyond the river along the San Pedro. The nest along the San Pedro River is on interesting example with respect to this hypothesis. Only 30 yards from the tree willow which supported this nest the humidity became strikingly lower. The extremely arid region adjacent to the river-bottom area was consistently less humid.

This suggestion again considers the genetic adaptation of the species as a whole throughout North America. The species population center in the eastern United States is concentrated in the deciduous forests and meadows which are consistently humid during the early summer breeding season of the species there. River bottoms in the west could be easily adapted as geographic barriers were penetrated. However, the utilization of a breeding terrain strikingly drier than that used by the species as a whole might be precluded by the lack of an adaptation permitting successful egg hatching under these conditions.

Adaptations to seasonal breeding. Compared with most temperate region songbirds, the yellow-billed cuckoo has an exceptionally long breeding season in the eastern part of its range. In the southeast and West Indies breeding begins in April, but may be delayed until June in the northen part of the range. In the southeastern United States the species may be double brooded, but this has only been inferred from the discovery of a progression of nests not necessarily by the same individual, as the season progresses. In every part of the species range exceptionally late nests have been located. Extremes are a nest with two young on September 9 in Missouri (Adams, 1933), incubated eggs in Alabama on August 11 (Golsan and Holt, 1914), eggs as late as August 15 in New Jersey (Harlow, 1918), four eggs in a nest in Illinois on September 5 (Hess, 1910), eggs in Alabama on August 10, 11, and 14 (Holt, 1925), fresh eggs in Florida on August 11 (Williams, 1904), and eggs in Michigan on August 27 (Swales, 1903). The latest date appears to be for the black-billed cuckoo, which was found sitting on four fresh eggs on September 14 in Michigan (Barrows, 1912) and with young in New York on September 10 (Bendire, 1895). These extremes point to the fact that in the breeding range as a whole reproduction may occur almost any time the species is present. This wide range of the reproductive season suggests at least a partial role of environmental control of reproduction. In addition it suggests a preadaptation to taking advantage of an abundant food source when it becomes available at a season not in phase with the usual breeding season. In the case of the yellow-billed cuckoo, however, the range of variability of the eastern populations includes the adaptive season in Arizona, and adaptation to this area would have been possible by selection from the genetic pool of the species: no new mutations would be necessary.

The wide range of breeding seasons presents an interesting problem with respect to the basis of their timing. If we accept Lack's (1954) hypothesis that the breeding season of altricial birds is timed to the maximum abundance of food, a well-supported hypothesis in general and one which seems to be supported in the case of these several populations of cuckoos, then the regulation of the timing of the breeding season presents a particularly interesting problem for this species. Several aspects of the breeding cycle in southern Arizona and southern California are compared in figure 2. The difference in breeding season
of these two populations could be based either upon local adaptations of mechanisms which permit the initiation of egg laying in anticipation of the maximum food supply or actual timing by the appearance of a satisfactory food supply.

The tent-building caterpillars in Arizona which were present in June provide interesting evidence with respect to these alternatives. If the mere presence of a rather abundant favorable food species triggered reproduction, this comparatively small outbreak could conceivably have triggered a flurry of breeding at a very inappropriate time. Yet breeding bypasses this false opportunity. During the latter rainy season in July and August when the flush of breeding occurs, not only are caterpillars available but alternate food resources such as other caterpillar species, grasshoppers and beetles would provide at least a partial substitute should the caterpillar crop fail.

It would be reasonable to suggest that breeding was timed by the seasonal rains here only if one assumed that this timing is a local population characteristic, since the nearby southern California populations breed at a season when there is no likelihood of any rain during their breeding season. And, lacking any evidence of large-scale genetic adaptations to local environments, it seems too much to expect that behavioral characteristics would be so different in these nearby populations.

Several features of the breeding cycle point to the possibility of adaptation to exogenous regulation. In particular, the tremendously abbreviated incubation period and rapid nestling development point in this direction. However, this could be an equally effective adaptation to a genetically timed cycle which takes advantage of the food supply available for only a brief period of time. If the clutch size of the Arizona population is actually reduced, as it seems to be, this could again be construed as evidence for genetic adaptation to a sharply resticted period of adequate food supply for the young.

Adaptations of the species. The field observations reported here and the general ecological situation suggest several aspects of the overall adaptation of American species of cuckoos to their niche not previously discussed elsewhere. A part of these imply specialization, but in general these adaptations seem relatively broad. In comparison with other species of similar size, the yellow-billed cuckoo is usually less abundant. This probably reflects the role of the cuckoo as a predator on sizable prey species.

A major adaptation which the yellow-billed cuckoo has made is with respect to a seasonally available, and comparatively abundant, source of food which has not been fully utilized by other species. In particular, the hairy tentbuilding caterpillars in the eastern portion of the range and certain species of spiny caterpillars which are rejected by other species are favored food items of the cuckoo. Combined with this predilection to secure food items which are not utilized by other species is an ability to time the breeding season to local


Figure 2. Breeding characteristics of yellow-billed cuckoos in southern California and southern Arizona. These dates are compiled from the literature, collections, and original observations. Five days were added to egg dates unless stage of incubation could be determined. The number of nests for southern California reflects the greater amount of study directed to cuckoos in that area. The departure dates are approximate and it is obvious that birds which hatch during the week of September 5 in Arizona can not leave that early. This discrepancy reflects inadequate data and a span of departure times; the entire population does not leave at once. Weather data are from U. S. Weather Bureau records.
conditions of food abundance. The observation of Bendire (1895) of cuckoos carrying a large number of sizable crickets (Anabus) to nestling young emphasizes that the yellow-billed cuckoo is adaptable, and not, at least as a species, restricted to a limited diet.

Timing of migration. In spite of the sharply different breeding seasons of the southern California and southern Arizona breeding populations, migration is accomplished by both populations at approximately the same time (fig. 2). In the case of the Arizona population this takes the species to the breeding grounds well in advance of the breeding season. There seem to be two plausible explanations for this characteristic.

First, it is possible that the time of migration of the species is adapted to
anticipate the season of maximum opportunity for the species as a whole. Since a relatively small part of the whole breeding population is breeding in a place with the late summer thunderstorm ecology of Arizona and Mexico, the fixed timetable of the vast majority of the population may swamp any tendency to adapt the migratory schedule more closely to the period of maximum food abundance.

Another possibility is that the premature arrival at the Arizona breeding locality simply reflects the necessity to vacate feeding grounds on the winter quarters which become inadequate, or at least less favorable, compared with what is available at the prebreeding Arizona environment.

Incubation pattern. Audubon (1849) was shown a yellow-billed cuckoo nest at Charlestown, South Carolina, which had two feathered young able to fly and three additional young of different sizes. In addition, the nest contained two eggs, one containing an embryo, the other fresh. None of the young were of the same size. Based upon the comments of the discoverer of the nest, Audubon felt that laying in the same nest continued over a prolonged period of time. It is now apparent, however, that the eggs of the American cuckoo species are laid in clutches. Incubation apparently begins soon after the first egg is laid. Thus, the young hatch either daily or every other day. Perhaps occasionally a longer span may separate hatching dates. This staggered incubation pattern is characteristic of owls, some hawks, coots, and a number of other species. It has often been suggested that the adaptive significance of this pattern is to insure that at least a part of the clutch receives adequate food. Thus, the firstborn will, with even a minimum amount of food, be vigorous and obtain food at every nest visit by the parent. During times of food shortage the last young to hatch will be neglected and will not limit the survival potential of the firstborn.

An alternative hypothesis is suggested by the limitations which seem to be imposed on cuckoos by the nature of their caterpillar food supply which they depend upon to such a great extent. If the amount of food which can be delivered to the young is restricted by time, i.e., the time required to fly out, obtain a caterpillar, return to the nest, treat the caterpillar, and deliver it to the young, rather than being limited by the overall abundance of food, then a staggered hatching sequence would be of considerable advantage. This would permit a greater number of trips for those young at a stage with maximum food requirements and would extend the period of productive food gathering.

The early fledging of the young and their especially early departure from the nest are also adaptive in connection with the considerable pretreatment which each caterpillar receives before it is ingested. If the young mature to a state of being able to move to the caterpillar source and do their own food manipulation at an early stage, a considerable time economy would be achieved.

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# THE LARVAL DEVELOPMENT OF CHITONS (AMPHINEURA) 

By

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Most species of chitons, as indicated by previous studies, develop in much the same manner as gastropod mollusks. Normally, the sexes are separate and during spawning periods the sex products are extruded into the surrounding sea water, fertilization being largely a matter of chance. The fertilized ova divide rapidly and in a period of a few hours hatch into free-swimming larval stages consisting of ciliated trochophores. In a few days to a week or more the trochophore starts to take on the form of an adult, developing a creeping foot and the beginnings of the shell structure. At this stage a larval chiton is said to "metamorphose" and moves to the bottom to carry on further development as a young individual with all eight plates or valves completely formed. While this is the usual procedure, there are exceptions upon which the purpose of this paper is intended to focus particular attention.

Because the literature on chiton development is scattered, a brief enumeration of studies made by both earlier and later workers in this field will be helpful. Although the spawning habits of chitons and their embryological and subsequent larval development have been reported by relatively few investigators, some of the earlier work has been thorough for the particular species studied.

Earlier workers dealt with Ischnochiton cinereus (Linné), a fairly common small chiton with a distribution in British and Scandinavian seas and extending into the Mediterranean. Some applied other species names because taxonomic relationships were not well understood at the time. Clark (1855), Lovén (1856), Garnault (1888), Schweikart (1905), Knorre (1925), Hoffman (1931), and

Thorson (1946) all worked with Ischnochiton cinereus. Other European students of chiton development include Kowalevsky (1833), who dealt with Chiton polii Philippi [ = Nuttallina (Middendorffia) cinerea (Poli, 1791)]; Plate (18991901), who reported on the embryology of Nuttallochiton hyadesi (Rochebrune) ; Lyngnes (1924), who studied both Ischnochiton cinereus and Lepidopleurus asellus (Spengler); Thiele (1906), who investigated Notochiton mirandus (Thiele); and Hammarsten and Rundström (1925), who did an excellent piece of research on Acanthochitona discrepans (Brown). Christiansen (1954) reported on the life history of Lepidopleurus asellus. Her paper on the methods used and the results achieved represents not only an important contribution to the subject of chiton development, but also contains by far the best review of the subject to date.

Heath (1899) started the study of New World chitons with a detailed investigation of the development of Ischnochiton magdalenensis (Hinds) [ $=$ Stenoplax heathiana Berry]. He also studied the breeding habits and development of Lepidozona mertensi (Middendorff), L. cooperi (Dall), Mopalia muscosa (Gould), Katharina tunicata (Wood), Trachydermon raymondi (Pilsbry) $\mid=$ Cyanoplax dentiens (Gould)], Nuttallina thomasi Pilsbry, and the giant chiton, Cryptochiton stelleri (Middendorff), all relatively common species in the vicinity of Stanford University's Hopkins Marine Station, where Heath lived and worked.

Metcalf's work (1892-93) on the Caribbean species Chiton squamosus Linné and C. marmoratus Gmelin was followed by that of Crozier (1918) on Chiton tuberculatus Linné, type species of the genus Chiton. Grave (1932) reported on the development of the western Atlantic species, Chaetopleura apiculata (Say); Okuda (1947) also worked with Cryptochiton stelleri. The most recent published report is by Thorpe (1962), who made a study of the spawning habits of a number of California species, including specific information on the larval development of Mopalia ciliata (Sowerby).

The investigations of all workers mentioned cover a total of 19 species, in 14 presently recognized genera, grouped into 7 families, which is a fairly representative coverage of the order Polyplacophora. Nearly all of the chitons studied have a developmental pattern consistent with that already briefly sketched. In a few instances, however, exceptions to the normal pattern have been found to occur.

Kowalevsky in 1883 and Plate in 1898 noticed deviations in the development of the larval stages based, respectively, on studies of Ischnochiton cinereus and $I$. imitator (E. A. Smith). Heath, reporting in 1905, called attention to similar deviations as a result of his work with Cyanoplax dentiens and Nuttallina thomasi, saying these species:

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Figure 1. Hemiarthrum setulosum (Dall). Female from below showing metamorphosed young in the branchial cavities. Length, about 10 mm . (After von Martens and Pfeffer.)

Figure 2. Same. Enlarged sketch of a single metamorphosed young animal. (After von Martens and Pfeffer.)

Figure 3. Callistochiton viviparus Plate. Enlarged sketch of a metamorphosed young specimen showing seven valves. (After Plate.)

Figure 4. Schizoplax branditi (Middendorff). Enlarged sketch of a female from below showing metamorphosed young in the branchial cavity. (After Kussakin.)

Figure 5. Same. (5a) Embryo at the stage of formation of the shell plates. (5b) Shell plates already formed but not fully developed. (5c) Young individual showing the divided intermediate shell plates and at a stage when ready to leave the mantle cavity of the mother. Length, about 0.75 mm . (After Kussakin.)
in the mantle cavity on each side of the foot. Plate speaks of their extending over the neighboring regions of the mantle and to some extent on the foot, but in the present case this removal of the eggs from the mantle cavity never occurs until the animal has been disturbed. . . .

Nuttallina thomasi, which breeds during the summer, carries its eggs in two rodshaped masses, each approximately 80 eggs, held in the mantle cavity on each side of the foot.

Commenting on the dioecious condition in chitons, Heath (1907) found in his work with the development of Cyanoplax dentiens that this species is normally hermaphroditic and that the young "are brooded by the parent as in the case of Chiton polii $[=$ Nuttallina cinerea $]$, Ischnochiton imitator, and two or three other species." ${ }^{11}$

Iredale and Hull (1923, p. 191) state that: "One of us took specimens of Heterozona subviridis at King Island, Bass Strait, with clusters of eggs disposed along the outer margin of the foot." Dell (1962), while examining specimens of Ischnochiton constanti (Vélain) collected by the William Scoresby off Gough Island, Tristan da Cunha Group, in 40 to 60 fathoms, noted that "one specimen had a clump of eggs fixed to the branchial groove on each side

Martens and Pfeffer (1886) apparently were the first to observe a further deviation from the normal whereby the eggs and the hatched larvae were retained in the mantle cavity through metamorphosis, including the development of fully formed shell plates, a phenomenon they termed brutpflege. The species in this instance was Hemiarthrum setulosum Dall from Antarctic seas. In his discussion of this species in the Manual of Conchology (1892, pp. 19-21) Pilsbry does not mention its larval development. His figure 1 on plate 5 of the Manual is a $1: 1$ reproduction of Martens and Pfeffer's original figure, which shows the ventral side of a female specimen with metamorphosed young arranged along the sides of the foot under the girdle. This would have been made clear had Pilsbry used the original caption for this illustration. Also, Pilsbry did not include the enlarged drawing of a metamorphosed young specimen of $H$. setulosum supplied by Martens and Pfeffer. In consequence, both original illustrations are included herein as figures 1 and 2.

Plate, in 1898, was the next to report on a chiton actually brooding its young through metamorphosis. He also commented on the possibility that some might be viviparous. He named no species at that time but in his comprehensive work on the South American chitons contained in the Fauna Chilensis, published in 1902, he described Callistochiton viviparus as a new

[^28]species from Isla de Pacheros, 12 nautical miles from Coquimbo, Chile. His figure of the young stage after metamorphosis is reproduced in figure 3.

In 1910, Thiele added another species to the deviate list, Sypharochiton nigrovirens (Blainville). Barnard (in Ashby, 1931) notes that: "Thiele refers to the presence of young under the mantle (girdle) edge. The same fact was observed in the case of specimens collected by me at Smitswinkel Bay, False Bay, in July 1912. The young are about 0.75 mm . in length." Dell (1962) states that a specimen of S. nigrovirens from Saldhana Bay, South Africa, has fully developed young clustered under the girdle edge, about 33 on the left and 22 on the right side. The Spencer Thorpe Collection has a series of 62 specimens, preserved dry, from Kleinmond, South Africa, 20 of which have similar metamorphosed young. One specimen measuring 16.9 mm . in length has a total of 42,23 on the right and 19 on the left side. The females bearing young range in length from about 9.5 to 18.5 mm ., the young themselves being about 0.7 mm . long.

Another report of a chiton brooding its young was made in 1960 by Dr. O. G. Kussakin of the Zoological Institute of the USSR, Department of Hydrobiology, Leningrad. In this instance the species is the peculiar Schizopla.r brandti (Middendorff), in which the intermediate shell plates are separated along the median line by a narrowly triangular wedge of cartilaginous material similar to that forming the hinge of a bivalve. This species occurs from the Okhotsk Sea, along the Aleutian Islands, and south on the Alaskan and Canadian side of western North America to at least as far as Graham Island off the coast of British Columbia. Kussakin's work was based on a yearround study of the development of $S$. brandti in the southern Kurile Islands in 1954-55. Because his paper may not be readily available to western specialists the somewhat revised English summary of it follows:

> A peculiar feature of the biology of $S$. brandti is the complete lack of a plankton larval stage; the whole development proceeds in the mantle (gill) cavity of the female from which the juveniles emerge with a completely formed shell resembling the adults. In this connection the development of $S$. brandti is considerably altered and simplified. Comparison of the development of this species with data available in the literature on other species indicates a trend in some chiton families toward a transition from a more complex to a more direct developmental process and toward viviparity.

Dr. Kussakin's drawings are indicative of the development of larval Schizoplax and they are reproduced with his permission as figures 4 and 5 of this report. Also, Dr. Kussakin has kindly furnished specimens in alcohol of S. brandti from the Kurile Islands, which contain both trochophore larvae and metamorphosed young. These have been deposited in the collection of preserved invertebrates in the Academy's Department of Invertebrate Zoology.

Mr. Spencer Thorpe informs me in connection with his study of the breeding habits of California chitons that he has found Nuttallina thomasi to be another species that mothers its young through metamorphosis, thus adding a fifth species to this category. Although Heath reported this species as carrying its eggs in the mantle cavity he made no mention of the stage at which the larvae emerged or were released from beneath the mantle.

To the five chiton species that follow a special development pattern, a sixth, may now be added, the particulars regarding which follow:

During a collection trip to Guadalupe Island, Mexico, in 1946, Mr. Woodbridge Williams made an interesting collection, principally in tide pools, of chitons and other species of mollusks (Smith, 1963). Among these was a large series of a small chiton that provides ample evidence of a propensity for mothering its young. Although original preservation of the specimens was in alcohol, unfortunately this particular lot was allowed to dry out. Careful microscopic examination of them disclosed that of 71 specimens, minute, white, perfectly-formed metamorphosed young were lying between the ctenidia and the side of the foot in 21 of them. Some of the specimens had from three to six young adhering to the dried-out animals, all with at least seven fairly well formed valves and an extremely narrow girdle with an outer fringe of well developed spicules. Although somewhat curled because of their dried-out condition, approximate measurements show a length of 0.25 to 0.35 mm ., which is considerably smaller than for comparable young specimens of Sypharochiton nigrovirens owing, no doubt, to the much smaller size of adults of the Guadalupe Island species. In size and other characters they resemble a specimen figured by Christiansen for an early stage of Lepidopleurus asellus (fig. 6).

Examination under higher magnification of some of the Guadalupe Island specimens with metamorphosed young showed as many as six or eight additional roundish bodies between the sides of the foot and the gill rows. Undoubtedly these are trochophore larvae in various stages of development. One of them, removed after careful softening, showed some of the characters of a typical trochophore larva of $L$. asellus at the end of eight or nine days' development, with three ciliary processes or flagella still intact projecting from the anterior end (fig. 7).

At first, the above evidence seemed impelling reason to describe this unusual little chiton species as new. However, in discussing the situation with Dr. S. Stillman Berry of Redlands, California, he mentioned finding very young examples under the girdles of his Lepidozona asthenes, making a check with his species imperative. It happens that I collected the original lot of $L$. asthenes in 1916 at White's Point, Los Angeles County, California, consisting of about 70 specimens. The Academy's collection has 28 specimens from this type lot, enough to make an adequate comparison with the series from Guadalupe Island. Observation under a magnification of $\times 90$ showed six
with metamorphosed young still adhering to the under sides of the girdles in spite of the fact that in many specimens a crude attempt at removing the foot and the underlying viscera had been made.

Further comparison between the two series of specimens (Smith, 1963) led to the conclusion that the Guadalupe Island series unquestionably belongs to $L$. asthenes based on the criteria of valve sculpture and configuration, and on the relative size, placement, and striated nature of the girdle scales.

Still more evidence that this species mothers its young through metamorphosis was discovered recently while studying a series of small chitons taken off the coast of southern California by Dr. William E. Ritter and Professor William J. Raymond in the summer of 1901 under the auspices of the San Diego Marine Biological Association (a predecessor of the Scripps Institution of Oceanography). Among the various lots was one containing 18 specimens of $L$. asthenes collected intertidally at White's Point, the type locality. Three of these also had metamorphosed young beneath the mantles; one still has eight of them plainly visible on both sides of the foot of the dried animal, along with nine or ten unmetamorphosed larvae.

## Development of Chiton Shell Plates

Although perhaps ancillary to the main subject of general chiton development in the early stages, the manner in which the shell plates form is of considerable interest. A number of accounts have been published about this but the reports of two or three specialists will serve to review our knowledge of the process.

Dall, writing in 1879 (p. 291), says: "The valves are first irregular, but increase from below, and deep notches, persistent in the adult, are formed on the front edges, one on each side. It will be seen that the valves are formed each in one piece, and by the coalescence of parts corresponding to the various areas of the adult valve. There are eight valves in all Chitons . . ." (fig. 8).

Heath's more detailed account (1899, Thesis, pp. 65-66) is as follows:
The first clearly marked indications of the shell [in Stenoplax heathiana] occur usually about the fourth or fifth day when a band of somewhat clear cells appears parallel with and a little posterior to the prototroch. Very soon after another appears a short distance behind the first and the process is continued until seven such bands alternate with six narrow rows of darkly staining cells. . . . When treated with methyl green they stain intensely and this reaction continues as far as I have traced the development of the shell, when these cells come to occupy positions between the valves of the shell. The narrow bands of cells apparently but little differentiated which alternate with these mucous (?) cells gradually increase in breadth . . . and ultimately the calcareous portions of the shell appear above them.

The calcareous salts are deposited in the cuticle covering the region of the shell and the presence of the tegmental sense organs (aesthetes) makes it evident that the first part of the shell to form is the tegmentum. The articulamentum appears later but the manner in which it forms is as yet unknown.


Kowalevsky ('83) has accurately described the formation of the calcareous portions of the shell and Ischnochiton [i.e. Stenoplax] affords no further important points on this subject, (figs. 10, 11).

In Lepidopleurus asellus during metamorphosis, Christiansen says the rudiments of the shells extend into the dorsal region of the cephalic portion of the developing larva and the calcareous plates themselves appear very irregularly, each plate being composed of three parts. The eighth shell plate is the last to appear. In a nearly two-month-old larva the eight calcareous plates cover the back and appear to be well developed.

Thus, from these accounts, the formation of the first six shell plates seems reasonably clear, allowing for possible minor differences between species. There appears to be no specific information, however, on just how and when the last two (valves vii and viii) are formed. Plate's illustration of the metamorphosed larva of Callistochiton viviparus (fig. 3, herein) shows but seven complete shell plates. Likewise, Kowalevsky's figure of a well developed larva of "Chiton polii" shows seven (fig. 9), while his figure of a "young form" shows eight, with the eighth just beginning to develop. Christiansen says the tail plate (valve viii) of Lepidopleurus asellus is the last to appear. In my detailed examination of the metamorphosed young of both Sypharochiton nigrovirens and Lepidozona asthenes, however, the line of demarcation between the last two is extremely difficult to make out. For L. asthenes, in fact, some of the young appear to have only seven valves at the stage of development when they were collected, valve vii not being well developed.

## Summary and Observations

To sum up from a survey of published accounts, the chiton species of the following list have been observed to deviate from the normal pattern of larval
$\leftarrow$
Figure 6. Lepidopleurus asellus (Spengler). Enlarged sketches of dorsal and ventral sides of a nearly two-month-old specimen after metamorphosis. (After Christiansen.)

Figure 7. Same. Enlarged sketches of dorsal and side views of a trochophore larva at $83 / 4$ days. (After Christiansen.)

Figure 8. Ischnochiton cinereus (Linné). (8a) Dorsal view of larva, the valves beginning to be formed. (8b) Same. Ventral view, showing foot, and eyes at the sides of the head. (8c) Older individual, showing diminished size of the anterior tuberculate lobe, or head. (Dall, after Lovén.)

Figure 9. Nuttallina (Middendorffia) cinerea (Poli, 1791). Enlarged sketch of young form showing seven valves in process of formation. (After Kowalevsky.)
Figure 10. Stenoplax heathiana Berry. Much enlarged sketch of young stage at end of fourth day, showing fusion of the three portions of the valves. (After Heath.)

Figure 11. Same. Young stage fifteen days after hatching, with metamorphosis complete. (After Heath.)
development, with the females depositing their eggs in the branchial cavity and retaining them there at least to the trochophore larval stage:

| Species | Family | AUTHORITy |
| :---: | :---: | :--- |
| Ischnochiton cinereus (Linné) | Ischnochitonidae | Thorson (1946) and others |
| $"$ | $"$ | Plate (1897-1901) |
| $"$ | imitator (E. A. Smith) | $"$ |
| subviridis (Iredale and May) | $"$ | Iredale and Hull (1923) |
| Cyanoplax dentiens (Gould) | $"$ | Dell (1962, 1964) |
| Nuttallina cinerea (Poli) | Callistoplacidae | Heath (1905) |
| Chiton bamesi Gray | Chitonidae | Plate (1897-1901) |

Species that mother their young through the final stage of metamorphosis, including the development of fully-formed shell plates are:

Species
Hemiarthrum setulosum Dall
Lepidozona asthenes (Berry)
Schizoplax brandti (Middendorff)
Callistochiton viviparus Plate Nuttallina thomasi Pilsbry Sypharochiton nigrovirens (Blainville)

Family
Lepidopleuridae Ischnochitonidae Schizoplacidae Callistoplacidae Callistoplacidae Chitonidae

Authority
Martens and Pfeffer (1886)
This report
Kussakin (1960)
Plate (1902)
Thorpe (unpubl.)
Thiele (1910) ; Barnard (in Ashby, 1931) ; Dell (1962) ; this report.

The geographical distribution of these species, taken as a group, is worldwide. It does not conform to any particular pattern. Neither do their presently assigned systematic positions follow a pattern as the family-groups represented range from the more primitive (Lepidopleuridae) to species considered to have a high evolutionary development (Chitonidae).

The fact that a small number of totally unrelated species of chitons are now known to follow a type of larval development that deviates from the normal process indicates that studies of other species, whose life histories are unknown, should be investigated. Additionally, for some of the chiton species listed above, we need to be sure that the reported condition characterizes a species as a whole and is not merely an aberrant situation exhibited by a single or a few individuals induced, perhaps, by unusual or abnormal ecological conditions or other circumstances. Obviously, the possibilities for such studies are enormous when one considers that the total Recent chiton fauna of the world comprises something like 500 described forms. An interesting point, at present apparently undescribed, would be to determine specifically when and how the trochophore larvae of some species escape from the branchial cavity of the female as free-swimming veligers before metamorphosis occurs. Of equal interest would be the circumstances surrounding the eventual escape of the metamorphosed larvae of those species that mother their young through this stage.

This brief account of chiton development is dedicated with the respect and sincere good wishes of the author to his long-time friend and close associate, Dr. G Dallas Hanna, whose helpful encouragement and sound advice have been a constant source of inspiration over many years of personal contact. Such dedication is all the more fitting in view of Dr. Hanna's many contributions to the Academy's Recent mollusk collection over a long period, including the large suites of chitons he has collected from Pt. Barrow, Alaska, to Cape San Lucas at the tip of the Baja California peninsula.

Appreciation is due to Mr. Spencer R. Thorpe, Jr., of El Cerrito, California, for loaning his set of Sypharochiton nigrovirens for study, and to Mr. Maurice Giles, California Academy photographer, for his preparation of the illustrations.

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# PROCEEDINGS <br> CALIFORNIA ACADEMY OF SCIENCES 

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REVISION OF THE NEARCTIC SPECIES OF SILIS (CANTHARIDAE: COLEOPTERA)<br>By<br>John Wagener Green<br>California Academy of Sciences, Sam Francisco, Califormia, 94118

The latest revision of the Nearctic species of Silis was published in 1918 by Van Dyke, who recognized 19 named taxa in the subgenus Silis and 8 in the subgenus Ditemnus. Since then only 2 new ones have been added, by Fender and Brown. Van Dyke separated the species solely on the basis of the pronotal armature of the males. It has been found that a number of his socalled species of Silis in the strict sense are actually evolutionary complexes depending almost entirely on the male genitalia for the identification of their components. A preliminary analysis of this totally unexplored field is the primary objective of this study. It has proved to be a taxonomic problem of very great difficulty.

The genus Silis, as at present constituted, is defined, in addition to the longitudinally divided eighth ventral segment common to all Silini, by the excised and modified lateral margins of the male pronota. The ramifications of this structure are so elaborate and varied that no rigid statement can be made that would include all of them. In general, the region of the posterior angles is excised, retracting these angles, and forming an angular prominence in front; while the excision is occupied by a posterior process arising from the hypomera. The angular prominence will be designated hereinafter as the anterior process. It is strictly marginal, and the term does not apply to any prominence or elevated area not extending to the lateral margin. Very little external structural diversity occurs elsewhere in the body.

Two subgenera are found in the Nearctic fauna: Silis (strict sense) and Ditemnus. Plectonotum, of the Leng catalogue, is not a subgenus of Silis. The Arizona species assigned thereto by Schaeffer is a member of the DiscodonPolemius association, with numerous related forms in the Mexican fauna.

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Silis (strict sense) occurs in Europe and Canada, and throughout most of the United States, but apparently not south of the Mexican border. Ditemnus, except for two species in eastern United States, is of southern distribution: Texas to California; and south through Mexico, and Central and South America. The propriety of assigning subgeneric status to Ditemnus is seriously questioned, but no change in the generic structure of the Silini is proposed at this time. A new, and perhaps significant, differential is given in the subgeneric key that follows. The species are quite constant in color pattern and structure, and are easily identified.

The male genitalia of Ditemnus are small, usually fragile, and structurally difficult to visualize. They have not been investigated in this study. In the genitalia of Silis (strict sense), as in most of the Cantharidae, the aedeagus arises within a largely sclerotized tegmen that has been considered a modification of the basal piece. It is suggested that the tegmen is an invaginated ninth abdominal segment that is visible externally only in the exposed tip of ventral segment nine, sometimes called the genital segment. In support of this contention, it should be noted that ventral segment 9 is attached to the underside of the tegmen near the base, and no dorsal or pleural parts of segment 9 are present, other than the tegmen itself. Comparing this to the structure of segment 9 in the related families Lampyridae and Lycidae, it is seen that in these two families ventral segment 9 unites with a dorsopleural portion to form a homogeneous structure completely inclosing the aedeagus.

The upper surface of the tegmen, designated hereinafter as the dorsal plate, is membranous except for a sclerotized distal portion. Its posterior margin is usually emarginate, with the emargination more or less unstable intraspecifically, and rarely entirely lacking. Sometimes the emarginate area is abruptly inflexed so the notch is posterior and does not show from a direct dorsal viewpoint. Lateral incisures separate a ventral lobe from the main body of the tegmen. The ventral lobe is not prominently emarginate, usually rounded or subangulate apically, or with at most a small median notch. In several specimens a deep and narrow emargination has been noted in the ventral lobe, supposedly fractures resulting from pressure. The tegmen is subject to considerable intraspecific variability in many of the details of its conformation, and differential characters derived therefrom cannot be rigidly interpreted.

In all the species there arise from the inner base of the tegmen, above the aedeagus, strongly sclerotized dual processes that may be separated throughout; or united basally, separating at or beyond the middle of their length; or completely united to form a single median process, or sometimes a broad plate. These processes, or basal apophyses, will be designated hereinafter as basophyses. They are directed backward and upward, their tips usually attaining the underside of the dorsal plate, or sometimes passing through its emargination. It is impossible to get a direct or completely unobstructed view
of these structures, so their delineation in the drawings is more or less diagrammatic.

The parameres of the aedeagus are of two radically different types, which would seem to constitute subgeneric division except that no external differentials are available. In one type, exemplified by S. difficilis, the parameres extend in a partially sclerotized process along either side of the median lobe nearly to its apex, and appearing to constitute an integral part thereof. In the second type, exemplified by $S$. cava, the parameres are shorter and visible, if at all, only toward the base of the median lobe, but are provided each side with a long and usually slender sclerotized process extending to or beyond the tip of the median lobe. These processes, or lateral apophyses, will be designated hereinafter as the laterophyses. Apparently they are capable of a limited rotary motion around a longitudinal axis, thereby altering their appearance from a fixed viewpoint.

Complete eversion of the internal sac of the aedeagus is highly desirable in cantharid studies, but this situation is rarely found in cabinet specimens. Drying distortion and varying degrees of expansion produce varying aspects of the median lobe, and these are responsible for most of the major difficulties encountered in a taxonomic analysis. The author has endeavored to limit the announcement of new species to those taxa in which the genitalia are positively distinctive; and to those more closely related forms in which apparent differences in the median lobe seem to be conclusive, provided that other structural characters and geographic isolation also are involved. A difficult situation, constantly recurring in all the evolutionary complexes, is the necessity of deciding whether an observable difference is due to normal intraspecific variability, or to valid interspecific differentiation. Such decisions are herein based on a study of sizable series, and on the general experience gained from endless observations throughout the genus. It seems likely, however, that final solutions will be found only when a practical method is discovered for everting the internal sac of the aedeagus in dried specimens.

In extracting the genitalia, it has been found impractical to try to press them out through the anus, except for recently collected individuals in a perfectly relaxed condition. The specimens must be thoroughly relaxed, three days in a very wet relaxing dish is not too much time for older ones. Abdominal segments 6 to 9 are removed, and dorsals 6 and 7 are opened with a chiselpointed needle. Water should be applied as needed, to prevent drying and to act as a lubricant. By prying with the needle and pressing on both sides with the tweezers, the genitalia will usually come out readily, backwards. It is essential not to apply pressure along the median line because of the danger of breaking the fragile processes of the aedeagus. It is the author's practice to mount the genitalia upright on a paper point, together with the detached
abdominal part, and to pin this below the specimen. Upright mounting insures an unobstructed dorsal, lateral, and ventral view.

In addition to the extensive collections of the California Academy of Sciences (indicated as CAS), valuable material and other assistance was received from the following institutions and individuals, to all of whom the author extends his sincere thanks and appreciation. The abbreviation symbols in parentheses are used in the text to indicate the present location of certain specimens.
(ANSP) -Academy of Natural Sciences of Philadelphia, H. J. Grant, Jr.
(AMNH) -American Museum of Natural History, J. G. Rozen, Jr. (CNC)—Canadian National Collection, H. F. Howden.
(CU)-Cornell University, Henry Dietrich.
(LAM) - Los Angeles County Museum, R. R. Snelling.
(MCZ)—Museum of Comparative Zoology, P. J. Darlington, Jr.
(OSU ) -Ohio State University, J. N. Knull, P. H. Freytag.
(OrSU)—Oregon State University, J. D. Lattin.
(SDNH)-San Diego Natural History Museum, C. F. Harbison.
(USNM) - U. S. National Museum, T. J. Spilman.
(UBC)—University of British Columbia, G. J. Spencer.
(UCB) —University of California at Berkeley, Jerry Powell.
(UCD)—University of California at Davis, A. T. McClay.
(UCR)—University of California at Riverside, Saul Frommer.
(UId)—University of Idaho, W. F. Barr.
(UK)—University of Kansas, G. W. Byers.
(UW) -University of Washington, M. H. Hatch.
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All the keys that follow apply to males only. No attempt has been made at this time to identify females of the subgenus Silis. Usually no trouble will be encountered in placing Ditemnus females. The length-width ratio given in some species descriptions is intended as a rough indication of the body form. The head, usually deflexed, is not included in length measurements, which are more or less approximate.

Key to Nearctic Subgenera of Silis
Hypomera completely divided by a more or less undefined concavity or depression that follows a production of anterior margin of posterior process, the front part flat or con-
vex, punctate and pubescent. Notch formed by longitudinal division of ventral segment 8 closed, its sides parallel and largely contiguous along median line $\qquad$ Ditemnus LeConte Hypomera not so divided, smooth, shining, and virtually glabrous, longitudinally concave. Notch formed by longitudinal division of ventral segment 8 open, V- or U-shaped Silis Charpentier

## Subgenus Ditemnus

The Nearctic species of this subgenus divide into three well defined categories, which should all be accorded generic rank if that status is given to Ditemnus. Number I, containing two species, is Ditemnus LeConte (1861), with $D$. bidentata Say as the genotype. Category number II, numerously represented in the Neotropical fauna, and number III, largely Nearctic, are at present nameless. Two new species of the third category have the modified tarsal claws of the male finely cleft, while in all the other species of Nearctic Ditemnus these claws are appendiculate. Cleft claws have also been noted in the Cuban D. marginella DuVal. This alone is not regarded as a character of generic weight. The punctate and pubescent hypomera characteristic of this subgenus occur also, predominantly, in the Discodon-Polemitus association, and have been noted in the Palearctic Silas ruficollis Fabricius. One of the new species, S. howdeni, will no doubt be otherwise disposed when the generic structure of the Silini is revised.

## Key to Nearctic Species of the Subgenus Ditemnus. Maies

1. Form shorter and broader. Antennae stout. Disk of pronotum with median impression

Form elongate. Antennae slender, subfiliform. Disk of pronotum without median impression
2. Disk of pronotum with shallow subreniform impression, deeper each side. Antennae subserrate. Fourth segment of front tarsi normal. Eastern and midwestern species

> Disk of pronotum with deep median fossa. Antennae subfiliform. Fourth segment of front tarsi larger than usual, subquadrate. Southwestern species

## Category I

3. Posterior process of pronotal armature arising in advance of hind angles, which are subrectangular and rather well defined $\qquad$ (1) S. (D.) bidentata Say Posterior process of pronotal armature broader, overlapping hind angles which are rounded and indistinct
(2) S. (D.) latiloba Blatchley

## Category II

4. Lateral border of elytra testaceous

Sutural border of elytra not testaceous
(4) $S$. (D.) fossiger LeConte
5. Pronotum pale, or with median dark area
(5) S. (D.) tricornis Van Dyke

Pronotum pale with all borders black
(6) S. (D.) obtusa LeConte

## Category III

7. Posterior process of pronotal armature continuous with base of pronotum, obscuring hind angles
Posterior process arising in front of hind angles, which are well defined and subrectangular
8. Body entirely black. Pronotal incisure feeble. Modified tarsal claws appendiculate
(7) S. (D.) howdeni Green, new species

Pronotum pale, incisure normal. Modified tarsal claws cleft
(8) $S$. (D.) vandykei Green, new species
9. Body entirely black
(9) S. (D.) nigerrima Schaeffer Pronotum pale, abdomen rufous or partly so 10
 Antennal vestiture decumbent 11
11. Legs black. Modified tarsal claws cleft. Eastern Texas
(11) S. (D.) knulli Green, new species

Legs partly pale. Modified tarsal claws appendiculate. Arizona
(12) S. (D.) abdominalis Schaeffer
(1) Silis (Ditemnus) bidentata Say.

Cantharis bidentata Say, 1825, Jour. Acad. Nat. Sci. Philadelphia, vol. 5, p. 169.
Silis lepida LeConte, Dejean Cat., 3rd ed., p. 121 (nomen nudum).
Black, prothorax rufous, apical borders of ventral segments pale. Varies with head and abdomen more or less pale.

Length-width ratio about $2.2: 1$. Antennae stout, subserrate, about threefourths as long as body, intermediate segments about one and one-third times as long as wide, vestiture short and decumbent. Pronotum as in figure 1P, posterior process narrower than in S. latiloba, arising in advance of hind angles which are subrectangular and rather well defined; disk with subreniform median impression deepest each side. Anterior claw of front tarsi with blunt exterior basal appendix, posterior claw simple; middle tarsi similar, appendix of anterior claw small and inconspicuous; hind tarsi with both claws simple. Length $3-3.5 \mathrm{~mm}$.

Distribution. MAINE, NEW HAMPSHIRE, MASSACHUSETTS, RHODE ISLAND, CONNECTICUT, NEW YORK, PENNSYLVANIA, OHIO, NEW JERSEY, MARYLAND, DISTRICT OF COLUMBIA, VIRGINIA, WEST VIRGINIA, TENNESSEE, NORTH CAROLINA, SOUTH CAROLINA, GEORGIA, ALABAMA, MISSISSIPPI, FLORIDA, and OKLAHOMA (the last possibly an error).
(2) Silis (Ditemnus) latiloba Blatchley.

Silis latiloba Blatchley, 1910, Coleop. of Indiana, p. 837.
Black, prothorax rufous, apical borders of ventral segments pale. Varies with scutellum rufous; abdomen paler.

Length-width ratio about $2.2: 1$. Antennae stout, subserrate, about threefifths as long as body, intermediate segments about one and one-half times as long as wide, vestiture short and decumbent. Pronotum as in figure 2 P , posterior process broad, overlapping hind angles which are rounded and indistinct; disk with shallow subreniform median impression deepest each side. Anterior claw of front tarsi with blunt exterior basal appendix, posterior claw simple; middle tarsi similar, appendix of anterior claw small and inconspicuous; hind tarsi with both claws simple. Length $3.7-5 \mathrm{~mm}$.

Distribution. KENTUCKY, OHIO, MICHIGAN, INDIANA, ILLINOIS, IOWA, WISCONSIN, MINNESOTA, MISSOURI, ARKANSAS, KANSAS, NEBRASKA, NORTH DAKOTA, TEXAS, MANITOBA.
(3) Silis (Ditemnus) freemani Brown.

Silis freemani Brown, 1940, Canadian Ent., vol. 72, p. 163.
Antennae and tips of palpi black. Head black posteriorly, pale in front. Pronotum and scutellum pale rufous. Elytra black; sutural borders narrowly, and lateral borders more widely, pale; pale color not extending around apex. Underside rufous anteriorly, metathorax black, abdomen largely black. Legs black, anterior femora pale basally; trochanters and coxae pale, the posterior more or less blackish.

Length-width ratio about $2.5: 1$. Antennae rather stout, about two-thirds as long as body, intermediate segments about twice as long as wide, vestiture short and decumbent. Pronotum as in figure 3 P , with broad median fossa, median line impressed or excavated basally. Elytral pubescence somewhat longer and more erect distally. Anterior claw of front tarsi with blunt exterior basal appendix, all other claws simple. Tarsi stout, fourth segment of front tarsi larger than usual, subquadrate. Length $4-5 \mathrm{~mm}$.

Distribution. TEXAS: Cameron County: Brownsville; Hidalgo; Laredo; Mission.

Specimens from Linares, Nuevo Leon, Mexico, identified as Silis biauriculata Champion, seen to be conspecific, differing externally in the backward extension of the anterior pronotal process being less developed. The genitalia of Mexican and Texas specimens seem to be similar, but they are so constructed that a comparison is difficult and inconclusive. H. S. Barber recognized this species as new to the United States fauna. He attached "glicki" type labels to USNM material, but did not publish on this. His specimens were intercepted at Brownsville and Laredo on agricultural imports from Mexico.
(4) Silis (Ditemnus) fossiger LeConte.

Silis fossiger LeConte, 1881, Trans. Amer. Ent. Soc., vol. 9, p. 58.
Antennae and tips of palpi black. Head black posteriorly, pale in front. Pronotum pale rufous, scutellum black. Elytra black, lateral borders narrowly

pale. Underside rufous, metathorax black, abdomen more or less dusky medially: Legs black, front coxae pale.

Length-width ratio about $2.5: 1$. Antennae rather stout, about threefourths as long as body, intermediate segments about twice as long as wide, vestiture short and decumbent. Pronotum as in figure 4P, disk with broad median fossa. Anterior claw of front tarsi with blunt exterior basal appendix, all other claws simple. Tarsi stout, fourth segment of front tarsi larger than usual, subquadrate. Length 4-5 mm.

Distribution. TEXAS: Devils River, Del Rio, Pleasanton.
This species is very much like the Mexican S. dilacerata Gorham, but the genitalia do not agree. It is probable that they are members of a more extensive complex of Neotropical species. A third one, from Colombia, is in the collection of the California Academy of Sciences.

## $\leftarrow$

Figures 1P-30P. Pronota of Silis species.

| Figure 1P | Silis (Ditemmus) bidentata Say. |
| :---: | :---: |
| Figure 2P | Silis (Ditemnus) latiloba Blatchley. |
| Figure 3P | Silis (Ditemnus) freemani Brown. |
| Figure 4P. | Silis (Ditemnus) fossiger LeConte. |
| Figure 5P. | Silis (Ditemnus) tricornis Van Dyke. |
| Figure 6P | Silis (Ditemnus) obtusa LeConte. |
| Figure 7P | Silis (Ditemnus) howdeni Green. |
| Figure 8P. | Silis (Ditemnus) vandykei Green. |
| Figure 9P | Silis (Ditemmus) nigerrima Schaeffer. |
| Figure 10P | Silis (Ditemnus) perforata LeConte. |
| Figure 11P | Silis (Ditemnus) knulli Green. |
| Figure 12P. | Silis (Ditemnus) abdominalis Schaeffer. |
| Figure 13P. | Silis (Silis) spinigera LeConte. |
| Figure 14P | Silis (Silis) rugosa Van Dyke. |
| Figure 15P. | Silis (Silis) percomis Say. |
| Figure 16P | Silis (Silis) spathulata LeConte. |
| Figure 17P | Silis (Silis) lutea group. |
| Figure 18P. | Silis (Silis) filicornis Van Dyke. |
| Figure 19P | Silis (Silis) filicornis variation. |
| Figure 20P | Silis (Silis) tardella Green. |
| Figure 21P | Silis (Silis) difficilis group. |
| Figure 22P | Silis (Silis) atra LeConte. |
| Figure 23P | Silis (Silis) deserticola group. |
| Figure 24P | Silis (Silis) emarginata Green. |
| Figure 25P | Silis (Silis) cava complex. |
| Figure 26P | Silis (Silis) arizonica Van Dyke. |
| Figure 27P | Silis (Silis) fenestrata Van Dyke. |
| Figure 28P | Silis (Silis) recta Green. |
| Figure 29P. | Silis (Silis) vulnerata group. |
| Figure 30P | Silis (Silis) pallida group. |

(5) Silis (Ditemnus) tricornis Van Dyke.

Silis tricornis Van Dyke, 1918, Jour. New York Ent. Soc., vol. 26, p. 177.
Antennae and palpi black. Head black posteriorly, pale in front. Pronotum entirely pale, or with median black area. Scutellum and elytra black. Underside black, prothorax pale. Legs black, trochanters pale.

Length-width ratio about $2.3: 1$. Antennae rather stout, filiform, about three-fourths as long as body, intermediate segments about two and one-third times as long as wide, vestiture short and decumbent. Pronotum as in figure 5P, disk with broad median fossa. Anterior claw of front tarsi with blunt exterior basal appendix, all other claws simple. Tarsi stout, fourth segment of front tarsi larger than usual, subquadrate. Length 4.5 mm .

Distribution. CALIFORNIA: Calipatria; Thousand Palms. ARIZONA: Bill Williams Fork; Globe.
(6) Silis (Ditemnus) obtusa LeConte.

Silis obtusa LeConte, 1874, Trans. Amer. Ent. Soc., vol. 5, p. 62.
Body black, pronotum pale rufous with all borders narrowly black, apical margins of ventral segments pale.

Length-width ratio about $2.4: 1$. Antennae stout, subserrate, about seventenths as long as body, intermediate segments about twice as long as wide, vestiture short and decumbent. Pronotum as in figure 6P, with broad median fossa. Anterior claw of front tarsi with small blunt exterior basal appendix, all other claws simple. Tarsi stout, fourth segment of front tarsi larger than usual, subquadrate. Length $4.5-5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Bakersfield; Camp Baldy (San Bernardino Mountains); Indian Canyon, San Diego County; Inyo County; Keeler; Lake Henshaw, San Diego County; Mojave Desert; Oil City, Kern County; Olanche, Los Angeles County; Oro Grande; Pasadena; Riverside; Saboda Springs, Riverside County; Victorville; Warners; Waterman Canyon.
(7) Silis (Ditemnus) howdeni Green, new species.

Holotype, male; Southwestern Research Station, Portal, Arizona, VI-17-56, H. and A. Howden. In Canadian National Collection.

Body and appendages entirely black.
Length-width ratio about 3.0:1. Antennae moderately slender, filiform, about seven-tenths as long as body, intermediate segments about two and one-half times as long as wide, vestiture erect and bristling. Pronotum as in figure 7P, base arcuate each side, region of hind angles not excised, disk with shallow undefined median impression extending from base nearly half way to apex. Anterior claw of front tarsi with blunt exterior basal appendix,
posterior claw simple; middle and hind tarsi similar to front, with basal appendix progressively smaller. Length 4.5 mm .

Variations. Nothing of importance noted. Length $3.5-4.5 \mathrm{~mm}$.
Distribution. ARIZONA: Chiricahua Mountains, Southwestern Research Station, Portal, H. and A. Howden, VI-17-56, holotype (CNC); VII-7-56, 1 paratype (CAS). Cochise County, Southwestern Research Station, 5 mi . W. of Portal, 5,400 ft., V-19-56, M. Statham, 1 paratype; V-31-56, E. Ordway, 1 paratype (AMNH).

This species, lacking the excision of the hind angles of the pronotum, and apparently without a definite posterior process, probably requires a new genus for its reception. It is assigned here tentatively, pending clarification of the confused generic conceptions involving Silis, Ditemnus, Polemius, and Discodon.
(8) Silis (Ditemnus) vandykei Green, new species.

Holotype, male; Jeff Davis County, Texas, VII-4-53, D. J. and J. N. Knull. In collection of Ohio State University.

Antennae and palpi black. Head black, mandibles and adjacent area dusky rufous; beneath pale rufous, black each side of gula. Pronotum and scutellum pale rufous. Elytra black. Ventral surface of meso- and meta-thorax black; abdomen dusky, lateral and apical borders of segments irregularly pale. Legs black.

Length-width ratio about $2.6: 1$. Antennae slender, filiform, about threefourths as long as body, intermediate segments about three times as long as wide, vestiture erect and bristling. Pronotum as in figure 8 P , base arcuate each side obliterating hind angles, disk without distinct median impression. Anterior claw of front and middle tarsi finely cleft, parts of divided tip parallel and subequal in length; anterior claw of hind tarsi more widely cleft, tooth much shorter than apical part; all teeth exterior. Posterior claw of all tarsi simple. Length 4.5 mm .

Variations. In one example the head in front of the antennal sockets is entirely pale rufous. Length $3.5-5 \mathrm{~mm}$.

Distribution. TEXAS: Jeff Davis County, VI-20-52, D. J. and J. N. Knull, 3 paratypes (OSU 2, CAS 1); VII-4-53, D. J. and J. N. Knull, holotype, female (OSU). Davis Mountains, VI-24-56, VI-14-56, D. J. and J. N. Knull, 2 paratypes (OSU). Ft. Davis, VI-1-59, Howden and Becker, 2 paratypes (CNC). Davis Mountains, IX-3-49, Werner-Nutting, 1 paratype (Fender). Chisos Basin, Big Bend, VII-16-56, H. and A. Howden, 1 female (Howden). Big Bend National Park, Chisos Basin: Boat Springs, 7,000 ft.; Pine Canyon, 5,000 ft.; and Green Gulch, 5,300 ft., V-4-59 to V-29-59, Howden and Becker, 20 paratypes, 4 females (CNC), 2 paratypes (CAS). Chisos Moutntains, VII-18, J. W. Green, 1 paratype, 4 females (CAS);

VI-20, 21-61, VII-28-62, D. J. and J. N. Knull, 5 paratypes, 5 females (OSU), 1 paratype (CAS).
(9) Silis (Ditemnus) nigerrima Schaeffer.

Silis nigerrima Schaeffer, 1908, Jour. New York Ent. Soc., vol. 16, p. 66.
Body entirely black except mandibles pale.
Length-width ratio about $2.8: 1$. Antennae slender, as long as body, intermediate segments about four times as long as wide, vestiture erect and bristling. Pronotum as in figure 9P. Anterior claw of front and middle tarsi with blunt exterior basal appendix, anterior claw of hind tarsi with appendix much reduced; posterior claws of all tarsi simple. Length $6-6.5 \mathrm{~mm}$. Closely resembling the Mexican S. armitagei Pic.

Distribution. ARIZONA: Chiricahua Mountains: Pinery Canyon; Onion Saddle; Rustlers Park. Huachuca Mountains: Carr Canyon; Ramsey Canyon; Miller Canyon. Santa Rita Mountains: Madera Canyon. Santa Catalina Mountains: Bear Wallow; Summerhaven, Pine County. White Mountains.
(10) Silis (Ditemnus) perforata LeConte.

Silis perforata LeConte, 1881, Trans. Amer. Ent. Soc., vol. 9, p. 57.
Antennae and palpi black. Head black posteriorly, pale in front. Pronotum and scutellum pale rufous. Elytra black. Underside black except prothorax and abdomen rufous, varying with abdomen dark medially. Legs black, front coxae pale.

Length-width ratio about $3.3: 1$. Antennae slender, filiform, about threefourths as long as body, intermediate segments about four times as long as wide, vestiture erect and bristling. Pronotum as in figure 10P, backward extension of anterior process overlapping posterior process, hind angles distinct. Anterior claw of front tarsi with blunt exterior basal appendix, posterior claw simple; middle and hind tarsi similar to front, with basal appendix progressively smaller. Length $5-6.5 \mathrm{~mm}$.

Distribution. TEXAS: Davis Mountains; Cypress Mills; Big Bend National Park, Chisos Basin; Kerrville; Austin; Gillespie County; Comal County; Randall County, Palo Duro Canyon; Bexar County, Fort Sam Houston, and Salada Creek; Real County, 26 mi . N. of Leakey; Rock Springs.
(11) Silis (Ditemnus) knulli Green, new species.

Holotype, male; Lake Corpus Christi, Texas, III-26-53, D. J. and J. N. Knull. In collection of Ohio State University.

Antennae and palpi black. Head black posteriorly, pale in front. Pronotum and scutellum rufous. Elytra black. Underside of metathorax and tip of abdomen black, balance of ventral surface pale rufous. Legs black, front and middle coxae pale.

Length-width ratio about $2.3: 1$. Antennae slender, filiform, about threefourths as long as body, intermediate segments about three times as long as wide, vestiture short and decumbent. Pronotum as in figure 11P, similar to S. perforata, backward extension of anterior process shorter, scarcely overlapping posterior process; hind angles distinct. Anterior claw of front and middle tarsi finely cleft, parts of divided tip parallel, subequal in length; anterior claw of hind tarsi more widely cleft, tooth much shorter than apical part; all teeth exterior. Posterior claw of all tarsi simple. Length 4 mm . Closely resembles $S$. perforata.

Variations. Nothing of importance noted. Length $3.5-5 \mathrm{~mm}$.
Distribution. TEXAS: Corpus Christi and Lake Corpus Christi, III-17 to III-30, 1952 and 1954, D. J. and J. N. Knull, holotype, 39 paratypes (OSU 30, MCZ 1, CAS 8), 24 females (OSU 20, CAS 4). Cameron County, III-24-60, D. J. and J. N. Knull, 6 paratypes, 3 females (OSU).
(12) Silis (Ditemnus) abdominalis Schaeffer.

Silis abdominalis Schaeffer, 1908, Jour. New York Ent. Soc., vol. 16, p. 66.
Antennae black, first segment largely pale; tips of palpi black. Pronotum and scutellum rufous. Elytra black. Underside rufous, metathorax black, abdomen variably dusky baso-medially. Legs rufous, tibiae in part black.

Length-width ratio about $2.7: 1$. Antennae moderately slender, filiform, about seven-tenths as long as body, intermediate segments nearly three times as long as wide, vestiture short and decumbent. Pronotum as in figure 12P. Anterior claw of front tarsi with blunt exterior basal appendix, posterior claw simple; other tarsi similar to front, with basal appendix progressively smaller. Length 4-5 mm.

Distribution. ARIZONA: Huachuca Mountains; Chiricahua Mountains, Southwestern Research Station, 5 mi . W. of Portal; Santa Rita Mountains, Madera Canyon.

## Subgenus Silis

The genus Silis was proposed by Charpentier (1825) with S. spinicollis Charpentier, a synonym of S. nitidula Fabricius, as the genotype. Specimens of S. nitidula, generously donated by Vladimir Vosyka of Czechoslovakia, have genitalia similar to those found in the "vulnerata" group, confirming the generic assignment of the Nearctic species. They also have the same smooth, shining, and glabrous hypomera.

Modification of the tarsal claws in the males is of the same type throughout, and mention of it will be omitted from the species descriptions that follow. The anterior claw of all tarsi is provided with a blunt exterior basal appendix, the posterior claw of all tarsi being simple. The antennal structure is also fairly constant: slender, subfiliform, about four-fifths as long as the body,
intermediate segments three to four times as long as wide. Length-width ratios are likewise omitted, unless they vary appreciably from the normal $2.75: 1$. The color of the mandibles is entirely or largely pale in all species, and the apical margins of the ventral segments are more or less distinctly pale. The most essential descriptive items are the genitalic and pronotal drawings, and these alone should be sufficient for species identification. It is not to be expected that every specimen is identifiable. Variability is often baffling, and unrecognized species are probably still numerous.

In the females the hypomera, unlike the males, are flat or convex, and usually punctate and pubescent. The females of those species with bicolored pronota have the black areas much reduced, and occasionally absent altogether.

## Key to Nearctic Species of tiie Subgenus Silis, Males

1. Prothorax small, narrower than elytra at base. Posterior process of pronotal armature broad, bidentate, anterior tooth long and acute $\qquad$ (1) S. (S.) spinigera LeConte Prothorax normal, as wide as elytra at base. Posterior process not bidentate
2


2. California species. Aedeagus with laterophyses .-.-.-.-. (2) S. (S.) rugosa Van Dyke Eastern or midwestern species. Aedeagus without laterophyses .................................... 4
3. Acute lateral margin of pronotum attaining tip of anterior process
(3) $S$. (S.) percomis Say

Acute lateral margin of pronotum not attaining tip of anterior process $\qquad$
(4) S. (S.) spathulata LeConte
5. Posterior process of pronotum, viewed ventrally, rapidly narrowing and terminating in a setiform spine directed anteriorly
Posterior process not as above, of substantial width throughout. .-.-.-.-.- 7
6. Posterior process abruptly curving forward, attaining tip of anterior process. Excision
at hind angles large and open $(S$. (S.) lutea Group)

Posterior process terminating in a small seta-like spine not attaining tip of anterior process. Excision at hind angles more or less completely closed by dorsal surface of extended hypomeron. Southern California
(8) S. (S.) filicornis Van Dyke
7. Posterior process combining with laterally produced hind angle of pronotum to form a bidentate structure in dorsal view. Basophyses united, forming a broad deeply emarginate plate
(9) S. (S.) tardella Green, new species

Not as above
8. Posterior process nearly straight, subspiniform, directed outward and slightly backward 9 Not as above
9. Pronotum pale with dark borders which are rarely lacking. Aedeagus without latero-
physes $(S .(S$.$) difficilis Group)$

Pronotum unicolorous, fulvous or black. Aedeagus with laterophyses (S. (S.) deserticola Group)

10. Posterior process simple, narrow, directed outward. Tips of anterior and posterior
processes widely separated

Posterior proces bending abruptly torward distally (S. (S.) pallida Group) ................ 67

In the following part of the key, all characters, except where otherwise stated, refer to the male genitalia.

## S. (S.) lutea Group

12. Dorsal plate with small median emargination not entering membraneous area. Figure 5
(5) $S$ (S.) carmelita Green, new species Dorsal plate with wide and deep emargination entering membraneous area ............... 13
13. Basophyses moderately bent inward submedially, exposed tips straight in lateral view: Emargination of dorsal plate narrower, deeper than wide. Pronotum with median dark area when elytra are black. Figure 6 $\qquad$ (6) S. (S.) lutea LeConte Basophyses strongly bent inward submedially, exposed tips slightly recurving or hooked in lateral view. Emargination of dorsal plate with depth and width subequal. Pronotum entirely pale, elytra black. Figure 7
(7) S. (S.) filigera LeConte

## S. (S.) bifficilis Group

In some of the species of this group, the upper margins of the lateral incisures of the tegmen, viewed ventrally, are more or less prominently angulate at about the distal third, the angulation sometimes convex and subcarinate, varying to a simple flat extension of the surface. When the angulation is fully developed, the margin of the incisure deflects around the tip of the angle, which is actually a small oblique lamina appearing acute from a direct ventral viewpoint. Nearly all of the $S$. difficilis group species with this modification are Californian, the only known exception being $S$. nevadica. The emargination of the dorsal plate foliows a general plan for each species, as shown in the drawings, but it is usually quite variable. There are no laterophyses. The antennal vestiture is short and decumbent.
14. Emargination of dorsal plate narrowing to apex, basophyses emerging close together and subparallel. In lateral view, tips of basophyses recurving or enlarged on proximal side. Elytra flavate
15. In ventral view, upper margins of lateral incisure of tegmen subangulate at about distal third. Emargination of dorsal plate usually with sides sinuate distally. Figure 10
(10) S. (S.) flavida LeConte In ventral view, upper margins of lateral incisure of tegmen not subangulate at distal third. Emargination of dorsal plate usually with sides straight, not, or very feebly, sinuate distally. Figure 11 .-- (11) S. (S.) lasseni Green, new species
16. In ventral view, upper margins of lateral incisure of tegmen subangulate at about distal third
In ventral view, upper margins of lateral incisure of tegmen not subangulate at distal third
17. In lateral view, tips of basophyses recurved or prominently enlarged on proximal side. Figure 12
(12) S. (S.) nevadica Green, new species In lateral view, tips of basophyses not recurved or prominently enlarged on proximal side
18. Exposed tips of basophyses very slender. In dorso-ventral view, median lobe of aedeagus broad, not narrowing distally, sides not striate. Ventral lobe of tegmen wider, with distinct apical notch. Figure 13 .--.... (13) S. (S.) tenuata Green, new species Exposed tips of basophyses normally wide. In dorso-ventral view, median lobe of aedeagus narrowing to apex, sides striate. Ventral lobe of tegmen narrower, without, or with minute, apical notch. Figure 14 $\qquad$ (14) S. (S.) carbo Van Dyke
19. In dorso-ventral view, median lobe of aedeagus broad, with small apical notch, sides not striate. Figure 15 (15) $S$. (S.) oregonensis Green, new species

In dorso-ventral view, median lobe of aedcagus clongate, narrowing to apex, sides in part sclerotized and with irregular longitudinal striation
20. Emargination of dorsal plate less broadly U-shaped, deeper than wide, sides subparallel or feebly diverging, usually not curving inward distally. Emargination not attaining membraneous area by a conspicuous distance. Figure 16
(16) S. (S.) striatella Green, new species

Emargination of dorsal plate broadly U - or V -shaped, about as deep as wide, sides curving inward distally
21. Elytra in part usually more or less flavate, this not apparent in darker individuals unless examined under brilliant illumination. Basophyses typically extending very little beyond emargination of dorsal plate, narrowing apically as seen in lateral view. Emargination of dorsal plate usually not attaining membraneous area by a conspicuous distance. Figure 17
(17) S. (S.) difficilis LeConte Elytra usually uniformly deep black. Basophyses typically extending conspicuously beyond emargination of dorsal plate, somewhat expanded apically as seen in lateral view. Emargination of dorsal plate usually attaining membraneous area. Figure 17 a (17a) S. (S.) difficilis occidens Green, new subspecies

## S. (S.) Deserticola Group

In this group the laterophyses are provided with a coriaceous and sparsely setiferous distal appendix. The appendix may be small and inconspicuous, or it may involve the entire tip of the laterophysis. In the latter case, the actual tip of the laterphysial rod is recognized by being strongly sclerotized and glabrous. This structure is also found in the S. vulnerata group and in the Palearctic genotype, S. nitidula Fabricius. The basophyses are united basally and furcate at about the middle of their length. A unique feature of this group, $S$. atra excepted, is the trilobed dorsal plate, with the lobes on each side at a level below that of the median part. This complicates the genitalic drawings, but it may be clarified to some extent by the posterior view diagrams of the tegmen. All of the Silis species with appendiculate laterophyses are apparently well established and not involved in current evolutionary development. The species allied to S. deserticola, having fulvous pronota, are rare in collections. Only eight males, representing seven species, are known at present. They are identical externally, differing radically in the male genitalia. All occur in southern California. The antennal vestiture is short and decumbent.
22. Dorsal plate simple, with deep and very wide emargination. Body entirely black
 Dorsal plate trilobed. Body black, pronotum fulvous ....................................................... 23
23. Ventral lobe of tegmen extending well beyond dorsal plate. Posterior orifice of tegmen not constricted below dorsal plate. Figure 19 $\qquad$ (19) S. (S.) egregia Green, new species Ventral lobe of tegmen not extending beyond dorsal plate. Posterior orifice of tegmen constricted below dorsal plate24
24. Laterophyses with tips squarely truncate ..... 25
Laterophyses with tips not squarely truncate, more or less acute ..... 26
25. Median part of dorsal plate feebly lobed, lobes on each side extending far beyond it.Figure 20 ......................................... S.) singularis Green, new speciesMedian part of dorsal plate not lobed, with shallow and broadly angulate emargina-tion. Figure 21
(21) S. (S.) eximia Green, new species
26. Median part of dorsal plate deeply triangularly emarginate. Figure 22
(22) S. (S.) abstrusa Green, new species

[^29]27. Median part of dorsal plate with prominent lobe about half as long as wide. Figure 23
(23) $S$. (S.) arida Green, new species
Median part of dorsal plate subtruncate 28
28. Lobes each side extending well beyond median part of dorsal plate. Median lobe of aedeagus with apical process. Figure 24 $\qquad$ (24) S. (S.) ursina Green, new species Lobes each side extending only slightly beyond median part of dorsal plate. Median lobe of aedeagus without apical process $\qquad$ (25) S. (S.) deserticola Van Dyke

## S. (S.) CAVA Group

 Genitalia with two basophyses $S$. (S.) emarginata Section .-.......................................... 31
30. Basophysis furcate at about middle of length S. (S.) cava Section .......................... 39 Basophysis not furcate, tip notched S. (S.) californica Section .-.............................. 40

## S. (S.) emarginata Section

31. Dorsal plate not emarginate, posterior margin convex. Figure 26
(26) S. (S.) incongrua Green, new species Dorsal plate emarginate; or subtruncate in dorsal view, emarginate in posterior view ...- 32
32. Laterophyses with prominent exterior distal tooth. Figure 27
(27) S. (S.) angulata Green, new species
Laterophyses without tooth
33. Laterophyses with tips somewhat widened and everted in dorso-ventral view .............. 34 Laterophyses slender distally, tips straight or feebly diverging -......................................... 36
34. Basophyses extending posteriorly as far as, or beyond, apex of deep emargination of dorsal plate. Elytra flavate, tips sometimes dark. Legs largely pale. Figure 28
(28) S. (S.) emarginata Green, new species Basophyses not extending posteriorly as far as apex of shallower emargination of dorsal plate. Elytra flavate with sutural bead and apex dark. Legs largely dark ........ 35
35. Dorsal plate with rather decp subtriangular emargination usually attaining membraneous area. Tips of laterophyses everted for a considerable distance. Figure 29
(29) S. (S.) fenderi Green, new species Dorsal plate with shallow arcuate emargination not attaining membraneous area by a conspicuous distance. Everted tips of laterophyses very short. Figure 30
(30) S. (S.) subtruncata Green, new species
36. In lateral view, median lobe of aedeagus not subtriangular, upper margin broadly arcuate or nearly straight
In lateral view, median lobe of aedeagus elongate subtriangular, widest at about distal third, where upper margin is subangulate38
37. Lobes of dorsal plate emargination not, or only feebly, deflected: in direct posterior view, emargination completely flattened or very broadly V-shaped. Laterophyses moderately slender .-. (31) S. (S.) macclayi Green, new species Lobes of dorsal plate emargination strongly deflected, forming a deep U-shaped emargination in direct posterior view. Laterophyses distinctly broader as compared to

38. Laterophyses broad except apically. Figure 33 _-..-(33) S. (S.) thermalis Green, new species Laterophyses rather slender throughout. Figure 34
(34) S. (S.) acuta Green, new species

## S. (S.) cava Section



## S. (S.) Californica Section

40. Dorsal plate not emarginate. Pronotum entirely pale fulvous. Figure 36
(36) S. (S.) arizonica Van Dyke Dorsal plate emarginate, emargination sometimes lacking in $S$. (S.) fenestrata, in which the pronotal borders are black
41. Dorsal plate with small variable emargination, rarely lacking. Pronotum pale fulvous with black borders; anterior process with narrow extension deflected below acute angle of posterior process, completely closing marginal incisure in direct dorsal view. Figure 37
(37) $S$. (S.) fenestrata Van Dyke Dorsal plate with normal, usually deep, emargination. Pronotum entirely pale fulvous or flavate; with distinct marginal incisure 42
42. Elytra dark, partly fusco-flavate under brilliant illumination ..... 43
Elytra pale flavate ..... 44
43. Laterophyses shorter, stout except apically, curving downward distally. Basophysis expanded apically. Figure 38

(38) S. (S.) californica Fender Laterophyses longer, slender throughout, curving upward distally. Basophysis not expanded apically. Figure 39
(39) S. (S.) reversa Green, new species
44. Laterophyses broad, tips bent strongly inward and downward. Emargination of dorsal plate wide, moderately deep, apex subtruncate. Figure 40
(40) S. (S.) solitaria Green, new species

45. Laterophyses slender throughout, tips not diverging. Figure 41
(41) $S$. (S.) recta Green, new species

Laterophyses broad except apically, tips diverging
46. In dorso-ventral view, laterophyses curving inward at about distal fourth, lyre-shaped. Figure 42
(42) S. (S.) angelica Green, new species In dorso-ventral view, laterophyses subparallel. Figure 43
(43) S. (S.) latestyla Green, new species

## S. (S.) vulnerata Group

47. With single basophysis, bilaterally enlarged at apex. Laterophyses slender, lyre-shaped,
without distal appendix. Pronotum without distinct median dark area. Figure 44 (44) S. (S.) fabulosa Green, new species

With two basophyses
48
48. Posterior margin of dorsal plate not inflexed or thickened, with at most only a minute denticulation each side
Posterior margin of dorsal plate inflexed or thickened ........................................... 50
49. Basophyses widely divaricate, tips broadly visible each side of ventral lobe in direct ventral view. Figure 45
(45) S. (S.) divaricata Green, new species Basophyses subparallel, tips not visible each side of ventral lobe in direct ventral view
(46) $S$. ( $S$ :) montanica Green, new species
50. Posterior margin of dorsal plate not bidentate, a short inflexed median lobe separating tips of basophyses. Laterophyses apparently without distal appendix. Figure 47
(47) S. (S.) lecontei Green, new species Posterior margin of dorsal plate more or less strongly bidentate, teeth inflexed, acute or obtuse
51. Marginal teeth of dorsal plate very large and prominent, plainly visible from direct lateral viewpoint. Basophyses not extending to dorsal plate, their tips separated therefrom by a considerable distance


#### Abstract

Marginal teeth of dorsal plate of normal size, not plainly visible from direct lateral viewpoint

53


52. Basophyses long, slender in more than distal half, curving outward and upward. Marginal teeth of dorsal plate extremely large, much retracted. Pronotum with black borders, disk entirely fulvous. Figure 48 .------- (48) S. (S.) dentigera Green, new species Basophyses short and stout. Marginal teeth of dorsal plate smaller. Pronotum largely black. Figure 49 (49) $S$. (S.) disjuncta Green, new species
53. Basophyses long, extending for a considerable distance beyond posterior margin of dorsal plate 54
Basophyses of normal length, at most with tips curving over posterior margin of dorsal plate, but not extending beyond for any appreciable distance 58
54. Appendix of laterophyses small and inconspicuous, sometimes not apparent . . . . . . 55 Appendix of laterophyses larger, conspicuous, not lineate ................................................. 56
55. In ventral view, tips of basophyses curving slightly inward. Laterophyses feebly sinuate in lateral view, curving downward distally ; parallel and straight in dorsal view. Figure 50
(50) S. (S.) triplicata Green, new species In ventral view, tips of basophyses curving strongly inward. Laterophyses nearly straight in lateral view, curving inward distally in dorsal view. Figure 51
(51) S. (S.) protracta Green, new species
56. Appendix larger than contiguous portion of laterophysis, which it may envelop and

Appendix not as above
57. In lateral view, laterophyses slender throughout. Figure 51a

Unidentified, near $S$. protracta
In lateral view, laterophyses much expanded on dorsal side. Figure 52
(52) $S$. (S.) simulata Green, new species
58. In lateral view, appendix large and prominent, nearly as large as, to larger than, contiguous portion of laterophysis
In lateral view, appendix small and inconspicuous, sometimes not apparent. Pronotum with median vitta
59. In lateral view, appendix foliate, considerably broader and extending far beyond slender tip of laterophysis60

In lateral view, appendix extending little or not at all beyond tip of laterophysis ......... 62
60. In ventral view, basophyses straight, divergent, tips visible each side of ventral lobe .... 61 In ventral view, basophyses diverging, abruptly converging from about distal fourth; tips not visible each side of ventral lobe. Figure 53
(53) S. (S.) introversa Green, new species
61. In dorsal view, diverging tips of laterophyses short, abruptly everted. Figure 54
(54) S. (S.) perfoliata Green, new species

In dorsal view, diverging tips of laterophyses longer, regularly arcuate. Figure 55
(55) S. (S.) proxima Green, new species
62. In ventral view, basophyses divergent, straight, tips visible each side of ventral lobe .-... 63

In ventral view, basophyses feebly arcuate, subparallel distally, tips not visible each side of ventral lobe
63. Disk of pronotum without median vitta. Figure 56
(56) S. (S.) abrupta Green, new species Disk of pronotum with median vitta. Figure 57 -... (57) S. (S.) lobata Green, new species
64. In lateral view, laterophysis asymmetric, somewhat L -shaped, its lower margin bending rather abruptly upward at about distal third, forming an obtuse angle; its upper margin concavely arcuate. In lateral view, basophyses with lower margin uniformly
$\left.\left.\left(00^{8} 8\right)(\sqrt{4})\right)^{\mathbb{D}}\right)^{2}$

(f)
arcuate. Figure 58
(58) S. (S.) vulnerata LeConte In lateral view, laterophyses not as above, nearly symmetrical. In lateral view, basophyses with lower margin usually subangulate. Figure 59
(59) S. (S.) parallela Green, new species
65. In lateral view, basophyses very stout, constricted near tip. Figure 60
(60) S. (S.) constricta Green, new species

Basophyses not as above
66. In lateral view, laterophyses abruptly bending downward at about middle of length; appendix setiform. Figure 61 $\qquad$ (61) S. (S.) barri Green, new species In lateral view, laterophyses curving feebly downward near tip; appendix not apparent. Figure 62
(62) S. (S.) insolita Green, new species

## S. (S.) Pallida Group

67. Median lobe of aedeagus narrowly subtriangular in dorso-ventral view, slender apically. Ventral lobe of tegmen subtriangular, apex more or less acute apex
68. Basophyses shorter, not attaining posterior margin of dorsal plate. Figure 63
(63) S. (S.) pallida Mannerheim

Basophyses attaining posterior margin of dorsal plate. Figure 64
(64) S. (S.) insperata Green, new species
69. Elytra black. Laterophyses curving downward at about distal third or fourth. Figure 65 (65) S. (S.) maritima Van Dyke Elytra flavate, sides and apices dark. Laterophyses various ........... Unidentified complex

## (1) Silis (Silis) spinigera LeConte.

Silis spinigera LeConte, 1874, Trans. Amer. Ent. Soc., vol. 5, p. 61.
Silis munita LeConte, 1881, Trans. Amer. Ent. Soc., vol. 9, p. 56.
Black; prothorax flavate, elytra flavate with apices more or less broadly dusky, legs partly pale. Varies with elytra and legs entirely black.

## $\leftarrow$

Figures 1-12. Male genitalia; ventral, lateral, and dorsal views, arranged in that order from left to right.

Figure 1. Silis (Silis) spinigera LeConte, dorsal view omitted
Figure 2. Silis (Silis) rugosa Van Dyke.
Figure 3. Silis (Silis) percomis Say.
Figure 4. Silis (Silis) spathulata LeConte.
Figure 5. Silis (Silis) carmelita Green, holotype.
Figure 6. Silis (Silis) lutea LeConte.
Figure 7. Silis (Silis) filigera LeConte.
Figure 8. Silis (Silis) filicornis Van Dyke.
Figure 9. Silis (Silis) tardella Green, holotype, dorsal view omitted, basophysial plate inserted.
Figure 10. Silis (Silis) flavida LeConte.
Figure 11. Silis (Silis) lasseni Green, holotype.
Figure 12. Silis (Silis) nevadica Green, holotype.

Form elongate, length-width ratio about $3.2: 1$. Antennal vestiture short and decumbent. Pronotum as in figure 13P, small, narrower than elytra at base. Genitalia as in figure 1, no laterophyses; median lobe large and stout, as wide as ventral lobe of tegmen. Length $7-8.5 \mathrm{~mm}$.

Distribution. CALIFORNIA, OREGON, BRITISH COLUMBIA, IDAHO, UTAH, WYONING, COLORADO.

This species, occurring over a wide range, is remarkably constant in structure, regardless of color. It probably should be removed from Silis to a new monobasic genus because of its radically different genitalia and facies.
(2) Silis (Silis) rugosa Van Dyke.

Silis rugosa Van Dyke, 1918, Jour. New York Ent. Soc., vol. 26, p. 169.
Body and appendages deep black; pronotum fulvous with all borders black, the lateral borders narrowly. Underside black except prothorax fulvous with lateral borders black.

Antennal vestiture erect and bristling. Pronotum as in figure 14P. Genitalia as in figure 2, basophyses widely divergent, surpassing sides of tegmen. Laterophyses each with acute external tooth distally. Dorsal plate shallowly emarginate throughout its width. Ventral lobe with apex acute. Length $4-5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Marin County: Mt. Tamalpais, Mill Valley; Lake County: Anderson Springs, Napa County: Oakville; Santa Cruz; Alameda County; Mendocino County: Ryan Creek, Fort Bragg.

All dates of capture are for February and March, except for a Fort Bragg specimen taken in December.
(3) Silis (Silis) percomis Say.

Cantharis percomis SAy, 1835, Boston Jour. Nat. Hist., vol. 1, p. 159.
Podabrus curtus LeConte, 1850, In: Lake Superior, by Louis Agassiz, p. 229 (female). Silis Longicornis LeConte, In: Lake Superior, by Louis Agassiz, p. 230 (male).

Black; pronotum pale rufous with anterior explanate border, and basal border medially, more or less blackish.

Antennal vestiture erect and bristling. Pronotum as in figure 15P, acute lateral margin continuing from apex to tip of anterior process. Genitalia as in figure 3, no laterophyses, ventral lobe of tegmen extending posteriorly beyond dorsal plate. Length 5-6 mm.

Distribution. NEIH BRUNSWICK, NOVA SCOTIA, ONTARIO, QUEBEC, MAINE, NEW HAMIPSHIRE, MASSACHUSETTS, CONNECTICUT, NEW YORK, PENNSYLVANIA, NEW JERSEY, MARYLAND, VIRGINIA, KENTUCKY, TENNESSEE, NORTH CAROLINA, SOUTH CAROLINA, ALABAMA, OHIO, INDIANA, ILLINOIS, MIICHIGAN, WISCONSIN, IOWA, MINNESOTA.
(4) Silis (Silis) spathulata LeConte.

Silis spathulata LeConte, 1881, Trans. Amer. Ent. Soc., vol. 9, p. 57.
Black, pronotum pale rufous with anterior border more or less blackish.
Antennal vestiture erect and bristling. Pronotum as in figure 16 P , acute lateral margin not extending to tip of anterior process. Genitalia as in figure 4, ventral lobe of tegmen not extending posteriorly beyond dorsal plate. No laterophyses. Length 5 mm .

Distribution. NEW YORK: Ithaca; TENNESSEE: Knoxville; NORTH CAROLINA: Chapel Hills; SOUTH CAROLINA: Clemson.

This species is rare in collections, most of the specimens so identified belonging to $S$. percomis. The genitalia of the two species are quite distinct, but externally the two are not so readily separated. The best character for that purpose is the acute lateral margin of the pronotum, which in $S$. percomis extends to the tip of the anterior process, while in S. spathulata the acute margin obsolesces at an appreciable distance before the tip.
(5) Silis (Silis) carmelita Green, new species.

Holotype, male; Carmel, Calif., Monterey County, IV-9-11, L. S. Slevin. In collection of California Academy of Sciences. CAS type number 9081.

Head and appendages black. Pronotum pale fulvous with entire median black vitta about one-third pronotal width, widest at base, narrowing anteriorly, expanding abruptly over anterior explanate border, margins of vitta irregular. Scutellum and elytra black. Underside, except prothorax, dark. Legs black.

Pronotum as in figure 17P. Genitalia as in figure 5, no laterophyses; emargination of dorsal plate small, not entering membraneous area. Basophyses feebly bending inward near middle of length. Length 5.5 mm .

Variations. The median pronotal vitta may be much constricted or entirely eliminated in anterior third or half. This occurs mostly in females, only one male showing a pronounced constriction. In two males the elytra are flavate with the sutural bead dark, and the lateral borders except basally, and the apex more broadly, infuscate. In one of these males the pronotum is entirely flavate, in the other it is flavate with a large medio-basal dark area. Two females also have similarly flavate elytra, but without pronotal maculation.

Distribution. CALIFORNIA: Carmel: holotype, 5 paratypes, 6 females. IV-9 to V-20, E. C. Van Dyke, or F. E. Blaisdell, or L. S. Slevin (CAS); 1 paratype (elytra flavate) II-22-16, Slevin (CAS); 1 female (elytra flavate) III-15-31, Slevin (CAS). Del Monte, 1 paratype, V-5-23, Slevin (CAS). San Simeon, 1 paratype, V-22-54, O. Bryant (CAS). Soquel Creck, Santa Cruz County, 1 paratype, 1 female (both with flavate elytra) V-30-19, Van Dyke (CAS). Seaside, Monterey County, 1 female, IV-11-13, Slevin (CAS).
(6) Silis (Silis) lutea LeConte.

Silis lutea LeConte, 1853, in Catalog-desc. Coleop. of U.S., by Melsheimer, Smithsonian Inst., p. 78.
Silis pallens LeConte, 1851, Proc. Acad. Nat. Sci. Philadelphia, vol. 5, p. 339 (preoccupied).
Head and appendages black. Pronotum pale fulvous with entire median black vitta about one-third pronotal width, widest at base, narrowing anteriorly, expanding abruptly over anterior explanate border, margins of vitta irregular; varying with partial elimination of dark area anteriorly, progressing posteriorly to pronotum entirely pale. Scutellum black. Elytra flavate with sutural bead dark, apex and lateral borders, except basally, usually somewhat infuscate. Varying with elytra entirely black, which is usually seen to be in part fuscoflavate or brunneous when examined under brilliant illumination. Pronotal vitta always present when elytra are dark.

Antennal vestiture short and decumbent. Pronotum as in figure 17P. Genitalia as in figure 6, no laterophyses; emargination of dorsal plate large, deeper than wide, entering membranous area. Basophyses feebly bending inward near middle of length. Length $4.5-6.5 \mathrm{~mm}$.

Distribution. BRITISH COLUMBIA, WASHINGTON, OREGON, northern half of CALIFORNIA.

The color of the elytra is of no taxonomic importance. The dark form extends from Humboldt County, in northern California, to British Columbia where it predominates over the pale phase. Pale and dark ones occur together in the same locality. Examples of S. lutea with dark elytra were considered by Van Dyke to be a color phase that he identified as S. filigera LeConte. The latter is a valid species quite different in genitalic structure, and occupying a different geographic range.

A specimen from Mt. Madonna, Santa Cruz County, California (UCD), having the elytra black and the pronotum entirely pale, is referred here tentatively. The basophyses differ slightly in being more slender, and apparently do not bend inwardly near middle of length. This feature is somewhat variable and cannot be considered conclusive without additional material.
(7) Silis (Silis) filigera LeConte.

Silis filigera LeConte, 1874, Amer. Ent. Soc., Trans., vol. 5, p. 62.
Body and appendages black, pronotum entirely pale rufous.
Pronotum as in figure 17P. Genitalia as in figure 7, no laterophyses, emargination of dorsal plate very large, as deep as wide, entering membraneous area, basophyses bending strongly inward near middle of length. Length $4.5-5 \mathrm{~mm}$.

Distribution. CALifornia: Pasadena, IV, Fenyes, 1 male, 1 female (CAS). Sierra Madre, VI, Fenyes, 1 male (CAS).

This is definitely a valid species and not a color phase of $S$. lutea. Only two males and one female have been seen. They are constant in color pattern, agreeing with LeConte's description, but probably additional material will show the color variability characteristic of the S. lutea group.
(8) Silis (Silis) filicornis Van Dyke.

Silis filicornis Van Dyke, 1918, Jour. New York Ent. Soc., vol. 26, p. 172.
Body and appendages black, pronotum pale fulvous.
Length-width ratio about $3: 1$. Form narrow, parallel-sided. Antennae slender, filiform, about as long as body, intermediate segments about four times as long as wide, vestiture short and decumbent. Pronotum as in figure 18 P , excision at hind angles more or less completely filled by dorsal surface of hypomeron which joins lateral margin of pronotum at tip of anterior process, and at its angular rear extremity is produced in a small extension (the posterior process) terminating in a forward-curving spiniform seta. Genitalia as in figure 8. Basophyses united to form a broad parallel-sided plate about half as wide as tegmen, shallowly emarginate distally. Laterophyses straight, spiniform. Median lobe of aedeagus with dual short spiniform processes at apex. Dorsal plate with raised median lobe extending backward, its tip meeting posterior margin of basophysial plate. Length $4-5 \mathrm{~mm}$.

A specimen from Pine Valley, San Diego County (CAS), varies in having the pronotum as in figure 19P. It is referred to this species as the genitalia seem not to differ in any way.

Distribution. CALIFORNIA: San Jacinto Mountains. Palm Springs; same, Andreas Canyon; same, Palm Canyon. White Water; same, Snow Creek. Thousand Palms. East Highlands. San Bernardino Mountains, Devil Canyon. 2 mi. W. of Jacumba. San Diego County, Pinc Valley.
(9) Silis (Silis) tardella Green, new species.

Holotype, male; California, no definite locality, Horn collection, H 4923, with identification label "S. filigera Lec." In collection of Academy of Natural Sciences of Philadelphia.

Head black, pale in front; antennae and palpi dark. Pronotum entirely fulvous. Scutellum and elytra black. Underside: head fulvous, dark each side of gula; prothorax fulvous; balance of ventral surface dark except apical borders of ventral segments pale. Legs and coxae dark.

Length-width ratio about $2.75: 1$. Antennae filiform, about four-fifths as long as body, intermediate segments about three and one-half times as long as wide, vestiture short and decumbent. Pronotum as in figure 20P, lateral explanate borders thin, subhyaline. Anterior claw of all tarsi with blunt exterior basal appendix, other claws simple. Genitalia as in figure 9, dorsal plate
not emarginate, no laterophyses, basophyses united in a broad deeply emarginate plate attaining posterior margin of dorsal plate. Length 5 mm .

Distribution. CALIFORNIA, no definite locality (ANSP).
This species is represented only by the holotype from the Horn collection. The possibility that it might be a mislabeled European specimen should be investigated.
(10) Silis (Silis) flavida LeConte.

Silis flavida LeConte, 1874, Trans. Amer. Ent. Soc., vol. 5, p. 61.
Antennae black, pale beneath basally; palpi black. Head black, pale in front. Pronotum flavate; varying with basal, apical, and sometimes lateral, borders black. Scutellum black. Elytra flavate with apices broadly, and sides except basally, black or dusky; sutural bead usually brunneous, varying to partly or entirely flavate. Underside, except prothorax, dark. Legs pale, coxae and base of femora black, metafemora largely black.

Pronotum as in figure 21 P . Genitalia as in figure 10, emargination of dorsal plate narrowing to apex, its sides usually sinuate distally; basophyses emerging close together, subparallel, tips recurving or enlarged on proximal side. In ventral view, upper margins of lateral incisure of tegmen subangulate at about distal third. Length $5-6.5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Nevada County: Sagehen Creek near Hobart Mills; Truckee. El Dorado County: Tahoe; Grass Lake; Echo Lake; Lake Tahoc; Fallen Lea! Lake; Mt. Tallac; Tallac; Wright's Lake; Angora Lake. Alpine County: Hope Valley; Ebbets Pass. Calaveras Big Trees. Sonora Pass; Tuolumne Meadows; Vosemite National Park; Vosemite Valley; Saylor Lake; May Lake; Strawberry; Summerdale (Fish Camp). Mono County: Tioga Crest; Sardine Creek; Sonora Pass. NEVADA: Lake Tahoe.

This species is quite variable and may be complex. Material from the Yosemite region usually has the emargination of the dorsal plate V -shaped with straight sides and often with the tips turning inward. A specimen labeled "Nev." (ANSP) has the tegminal structure of S. flavida and the aedeagus of S. lasseni, and is possibly a hybrid.
(11) Silis (Silis) lasseni Green, new species.

Holotype, male; Duck Lake, Lassen County, California, V-8-21, J. O. Martin. In collection of California Academy of Sciences. CAS type number 9082.

Antennae black, three basal segments pale beneath; palpi dark. Head black, pale in front. Pronotum flavate with all borders narrowly black. Scutellum black. Elytra flavate, becoming darker rufo-brunneous in more than distal
half. Underside, except prothorax, dark. Legs dark, tibiae and tips of femora pale.

Pronotum as in figure 21P. Genitalia as in figure 11, emargination of dorsal plate narrowing to apex, sides not sinuate distally; basophyses emerging close together, subparallel, tips recurving or enlarged on proximal side. In ventral view, upper margins of lateral incisure of tegmen not subangulate distally. Length 5 mm .

Variations. The dark pronotal borders vary by reduction, leaving only the apical and basal narrowly dusky. The holotype, described above, was selected because of the clear visibility of the genitalic structure. Normally the elytra are more or less broadly black or dusky at apex and sides, the lateral dark area narrowing anteriorly and not reaching the base. The sutural bead is usually dark except near the scutellum.

The genitalia vary considerably. The emargination of the dorsal plate, normally V-shaped, sometimes has the sides sinuate as in S. flavida. Occasional examples occur in which a slight angulation is apparent at about distal third of the upper margins of the lateral incisure of the tegmen, viewed ventrally. The formation of the median lobe of the aedeagus offers the most decisive character for separating this species from $S$. flavida, but unfortunately this structure is often distorted and inconclusive. Length $5.5-6.5 \mathrm{~mm}$.

Typical specimens of S. lasseni, from the Cascade Range, and typical examples of $S$. flavida, from the Sierra Nevada Mountains, are readily identifiable. Possibly cross breeding has occurred where their habitats overlap, resulting in hybrids that cannot be confidently assigned to either species.

Distribution. CALIFORNIA: Modoc County: Blackmore, VII-3-50, M. Wasbauer, 1 paratype (UCB). Shasta County: Shingletown, V-24-11, C. D. Michener, 1 paratype (UCB). Lassen National Park, VI-28, 29-60, D. J. and J. N. Knull, 5 paratypes, 6 females (OSU); same, Kelly's Resort, VI-14-31, Van Dyke, 1 paratype (CAS); same, Manzanita Lake, VI-8-41, 1 paratype (Fender); same, Manzanita Camp, VI-18-60, 1 paratype (Edwards). Mt. Lassen, VII-5-63, D. J. and J. N. Knull, 2 females (OSU); same, 3 mi. SE., VII-8-55, D. L. Dahlston, 1 paratype (UCD). Manzanita Lake, VI-12-41, C. Michener, 1 paratype (CNC). Facht, VI-24, 27-22, V-3-23, J. O. Martin, 4 paratypes (CAS). Duck Lake, V-8-21, J. O. Martin, holotype (CAS). Plumas County: Bucks Lake, VII-1-49, W. R. Schreader, 1 paratype (UCD); same, Clover Valley, VI-17-23, J. O. Martin, 1 paratype (CAS); same, Chester, VI-7, 13-60, D. J. and J. N. Knull, 4 paratypes, 11 females (OSU). Mineral, 5 mi. E., VI-9, 26-60, D. J. and J. N. Knull, 24 paratypes (OSU 22, CAS 2), 46 females (OSU). Sierra County: Webber Lake, VII-2-59, Linsley, 1 paratype (UCB). Placer County: Baxters, VI-3-45, A. T. McClay, 1 paratype (UCD).
(12) Silis (Silis) nevadica Green, new species.

Holotype, male; Carson City, Nevada, V-12-41, A. T. McClay. In collection of University of California at Davis.

Body and appendages black, pronotum pale fulvous with all borders black.
Pronotum as in figure 21P. Genitalia as in figure 12, dorsal plate with broad U-shaped emargination, basophyses emerging widely separated, converging apically, tips prominently enlarged on proximal side in lateral view. In ventral view, upper margins of lateral incisure of tegmen strongly angulate at about distal third. Length 6.5 mm .

Distribution. NEVADA: Carson City, V-12-41, A. T. McClay, holotype. 1 paratype (UCD).
(13) Silis (Silis) tenuata Green, new species.

Holotype, male; Giant Forest, Tulare County, California, 6,500 ft., VII-1915, G. Hopping. In collection of California Academy of Sciences. CAS type number 9083.

Antennae dark, four basal segments pale beneath; palpi dark. Head black, pale in front. Pronotum flavate, anterior border blackish medially, posterior border narrowly dusky. Scutellum black. Elytra flavate, broadly dusky at apex and sides, lateral dark area narrowing anteriorly, not reaching base. Underside black, prothorax pale, ventral segments with paler lateral and apical borders. Legs pale, coxae and femora, except at apex, black; profemora largely pale, metafemora largely black.

Pronotum as in figure 21P. Genitalia as in figure 13, basophyses with exposed tips narrowing to very slender apically. In ventral view, upper margins of lateral incisure of tegmen strongly angulate at about distal third. Median lobe of aedeagus broad in dorso-ventral view, sides not striate. Ventral lobe of tegmen with distinct apical notch, sides subparallel. Length 6.5 mm .

Variations. The pronotum may have the lateral borders also dark. Specimens occur at high altitudes that are black with only the mandibles pale, or with the elytra partly fusco-flavate. Length $5.5-6.5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Fresno County: Huckleberry Meadow, $6,500 \mathrm{ft} ., \mathrm{V}-25-10, \mathrm{R}$. Hopping, 1 paratype: V-VII, 1 paratype (CAS). Round Meadow, Giant Forest, 6,400 ft., VII-1915, R. Hopping, 1 paratype (CAS). Fresno County: Piute Creek, VII-6-52, 6,200 ft., Peter Raven, 1 paratype (CAS). Fresno County: Cedar Grove, V-25-11, R. Hopping, 1 paratype (CAS). Tulare County: Giant Forest, 6,500 ft., VII-1915, G. Hopping, holotype (CAS). Fresno Cotnty: MeGee Creek, VII-10-52, 11,000 ft., Peter Raven, 1 male, 1 female (CAS). Huntington Lake, VI-26-46, VI-28-40, A. T. McClay, 2 paratypes (UCD); same, Badger Flat, VII-20, 22-37, VII-27-48, A. T. Mcclay, 3 paratypes (UCD). Tulare County: Dinuba, VI-19-57, A. T. Mc(lay, 1 paratype (UCD). Above Lundy, VII-9, 9-11,000 ft., Wickham, 1
paratype (USNM). Shaver Lake, VI-3-37, 1 paratype (Fender). Inyo County: Mono Pass, VIII-11-63, R. M. Brown, 1 paratype (CAS).
(14) Silis (Silis) carbo Van Dyke.

Silis difficilis carbo Van Dyke, 1918, New York Ent. Soc., Jour., vol. 26, p. 168.
Body black, underside of prothorax more or less pale anteriorly each side. Varying with pronotum flavate with black borders, disk sometimes partly blackish, elytra dark fuscous; or with both pronotum and elytra in large part flavate, as in $S$. flavida.

Pronotum as in figure 21P. Genitalia as in figure 14, exposed tips of basophyses normally broad. In ventral view, upper margins of lateral incisure of tegmen angulate at about distal third. In dorso-ventral view, median lobe of aedeagus narrowing to apex; sides longitudinally striate. Ventral lobe of tegmen without, or with very minute, apical notch; sides converging apically. Length $5-6.5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Fresno County: Rea Lake, 10,500 ft.; Bubbs Creek Canyon, Kings River, 9,700 ft.; 60 Lake Basin, 10,500 ft.; Bullfrog Lake, 10,600 ft.; East Lake, 10,000 ft.; Huntington Lake, 7,000 ft. Tulare County: Rattlesnake; Atwells Mill; Colony Road; Siberian Outpost, 10,500 ft. Kaweah, 7,500 ft. Monarch Lake. Mt. Mitchell. Sequoia National Park, Alta Peak, 9,500 to 11,000 ft. Kings Canyon National Park, Deadman Canyon. Mt. Whitney, 11,000 ft. Inyo County: Lone Pine Lake; Monache; Whitney Portal, 11,500 ft.

This species was described by Van Dyke as a color variety of S. difficilis. It is raised to specific rank because of its isolated habitat, accompanied by apparently constant structural differences in the tegmen, namely, the narrower ventral lobe lacking the apical notch, and the subangulate upper margins of the lateral incisure. The available data indicates that the all-black phase occurs only at altitudes of ten thousand feet or higher.
(15) Silis (Silis) oregonensis Green, new species.

Holotype, male; Warner Mountains, Lake County, Oregon, VI-18-22, Van Dyke. In collection of California Academy of Sciences. CAS type number 9084.

Black, pronotum fulvous with all borders narrowly black.
Pronotum as in figure 21P. Genitalia as in figure 15. In lateral view, tips of basophyses straight, rather broad, not narrowing apically. In ventral view, upper margins of lateral incisure of tegmen not angulate at distal third. Emargination of dorsal plate broadly $V$-shaped, attaining membraneous area. In dorsoventral view, median lobe of aedeagus broad, with small apical notch, sides not striate. Length 6.5 mm .


Variations. The elytra may be partially flavate, as in many S. difficilis; or they may be largely flavate, as in S. flavida. The apical notch of the median lobe of the aedeagus is often not apparent, due to drying distortion.

Distribution. OREGON: Lake County: Warner Mountains, VI-16-22, Van Dyke, holotype, 3 paratypes (CAS); Klamath County: Williamson River near head, V-30-59, Joe Schuh, 1 paratype (Fender); 11 mi . NE. of Bly, VI-7-59, Joe Schuh, 5 paratypes (Fender); 20 mi . N. of Beatty, Sycan River, V-30-59, Joe Schuh, 6 paratypes (Fender); 7 mi . W. of Kano, 3,000 ft., V-24-58, K. M. Fender, 1 paratype (Fender); 11 mi . NE. of Bly, V-5-62, Scott and Schuh, 3 paratypes (Schuh); Pelican Butte, VII-8-60, 2 paratypes (Schuh) ; Sun Creek, VI-14-62, J. D. Vertrees, 1 paratype (Schuh); Fremont National Forest, 5,000 ft., VI-17-22, Van Dyke, 1 paratype (CAS); Sun Mountain, VI-11-56, J. D. Vertrees, 1 paratype (Schuh); 1 mi . N. Ft. Klamath Junction, V-25-58, R. K. Eppley, 1 paratype (Edwards). Upper Klamath Lake, Three Mile Creek, V-30-60, Joe Schuh, 3 paratypes (Schuh). Ochoco National Forest, VI-14-41, Fender, 1 paratype, 1 male (Fender); same, Wildwood, V-26-50, 1 paratype (Fender). Crater Lake, 7,00n ft., VII-16-22, Van Dyke, 1 paratype (CAS); VII-14-38, A. T. McClay, 1 paratype (UCD); same, Park HQ. D. H. Huntzinger, 3 paratypes (Edwards); same, Garficld Peak, VI-27-57, D. H. Huntzinger, 2 paratypes (Edwards). Jackson County: Butte Falls, V-22-41, 1 paratype (UCD). Douglas County: Kelsey Valley, VI-20-62, J. D. Vertrees, 2 paratypes (Schuh). Anthony Lake, VI-12-39, 1 paratype (Fender). Bear Springs, VI-6-39, V-4, 26-40, Fender, 4 paratypes (Fender). Odell Lake, 3 mi. SE., VI-8-41, Schuh and Gray, 1 paratype (Schuh). CALIFORNIA: Trinity County: Carville, VI-16-13, Van Dyke, 1 paratype

[^30](CAS); Siskiyou County: Paynes Mcadow, VII-5-60, D. Q. Cavagnaro, 1 paratype (UCD).
(16) Silis (Silis) striatella Green, new species.

Holotype, male; Paradise Valley, Mt. Rainier, Washington, VII-24-20, Van Dyke. In collection of California Academy of Sciences. CAS type number 9085.

Head and antennae black. Pronotum pale fulvous with all borders black. Scutellum black. Elytra bicolored, broadly fulvous at base, pale area narrowing distally, extending to about apical fourth, its margins obscure; sutural bead, sides, and apex dark fuscous. Underside and legs mostly dark.

Pronotum as in figure 21P. Genitalia as in figure 16. Emargination of dorsal plate rather narrowly U-shaped, deeper than wide, sides subparallel or somewhat diverging, not curving inward distally, emargination not attaining membraneous area by a conspicuous distance. Upper margins of lateral incisure of tegmen not angulate at distal third. Median lobe of aedeagus with sides longitudinally striate. Length 6 mm .

Variations. The color of the elytra varies from entirely black to almost entirely fulvous. Rarely the sides of the dorsal plate emargination curve somewhat inward distally. Length 6-7.5 mm.

Distribution. BRITISH COLUMBIA: Midday Valley, Merritt, V-12, 27-26, E. Rendell, 2 paratypes; V-17-25, J. Stanley, 1 paratype; VI-4-23, R. Hopping, 1 paratype; V-24-23, R. Hopping, 1 paratype (CAS). Same, VI-4, 7-23, R. Hopping, 2 paratypes (CNC). WASHINGTON: Mt. Rainier: Paradise Valley, VII-24-20, Van Dyke, holotype, 12 paratypes (CAS); Paradise Park, 6,000 ft., VII-5, 31-05, Van Dyke, 2 paratypes (CAS); Paradise, VII-1, 4-34, O. Bryant, 8 paratypes (CAS); Longmire Springs, 2,500 ft., VII-25-19, Blaisdell, 1 paratype (CAS). Mt. Rainier, VII-22-40, 1 paratype (Fender). Rainier National Park, Sunrise Peak, VII-24-36, Van Dyke, 1 paratype (CAS). Pierce County, Fort Lewis, V-3-46, P. H. Arnaud, 2 paratypes (CAS). Rimrock, VI-8-54, H. P. Lanchester, 2 paratypes (Fender). Spirit Lake, VII-22-56, 3,800 ft., J. D. Lattin, 1 paratype (OSU).

OREGON: Bear Springs, VI-6, 7-39, V-26-40, K. M. Fender, 6 paratypes (Fender). Mt. Hood, Homestead Inn, VI-30-27, Van Dyke, 1 paratype (CAS). Mt. Hood, 3,000-6,000 ft., VI-23-25, Van Dyke, 3 paratypes (CAS). Kirby, IV-27-37, Fred Lawrence, 1 paratype (CAS). Ochoca National Forest, VI-13-41, 1 paratype (Fender). Swim, VII-2-42, Schuh and Gray, 1 paratype (Schuh). Parkdale, VII-1-38, Schuh and Gray, 1 paratype (Schuh). Klamath County, Little Deschutes River, VI-5-58, 5 paratypes (Schuh). LamolaTokatec Falls, North Umpqua River, VI-26-62, 1 paratype (Schuh).
(17) Silis (Silis) difficilis LeConte.

Silis difficilis LeConte, 1850, In: Lake Superior, by Louis Agassiz, p. 230.

Head black. Pronotum flavate or fulvous with all borders black, varying by reduction but never entirely pale in the male. In one example median extensions of front and rear black borders extend on disk. Scutellum black. Elytra flavate with apex and sides more or less black or fuscous; varying to entirely dark with more or less extensive pale color nearly always evident under brilliant illumination. Underside and legs mostly black.

Pronotum as in figure 21P. Genitalia as in figure 17. Emargination of dorsal plate broadly V - or U-shaped, about as deep as wide, not attaining membraneous area, sides curving inward distally. Basophyses usually extending only slightly through emargination of dorsal plate, narrowing apically in lateral view. Upper margins of lateral incisure of tegmen not angulate at distal third. Median lobe of aedeagus with sides longitudinally striate. Length 5-6.5 mm.

Distribution. QUEBEC: Gaspe County; Duparquet. SASKATCHEWAN: Rockglen; Attons Lake; Saskatoon; Cypress Hills; Prince Albert; Bounty; Beaver Creek; Katepwa. ALBERTA: McMurry; Lethbridge; Waterton; Elkwater; Banff; Edmonton; Olds; Pinehen Creek. BRITISH COLUMBIA: Atlin; Trinity Valley; Oliver; Creston; Cranbrook; Vernon; Adams Lake. MICHIGAN: Marquette. WISCONSIN: Sauk County, SOUTH DAKOTA: Custer; Spearfish Canyon; Blue Bell. NEW MEXICO: Jemez Mountains; Lincoln County. WYOMING: Yellowstone National Park; Curtis Canyon near Jackson; Teton National Park; Sublette County; Wind River Range. MONTANA: Glacier National Park; Mineral County; Fergus County; Big Snowy Peak. IDAHO: Wallace; Twin Creek Camp; Moscow; Stanley; Targhee Pass; Baker Creek NW. of Kctchum. WASHINGTON: Easton. OREGON: Lake Wallowa; Meacham; Pine Creek, Baker County; Tollgate, Blue Mountains; Durkee; Jackson County; Pinehurst; Butte Falls; Ashland; Buckhorn Mineral Springs; Deschutes County between Suttle Lake and Sisters.

This very widely distributed species is undoubtedly a complex as it is here recognized. It has not been found possible to segregate definitely recognizable taxa, with the exception of the somewhat unstable subspecies following. Exceptions to the bicolored elytra of S. difficilis are rare, and occur mostly in Idaho, Montana, and Wyoming. Some Oregon examples with an unusually wide smooth band separating the apex of dorsal plate emargination from the membraneous area, have the elytra usually entirely black.
(17a) Silis (Silis) difficilis occidens Green, new subspecies.
Holotype, male: 7 mi . W. of Westgard Pass, Inyo County, California, VI-26-53, W. D. McClellan. In collection of University of California at Davis.

Deep black, pronotum fulvous with all borders black, elytra without trace of paler coloration.

Pronotum as in figure 21P. Genitalia as in figure 17a, similar to S. difficilis, differing in basophyses extending well beyond emargination of dorsal plate, somewhat expanding apically as seen in lateral view, emargination attaining membraneous area. Length 5.5 mm .

Variations. No significant variation is noted in this subspecies as it occurs in California east of the Sierra Nevada Range. Progressing eastward through northern Arizona, Utah, and Colorado, the characteristic genitalic distinctions become less obvious, and no paratypes have been designated except from the California area. There are few exceptions to the uniform deep black coloration of the elytra. Length $4.25-6 \mathrm{~mm}$.

Distribution. CALIFORNIA: Inyo County: 7 mi . W. of Westgard Pass, VI-28-53, W. D. McClellan, holotype, 4 paratypes (UCD); Big Pine Creek, 8,000 ft., V-19-47, R. M. Bohart, 2 paratypes (UCD) ; Lone Pine, VI-18-37, N. W. Frazier, 2 paratypes (UCB); Upper Big Pine Creek, 8,500-9,500 ft., VII-1-60, W. F. Barr, 2 paratypes (UId). Mono County: Blanco's Corral, White Mountains, 10,000 ft., VI-20, 23-53, VII-7-53, J. W. McSwain, 8 paratypes (UCB) ; same, VI-23, 29-53, 5 paratypes (UCD); same, VI-23-53, H. Nakahihara, 2 paratypes (UCR); White Mountains, 10,000 ft., VI-19, 26-61, Buckett, Miller, and Lange, 7 paratypes (UCD 6, CAS 1). Siskiyou County: Macdoel, IV-28-49, Joe Schuh, 1 paratype (Schuh). Gilbert Lake to Independence, VII-17, Wickham, 1 paratype (USNM). Bubbs Creek, VII-29, 8,000 ft., Wickham, 1 paratype (USNM). ARIZONA: White Mountains; Diamond Creek; Grand Canyon; San Francisco Mountains; 20 mi . S. of Jacobs Lake; Williams; Flagstaff. NEVADA: Elko County: Grcen Mountain Creek; Angel Lake, 12 mi. SW. Wells. UTAH: Springville; Ft. Duchesne; Kanesville; Millville; Indian Canyon; Utah Experiment Station; Mapleton; Providence; Daniel Pass, 2 mi. E. of Strawberry; Salt Lake County: Dry Canyon; Morgan County: E. Canyon Dam; Wasatch County: Heber; Salt Lake City; Logan Canyon; Cowley Canyon; Card Canyon; Y Mountain, Utah County; Vineyard; Navajo Mountain. COLORADO: Coal Creek; Longs Peak Inn; Colorado Agricultural College; Denver; Colorado Springs; Boulder; Camp Creek Railroad Station; Chimney Gulch; Glenwood.

In a series from French Glen, Oregon (Fender), the tips of the basophyses are variably recurved or enlarged on proximal side, as viewed laterally. They may represent another subspecies, and have been labeled "Silis near occidens."
(18) Silis (Silis) atra LeConte.

Silis atra LeConte, 1884, Trans. Amer. Ent. Soc., vol. 12, p. 22.
Black, elytra varying to dark rufo-brunneous.
Pronotum as in figure 22P. Genitalia as in figure 18. Dorsal plate simple, with deep and very wide emargination. Laterophyses with small inconspicuous appendix. With single basophysis furcate submedially. Length $4-5 \mathrm{~mm}$.

Distribution. OREGON: Odell Lake; Mt. Hood; Tilly Jane Creek; near Grant Camp; Summit Meadow, Homestead Inn; Hood River Meadow; Three Sisters, Frog Camp; Diamond Lake; Klamath County, Summit Lake; Wascoe County, Bear Springs; Marion County, Park Butte; Lake County, Beaver Marsh; Mt. Jefferson. WASHINGTON: Mt. Rainier, Sunrise; Mt. Adams, Bird Creek; Rimrock; Lake Cle Elum. NORTHWEST TERRITORY: Horse Lake Area.
(19) Silis (Silis) egregia Green, new species.

Holotype, male; Warners Hot Springs, California, IV-6-40, G. P. Mackenzie. In collection of California Academy of Sciences, on indefinite loan from K. M. Fender. CAS type number 9086.

Black, prothorax pale fulvous above and beneath.
Pronotum as in figure 23P. Genitalia as in figure 19. Dorsal plate feebly trilobed, posterior orifice of tegmen not constricted below it. Ventral lobe extending well beyond dorsal plate. Laterophyses with small inconspicuous distal appendix. With single basophysis furcate submedially. Length 5.5 mm .

Distribution. CALIFORNIA: Warners Hot Springs, IV-6-40, G. P. Mackenzie, holotype (CAS). Mission Valley, III-8-28, 1 paratype (SDNH).
(20) Silis (Silis) singularis Green, new species.

Holotype, male; Lebec, California, altitude 4,000 ft., V-15-25, J. O. Martin. In collection of California Academy of Sciences. CAS type number 9087.

Black, prothorax pale fulvous above and beneath.
Pronotum as in figure 23P. Genitalia as in figure 20. Dorsal plate trilobed, side lobes prominent, extending far beyond feebly lobed median part. Posterior orifice of tegmen strongly constricted below dorsal plate. Ventral lobe of tegmen and dorsal plate subequal in length. Laterophysis (one missing in holotype) with tip everted and squarely truncate, surpassed by foliately expanded (in lateral view) distal appendix. With single basophysis furcate submedially. Length 8 mm .

Distribution. CALIFORNIA: Lebec, 4,000 ft., V-15-25, J. O. Martin, holotype (CAS).
(21) Silis (Silis) eximia Green, new species.

Holotype, male; Lockwood Creek near Stauffer Post Office, Ventura County, California, V-7-59, G. I. Stage. In collection of California Academy of Sciences, on indefinite loan from the University of California at Berkeley. CAS type number 9107.

Black, prothorax pale rufous above and beneath.

Pronotum as in figure 23P. Genitalia as in figure 21. Dorsal plate trilobed, side lobes extending moderately beyond median part, which has a shallow broadly angulate emargination. Posterior orifice of tegmen constricted below dorsal plate. Ventral lobe of tegmen not extending as far posteriorly as dorsal plate. Laterophyses with tips everted and squarely truncate, surpassed by tip of foliately expanded (in lateral view) distal appendix. With single basophysis furcate submedially. Length 6.5 mm .

Distribution. CALIFORNIA: Lockwood Creek, near Stauffer Post Office, Ventura County, V-7-59, G. I. Stage, holotype (CAS). Pine Creek, Alamo Mountain, V'entura County, V-6-59, C. W. O'Brien, 1 female, presumably of this species (UCB).
(22) Silis (Silis) abstrusa Green, new species.

Holotype, male; San Bernardino County, California, 6 mi . NNE. of Hesperia, IV-16-62, MacNeill, Rentz, Brown, and Lundgren. In collection of California Academy of Sciences. CAS type number 9088.

Black, prothorax pale fulvous above and beneath.
Pronotum as in figure 23P. Genitalia as in figure 22. Dorsal plate trilobed, side lobes extending far beyond median part which is deeply triangular emarginate. Posterior orifice of tegmen constricted below dorsal plate. Ventral lobe of tegmen slightly shorter than dorsal plate. Laterophyses with tips acute, slightly diverging, surpassed by small lineate distal appendix. With single basophysis furcate submedially. Length 6.5 mm .

Distribution. CALIFORNIA: San Bernardino County, 6 mi. NNE. of Hesperia, IV-16-62, MacNeill et al., holotype (CAS).
(23) Silis (Silis) arida Green, new species.

Holotype, male; Isabella, California, IV-5-14. In collection of American Museum of Natural History.

Black, prothorax pale fulvous above and beneath.
Pronotum as in figure 23P. Genitalia as in figure 23. Dorsal plate trilobed, side lobes extending well beyond median part which is prominently lobed. Posterior orifice of tegmen constricted below dorsal plate. Ventral lobe of tegmen slightly shorter than dorsal plate. Laterophyses with tips acute, not diverging, extending about as far posteriorly as tips of large foliately expanded (in lateral view) distal appendix. With single basophysis furcate submedially. Length 7 mm .

Distribution. CALIFORNIA: Isabella, IV-5-14, holotype (AMNH). (24) Silis (Silis) ursina Green, new species.

Holotype, male; Bear Valley, California, VI-6-14, R. S. Woglum. In collection of California Academy of Sciences on indefinite loan from the University of California at Riverside. CAS type number 9165.

Black, prothorax pale fulvous above and beneath.
Pronotum as in figure 23P. Genitalia as in figure 24. Dorsal plate trilobed, deeply emarginate, side lobes extending well beyond subtruncate median part. Ventral lobe of tegmen slightly shorter than dorsal plate. In dorso-ventral view, laterophyses arcuately converging distally, tips reversing, acute; appendix inconspicuous, setiform. With single basophysis furcate submedially. Median lobe of aedeagus with horizontally flattened apical process. Length 7 mm .

Distribution. CALIFORNIA: Bear Valley, VI-6-14, R. S. Woglum, holotype (UCR). The exact location of Bear Valley, in southern California, could not be determined.
(25) Silis (Silis) deserticola Van Dyke.

Silis deserticola Van Dyke, 1918, Jour. New York Ent. Soc., vol. 26, p. 173.
Black, prothorax pale fulvous above and beneath.
Pronotum as in figure 23P. Genitalia as in figure 25. Dorsal plate trilobed, feebly emarginate, side lobes extending but little beyond truncate median part. Posterior orifice of tegmen prominently constricted below dorsal plate. Ventral lobe of tegmen slightly shorter than dorsal plate. Laterophyses with tips acute, not diverging, surpassed by moderately expanded (in lateral view) distal appendix. With single basophysis furcate submedially, Length 7 mm .

Distribution. CALIFORNIA: Argus Mountains, May, holotype, and 1 female (USNM). The holotype is USNM number 21695.
(26) Silis (Silis) incongrua Green, new species.

Holotype, male; Santa Cruz Mountains, California, Koeble. In collection of California Academy of Sciences. CAS type number 9089.

Head blackish, paler in front, antennae and palpi dusky. Pronotum flavate. Scutellum black. Elytra flavate, sutural bead slightly darker, apices black. Beneath, except prothorax, dark. Legs flavate, middle and hind femora basally, and hind tibiae apically, dark.

Pronotum similar to figure 25 P except front margin of posterior process not angulate. Genitalia as in figure 26. Dorsal plate not emarginate, posterior margin convex, preceded by broad sclerotized area. Laterophyses long, slender throughout, curving strongly downward and feebly inward. With two basophyses. Length 5.25 mm .

Distribution. CALIFORNIA: Santa Cruz Mountains, Koeble, holotype (CAS).
(27) Silis (Silis) angulata Green, new species.

Holotype, male; Adams Springs, Lake County, California, F. E. Blaisdell. In collection of California Academy of Sciences. CAS type number 9090.


Head black, clypeus pale, antennae dusky; palpi dark (ex paratype). Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead brunneous. Beneath, except prothorax, dark. Legs flavate, femora largely dark, pale apically.

Pronotum similar to figure 24P. Genitalia as in figure 27. Dorsal plate with broad shallow emargination attaining membraneous area. Laterophyses long, moderately stout, nearly straight, with prominent exterior tooth at about distal third, tips diverging. With two basophyses failing by far to attain apex of dorsal plate emargination. Length 6 mm .

Distribution. CALIFORNIA: Lake County: Adams Springs, F. E. Blaisdell, holotype (CAS). Mark West Springs, V-11-30, E. P. Van Duzee, 1 paratype (CAS). Mt. St. Helena, V-12-26, E. P. Van Duzee, I paratype (CAS) ; same, V-10-20, S. F. Bailey and E. J. Taylor, 1 paratype (UCD).
(28) Silis (Silis) emarginata Green, new species.

Holotype, male; Yosemite Valley, California, V-26-25, Blaisdell. In collection of California Academy of Sciences. CAS type number 9091.

Head black, pale in front; antennae dusky, paler beneath basally; terminal palpal segments dark. Pronotum flavate. Scutellum black. Elytra entirely flavate. Beneath dark, front of head and prothorax pale. Legs flavate, tarsi darker, front coxae pale, others largely dark.

Pronotum as in figure 24 P . Genitalia as in figure 28. Dorsal plate with large deep U-shaped emargination entering membraneous area. Laterophyses moderately long, curving upward and inward, tips widened and everted. With two basophyses extending beyond apex of dorsal plate emargination. Length 6.5 mm .
$\leftarrow$
Figures 22-31. Male genitalia; ventral, lateral, and dorsal views, arranged in that order from left to right.
Figure 22. Silis (Silis) abstrusa Green, holotype. Diagram of posterior orifice of tegmen inserted.
Figure 23. Silis (Silis) arida Green, holotype. Diagram of posterior orifice of tegmen inserted.
Figure 24. Silis (Silis) ursina Green, holotype. Diagram of posterior orifice of tegmen inserted.
Figure 25. Silis (Silis) deserticola Van Dyke, holotype. Diagram of posterior orifice of tegmen inserted.
Figure 26. Silis (Silis) incongrua Green, holotype.
Figure 27. Silis (Silis) angulata Green, holotype.
Figure 28. Silis (Silis) emarginata Green, holotype.
Figure 29. Silis (Silis) fenderi Green, holotype.
Figure 30. Silis (Silis) subtruncata Green, holotype.
Figure 31. Silis (Silis) macclayi Green, holotype.

Variations. Rarely the elytra are tipped with black, the sutural bead remaining pale almost without exception. Only one individual has been seen with the sutural bead slightly darkened. The middle and hind femora and hind tibiae are sometimes partly dark. The dorsal plate emargination varies greatly to widely V-shaped with the lobes each side rather acutely angulate. Length $4.5-6.5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Plumas County: Quincy, VI-5-63, G. Leskey, 4 paratypes (UCD). Placer County: Emigrant Gap, VI-13-39, Cazier, 1 paratype (AMNH). El Dorado, 1 paratype (ANSP). Tallac, VI-1899, Van Dyke, 1 paratype (CAS). Calaveras Conty: Murphy's Canyon, 2,500 ft., V-15-36, Blaisdell, 1 paratype (CAS). Tuolumne County: Basin Creek, 5 mi. S. of Tuolumne City, V-31-64, Lundgren, 1 paratype (CAS). Yosemite, VI, 1 paratype (Fender); same, 4,000 ft., VI-17-28, VI-12-31, V-20-31, E. O. Essig, 3 paratypes (UCB). Yosemite National Park, VI-27-57, P. J. Santana, 1 paratype (Edwards). Yosemite Valley, V-22-21, 2 paratypes (UCB); same, V-26-25, Blaisdell, holotype (CAS). Ahwahnee, V, Fenyes, 1 paratype (CAS). Mariposa County: Miami Ranger Station, V-17, 23-42, C. Kennett, 2 paratypes (UCB); same, V-27-42, W. W. Allen, 2 paratypes (UCB). Mariposa, VI, Wickham, 1 paratype (USNM). Madera County, Coarsegold, V-12-42, C. Kennett, 1 paratype (UCB). Fresno County: Cedar Grove, V-25-11, R. Hopping, 2 paratypes (CAS); Huckleberry Meadows, 6,500 ft., VII-19-17, R. Hopping, 1 paratype (CAS); Sierra National Forest, Stevenson Creek, V-2915, R. Hopping, 1 paratype (CAS); Dalton Creek, 4,800 ft., V-6-20, H. Dietrich, 1 paratype, 1 female (CU); Bubbs Creek Canyon, Kings River, $9,700 \mathrm{ft} ., \mathrm{VI}-8-10$, Van Dyke, 1 paratype (CAS). Tulare County, VI-12-39, Nunenmacher, 1 paratype (CAS); same, Kaweah, IV-12-31, 1 paratype (Fender). Kaweah, R. Hopping, 1 paratype (CAS); same, VII-1-35, Fred Lawrence, 3 paratypes (CAS); same, IV-12-31, 3 paratypes (SDNH); same, 1 paratype, 1 male, 3 females (UK). Sequoia National Park, V-30-29, VI-13-29, A. T. McClay, 2 paratypes (UCD); same, VI-27, Edith Mank, 1 paratype, 3 females (CU). North Fork, V-23-20, H. Dietrich, 1 paratype (CU). Kern County, Hubbard and Schwarz, 1 paratype (USNAI). Monarch Lake, VI-1313, Van Dyke, 1 paratype (CAS). Sugar Pine, Fenyes, 1 paratype (CAS). Atwell Mill, ${ }^{\prime}-30-29$, A. T. McClay, 1 paratype (UCD). Mono County: W. Walker River, $6,000 \mathrm{ft}$., N. W. Frazier, 1 paratype (UCB). Southern California, Horn collection, 1 paratype (ANSP). Monterey County: Stone Canyon, IV-21, 27-19, Van Duzee, 3 paratypes (CAS). San Benito County: Waltham Creek, V-11-09. R. Hopping, 2 paratypes (CAS). Diablo Range, 2,000-4,000 ft., V-12-52, O. Bryant, 1 paratype (CAS).
(29) Silis (Silis) fenderi Green, new species.

Holotype, male; Peavine Ridge, near Mcainnville, Oregon, VI-9-48, K.
M. Fender. In collection of California Academy of Sciences on indefinite loan from K. M. Fender. CAS type number 9092.

Head black, pale in front; antennae and terminal palpal segments black. Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead brunneous. Beneath dark, except prothorax and head in front. Legs and coxae largely black, tips of femora, protibiae, and base of other tibiae, pale.

Pronotum similar to figure 24 P . Genitalia as in figure 29. Dorsal plate with rather deep triangular emargination attaining membraneous area. Laterophyses extending somewhat beyond dorsal plate, tips subrectangularly everted for a considerable distance. With two basophyses not extending as far posteriorly as apex of dorsal plate emargination. Length 5.5 mm .

Variations. The dorsal plate emargination varies in depth, and sometimes does not attain the membraneous area. The everted tips of the laterophyses may be either acute or blunt, and the angle of eversion may be somewhat obtuse. In one example the sutural bead of the elytra is not appreciably darker. Length $5-6 \mathrm{~mm}$.

Distribution. OrEGON: Peavine Ridge, near McMinnville, VI-9-48, K. M. Fender, holotype (CAS) ; same, VI-11-46, VI-5-45, 2 paratypes (Fender). Matulius River, VI-13-47, 1 paratype (Fender). Corvallis, VI-12-25, Van Duzee, 1 paratype (CAS) ; same, VII-3-46, K. R. Hobbs, 1 paratype (OrSU). Josephine County: Selma, 3.5 mi W., V-27-62, Joe Schuh, 1 paratype (Schuh). CALIFORNIA: Blocksburg, V-18-35, E. W. Baker, 1 paratype (AMNH). Humboldt County, VI-47, Bryant, 1 paratype (CAS).

## (30) Silis (Silis) subtruncata Green, new species.

Holotype, male; Fairfax, Marin County, California, V-7-11, Van Dyke. In collection of California Academy of Sciences. CAS type number 9093.

Head black, clypeus pale, antennae and palpi dusky. Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead brunneous. Beneath, except prothorax, dark. Legs largely dark, front tibiae and base of other tibiae pale.

Pronotum similar to figure 24 P . Genitalia as in figure 30. Dorsal plate with very shallow arcuate emargination, as seen in direct dorsal view, failing to attain membraneous area by a conspicuous distance. Laterophyses not surpassing dorsal plate, everted tips very short. With two basophyses not extending as far posteriorly as apex of dorsal plate emargination. Length 5.5 mm .

Variations. The laterophyses vary in length, often surpassing the dorsal plate by a short distance; and the everted tips are not at all constant in size or shape. In one example from Fort Seward, tentatively assigned, the laterophyses are more nearly as in S. fenderi, while the other diagnostic characters indicate its position here. Specimens from Berkeley and Oakland, and one from



Mill Valley, all unidentified at this time, suggest that several additional species may be involved. Length $5.5-6.5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Marin County: Fairfax, V-7-11, Van Dyke, holotype (CAS); V-20-11, Van Dyke, 1 paratype (CAS); V-7, 2911, Blaisdell, 2 paratypes (CAS); V-11, 25-19, Van Duzee, 2 paratypes (CAS) ; Fairfax Canyon, V-18-46, J. J. Dubois, 1 paratype (UCB); Phoenix Lake, IV-28-40, C. D. Duncan, 1 paratype (Edwards); Mill Valley, V-10-58, H. B. Leech, 1 paratype (CAS) ; Mt. Tamalpais, V-23-09, Van Dyke, 1 paratype (CAS); same, V-7-11, Blaisdell, 1 paratype (CAS). Sylvania (Camp Meaker, Sonoma County), May, R. Ecker, 3 paratypes (CAS); same, V-24-1895, 1 paratype (UK). (?)Humboldt County: Fort Seward, V-18-35, E. O. Essig, 1 male, tentative identification (UCB).
(31) Silis (Silis) macclayi Green, new species.

Holotype, male; Arbuckle, Colusa County, California, IV-20-62, P. M. Marsh. In collection of the University of California at Davis.

Head black, pale in front; antennae and tips of palpi dark, antennae pale beneath basally. Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead brunneous. Beneath, except head in front and prothorax, black. Front and middle legs, including coxae, flavate; tarsi and base of mesofemora dark. Hind legs and coxae black, knees pale.

Pronotum similar to figure 24P. Genitalia as in figure 31. Median lobe of aedeagus not subtriangular in lateral view, its upper margin nearly straight. Dorsal plate with small median V-shaped emargination, lobes each side scarcely deflected, emargination appearing nearly flat transversely in direct posterior

[^31]view. Laterophyses moderately slender, curving downward distally; tips slender, not everted. With two basophyses not extending posteriorly as far as apex of dorsal plate emargination. Length 6 mm .

Variations. The lobes each side of the dorsal plate emargination may be slightly deflected so that the emargination is very broadly and shallowly Vshaped in direct posterior view. The tips of the laterophyses may be straight or diverging in dorsoventral view. Specimens not from the type locality are believed to be conspecific, but they are atypical and have not been designated paratypes. In these the emargination of the dorsal plate is larger and deeper, broadly V-shaped, with the lobes each side somewhat deflected; and the legs are more extensively black. Length $5.5-6.5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Colusa County: Arbuckle, IV-20-62, P. M. Marsh, holotype (UCD) ; IV-13 to V-4-62, P. M. Marsh, 6 paratypes (UCD). Yreka, V-10-32, E. O. Essig, 3 males (UCB). OREGON: Klamath County: 20 mi . N. Beatty, Sycan River, V-30-59, Joe Schuh, 4 males (Fender); Keno, V-25-58, J. D. Vertrees, 1 male (Schuh). Jackson County, Pinehurst, V-21-61, Joe Schuh, 1 male (Schuh).
(32) Silis (Silis) crucialis Green, new species.

Holotype, male; Ben Lomond, Santa Cruz County, California, V-16-31, Van Dyke. In collection of California Academy of Sciences. CAS type number 9094.

Head black, pale in front; antennae and tips of palpi dark, antennae pale beneath basally. Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead dark brunneous. Beneath, except head in front and prothorax, black. Legs including coxae largely dark, protibiae pale, other tibiae pale basally, tips of femora pale.

Pronotum similar to figure 24P. Genitalia as in figure 32. Median lobe of aedeagus not subtriangular in lateral view, its upper margin broadly arcuate. Dorsal plate with large broadly V-shaped emargination, lobes each side strongly deflected, forming a deep U -shaped emargination in direct posterior view. Laterophyses stout, curving downward distally, tips slender, not everted. With two basophyses not extending as far posteriorly as apex of dorsal plate emargination. Length 6 mm .

Variations. The posterior aspect of the dorsal plate emargination is usually more or less V -shaped. The legs vary in color to almost all black, only the knees pale.

Distribution. CALIFORNIA: Ben Lomond, VI-7-24, 8 paratypes, 16 females (LAM): IV-31, Saylor, 2 paratypes (UA). Santa Cruz County: Ben Lomond, V-16-31, Van Dyke, holotype (CAS). Santa Cruz, VI-1-19, Van

Duzee, 1 paratype (CAS). Felton, Santa Cruz Mountains, V-15 to 19-07, Bradley, 1 paratype (CU). La Honda, V-20-52, O. Bryant, 1 paratype (CAS). Santa Clara County, Alma College, V-10-51, H. B. Leech, 1 paratype (CAS).
(33) Silis (Silis) thermalis Green, new species.

Holotype, male; Paraiso Springs, California, IV-22-14, L. S. Slevin. In collection of California Academy of Sciences. CAS type number 9095.

Head black, pale in front; antennae and palpi dusky. Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead brunneous. Beneath, except prothorax and head in front, dark. Legs largely dark, tibiae paler.

Pronotum similar to figure 24 P . Genitalia as in figure 33. Median lobe of aedeagus elongate subtriangular in lateral view, widest at about distal third where upper margin is subangulate. Dorsal plate with large V-shaped emargination. Laterophyses stout, nearly straight in lateral view, tips slender, not everted. With two basophyses not extending posteriorly as far as apex of dorsal plate emargination. Length 6 mm .

Variations. Nothing of importance noted. Length $5.5-6 \mathrm{~mm}$.
Distribution. CALIFORNIA: Paraiso Springs, IV-22-14, L. S. Slevin, holotype (CAS); IV-8-34, IV-18-32, V-6-28, VI-31-23, L. S. Slevin, 4 paratypes (CAS). Paraiso Hot Springs, V-4-22, L. S. Slevin, 2 paratypes (CAS).
(34) Silis (Silis) acuta Green, new species.

Holotype, male; Carrville, Trinity County, California, VI-26-14, Van Dyke. In collection of California Academy of Sciences. CAS type number 9096.

Head black, clypeus pale; antennae and palpi dusky. Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead brunneous. Beneath, except prothorax and head in front, dark. Front and middle legs flavate, femora basally and mesotibiae distally, dark; hind legs largely dark.

Pronotum similar to figure 24 P . Genitalia as in figure 34. Median lobe of aedeagus elongate subtriangular in lateral view, widest at about distal third where upper margin is subangulate. Dorsal plate with large V-shaped emargination. Laterophyses long, rather slender throughout, nearly straight in lateral view, tips feebly diverging. With two basophyses extending posteriorly about as far as apex of dorsal plate emargination. Length 6 mm .

Variations. The upper margin of the median lobe of the aedeagus, beyond the subangulation, may be abruptly re-entrant, forming a protuberance in lateral view. Length $4.5-6 \mathrm{~mm}$.

Distribution. CALIFORNIA: Trinity County: Carrville, VI-28-14, Van Dyke, holotype (CAS); VI-4, 16-13, Van Dyke, 2 paratypes (CAS). Humboldt County: Green Point, VI-5-16, Blaisdell, 1 paratype (CAS). Humboldt County: Redwood Canyon, VI-4-16, Blaisdell, 1 paratype (CAS).
(35) Silis (Silis) cava LeConte.

Silis cava LeConte, 1874, Trans. Amer. Ent. Soc., vol. 5, p. 61.
Head flavate in front, black posteriorly; antennae dusky, paler beneath basally; terminal palpal segments black. Pronotum flavate. Scutellum black. Elytra flavate tipped with black, sides dark apically, sutural bead brunneous. Beneath, except head and prothorax, dark. Front and middle legs, including coxae, largely pale; hind legs largely dark.

Pronotum similar to figure 25 P . Genitalia as in figure 35 . With single basophysis furcate submedially. Laterophyses slender, not extending posteriorly beyond median lobe of aedeagus, turning more or less abruptly downward for a short distance apically. Dorsal plate subtruncate in direct dorsal view. Length $4.5-5.5 \mathrm{~mm}$.

Distribution. OREGON: No definite locality, LeConte type (MCZ). Josephine County: Cave Junction, IV-25-38, A. T. McClay, 8 males (UCD 7, ('AS 1).

Through the courtesy of Dr. P. J. Darlington, Jr., the author was able to study LeConte's type of this species. In the abundant material available, only the Josephine County series, cited above, agrees accurately in genitalia with the LeConte type. They have been labeled "Silis cava Lec., typical."

All others keying here have been labeled "Silis cava complex." Some of these, representing variability, may be conspecific with $S$. cava, while others undoubtedly comprise several valid species. All attempts at segregating these have failed. The specimens all have in common a single basophysis furcate submedially, and the dorsal plate subtruncate in direct dorsal view. They differ confusingly in the length and curvature of the laterophyses, the length of the ventral lobe compared with the dorsal plate, and the posterior formation of the latter (figures 35a, 35b). Their distribution follows.

Distribution. OREGON: Yamhill County, Meadow Lake. Peavine Ridge, near McMinnville. Josephine County, Wilderville. Jackson County: Butte Falls; Griffin Creek; summit Green Springs Highway, Jacksonville. Ashland. Klamath County, Rocky Point. Klamath Falls: above Geary Ranch; Algoma. Upper Klamath Lake. CALIFORNIA: Trinity County: Eagle Creek. Mendocino County: Yorkville; Big Dam Creek. Lake Connty: Lakeport. Yolo County, Cache Creck Canyon. Plumas County: Belden; Quincy; Johnsville. Oroville. Placer County, Baxters. Applegate. El Dorado County: Fallen Leaf; Pollock Pines. El Dorado. Tallac. Mokelumne Hill. Calaveras County, near Dorrington. Yosemite. Yosemite National Park. Mariposa County: Mami Ranger Station. San Diego County.

A single specimen from a series of " $S$. cava complex" collected at Quincy, Placer County, California, has the ventral lobe of the tegmen longitudinally divided by a deep and narrow emargination. The emargination is perfectly
symmetrical and shows no indication of having been caused by a fracture. A somewhat similar deformity has been noted in several specimens of the Silis pallida group.
(36) Silis (Silis) arizonica Van Dyke.

Silis arizonica Van Dyke, 1918, New York Ent. Soc., Jour., vol. 26, p. 174.
Black, prothorax pale fulvous above and beneath.
Pronotum as in figure 26P. Genitalia as in figure 36. Dorsal plate not emarginate. Laterophyses moderately slender, curving downward distally, shorter than median lobe of aedeagus. With single basophysis, tip expanded and notched. Length $6-7 \mathrm{~mm}$.

Distribution. ARIZONA: Williams, V-27 to VI-7, Barber and Schwarz, 8 males, 1 female (USNM). Ashfork, V-31-62, G. H. Nelson, on Pinus ponderosa, 2 males (Nelson). Prescott, holotype (CAS).
(37) Silis (Silis) fenestrata Van Dyke.

Silis fenestrata Van Dyke, 1918, Jour. New York Ent. Soc., vol. 26, p. 175.
Black, pronotum pale fulvous with all borders black. Beneath, except prothorax, black.

Pronotum as in figure 27P, lateral incisure closed by backward extension of anterior process. Genitalia as in figure 37. Dorsal plate with small variable emargination, sometimes lacking. Laterophyses long, very slender throughout, turning downward distally, sometimes rotated to form a lyriform pattern as shown in figure. With single basophysis, tip expanded and notched. Length $5-5.5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Bear Lake, VI-15-17, Van Dyke, 1 male (CAS). San Bernardino County: Barton Flats, V-30-58, M. E. Erwin, 2 males (UCD). San Jacinto Mountains, Marion Mountain Camp, VII-1-52, A. T. McClay, 1 male (UCD). Tahquitz Valley, VI-3-40, H. T. Reynolds, 2 males (UCB, Fender). San Bernardino Mountains, Mill Creek, V-6, 16, 23-48, Timberlake, 4 males, 1 female (Timberlake); same, 6,200 ft., V-22-38, 1 male (Timberlake) Mt. San Jacinto, holotype (CAS).

The emargination of the dorsal plate is more or less variable in most Silis species, but nowhere else has there been encountered such extreme variation as that occurring in S. fenestrata. In the female the black pronotal borders are reduced to the anterior border and the median half of the basal border.
(38) Silis (Silis) californica Fender.

Silis californica Fender, 1948, Wasmann Collector, vol. 7, p. 119.
Head black, pale in front, antennae and palpi dark. Pronotum fulvous. Scutellum black. Elytra appearing totally black, but disk usually showing
partly fusco-flavate under brilliant illumination. Beneath, except prothorax, dark. Legs and coxae black, anterior pair partly pale.

Pronotum similar to figure 28P. Genitalia as in figure 38. Dorsal plate with large deep emargination. Laterophyses broad except apically, curving downward distally for a variable part of their length. With single basophysis, tip expanded and notched. Length $5-7 \mathrm{~mm}$.

Distribution. CALIFORNIA. Inyo County: Panamint Mountains; Whitney Portal. San Jacinto Mountains; Idyllwild; Tahquitz Valley. Keen Camp. Laguna. San Diego County: Otay Mountains. NEVADA: Charleston Mountains, Kyle Canyon.

A specimen from Wrightwood, San Bernardino County, California, agrees with the description of $S$. californica, except the tip of the basophysis is not expanded, like in S. reversa. It has been labeled "near californica" (UCD).
(39) Silis (Silis) reversa Green, new species.

Holotype, male; Santa Rosa Mountain, California, VI-15-46, D. J. and J. N. Knull. In collection of Ohio State University.

Head black, clypeus pale; antennae black, paler beneath basally; terminal palpal segments black. Pronotum pale fulvous. Scutellum black. Elytra appearing totally black, but disk showing partly fusco-flavate under brilliant illumination. Beneath, except prothorax, dark. Legs black, anterior coxae partly pale.

Pronotum similar to figure 28P. Genitalia as in figure 39. Dorsal plate with large deep emargination. Laterophyses long, slender, curving upward distally. With single basophysis, tip notched but not expanded. Length 6.5 mm .

Variations. The color of the elytra, under brilliant illumination, varies from almost entirely dark to fusco-flavate with base, sides, and apex blackish. The front legs may be largely pale. Length $5.5-6.5 \mathrm{~mm}$.

Distribution. CALIFORNIA: Santa Rosa Mountain, VI-15-46, D. J. and J. N. Knull, holotype, 1 paratype (OSU), 1 paratype (Fender). Keen Camp, V-14-46, D. J. and J. N. Knull, 4 paratypes (OSU 2, Fender 2); same, V-24-46, 1 paratype (OSU). San Jacinto Mountains, Pine Cove, VI-4-39, E. S. Ross, 1 paratype (UCB).
(40) Silis (Silis) solitaria Green, new species.

Holotype, male; Sequoia National Park, California, 2,000-3,000 ft., V-1729, A. T. McClay. In collection of California Academy of Sciences. CAS type number 9097.

Head black, pale in front, terminal segment of maxillary palpi black; basal segment of antennae pale, others missing. Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead not darker. Beneath, except prothorax, dark. Legs, including coxae, largely pale; tarsi, basal half of middle and hind femora, and metacoxae, dark.

Pronotum similar to figure 28 P . Genitalia as in figure 40. Dorsal plate with wide subtruncate emargination. Laterophyses broad, tips bent strongly inward and downward. With single basophysis, tip expanded and notched. Length 6.5 mm .

Variations. The two paratypes have the inverted tips of the laterophyses longer and more acute than in the holotype. Length $6.5-7 \mathrm{~mm}$.

Distribution. CALIFORNIA: Sequoia National Park, 2,000-3,000 ft., V-17-29, A. T. McClay, holotype (CAS). Kings River Canyon, V-25, 26-48, A. T. McClay, 2 paratypes (UCD).
(41) Silis (Silis) recta Green, new species.

Holotype, male; Ahwahnee, California, May, A. Fenyes. In collection of California Academy of Sciences. CAS type number 9098.

Head black, pale in front; antennae and tips of palpi black. Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead not darker. Beneath, except prothorax, dark. Legs and coxae largely pale; tarsi, base of middle and hind femora, tips of hind tibiae, and metacoxae, dark.

Pronotum as in figure 28P. Genitalia as in figure 41. Dorsal plate with deep rounded emargination. Laterophyses nearly straight, slender throughout, tips not diverging. With single basophysis, tip expanded and notched. Length 7 mm .

Variations. The laterophyses may curve more obviously inward and downward than in the holotype, but always they are slender with the tips not diverging. The emargination of the dorsal plate may have the apex subtruncate. Length $5.25-7 \mathrm{~mm}$.

Distribution. CALIFORNIA: Ahwahnee, May, A. Fenyes, holotype, 1 paratype, 1 female (CAS). Yosemite Valley, VII-8-30, F. E. Blaisdell, 1 paratype (CAS); VI-27-21, 1 paratype (CAS). Lebec, V-30-37, Andrews and Martin, 1 paratype (LAM). No definite locality, 2 paratypes (ANSP).
(42) Silis (Silis) angelica Green, new species.

Holotype, male; Waterman Canyon, California, V-28-16, J. O. Martin. In collection of California Academy of Sciences. CAS type number 9099.

Head black, pale in front; antennae and palpi dark. Pronotum flavate. Scutellum black. Elytra flavate, tips black, sutural bead slightly darker. Beneath, except prothorax, dark. Front legs and coxae largely pale, others largely dark.

Pronotum similar to figure 28P. Genitalia as in figure 42. Dorsal plate with rather small rounded emargination. Laterophyses moderately broad, curving inward at about distal fourth, tips diverging forming a lyre-shaped pattern. With single basophysis, tip expanded and notched. Length 6 mm .

Variations. In one example the tips of the laterophyses are almost

rectangularly everted, and the dorsal plate emargination is wide and subtruncate (LAM). Length $5.5-6 \mathrm{~mm}$.

Distribution. CALIFORNIA: Waterman Canyon (south slope, San Bernardino Mountains, San Bernardino County), V-28-16, J. O. Martin, holotype; same, V-27-16, 1 paratype (CAS). San Bernardino Mountains, 6,000 ft., VI-7-1898, 1 paratype (LAM) ; same, 4 mi . S. of Camp Angelus, V-24-58, G. H. Nelson, 1 paratype, 3 females (Nelson). Los Angeles County: San Gabriel Canyon, V-18-32, 1 paratype (AMNH). Mt. San Antonio (Los Angeles County), $10,700 \mathrm{ft}$. (corrected, 10,059 ft.), VII-3-11, P. H. Timberlake, 1 paratype (USNM).
(43) Silis (Silis) latestyla Green, new species.

Holotype, male; Fort Tejon, Kern County, California, V-14-28, Van Dyke. In collection of California Academy of Sciences. CAS type number 9100.

Head black, pale in front; antennae and terminal palpal segments dark. Pronotum flavate. Scutellum black. Elytra flavate, tips and sides distally black. sutural bead not darker. Beneath, except prothorax and metasternum, dark. Legs and coxae largely pale, tarsi and basal half of metafemora black.

Pronotum similar to figure 28P. Genitalia as in figure 43. Dorsal plate with wide subtruncate emargination. Laterophyses broad, curving feebly downward, tips somewhat diverging. With single basophysis, tip notched, not appreciably expanded. Length 6.5 mm .

Variations. The dark color of the sides of the elytra distally is variable in extent, sometimes lacking; the sutural bead varies to more or less dark. The color of the legs varies to largely dark. Length 6-7 mm.

Distribution. CALIFORNIA: Fort Tejon, Kern County, V-14-28, Van Dyke, holotype, 2 paratypes (CAS); same, V-29-27, 1 paratype (USNM). Ventura County, Mt. Pinos, VI-12-04, F. Grinnell, 2 paratypes (CAS). Lebec,

[^32]4,000 ft., V-13-28, J. O. Martin, 1 paratype (CAS). Los Angeles County: Camp Baldy, VI-26-50, J. D. Paschke, 1 paratype (UCB). San Bernardino County: Camp Baldy, VI-20-37, A. T. McClay, 1 paratype (UCD); same, VI-29-56, H. R. Moffitt, 1 paratype (UCD). San Bernardino Mountains, 6,000 ft., VI-7-1898, 1 paratype (LAM).
(44) Silis (Silis) fabulosa Green, new species.

Holotype, male: Grand Coulee, Washington, IV-4-34, L. T. Turner. In collection of California Academy of Sciences. CAS type number 9101.

Body and appendages deep black; pronotum fulvous with all borders black, basal black border extending indefinitely forward, no median maculation of disk. Underside of head in front, and of prothorax except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 44. Dorsal plate with small semicircular emargination in the inflexed sclerotized posterior border. Laterophyses long, slender, lyrate, without distal appendix. With single basophysis bilaterally enlarged at tip. Length 5.5 mm .

Variations. The lateral black border of the prothorax may be much reduced above and beneath; the basal black border may not extend forward. Length 5-6 mm.

Distribution. WASHINGTON: Grand Coulee, IV-4-34, L. T. Turner, holotype (CAS). Grand Coulee, Dry Falls, IV-20-35, M. H. Hatch, 6 paratypes (UW). Grant County: Electric City, IV-12-42, Rogers, 2 paratypes (UW).
(45) Silis (Silis) divaricata Green, new species.

Holotype, male; Lind, Washington, IV-23-19, F. R. Cole. In collection of California Academy of Sciences. CAS type number 9102.

Body and appendages deep black; pronotum fulvous with all borders black, basal black border extending indefinitely forward, no median maculation of disk. Underside of head in front, and of prothorax except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 45. Basophyses widely divaricate, attaining posterior margin of dorsal plate exterior to a minute marginal denticulation each side, margin between denticulations not inflexed or thickened. Laterophyses without distal appendix. Length 5.25 mm .

Distribution. WASHingTON: Lind, IV-23-19, F. R. Cole, holotype (CAS).
(46) Silis (Silis) montanica Green, new species.

Holotype, male: Florence, Montana, V-16-13, H. P. Wood. In collection of U. S. National Museum.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 46. Basophyses arcuately subparallel, not surpassing posterior margin of dorsal plate, this not inflexed and without marginal teeth. Laterophyses moderately slender, feebly curving upward, appendix large and prominent, surpassing tip of laterophysis. Length 5.5 mm .

Variations. The median black vitta of the pronotum may be narrowly interrupted in front, not quite attaining the anterior black border. Length $5.5-6 \mathrm{~mm}$.

Distribution. MONTANA: Florence, V-16-13, H. P. Wood, holotype, 2 paratypes (USNM).
(47) Silis (Silis) lecontei Green, new species.

This name is proposed for a specimen in the LeConte collection, at the Museum of Comparative Zoology, bearing labels "Van., male" and "vulnerata TYPE 3379," the latter an MCZ label. LeConte's locality designation presumably refers to Vancouver, British Columbia, which disqualifies the specimen as the original type of S. vulnerata, described from Oregon.

Body and appendages black, disk of pronotum with large fulvous spot each side.

Pronotum similar to figure 29P. Genitalia as in figure 47. Basophyses attaining posterior margin of dorsal plate, tips not visible beyond sides of ventral lobe in direct ventral view. Posterior margin of dorsal plate without distinct marginal teeth, a single short inflexed median lobe separating tips of basophyses. Laterophyses apparently without distal appendix. Length below average (not measured).

Distribution. "Van.," presumably Vancouver, British Columbia, holotype (MCZ).
(48) Silis (Silis) dentigera Green, new species.

Holotype, male; Hood River, Oregon, Childs Collection, 4-15 (mounted with female). In collection of California Academy of Sciences on indefinite loan from Oregon State University. CAS type number 9051.

Body and appendages deep black, pronotum fulvous with all borders black, disk without median vitta. Underside of head in front, and of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 48. Basophyses long, slender in more than distal half, curving outward and upward but not attaining dorsal plate (taken from copulating pair, may not be normal position).

Marginal teeth of dorsal plate very large and much retracted, plainly visible from direct lateral viewpoint. Laterophyses slender, ascending, appendix inconspicuous. Length 5 mm .

Distribution. OREGON: Hood River, Childs, 4-15, holotype, 1 female (CAS).
(49) Silis (Silis) disjuncta Green, new species.

Holotype, male; Gifford, Idaho, 2,900 ft., V-6-49, W. F. Barr. In collection of California Academy of Sciences on indefinite loan from the University of Idaho. CAS type number 9052.

Body and appendages deep black, pronotum largely black, disk with dusky fulvous area each side. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29 P , paler areas irregularly elevated, forming a rough semicircle (perhaps not normal). Genitalia as in figure 49. Basophyses short and stout, curving upward but not attaining dorsal plate. Marginal teeth of dorsal plate larger than usual, retracted, plainly visible from direct lateral viewpoint. Laterophyses straight, appendix inconspicuous. Length 5 mm .

Distribution. IDAHO: Gifford, V-6-49, 2,900 ft., W. F. Barr, holotype (CAS).
(50) Silis (Silis) triplicata Green, new species.

Holotype, male; Noscow, Idaho, May 13, 1928, altitude $2,800 \mathrm{ft}$. In collection of California Academy of Sciences on indefinite loan from the University of Idaho. CAS type number 9059.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 50. Basophyses long, divergent, extending well beyond posterior margin of dorsal plate, tips curving slightly inward in ventral view. Marginal teeth of dorsal plate large and acute. In lateral view, laterophyses feebly sinuate, curving downward distally, parallel and straight in dorsal view; appendix not apparent. Length 5.25 mm .

Distribution. IDAHO: Moscow, V-13-28, 2,800 ft., holotype (CAS); 5 paratypes (UId). Moscow, Paradise Ridge, V-7-32, 3,000 ft., J. Gillette, 2 paratypes (Uld). Lenore, V-7-38, 1,000 ft., E. Ritzheimer, 1 paratype (UId). WASHINGTON: Uniontozon, V-3-60, V-20-39, 2 paratypes (Fender). Pullman, August, 1 paratype (USNMI).
(51) Silis (Silis) protracta Green, new species.

Holotype, male; Spalding, Idaho, Nez Perce County, IV-18-48, W. F. Barr. In collection of California Academy of Sciences on indefinite loan from the University of Idaho. CAS type number 9057.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 51. Basophyses long, divergent, extending well beyond posterior margin of dorsal plate, tips curving strongly inward in ventral view. Marginal teeth of dorsal plate large and acute. Laterophyses nearly straight in lateral view, curving inward distally in dorsal view, appendix small and inconspicuous. Length 5.25 mm .

Variations. The basophyses vary in length, and the inward curvature of the tips varies in degree but is always evident. A single specimen of doubtful position, from Lenore, Idaho, figure 51a (Nelson), differs from S. protracta mainly in the expanded appendix of the laterophyses, plainly visible in dorsoventral view. Both the laterophyses and basophyses are more widely divergent. It is possible that these differences may be explained as being preliminary to, or immediately following, copulation. Length $5-5.75 \mathrm{~mm}$.

Distribution. IDAHO: Spalding, Nez Perce County, IV-18-48, W. F. Barr, holotype (CAS); 6 paratypes (UId); same, III-28-53, C. J. Tarhaar, 1 paratype (UId). Lewiston, Lewiston Grade, IV-23-38, J. W. Zuckel, 1 paratype (UId). Lewiston, IV-23-38, M. D. Bentley, 1 paratype (UId). WASHINGTON: Colton, V-3-60, W. W. Cone, 2 paratypes, 1 female (UW).
(52) Silis (Silis) simulata Green, new species.

Holotype, male; Lenore, Idaho, V-7-38, altitude $1,000 \mathrm{ft}$., H. C. Eig. In collection of California Academy of Sciences on indefinite loan from the University of Idaho. CAS type number 9058.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta of nearly, uniform width, except for a submedian constriction, connecting anterior and basal black borders. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 52. Basophyses long, divergent, extending well beyond posterior margin of dorsal plate, tips not appreciably curving inward in ventral view. Marginal teeth of dorsal plate large and acute. Laterophyses straight, much expanded on dorsal side in lateral view, appendix conspicuous. Length 5 mm .

Distribution. IDAHO: Lenore, V-7-38, altitude 1,000 ft., H. C. Eig, holotype (CAS).

(53) Silis (Silis) introversa Green, new species.

Holotype, male; 4 mi . S. of Whitebird, Idaho County, Idaho, IV-4-60, A. R. Gittins. In collection of California Academy of Sciences on indefinite loan from the University of Idaho. CAS type number 9053.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 53. Basophyses diverging, abruptly converging from about distal fourth, not visible each side of ventral lobe of tegmen in direct ventral view, tips resting on apices of small closely placed marginal teeth of dorsal plate. In lateral view, appendix prominent, foliate, much larger than contiguous portion of laterophysis and surpassing its tip. Length 6 mm .

Distribution. IDAHO: 4 mi . S. of Whitebird, Idaho Colmty, IV-4-60, A. R. Gittins, holotype (CAS), 1 paratype (UId).
(54) Silis (Silis) perfoliata Green, new species.

Holotype, male; Lewiston, Idaho, IV-30-32, J. Gillette. In collection of California Academy of Sciences on indefinite loan from the University of Idaho. CAS type number 9055.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of head in front, and of prothorax except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 54. Basophyses divergent, straight, tips visible each side of ventral lobe of tegmen in direct ventral view, extending around posterior margin of dorsal plate exterior to
$\leftarrow$
Figures 53-64. Male genitalia; ventral, lateral, and dorsal views arranged, in that order from left to right.
Figure 53. Silis (Silis) introversa Green, holotype.
Figure 54. Silis (Silis) perfoliata Green, holotype.
Figure 55. Silis (Silis) proxima Green, holotype.
Figure 56. Silis (Silis) abrupta Green, holotype.
Figure 57. Silis (Silis) lobata Green, holotype.
Figure 58. Silis (Silis) vulnerata LeConte.
Figure 59. Silis (Silis) parallela Green, holotype.
Figure 60. Silis (Silis) constricta Green, holotype.
Figure 61. Silis (Silis) barri Green, holotype.
Figure 62. Silis (Silis) insolita Green, holotype.
Figure 63. Silis (Silis) pallida Mannerheim, Sitka, Alaska.
Figure 64. Silis (Silis) insperata Green, holotype.
marginal tooth each side. In lateral view, appendix prominent, foliate, much larger than contiguous portion of laterophysis and surpassing its tip. In dorsal view, diverging tips of laterophyses short, abruptly everted. Length 4.5 mm .

Variations. In one paratype the basophyses extend beyond the dorsal plate, as in S. protracta and allied species. Any individuals keying to that section are removed by couplet 54 . Length $4.5-5.5 \mathrm{~mm}$.

Distribution. IDAHO: Lewiston, IV-30-32, 550 ft., J. Gillette, holotype (CAS). Nez Perce County, Central Grade, IV-13-60, A. R. Gittins, 2 paratypes (UId).
(55) Silis (Silis) proxima Green, new species.

Holotype, male; Webb, Nez Perce County, Idaho, IV-8-49, W. F. Barr. In collection of California Academy of Sciences on indefinite loan from the University of Idaho. CAS type number 9056.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of head in front, and of prothorax except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 55. Basophyses divergent, straight, tips visible each side of ventral lobe of tegmen in direct ventral view, extending around posterior margin of dorsal plate exterior to marginal tooth each side. In lateral view, appendix prominent, foliate, much larger than contiguous portion of laterophysis and surpassing its tip. In dorsal view, diverging tips of laterophyses longer than in $S$. perfoliata, regularly arcuate. Length 5.5 mm .

Distribution. IDAHO: Webb, Nez Perce County, IV-8-49, W. F. Barr, holotype (CAS). Gifford, V-27-49, 2,900 ft., W. F. Barr, 2 paratypes (UId).
(56) Silis (Silis) abrupta Green, new species.

Holotype, male; 33 mi . W. of Yakima, Washington, V-8-49, G. H. Nelson. In collection of California Academy of Sciences. CAS type number 9103.

Body and appendages deep black; pronotum fulvous with all borders narrowly black, disk without median vitta. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 56. In ventral view, basophyses divergent, straight, tips visible each side of ventral lobe of tegmen, attaining posterior margin of dorsal plate exterior to marginal tooth each side. In lateral view, basophyses turning abruptly upward distally. Laterophyses straight and rather slender in lateral view, appendix broader than, but not surpassing, tip of laterophysis. Length 6 mm .

Variations. The laterophyses vary somewhat in width, and in one example they curve slightly downward distally. Length $5-6 \mathrm{~mm}$.

Distribution. WASHINGTON: Yakima, VI-8-54, H. P. Lanchester, 1 paratype (Fender). 33 mi . W. of Yakima, V-8-49, G. H. Nelson, holotype, 2 paratypes, 1 female (CAS); same, C. Chastain, 1 paratype (UId). $35 \mathrm{mi} . \mathrm{W}$. of Yakima, V-8-49, Francis Ritz, 1 paratype (UId). Mt. Adams, VI-11-41, 4 paratypes (Fender). Ellensburg, V-5-41, Lewis, 1 paratype (UW). Virden, IV-23-36, J. Wilcox, 1 paratype (OrSU).
(57) Silis (Silis) lobata Green, new species.

Holotype, male; Gifford, Idaho, 2,900 ft., V-27-47, W. F. Barr. In collection of California Academy of Sciences on indefinite loan from the University of Idaho. CAS type number 9054.

Body and appendages deep black; pronotum fulvous with all borders biack, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of prothorax fulvous each side, lateral borders black.

Pronotum similar to figure 29P. Genitalia as in figure 57. In ventral view, basophyses divergent, straight, tips visible each side of ventral lobe of tegmen, attaining posterior margin of dorsal plate exterior to marginal tooth each side. In lateral view, basophyses curving upward distally. Laterophyses straight and rather stout in lateral view; appendix conspicuous, not surpassing tip of laterophysis. Median lobe of aedeagus broadly subtriangular in lateral view. Length 5.5 mm .

Distribution. IDAHO: Gifford, 2,900 ft., V-27-47, W. F. Barr, holotype (CAS).
(58) Silis (Silis) vulnerata LeConte.

Silis vulnerata LeConte, 1874, Trans. Amer. Ent. Soc., vol. 5, p. 61.
The type of this species, described from a single Oregon specimen without a more definite locality, is presumably lost, for it is not in the LeConte or in the Horn collection. It is accordingly necessary to select a neotype so the name may be retained in the list of recognizable species. This does not need to be a random choice, because apparently only one of the numerous species at hand, having the pronotum bimaculate as described by LeConte, occurs in Oregon. Nothing else in LeConte's description is of any identification value, the only known differentials being derived from the male genitalia. One other species of the "vulnerata" group has been taken in Oregon, S. dentigera. It has the disk of the pronotum entirely fulvous. This character is not invariable, but it is the only available evidence of identity.

Neotype, male; Tumalo, Oregon, V-1-49, from the K. M. Fender collection, Deposited in the LeConte collection at the Museum of Comparative Zoology.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, broad at base and narrowing anteriorly, not quite attain-
ing anterior black border. Underside of head in front, and of prothorax except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 58. In ventral view, basophyses diverging, curving slightly inward distally, tips not visible each side of ventral lobe of tegmen, attaining posterior margin of dorsal plate exterior to marginal tooth each side. In lateral view, lower margin of basophyses uniformly arcuate. In lateral view, laterophyses stout, somewhat Lshaped, lower margin bending rather abruptly upward at about distal third forming an obtuse angle, upper margin concavely arcuate, tip acute; appendix large, surpassing tip of laterophysis. Length 5.75 mm .

Variations. The median pronotal vitta varies by reduction, and may occasionally extend less than half way to the apex and be confined to the median basal impression. Length 5-6 mm.

Distribution. OREGON: Tumalo, V-1-49, neotype (MCZ); 33 males, 2 females (Fender, CAS 1 male). Lake County: Fossil Lake, V-16-57, 2 males (Fender); 2 males (OrSU). Redmond, IV-20-39, Schuh and Gray, 1 male (Schuh).
(59) Silis (Silis) parallela Green, new species.

Holotype, male; Richter Pass, British Columbia, III-29-41, H. Leech. In collection of California Academy of Sciences. CAS type number 9104.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow and nearly interrupted in front, broad at base, connecting anterior and basal black borders. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 59. In ventral view, basophyses subparallel, feebly arcuate, outer margins convex, tips not visible each side of ventral lobe of tegmen, attaining posterior margin of dorsal plate exterior to marginal tooth each side. In lateral view, lower margin of basophyses subangulate. In lateral view, laterophyses stout, nearly straight, symmetrical, narrowing to apex: appendix large, slightly surpassing tip of laterophysis. Length 6 mm .

Variations. In one example, from Oliver, the subangulation of the lower margin of the basophyses, in lateral view, is much less apparent. Length $4.5-6 \mathrm{~mm}$.

Distribution. BRitish COLUMBIA: Richter Pass, III-29-41, H. Leech, holotype, 1 paratype, 1 female (CAS). Osoyoos, V-23-25, E. R. Buckell, 1 paratype (CAS): same, V-3-54, Roy Scott, 2 paratypes, 1 female (UBC). Oliver, V-19-59, E. E. MacDougall, 1 paratype (CNC).
(60) Silis (Silis) constricta Green, new species.

Holotype, male; Republic, Washington, V-7-36, G. R. Hopping. In collection of California Academy of Sciences. CAS type number 9105.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 60. In ventral view, basophyses feebly diverging, nearly straight, tips not visible each side of ventral lobe of tegmen, attaining posterior margin of dorsal plate exterior to marginal tooth each side. In lateral view, basophyses very stout, constricted at tip. In lateral view, laterophyses slender, curving downward at about distal third; in dorsal view, slender, not expanding distally; appendix minute, setiform. Length 5 mm .

Variations. In the paratype the pronotum is nearly all black, the fulvous areas each side much reduced. Length $4.5-5 \mathrm{~mm}$.

Distribution. WASHINGTON: Republic, V-7-36, G. R. Hopping, holotype, 1 paratype (CAS).
(61) Silis (Silis) barri Green, new species.

Holotype, male; Wawawai, Whitman County, Washington, IV-4-49, Ralph Schopp. In collection of California Academy of Sciences on indefinite loan from the University of Idaho. CAS type number 9050.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 61. In ventral view, basophyses divergent, straight, attaining posterior margin of dorsal plate exterior to marginal tooth each side. In lateral view, lower margin of basophyses feebly arcuate. In lateral view, laterophyses slender, widest and bending subrectangularly downward near middle of length; in dorsal view, slender, not expanded distally; appendix minute, setiform. In lateral view, median lobe of aedeagus broadly subtriangular. Length 5 mm .

Variations. The subtriangular outline of the median lobe of the aedeagus varies by the withdrawal of the shorter upper part within a cavity formed by the overlapping sides of the longer lower part.

Distribution. WASHINGTON: Wawawai, Whitman County, IV-4-49, Ralph Schopp, holotype (CAS); 2 paratypes (UId). Wawawai, V-12-48, 1 paratype (USNM). Pullman, IV-32, Bales, 1 paratype (UW).
(62) Silis (Silis) insolita Green, new species.

Holotype, male; "W. T." (Washington Territory). In collection of Academy of Natural Sciences of Philadelphia.

Body and appendages deep black; pronotum fulvous with all borders black, a black median vitta, narrow in front and broad at base, connecting anterior and basal black borders. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 29P. Genitalia as in figure 62. In ventral view, basophyses subparallel, feebly arcuate, outer margins convex, tips not visible each side of ventral lobe of tegmen. In lateral view, basophyses strongly arcuate, failing to reach posterior margin of dorsal plate (possibly not a normal position). Dorsal plate with usual marginal tooth each side. In lateral view, laterophyses very slender, curving slightly downward distally; in dorsal view, nearly straight, somewhat expanded distally; appendix not apparent. Length 4.5 mm .

Distribution. "W. T." (Washington Territory, includes Oregon), holotype (ANSP).
(63) Silis (Silis) pallida Mannerheim.

Silis pallida Mannerheim, 1843, Bull. Moscou, vol. 2, p. 246.
Head and appendages black. Pronotum flavate, anterior and basal borders black, lateral borders more or less dusky. Scutellum black. Elytra flavate; sutural bead, lateral borders narrowly, and apices, dark. Underside black, prothorax pale with lateral borders dark. Legs largely black.

Pronotum similar to figure 30 P . Genitalia as in figure 63. In ventral view, basophyses subparallel or somewhat diverging, not attaining posterior margin of dorsal plate. In posterior view, emargination of dorsal plate with prominent acute basal angles, these partly visible in direct lateral view as an obtuse anteapical projection extending below upper margin of lateral incisure of tegmen. Laterophyses rather stout, curving slightly upward in lateral view, nearly straight in ventral view. Ventral lobe of tegmen subtriangular, apex more or less acute, usually extending as far posteriorly as dorsal plate. In dorso-ventral view, median lobe of aedeagus narrowly subtriangular, slender distally. Length $5.25-6.5 \mathrm{~mm}$.

Rare in collections, only fifteen males of this species have been seen. It was described by Mannerheim from Sitka, Alaska. A National Museum specimen from that locality constitutes the determining factor in its identification. It differs from all other members of the "pallida" group in the shorter basophyses not attaining the posterior margin of the dorsal plate. No variation of importance has been noted.

Distribution. ALASKA: Sitka, Vi-16, Harriman Expedition, T. Kincaid, 1 male (USNMI). BRITISH COLUMBIA: Metlakatla, Wickham, 2 males (USNM). Massett, Queen Charlotte Island, Rev. Keene, 1 male (USNM) ; same, VI-3-57, E. E. MacDougall, 1 male (CNC). Zymagotitz River, 6 mi. W. of Terrace, VI-20-60, W. W. Moss, 1 male (CNC). Tyee, 27 mi. E. of Prince Rupert, VI-24-60, B. S. Heming, 1 male (CNC). Prince Rupert, VI-15-

59, G. G. Scudder, 3 males (UBC); same, VI-1926, R. W. Pillsbury, 1 male (UBC). Kwina Point, Sandspit, Queen Charlotte Island, VI-26-46, M. G. Thomson, 1 male (UBC). OREGON: Olney, VI-15-25, Van Dyke, 3 males (CAS).
(64) Silis (Silis) insperata Green, new species.

Holotype, male; Homestead Inn, Mt. Hood, Oregon, VII-2-27, Van Dyke. In collection of California Academy of Sciences. CAS type number 9106.

Head and appendages black. Pronotum flavate with all borders black, basal black border extending forward in median impression, not attaining anterior black border. Scutellum black. Elytra flavate; sutural bead, lateral borders, and apices, black; lateral black border expanding toward apex. Underside black, prothorax pale with lateral borders black. Legs and coxae black.

Pronotum similar to figure 30P. Genitalia as in figure 64. In ventral view, basophyses subparallel, attaining posterior margin of dorsal plate. Laterophyses slender, nearly straight in lateral view, curving somewhat inward and reversing distally in dorso-ventral view. Ventral lobe of tegmen extending about as far posteriorly as dorsal plate. In dorso-ventral view, median lobe of aedeagus narrowly subtriangular, slender distally. Length 5 mm .

Variations. The elytra are entirely black in a few specimens, otherwise normal, from Siltcoos Lake and Gardiner, Oregon. The forward extension of the basal black border of the pronotum may be much reduced, or entirely lacking. Rarely the lateral black borders of the elytra are narrow throughout. Three males have been noted in which the ventral lobe of the tegmen is deeply and narrowly emarginate. This is an accidental deformity that has been found also in the "cava" group. The ventral lobe, typically subtriangular with the apex acute, varies in length and shape with the sides sometimes convex and the apex more or less obtuse. The median lobe of the aedeagus may be partly expanded, obscuring its normal shape. In this case there is usually visible in ventral view a narrow median longitudinal convexity each side of which rest the laterophyses. The laterophyses may curve definitely downward in lateral view, reversing slightly upward distally. Length $4.5-5.75 \mathrm{~mm}$.

Distribution. OREGON: Homestead Inn, Mt. Hood, VII-2-27, Van Dyke, holotype, 9 paratypes (CAS). Elk Lake, VII-3-38, K. Fender, 3 paratypes (CAS); VII-9-39, K. M. Fender, 2 paratypes (Fender). Cannon Beach, VI-16-27, Van Dyke, 1 paratype (CAS). Corvallis, VI-11-25, Van Dyke, 1 paratype (CAS). Siltcoos Lake, VI-20-34, Bryant, 6 paratypes (CAS). McMinnville, VI-25-42, 1 paratype (Fender). Sheridan Peak, Yamhill County, VII-12-42, 8 paratypes (Fender). Still Creek, Mt. Hood, VII-17-47, VII-15-54, 4 paratypes (Fender). Government Camp, VII-5-42, 3 paratypes (Fender). Mt. Hood, 3,000-6,000 ft., VT-20-25, 1 paratype (Fender). Glenada, Lane County, VI-16-52, B. Malkin, 1 paratype (Fender). Florence, Lane County,


Figures 65-65b. Male genitalia; ventral, lateral, and dorsal views arranged, in that order from left to right.
Figure 65. Silis (Silis) maritima Van Dyke.
Figure 65a. Silis (Silis) maritima complex, Woods, Tillamook County, Oregon.
Figure 65b. Silis (Silis) maritima complex, Newport, Oregon.

VI-14-50, Malkin and Leeper, 1 paratype (Fender). Gardiner, Douglas County, V-14-49, F. M. Beer, 1 paratype (Fender). Independence, VI-6, 8-34, N. P. Larson, 2 paratypes (Schuh). Eagle Creek, VII-4-40, Joe Schuh, 1 paratype (Schuh). Linn County, Montment Park, VI-16-60, J. D. Lattin, 1 paratype (OrSU). Wasco County, Mayer State Park, V-23-59, 1 paratype (OrSU). Portland, V-28, 1 paratype (USNM). WASHINGTON: Near Snowqualmie Pass, VII-9-36, Van Dyke, 1 paratype (CAS). Paradise Valley, Mt. Rainier, 6,000-8,000 ft., VIII-2-19, Blaisdell, 1 paratype (CAS). Paradise, Mt. Rainier, VII-4-34, Bryant, 2 paratypes (CAS). Longmires, Mt. Rainier National Park, VII-12-36, Van Dyke, 2 paratypes (CAS). Mt. Rainier National Park, Longmire Springs, VII-26-53, K. M. Fender, 1 paratype (Fender). Mt. Rainier National Park, VI-26-62, 2 paratypes (Edwards). Puyallup, $40 \mathrm{ft} ., \mathrm{V}-14-31$, A. J. Hanson, 2 paratypes (CAS). Seattle, V-23-14, 7 paratypes; V-14-07, 2 paratypes (CAS); same, V-1951, B. Malkin, 1 paratype (Fender). Sol Duc Hot Springs, VI-24-36, Van Dyke, 1 paratype (CAS). Skye, VI-12, 19-36, 2 paratypes (Fender). Berkeley Park, Mt. Rainier National Park, VII-20-41, 1 paratype (Fender). Factoria, King County, VI-4-49, E. C. Johnston, 1 paratype (CNC). Bremerton, V-27-48, Don Frechin, 1 paratype (CNC). Fort Lewis, Pierce County, V-29-51, R. Schuster, 3 paratypes (UCB). Bothell, V-25 to VI-3-49, Geo. Schenk, 7 paratypes (UId). Tenino, Hubbard and Schwarz, 4 paratypes (USNMI). Easton, 1 paratype (USNM). "W. T." (Wash-
ington Territory) 2 paratypes (AMNH). BRITISH COLUMBIA: Steelhead, V-31 to VI-20-33, H. B. Leech, 8 paratypes (CAS). Pender Harbor, G. R. Hopping; same, R. T. Turner, 7 paratypes (CAS, UBC 1). Vancouver, VI-330, V-22-30, H. B. Leech, 2 paratypes (CAS) ; same, V-10-31, H. B. Leech, 2 paratypes (Fender); same, V-31-31, H. B. Leech, 1 paratype (CNC); same, VI-12-30, V-31-31, H. B. Leech, 3 paratypes (UBC); same, VI-29-32, R. Hopping, 1 paratype (UBC) ; same, VI-16-55, G. Stace Smith, 1 paratype (UBC) ; same, VI-11-27, G. J. Spencer, 1 paratype (UBC). Mission, V-25-30, E. E. Peden, 1 paratype (Fender). North Bend, Chas. Palm collection, 1 paratype (AMNH); same, VI-6, Hubbard and Schwarz, 4 paratypes (USNM). Forestry Station, New Westminster, VI-6-39, R. H. Longmire, 1 paratype (CNC). Hope Trail, VII-4-30, G. Stace Smith, 2 paratypes (UBC). Langley Pr., V-20-30, K. Graham, 1 paratype (UBC). B. A., Chas. Palm collection, 1 paratype (AMNH). No definite locality, 1 paratype (Fender).

This species may be composite, or, more likely, in a state of continuing evolutionary development. Typical specimens are easily recognized by the male genitalia; but in many others the variable shape of the ventral lobe of the tegmen, and supposed partial expansion of the median lobe of the aedeagus, produce a more or less confusing atypical appearance. The fact that these possibly atypical forms occur with typical ones in series from the same locality, and that no definable line of demarcation separates them, seems to justify the inclusion of all under this heading. Some material at hand has not been so included, but is labeled simply "pallida group." Among these are two specimens from near Orick, Humboldt County, California (CAS), the southernmost record for the group.
(65) Silis (Silis) maritima Van Dyke.

Silis pallida maritima Van Dyke, 1918, Jour. New York Ent. Soc., vol. 26, p. 170.
Body and appendages black, pronotum pale fulvous with all borders black, basal black border extending forward a variable distance in median depression, not attaining apical black border. Underside of prothorax, except lateral borders, fulvous.

Pronotum similar to figure 30P. Genitalia as in figure 65. In ventral view, basophyses subparallel, attaining posterior margin of dorsal plate. In ventral view, laterophyses subparallel, tips acute; in lateral view bending downward at about distal third or fourth, tips usually not at all reversing upward. In ventral view, median lobe of aedeagus broad, tip sometimes contracted to a triangular shape, then more or less abruptly widening. Ventral lobe of tegmen usually not extending as far posteriorly as dorsal plate. Length 4.25-6 mm.

Distribution. OREGON: Marshfield, IV-14-14, VI-11-14, Van Dyke (CAS). Charleston, Coos County, VI-17, 20-57, Fender, VI-17-52, Malkin (Fender).

One specimen, not differing in any particular from the above description, is labeled "Carmel, Cal., V-19-13, Van Dyke" (CAS). This is obviously a labeling error. A specimen from Humboldt County, California (Fender), is black with the pronotum entirely pale. It has been labeled "near maritima."

All specimens with flavate elytra keying here have been labeled "Silis maritima complex." Extremes in genitalic structure, figures 65a and 65b, indicate that at least two species are involved. Neither can be positively defined because of the occurrence of numerous intermediates of doubtful position. Members of this complex have been taken in the following localities.

Distribution. OREGON: Waldport; Marys Peak, Benton County; Newport; Corvallis; Woods, Tillamook County; Sandlake; Baker Creek; McMinnville; Depot Bay; Xena; Little Nestuca River; Boyer; Gold Beach. WASHINGTON: Long Beach, Pacific County.

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# PROCEEDINGS <br> of the 

## CALIFORNIA ACADEMY OF SCIENCES FOURTH SERIES

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# OBSERVATIONS ON PLEUROBRANCHAEA CALIFORNICA MACFARLAND, 1966 (OPISTHOBRANCHIA, NOTASPIDEA) 

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The large notaspidean opisthobranch Pleurobranchaea californica was described by MacFarland (1966). In October, 1964, two large specimens of this species were brought to Steinhart Aquarium, San Francisco, by Richard Poole of the California Department of Fish and Game. The larger individual measured 355 mm . in length by 125 mm . in width and was nearly twice the size of the other specimen. These notaspideans, taken from commercial crab pots set in waters of 30 to 40 fathoms near the southeast Farallon Island, were placed in a 55 -gallon aquarium containing circulating refrigerated salt water $\left(10-13^{\circ} \mathrm{C}\right.$.). Because the entire animal was not illustrated in connection with the original description of this species, it was felt desirable to provide a photograph of one of these fine specimens, as well as to record certain observations relating to them and to several other specimens (fig. 1).

Unfortunately, within 2 weeks of the time of capture the smaller individual had apparently disintegrated or had been eaten by the larger. Coan (1964) observed that this species is carnivorous and that its members will attack any animal offered, including those of its own species. The author has observed a large specimen of $P$. californica attack and almost completely devour a mediumsized anemone (Anthopleura clegantissima) in less than 10 minutes. The buccal armature and the extremely large radula would seem to lend themselves well to a predatory habit.

## Color Variation

The over-all color of eight living specimens of Pleurobranchaea californica observed by the author showed little variation. These specimens were all taken in the vicinity of the Farallon Islands and Bodega Bay, California. The southeast Farallon Island individual (now faded) was quite typical of the northern color phase. The warty dorsal surface of the mantle was covered with a mottled


Figure 1. Plenrobranchaea californica MacFarland, 1966. Southeast Farallon Island, California, in 30-40 fathoms, 355 mm . in length.
pattern of brown pigment. Areas lacking pigment appeared as a series of rather large, irregular, translucent white patches. The dorsum of the foot and oral veil were lighter in color. An irregular network of fine wrinkles gave the entire dorsum a crepe-like appearance. A single living southern California specimen observed exhibited a much deeper shade of pigmentation, although the pattern was essentially the same (fig. 2).

## Egg Mass and Veligers

On 13 November, an egg mass was noted attached to a stone in the aquarium (fig. 3). The entire mass had been laid the previous night. Subsequently, the remaining large animal and its egg mass were placed in a 30 -gallon tank and photographed. The veligers began to hatch from the gelatinous matrix of the egg ribbon 22 November, and by the next day the ribbon had disintegrated. At the time of hatching, alternating rows of egg capsules were observed within the egg ribbon, and each capsule contained many active veligers. The number of veligers per capsule appeared to range from 10 to 15 (fig. 4). The freeswimming larvae were so numerous on the morning of 23 November that the water in the tank became quite murky. Samples of the veligers were taken over a period of 2 days, until living individuals could no longer be found in the


Figure 2. Pleurobranchaea californica MacFarland, 1966. Santa Cruz Island, California, in 30-60 feet, 145 mm . in length, showing the gill on the right side.
aquarium. Upon hatching, the tiny shells measured $150 \mu$ and consisted of one and one-half whorls.

## Narcotization

Considerable difficulty was encountered in the narcotization of the large adult of $P$. californica. On 27 November the specimen was placed in a solution of magnesium chloride and sea water. Five hundred ml . of 7 percent magnesium chloride solution were added to 8 liters of sea water and placed under refrigeration at approximately $+5^{\circ} \mathrm{C}$. After 7 hours the animal appeared to be unaffected, except for the production of large quantities of viscous mucus. That this mucus may have defensive qualities for the organism is suggested by the report of Paine (1963) who found that the mucus secretions of an individual belonging to Pleurobranchaea sp. (in all probability P. californica) collected in southern California waters, had a pH of 1.0. The morning of 28 November the magnesium chloride appeared to have had no narcotizing effect; therefore, 10 gms . of chloral hydrate crystals were added and the temperature reduced to approximately $-1^{\circ} \mathrm{C}$. Twenty-four hours later the animal still actively responded to touch by retracting its rhinophores and oral veil. An additional 10 gms . of chloral hydrate was added at this time.


Figure 3. Egg ribbon of Farallon Island specimen shown in figure 1. Length about 6 inches.


Figure 4. Egy capsules with unhatched veligers of Farallon Island specimen.

On 30 November, there was no change in the specimen's ability to respond to mechanical stimulation. Consequently, 70 percent ethyl alcohol was slowly added, 15 ml . at a time over a 4 day period. By 4 December, 270 ml . of 70 percent ethyl alcohol had been added and although the solution had become quite murky, the opisthobranch retracted its rhinophores and oral veil when prodded. The solution was maintained at this concentration until mechanical stimulation failed to cause visible contraction of any part of its external anatomy. On 7 December, 11 days after the beginning of the narcotizing process, the animal failed to respond.

## Geographic Distribution

Acquisition of this fine specimen of Pleurobranchaea californica brings the total number of specimens of this species contained in the Academy's preserved invertebrate collection to 39 . The over-all length of individuals ranges from 165 mm . down to 8 mm . The geographic range of the Academy's specimens is from lat. $41^{\circ} 27^{\prime} \mathrm{N}$.; long. $124^{\circ} 29^{\prime} \mathrm{W}$. to lat. $32^{\circ} 43^{\prime} \mathrm{N}$.; long. $117^{\circ} 14^{\prime} \mathrm{W}$., or approximately from off the mouth of the Klamath River to San Diego, California. All specimens which carried data regarding bottom conditions were found on a substrate consisting predominantly of fine "green mud." The bathymetric range of our specimens is from 30-60 feet to approximately 200 fathoms.

Following is a list of the 20 specimen lots of $P$. californica contained in the collection of the California Academy of Sciences, Department of Invertebrate Zoology. All are from the California coast:
Lot no. 1, 115-119 fms., WSW. of the mouth of the Klamath River, lat. $41^{\circ} 27^{\prime}$ N., long. $124^{\circ} 29^{\prime}$ W., Peter Isaacson, collector, 10 September 1964. Single specimen.
Lot no. 2, 70-74 fms. off Bodega Bay, California Fish and Game Block no. 249. Phil Hanson and Dan Clark, collectors. May, 1949. Single specimen. Lot no. 3, 68 fms., fine green sand, Farallon Light, N. $11^{1 / 22^{\circ}}$ East, 3.8 miles. United States Fish Commission Steamer Albatross, collector. Station no. D-5788, 21 October 1912. Two specimens. Syntypes.
Lot no. 4, 46 fms., fine green sand, Farallon Light, N. $42^{1 / 2}{ }^{\circ}$ W., 3.9 miles. United States Fish Commission Steamer Albatross, collector. Station no. D-5789, 21 October 1912. Single specimen.
Lot no. 5, 60 fms., Farallon Light, 4 miles, $10^{\circ} \mathrm{W}$. California Departmen: of Fish and Game R/V. N. B. Scofield, collector, 21 April 1948. Single specimen.
Lot no. 6, 60-80 fms. Farallon Islands, area of the southeast Farallon. Richard Poole, California Department of Fish and Game, collector. Taken in commercial crab pot. October, 1964. Single specimen.
Lot no. 7, 15-20 fms. off Ocean Beach, San Francisco, near Fleishhacker Pool. Dennis Sullivan, collector, 7 December 1962. Single specimen.

Lot no. 8, 100 fms. off Davenport, Santa Cruz County. Captain C. Davies of the drag boat Warrior, collector. June, 1962. Single specimen.
Lot no. 9, 76 fms. Dark green mud and sand, off of Santa Cruz light, Monterey Bay. N. $31^{\circ}$ W., 6.1 miles. United States Fish Commission Steamer, Albatross, collector, 12 May 1904. Station no. D-4480. Single specimen.
Lot no. 10, 37 fms . On dark green mud, fine sand, black specks. Off Monterey, Point Pinos Light House. Six miles S. $35^{\circ} \mathrm{W}$. United States Fish Commission Steamer Albatross, collector. Station no. D-4458, 12 May 1904. Single specimen.
Lot no. 11, 92 fms . Off Avila, San Luis Obispo County. Ten miles, $348^{\circ}$ True SW. of Avila. G D. Hanna, collector, 25 February 1951. Two specimens.
Lot no. 12, 30-60 ft. Off Santa Cruz Island. Dr. James Case, collector. Taken with SCUBA. Single specimen. Figure 2.
Lot no. 13, 80-92 fms. Off Santa Barbara. Ten miles, $65^{\circ}$ True. G D. Hanna, collector, 19 February 1951. Single specimen.
Lot no. 14, About 200 fms., green mud, $198^{\circ}$ True from Point Fermin, 8.5 miles. Crocker-Stanford 1938 Deep Sea Expedition. G. S. Myers, R. L. Bolin et al., collectors. Station no. 28, 17 September 1938. Thirteen specimens all less than 25 mm . in length.
Lot no. 15, 440-470 meters. Off San Pedro, lat. $33^{\circ} 38^{\prime}$ to $33^{\circ} 41^{\prime} \mathrm{N}$.; long. $118^{\circ} 17.6^{\prime}$ to $118^{\circ} 19.5^{\prime}$ W. W. E. Ritter and W. J. Raymond, collectors. San Diego Marine Biological Association. Station no. XIV-H2, 13 June 1901. Single specimen less than 25 mm . long.
Lot no. 16, 60 fms . Santa Catalina Island. One and three-quarters miles, $105^{\circ}$ True from Long Point. Lat. $33^{\circ} 22^{\prime} \mathrm{N}$.; long. $118^{\circ} 20^{\prime} \mathrm{W}$. CrockerStanford 1938 Deep Sea Expedition. G. S. Myers, R. L. Bolin et al., collectors. Station no. 47, 20 September 1938. Three specimens, one less than 25 mm . long.
Lot no. 17, 178 fms . On fine gray sand and rock off Santa Catalina Island. N. $79^{\circ} \mathrm{W} ., 2.8$ miles off Long Point. United States Fish Commission Steamer Albatross, collector. Station no. D-4410, 11 April 1904. Single specimen.
Lot no. 18, 80 fms . On dead and bleached corallines. Santa Catalina Island, $33^{\circ} 23^{\prime}$ N., $118^{\circ} 20^{\prime} \mathrm{W}$., off Avalon. Crocker-Stanford 1938 Deep Sea Expedition. G. S. Myers, R. L. Bolin et al., collectors. Station no. 30, 17 September 1938. Two specimens.

Lot no. 19, 110 fms . Green mud and shale, off La Jolla, 3.2 miles S. $34^{\circ}$ E. from Soledad Hill Point. United States Fish Commission Steamer Albatross, collector. Station no. D-4322, 7 March 1904. Two specimens.
Lot no. 20, 35-38 fms. Green mud and sand. Off Point Loma. M. W. Williams and K. W. Kenyon, collectors, 9 October 1946. Two specimens under 25 mm . long.

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# LOWER CRETACEOUS FORAMINIFERA OF THE ORCHARD PEAK-DEVILS DEN AREA, CALIFORNIA 

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The microfaunas of the lower Cretaceous of California have received very little attention from micropaleontologists in the past and only in recent years has anything been published about them. This has been partly because of a lack of economic interest in this part of our extensive Cretaceous section, in part to its limited areal extent when compared to the more widespread upper Cretaceous, and possibly, in a large measure, to the fact that well-preserved faunas are scarce in many of the better known outcrop sections. With regard to the macro fossils the opposite of this situation has prevailed. Numerous papers on the stratigraphy and paleontology of the lower Cretaceous have appeared from the beginning of geologic work in California. The most recent paper describing lower Cretaceous beds in the area under consideration, is by Owen T. Marsh (1960). In it Marsh names and describes in detail seven new formations. One of the lower formations, the Badger shale, is questionably listed as of lower Cretaceous age. A limited outcrop of serpentine is within or in fault contact with the Badger at its base. Below the Badger shale in structural discordance, is the Hex formation which Marsh, with considerable doubt, assigns to the late Jurassic. The doubtful assignment was based on the identification of belemnites by Professor Leslie Baristow of the British Museum of Natural History and Dr. J. A. Jeletzky of the Geological Survey of Canada. Professor Baristow suspected the belemnites were of late Jurassic age but stated that his conclusions were only provisional. Dr. Jeletzky's opinion was quoted as follows, ". . . the following suggestions are to be considered quite tentative. It would
appear to me that the fragment belongs to a large and sturdy Belemnopsis probably of the group of Belemnopsis sulcatus Phillips or Belemnopsis gerardi ... Its being of the group of Indo-Pacific Belemnopsis gerardi Oppel, 1863 . . appears to be more probable . . . Should the above assumption be correct . . . upper Jurassic age would be indicated for the beds containing it." Marsh further stated that a different opinion of the age was reached by John P. Wagner whose MS. thesis (University of California, 1947) deals with the geology of the Sawtooth Ridge Quadrangle. One of the several species of belemnites found in the Hex formation was identified by Dr. J. Wyatt Durham of the University of California at Berkeley, as Acroteuthis winslowensis Anderson, 1938. This identification was subsequently confirmed by Dr. J. A. Jeletzky who stated that the form should be, "tentatively assigned to early to mid-lower Cretaceous (not younger than Barremian, though)."

In a further attempt to determine the age of the Hex formation, Marsh collected samples for microfossil determinations and submitted them to Mr. J. D. Bainton of the Standard Oil Company laboratory for study. Both radiolarians and foraminifera were found and these, mostly long ranging species, were tentatively considered to be of late Cretaceous age. However, the concluding statement by Bainton was that, "the fauna is not definitely definitive of age and therefore the age assignments . . . should not be considered conclusive." Thus faced with three possible age assignments for the Hex, Marsh concluded, "It is possible that all three ages are represented by the Hex, but this possibility cannot as yet be proved because none of the age assignments can be stated as being conclusive. For the sake of convenience, the Hex formation will be designated provisionally in this report as upper Jurassic (?)."

In the Devils Den outcrop the Hex formation is in fault contact with Eocene and Miocene at its eastern extremity and probably Eocene and Paleocene at the west where its limits are not so clearly defined. In the Hex Hill occurrence both folding and faulting appear to account for the outcrop which extends over a much wider area than the more easterly outcrop. In describing the Hex Hill exposure Marsh stated, "The Hex formation crops out east of Orchard Peak as a single band about a half mile wide and more than four miles long, paralleling the base of the scrap formed by Avenal Ridge. The unit occupies the core of the Avenal Ridge piercement anticline. Apparently the soft, plastic shales of the Hex formation, originally at an unknown depth below their present position, were squeezed up through the overlying formation during folding and thrust faulting of the Avenal Ridge anticline." In whatever way this extensive body of plastic clay arrived at its present position, there are very few contrasting beds of silt or sand to suggest a structural pattern. In only one small area, in a deep gully in the central part of the Devils Den proper, have beds been found which show definite stratification. Here the strike is approximately north-south which is at right angles to the Eocene and Miocene on its north and south
flanks. As most of the Hex formation is a massive claystone with little evidence of bedding, the only relief from its sameness are the occasional outcrops of lenses and pods of impure, whitish to buff limestone which, because of its superior resistance to weathering, stands out above the clays. It is these limy masses which have yielded the few ammonites found. They also contain numerous radiolaria and occasional foraminifera. Belemnites have also been found in them in rare instances but most of these weather out of the clay and occur as fragments on the rain-washed surface.

Foraminifera were found in virtually all fresh samples of the clay but in many of them only arenaceous species were present.

## History of Present Work

From August to October of 1932, Mr. F. A. Menken, then a field geologist with the Associated Oil Company (later Tidewater Oil Company), made a geologic study of the Devils Den-Orchard Peak area and mapped the various geologic units. From time to time during the course of his work he submitted macrofossil and microfossil samples to the laboratory for identification and age determination. Among the samples were a few soft claystone samples from the deeply dissected, low, rounded hills long known as Devils Den, and from the smoothly contoured, flat-topped clay hill on the southeast slope of Orchard Peak, more recently named Hex Hill by Marsh. These samples yielded foraminifera which were new to our experience in California foraminifera, but from their similarities with faunas from the lower Cretaceous of Europe and Texas and the association with the belemnites, they were tentatively considered to be of lower Cretaceous age. Because of our uncertainty as to the age of the fauna and its unusual character, Dr. G D. Hanna, then senior Paleontologist for the company, and the author, accompanied by J. B. Stevens, went to the Devils Den-Orchard Peak area with the hope of finding more conclusive evidence for the age. Samples of claystone were collected at Devils Den and from the claystone hill on the eastern flank of Orchard Peak. These samples later yielded foraminifera similar to those collected by Mr. Menken. In the Hex formation belemnites like those from Devils Den were found along with a single ammonite of the genus Lytoceras which Dr. F. M. Anderson later named Lytoceras saturnale. A few aucellas were also found which Dr. Anderson identified as Aucella solida Lahusen and A. inflata Toula, all known to him from the lower Cretaceous Paskenta beds of the Shasta Series. This was our first definite indication of the true age of these beds. In his paper (Anderson, 1938, p. 105) on the lower Cretaceous deposits in California and Oregon, he made the following statement regarding Aucella solida. "This species has been found with A. inflata, A. uncitoides and Lytoceras saturnale nov., in the lower beds of the Paskenta group in the type district, and in the same horizon in the Devils Den district, Kern County, where it was collected by Hanna and Church."

More recently (1962-1964), the author made several visits to the area which permitted a more detailed examination of the outcrop and more extensive and selective sampling of the clays and fossils. Two more specimens of the ammonite species, Lytoceras saturnale, were found in the Devils Den outcrop as well as an aucella and a better preserved collection of belemnites. A good series of the clays were collected from both Devils Den and Hex Hill which furnished a wide variety of well preserved foraminifera. These faunas were similar to those collected at the earlier date but in the variety of species, far exceeded any previously collected. The microfaunas from the two areas were studied and compared and while many species are common to the two areas, there are some notable differences in the two faunas. A number of distinctive species from no. 7 of Hex Creek have not been found at Devils Den and some equally distinctive species found at Devils Den have not been found at Hex Creek, a circumstance possibly due to insufficient sampling. It does seem quite certain, however, that with the number of species, both calcareous and arenaceous, common to the two areas, the formations are of essentially the same age. This belief is further strengthened by the fact that such uncommon species as the new genus Menkenina and certain species of Citharina are found at both localities. Also, as has been mentioned earlier in the text, the same species of macrofossils, have been found at both outcrops and these well authenticated time markers are the key to the age of the Hex. As indicated earlier, the isolated nature of the Hex formation offers little opportunity for an age assignment from its relationships with contiguous beds of established zones and ages. The beds in fault contact with it are from upper to possibly lower Cretaceous but Marsh had no definite proof of the true age of the Badger shale which is the oldest of the strata pierced by the Hex. Foraminifera from the lowest part of the Serpiente formation in fault contact with the Hex are G-2 (Turonian) in age but according to Marsh's mapping this would be in the upper few hundred feet of the formation. The determination of the exact age of the Hex formation therefore must be decided entirely on the basis of the fossils found in it. Marsh placed the age of the Hex formation in the Jurassic with considerable doubt, for reasons already stated but apparently was not aware of Anderson's identification of the ammonite and the aucellas, all of which had been found previously in the lower Paskenta group of the type district in northern California. In the light of Anderson's age assignment, it now seems more significant that J. Wyatt Durham identified the belemnite found by John P. Wagner in the Hex formation, as Acroteuthis winslowensis Anderson, a lower Cretaceous species. In the present study of the Foraminifera many species were identified from the Valanginian of Europe but some do range much higher. It was apparent early in the study that a Jurassic age could be ruled out and further comparisons indicated rather strongly that a correlation with the Valanginian, as suggested by the macrofossils, was the most likely possibility.

This view is supported in a recent study of the aucellas (now called buchias), by Dr. Ralph W. Imlay of the United States National Museum. He critically examined numerous suites of the genus from Pacific Coast states, particularly Alaska and California, the express purpose of his study being to determine the validity of the numerous named species, many of which were described from single localities. Of particular import to the present problem, to determine the age of the Hex formation, is his conclusion concerning the species Aucella crassicollis Keyserling. As stated earlier, Anderson identified the two species of Aucella from the beds containing the ammonite, Lytoceras saturnale, as A. solida Lahusen and A. inflata Toula. Both of these species, as well as A. uncitoides Pavlow, are considered by Imlay to be named variations of a single species, $A$. crassicollis Keyserling. In his range chart of the various species of Aucella, Imlay places this species in the upper two-thirds of the Valanginian of the lower Cretaceous, where it is often abundant, but he does not show it ranging above this zone into the Hauterivian. This opinion of the age level of A. crassicollis appears to be shared by Dr. J. A. Jeletzky who examined the Hex Hill-Devils Den macrofossils at the California Academy of Sciences in San Francisco, California, 23 November 1966. He identified the buchias [aucellas] from the Hex formation as being of the $B$. crassicollis group and illustrated, by means of a chart (information received by Dr. L. G. Hertlein, of the Academy's Department of Geology), that Buchia crassicollis, B. inflata, and B. solida were of the uppermost Valanginian but not extending above that stage. Anderson (1932, p. 103) also stated that, "They [Aucella crassicollis] are not known to occur in any part of the Knoxville series (upper Jurassic) or in any beds later than Paskenta," again placing an upper limit on the species. If these specialists in the field of lower Cretaceous fossils are correct in their opinions, that Aucella crassicollis Keyserling is confined to the Valanginian stage, at least on the Pacific Coast of North America, and there seems little reason to doubt it, then the Hex formation must be accepted as being of upper Valanginian equivalence. From a historical viewpoint the finding of fossils of lower Cretaceous age here should cause little surprise because, as far back as 1910, Paskenta fossils (then called Knoxville), were reported found in McLure Valley, only a few miles northeast of Devils Den by Arnold and Anderson (1910). The most significant fossil reported found was Aucella crassicollis Keyserling. A few years later Dr. G D. Hanna found the same species in this locality. The clay shale in which the aucellas were found is very similar to that at Devils Den and Hex Hill but it yielded no foraminifera.

## Recent Zonation of the Lower Cretaceous

At the time of the first reading of this paper in Bakersfield, California, 1 April 1965 (Fortieth Annual Meeting of the Pacific Section, American Association of Petroleum Geologists, Society of Exploration Geophysicists and Society of Eco-


Figure 1. Chart showing foraminiferal zonation, late Mesozoic of the Sacramento Valley, California. Chart reproduced through the courtesy of Keith D. Berry, Standard Oil Company, Oildale, California.
nomic Paleontologists), a paper was presented by Mr. Keith D. Berry on, "New Foraminiferal Zonation, upper Mesozoic, Sacramento Valley, California." This paper was based on a detailed study of a large number of surface and well samples from the upper Jurassic Knoxville to the base of the upper Cretaceous where the established zones of Goudkoff were encountered. In this study Berry described and named six new zones, I, J1, J2, K, L, M, extending the zonation of Goudkoff downward from the base of the upper Cretaceous to the upper Jurassic. He also established more definite criteria for the "H" Zone of Goudkoff and defined its limits, placing it on a par with the other more adequately defined zones. In naming the new zones he continued the alphabetical system begun by Goudkoff. Zone I to L embrace the lower Cretaceous and M the upper Jurassic, Tithonian.

In the abstract of his paper he stated that the K , L , and M Zones are "more difficult to differentiate, because of the absence of planktonics and the predominance of many similar Nodosariidae." The latter part of this statement is strikingly descriptive of the Devils Den faunas which are largely composed of Nodosariidae. The statement about the "absence of planktonics" however, does not apply as several species were found in the Hex Hill fauna. This may be because of better preservation of the fossils in the Hex Hill and its quick and complete disintegration in water in preparing samples for study. Berry's new zones are approximately correlated with the European stages on the basis of both benthonic and planktonic foraminifera and where possible, tied in to the known macrofossil localities which had been equated with the European standard section. Where uncertainties existed between zones he inserted question marks to allow for them. This new zonation, based on normal, relatively undisturbed lower Cretaceous and upper Jurassic sections, presented the first available opportunity for a comparison of the Hex Hill-Devils Den faunas with an established lower Cretaceous stratigraphic and faunal sequence. Through the considerate cooperation of Mr. Berry, a comparison was made between faunas of the Hex formation and those from the Sacramento Valley sections. In this examination a fauna was found which contained some of the more distinctive species common to the Devils Den faunas. It is representative of Berry's K Zone which he believed to be of Hauterivian, Barremian equivalence. The rich fauna of Hex Creek no. 7 was not recognized among Berry's slides but he was of the opinion that it represented beds younger than those at Devils Den. This determination of the age is at variance with Anderson's and Jeletzky's placement of the macrofossils of the Hex Hill in the Valanginian, but the foraminiferal comparisons were admittedly brief and more detailed work and comparisons of these lower Cretaceous faunas may reveal the reasons for the apparent difference in correlation. From the variations now known to exist in the Hex Hill faunas it may be found that some part of it is younger than the upper Valanginian.

## Distinguishing Features of the Hex Hill Fauna

There are many features about this fauna which serve to distinguish it from the later Cretaceous of the Pacific Coast, some of the more important being, (1) The great preponderance of the Nodosariidae (Lagenidae), number at least 50 of the listed species and many more if all the nodosarias not listed were to be included; (2) The small number of planktonic species present and their small size; (3) The presence of genera not found in the upper Cretaceous of California; (4) The similarity of the fauna with that of the lower Cretaceous Valanginian of Northwestern Germany and Trinidad, British West Indies; (5) Also the presence of genera and species heretofore not described from California. Of the 88 species listed, 69 are calcareous and 19 arenaceous. The few, small pelagic species were found in only a few places but are usually quite common when
present. There are at least seven rotaloid genera present and where they occur they are usually quite common.

Of the other microfossils, radiolarians are quite abundant in the limestone masses and more rarely they may be common in the clays. Ostracods are very rare and small. Minute carbonaceous fragments are occasionally quite abundant so it is probable that spores and pollen are also present. The claystones have not, to my knowledge, been examined for the smaller microfossils such as discoasters, coccoliths or hystrichospherida. The limestone was examined for diatoms by Dr. G D. Hanna but not one was found.

## Acknowledgments

In the preparation of this paper I am especially indebted to Dr. and Mrs. G D. Hanna of the California Academy of Sciences. This applies not only for the preparation of photographic plates but to never-failing encouragement and assistance in many other ways. To Mrs. Hanna I owe my special thanks for her expert illustration of the fauna. Her accurate and detailed drawings of foraminifera have long been known to most paleontologists and recognized as a standard of excellence among illustrators. Without her generous assistance in making the drawings this paper would not have been attempted. Dr. L. G. Hertlein, also of the Geological Department of the California Academy of Sciences, was of great assistance in editorial and technical advice.

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## California Academy of Sciences Localities <br> Devils Den

Locality 27502 (CAS). Number 49. About 150 feet west and 400 feet north of the south quarter corner of the northeast quarter of Section 20. Township 25 south, Range 18 east of the Mount Diablo base and meridian northwestern Kern County, California. F. A. Menken, collector.

Number 50. About 600 feet west and 100 feet north of center of Section 20, Township 25 south, Range 18 east of the Mount Diablo base and meridian. F. A. Menken, collector.

Locality 40081 (CAS). Head of east-west trending gully, about 800 feet northwest of the center of Section 21, Township 25 south, Range 18 east of the Mount Diablo base and meridian, Kern County, California, Sawtooth Ridge quadrangle, 7.5 minutes, 1935 Edition. C. C. Church, collector.

Number 47. North side of east-west gully above and about 500 feet southwest of first sample. Earlier localities 16196 and 27501 (CAS) same locality, described as "center Section 21, Township 25 south, Range 18 east of the Mount Diablo base and meridian, Devils Den area." F. A. Menken, collector.

Number 48. About 300 feet northwest of no. 47 near head of small side gully. Also listed under 16196 and 27501 (CAS). F. A. Menken, collector.

Locality 40091 (CAS). Station numbers 1 to 8. From deep north-south trending V-shaped gully beginning 500 feet south and 700 feet west of the east quarter corner of Section 20, Township 25 south, Range 18 east of the Mount Diablo base and meridian, Kern County, California. C. C. Church, collector.

Number 1. East bank of gully near base, approximately 75 feet north of gully mouth.

Number 2. About 75 feet up stream north of no. 1, in a straight line.
Number 3. About 30 feet north of no. 2.
Number 4. About 25 feet north of no. 3.
Number 5. About 20 feet north of no. 4.
Number 6. About 50 feet north of no. 5.
Number 7. About 75 feet north of no. 6 .
Number 8. From steep east bank of gully about 20 feet south of junction with first northeast trending branch; this is about 600 feet due west of the east quarter corner of Section 20, Sawtooth Ridge quadrangle, 1953 Edition. Lytoceras saturnale was found on the side of this gully near station no. 7.

## Hex Hill

This flat-topped hill with deeply dissected sides occupies much of the northeast quarter of Section 31 and the northwest quarter of Section 32, Township 25 south', Range 18 east of the Mount Diablo base and meridian, northwestern

Kern County, California. It is terminated on the west side by a deep V-shaped gully which is dry most of the year. This creek has no official name on the topographic sheet but is referred to here as "Hex Creek."

The mouth of this gully is at about the exact center of Section 31 and the creek trends due north upstream a quarter mile, then turns northeast and divides into two branches near the fault contact of the Hex formation and the overlying, well bedded and steeply dipping shale and sandstone of the Serpiente formation of late Cretaceous age. The Sawtooth Ridge, 7.5 minute quadrangle, is the basis for all measurements.

Locality 40092 (CAS). Station no. 1, from west slope of the most easterly deep gully of Hex Hill, about 200 feet north and 400 feet west of center of Section 32, Township 25 south, Range 18 east of the Mount Diablo base and meridian, northwestern Kern County, California. C. C. Church, collector.

Locality 40093 (CAS). Station no. 15, from the upper end of the second west trending side gully from the mouth of the most easterly deep gully of Hex Hill, about 1000 feet west and 200 feet north of center of Section 32. Good foraminiferal fauna similar to no. 7 of Hex Creek, 40095 (CAS). C. C. Church, collector.

Locality 40094 (CAS). Clay test pit, southwestern extremity of Hex Hill about 75 feet east of the mouth of Hex Creek and the center of Section 31. C. C. Church, collector.

Locality 40095 (CAS). Station no. 7, Hex Creek. From the lower slope of a south-facing small ridge projecting into Hex Creek from the west causing it to veer to the northeast, about 1150 feet south and 200 feet east of north quarter corner, Section 31, Township 25 south, Range 18 east of the Mount Diablo base and meridian calcareous and arenaceous foraminifera. Station no. 8, from creek bed about 100 feet north of no. 7 is also included in Locality 40095 (CAS). Fauna same as no. 7. C. C. Church, collector.

Locality 40096 (CAS). Field numbers 10 and 11, late Cretaceous from clay shale bed 3 feet thick above thick bedded sandstone, dipping about 85 degrees north, south side of gully from northwest near bend in Hex Creek and 70 feet up gully from creek. About 1000 feet south and 600 feet east of the north quarter corner, Section 31. Turonian, G-2 stage. C. C. Church, collector.

## DESCRIPTION OF FORAMINIFERA

Order FORAMINIFERIDA
Suborder TEXTULARIINA
Superfamily Ammodiscacea
Family Ammodiscidae Reuss, 1862
Subfamily aminodiscinae Reuss, 1862
Genus Ammodiscus Reuss, 1862

Ammodiscus glabratus Cushman and Jarvis, 1928.
(Plate 7, figure 9.)
Ammodiscus glabratus Cushman and Jarvis, 1928, Contrib. Cushman Lab. Foram. Res., vol. 4, p. 86, pl. 12, figs. 6 a, b.

This species occurs commonly in strata of upper Cretaceous and of Paleocene age and seems to be very much the same in the Devils Den-Hex Hill area. It was found at sample localities nos. 1, 2, and 5 of Devils Den and no. 46 (F. A. Menken). At Hex Hill it was found at nos. 1 and 15 and the clay pit near the mouth of Hex Creek.

The same species was described by Lewis Martin in his paper on the upper Cretaceous of the Panoche Hills, Fresno County, California (1964) but he applied the generic name Involutina. This use of the generic name, Involutina, was, no doubt, due to the confusion which involved the two names for so long. This appears to have been straightened out by the research of A. R. Loeblich and Helen Tappan (1961, p. 187). They conclude that the name Ammodiscus applies only to the arenaceous species while Involutina includes the calcareous species. This point is stressed here because both genera are present in the Devils Den material and, to this author's knowledge, true Involutina has not been previously reported from the early Cretaceous of California. Length .61 mm .

Superfamily Lituolacea
Family Trochamminidae Schwager, 1877
Subfamily trochammininae
Genus Trochammina Parker and Jones, 1859
Trochammina species.
(Plate 1, figures $1 \mathrm{a}, \mathrm{b}, \mathrm{c}$.)
A fairly common species at nos. 7 and 8 of Hex Creek and no. 15 of Hex Hill but not found at Devils Den.

Trochammina species.
This questionable arenaceous species .84 mm . long, is trochospiral and in shape and arrangement of the chambers similar to the genus Gyroidina. It is irregularly flattened on the dorsal side and tapers to a conical point at the base. The chambers are broad and narrow and somewhat longer than wide and the apertural face correspondingly narrow. There are five chambers in the outer whorl and their overlapping at the base forms a conical depression. There is also a rounded pit or depression in the center of the dorsal side. There is a suggestion of a small arched opening or aperture about midway of the base of the apertural face in one or two specimens but in most of them no aperture can be seen.

This is one of the more distinctive species in this fauna but in the literature consulted, nothing like it was found. It was found in only two of the localities at Hex Hill, one at the mud pit near the mouth of Hex Creek in the southwest corner of the northeast quarter of Section 31, Township 25 south, Range 18 east and the other on the west face of a deep gully in the southeast corner of northwest quarter of Section 32, Township 25 south, Range 18 east of the Mount Diablo base and meridian.

Trochammina orchardensis Church, new species.
(Plate 2, figures $11 \mathrm{a}, \mathrm{b}, \mathrm{c}$.)
Test free, trochospiral, agglutinated, dorsal side concave with the rim of the final whorl curving upward, surface roughened by irregularly raised chambers and slightly depressed sutures giving the edge a gently scalloped effect; sutures composed of more transparent cementing material, slightly depressed near central areas on the umbilical side, flush with surface or slightly raised on the dorsal side, sutures straight on umbilical side, sharply curved on the dorsal side. The thickness of the test and degree of concavity varies, the concavity on the umbilical side being smoothly rounded and shallow, the dorsal side concave to nearly flat with a rugose surface, there are ten chambers in the final whorl, the aperture appears to be a narrow opening at the base of the final chamber. Length .59 mm . Width .45 mm .

Holotype no. 12968 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40092 (CAS), from west slope of the most easterly deep gully on Hex Hill, about 200 feet north and 400 feet west of the center of Section 32, Township 25 south, Range 18 east of the Mount Diablo base and meridian, northwestern Kern County, California; C. C. Church, collector; early Cretaceous.

This species has been found at Hex Hill no. 1 and nos. 1 and 5 of Devils Den, also more easterly, no. 46 (F. A. Menken). At Hex Hill it is quite common.

Genus Glomospira Rzehak, 1885
Glomospira gordialis (Jones and Parker).
(Plate 1, figure 2.)
Trochammina squamata var. gordialis Jones and Parker, 1860, Quart. Journ. Geol. Soc., vol. 16, p. 304.
Glomospira gordialis Cushman, 1918, U. S. Nat. Mus., Bull. 104, pt. 1, p. 99, pl. 36, figs. 7-9.

Of all the species found in this fauna, the present species is one of the most common. It is also probably one of the longest ranging species as it has been reported from the Silurian to the Recent. It was found in most samples from Devils Den, particularly from stations nos. 1, 5, 8, and no. 46 (F. A. Menken).

It was found at Hex Hill at nos. 1 and 15 and the Clay pit, also no. 3 of Hex Creek. Diameter . 25 mm .

Family Lituolidae de Blainville, 1825
Subfamily lituolinae de Blainville, 1825
Genus Bulbophragmium Maync, 1952
Bulbophragmium species.
(Plate 2, figure 2.)
This small, arenaceous species would seem to fall in the above genus since it appears to have a cribrate aperture and a bulbous, streptospiral initial stage, the transitional stage to the uniseral is very short and the biserial stage not clearly demonstrated. There are eight to ten uniseral chambers, all very thin and much broader than high, they are rounded to oval in cross section, the increase in diameter with growth is very slight. The test in general, is very similar in appearance to Ammobaculoides romaensis Crespin from the lower Cretaceous of Australia except for the aperture.

This is not a common species and so small that it is easily overlooked. It was found in only one sample of the Hex Formation of Hex Hill, Station no. 1 and at nos. 1 and 5 of Devils Den. Length .59 mm .

## Genus Triplasia Reuss, 1854

Triplasia species.
This very small, arenaceous species is not common in the Hex Formation but was found at stations no. 1 of Hex Hill and no. 46 (F. A. Menken) of Devils Den. It also was found at no. 5 and above in the same canyon. It appears to be uniserial and concave triangular from the beginning and the three edges are beaded and irregular with most tests having a curved and somewhat twisted shape. There is no apparent neck or projection at the apertural end.

## Subfamily Haplophragmoidinae Maync, 1952 <br> Genus Cribrostomoides Cushman, 1910

Cribrostomoides species.
A rather robust species, fairly common where it does occur as at stations nos. 3, 4, 6, 7, 8, and 15 of Hex Creek, not found at Devils Den.

This is a very thick, close coiled species, almost completely involute, rounded in cross section, sutures at right angles to periphery, very slightly to moderately depressed, seven to nine chambers to a whorl, aperture obscure but appears to be cribrate, .6 mm . to .7 mm . in diameter composed to fairly coarse sand grains but smoothly finished.

## Genus Haplophragmium Reuss, 1860

Haplophragmium aequale (Roemer) 1841.
(Plate 2, figure 10.)
Spirolina aequalis Roemer 1841, Kreidegeb. 98, pl. 15, fig. 27.
Haplophragmium aequale Roemer sp., 1863, Reuss, Hils u. Gault, p. 29, pl. 1, figs. 1-7.
Haplophragmium aequale (Roemer) 1841, Bartenstein, 1952, Senckenbergiana, vol. 33, nos. $4-6$, p. 325 , pl. 1, figs. $2-11$; pl. 2, figs. $17-26$; pl. 3, figs. $1-6$; pl. 6, figs. 6-8; pl. 7, figs. 1-2.

Of the arenaceous species this one is very common at Devils Den, Stations 1 to 7 and at Hex Hill no. 1. In the paper by Bartenstein (1952), a wide variation in this species is shown. In the present instance the species shows very little variation. Length .48 mm .

Genus Haplophragmoides Cushman, 1910

## Haplophragmoides species.

(Plate 1, figures 7 a, b.)
This species is irregular, trochospiral, somewhat compressed and distorted, aperture not apparent, not a common species where it occurs at Hex Hill no. 1. Length .53 mm .

Family Ataxophragmiddae Schwager, 1877
Subfamily globotextulariinae Cushman, 1927
Genus Dorothia Plummer, 1931
Dorothia Plummer, 1931, Bureau Econ. Geol., Texas Univ., Bull. no. 3101, p. 130.
Marssonella Cushman, 1933, Cushman Lab. Foram. Res., Contrib., vol. 9, pt. 2, p. 136.
Dorothia oxycona (Reuss).
(Plate 1, figures 4, 6 a, b.)
Gaudryina oxycona Reuss, 1860, K. Akad. Wiss. Wien, Math.-Naturw. Cl. Sitzungsber, vol. 40 , p. 229, pl. 12, fig. 3.
Marssonella oxycona Cushman, 1933, Cushman Lab. Foram. Res., Contrib., vol. 9, p. 36, pl. 4, fig. 13.
Dorothia oxycona (Reuss), Trufillo, 1960, Jour. Paleo., vol. 34, no. 2, p. 309, pl. 44, figs. $5 \mathrm{a}, \mathrm{b}$.

This widespread and generally long range species is one of the most common forms found in the Devils Den section, particularly in the part from nos. 2 to 6 . There is considerable variation in the species from the typical $D$. oxycona to specimens with a wide, flaring, final two chambers and figured as M. trochus (d'Orbigny) in a number of papers, e.g., lower Cretaceous of Trinidad by Bartenstein, Bettenstaedt, and Bolli, plate 3, figure 44. Smaller and less typical
specimens were found at station no. 1 of Hex Hill. Length .92 mm . (fig. 4). Length .49 mm . (figs. $6 \mathrm{a}, \mathrm{b}$ ).

## Dorothia species.

(Plate 2, figure 5.)
Test small with a very short triserial initial stage followed by nine pairs of short, slightly inflated chambers very faintly outlined by the very gently depressed sutures, test slightly curved and with a partial twist, oval in cross section, composed of very fine sand grains and having a quite smooth surface. One of the commoner species at no. 5 at Devils Den and no. 40 (F. A. Menken). Length .71 mm .

Genus Eggerella Cushman, 1933
Eggerella species B, Stelck, Wall, Bahan, and Martin.
(Plate 1, figure 5.)
Eggerella sp. B, Stelck, Wall, Bahan, and Martin, 1956, Res. Council Alberta, Canada, Rep. no. 75, p. 31, pl. 4, fig. 7.

The species with which the Devils Den form is identified is from the middle Albian of western Canada. The Devils Den species is one of the rarer forms in that fauna having been found at only one station, no. 5 where only a few were found. As in many of the other arenaceous species in this fauna, the aperture is obscure. Length .30 mm .

## Subfamily verneuilininae Cushman, 1911

Genus Pseudoreophax Geroch, 1961

## Pseudoreophax cisovnicensis Geroch.

(Plate 2, figure 1.)
Pseudoreophax cisovnicensis Geroch, 1961, Polskiego Towarzystwa, Rocznik., vol. 31, pt. 1. pp. 159-167, pl. 17, text figs. 1, 2.

Where it was found this was one of the common species and while it is small it is very distinctive. The five uniserial chambers are, in general, shorter than they are broad and variable in shape and size. The test is usually curved and the chambers increase very little in diameter with growth.

The aperture is indicated by a short, pointed projection, usually well to one side of the final chamber or just off center. The test varies in cross section from round to oval and the initial end is rounded and bulbous.

It was found at stations no. 1 at the east end of Hex Hill and at no. 46 (F. A. Menken) of Devils Den, the farthest east of the samples in that locality. Length .53 mm .

Plate 1
All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection.

Figure 1. Trochammina species. Length .84 mm ; (a) ventral view; (b) dorsal view; (c) peripheral view. Hypotype no. 12951 (CAS). From Locality 40093 (CAS), southeast side of Hex Hill, northwestern Kern County, California. Page 533.

Figure 2. Glomospira gordialis (Jones and Parker). Length .25 mm .; side view. Hypotype no. 12952 (CAS). From Locality 40092 (CAS) ; east side of Hex Hill, NW. Kern County, California. Page 535.

Figure 3. Gaudryinella almgreni Church, new species. Length 1.24 mm ., width .59 mm ; side view. Holotype no. 12953 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 540.

Figure 4. Dorothia oxycona (Reuss). Length .92 mm .; side view. Hypotype no. 12954 (CAS). From Locality 40091 (CAS), sample 5, deep north and south gully, east side of Devils Den, NW. Kern County, California. Page 536.

Figure 5. Eggerella species B, Stelck, Wall, Bahan and Martin, Length . 30 mm .; side view. Hypotype no. 12955 (CAS). From Locality 40091 (CAS), sample 5, deep northsouth gully, east side of Devils Den, NW. Kern County, California. Page 537.

Figure 6. Dorothia oxycona (Reuss). Length .49 mm .; (a) side view; (b) apertural view. Hypotype no. 12957 (CAS). From Locality 40092 (CAS), most easterly deep gully of Hex Hill, NW. Kern County, California. Page 536.

Figure 7. Haplophragmoides species. Length .53 mm .; (a) side view; (b) peripheral vicw. Holotype no. 12957 (CAS). From Locality 40092 (CAS), most easterly deep gully of Hex Hill, NW. Kern County, California. Page 536.


Family Astrorhizidae Brady, 1881
Subfamily hippocrepininae Rhumbler, 1895
Genus Hyperammina Brady, 1878
Hyperammina elongata Brady, 1878.
Hyperammina elongata Brady, 1878, Ann. and Mag. Nat. Hist., ser. 5, vol. 1, p. 433, pl. 20, figs. 2 a, b. Cushman, 1946, U. S. Geol. Surv., Prof. Pap. 206, p. 15, pl. 1, figs. 12, 13.

This long-range species occurs at stations no. 7 of Hex Creek and nos. 5 and 6 of Devils Den. From its long range it could be expected to occur in any of the samples where other arenaceous species are preserved. In its present occurrence it was not a common species.

Family Textulariidae Subfamily textulariinae Genus Bigenerina d'Orbigny, 1826

## Bigenerina antiquissima Bartenstein and Brand.

(Plate 2, figure 4.)
Bigenerina antiquissima Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 275, pl. 3, figs. 73, 74.

The first few chambers are irregularly biserial and twisted, short and closely set (microspheric form), with the next few chambers larger and longer and quickly becoming cuneate before the final one or two uniserial chambers. The megalospheric form is inflated and bulbous in the initial stages with the biserial stage short and less distinct, the test curved and twisted, aperture centrally located, rounded and projecting with a short neck having a rough, irregular edge. In the later chambers the degree of inflation varies so much that the tests have a knobby, twisted shape. The test is composed of a high percentage of cement and fine sand resulting in a smooth and somewhat translucent surface.

This species was found most abundant in the most northerly of the samples, near the center of the Devils Den, its is also found at stations nos. 5, 6, and no. 46 (F. A. Menken) of Devils Den, also at no. 1 at the easterly end of Hex Hill. Length .47 mm .

Bigenerina deciusi Church, new species.
(Plate 2, figure 9.)
Test finely arenaceous, biserial for the first four pairs of chambers, chambers enlarge very rapidly with growth becoming inflated and cuneate and finally uniserial in mature specimens, the uniserial part consisting of one or two chambers, test slightly twisted in early portion and curving with the change to the uniserial stage, biserial stage best developed in the microspheric form, in the megalospheric form only one or two biserial pairs of chambers can be recognized,
initial chamber blunt and rounded, aperture rounded with a ring-like neck raised very slightly above the spherical surface at the apex of the final chamber, the position remaining the same for both biserial and uniserial stages, in its early stages it is similar in appearance to Bimonilina variana Eicher but that species has an elongate, slit-like aperture and does not develop a uniserial stage, it also closely approximates the genus Haeuslarella in its cuneate chamber development but the aperture is more centrally located and mature specimens are uniserial. Length . 43 mm .

Holotype no. 12966 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40092 (CAS), from west slope of the most easterly deep gully on Hex Hill, about 200 feet north and 400 feet west of the center of Section 32, Township 25 south, Range 18 east, Mount Diablo base and meridian, northwest Kern County, California; C. C. Church collector; early Cretaceous.

Bigenerina deciusi was found at Locality 40092 (CAS) and Locality 40081 (CAS) in Devils Den area.

This species is named in honor of Mr. L. C. Decius, Geologist, San Francisco, California.

> Subfamily verneuilininae Genus Gaudryinella Plummer, 1931

## Guadryinella almgreni Church, new species.

(Plate 1, figure 3.)
Test finely arenaceous, triserial and triangular in the initial stage with flat to gently concave faces, biserial and compressed laterally for the next three paired chambers and finally uniserial for one or two chambers, the biserial portion may be less than three paired chambers or not apparent at all, in the uniserial stage the chambers may be irregularly rounded, triangular or quadrate and compressed with distinct downward curving lobes which project as knobs, giving the upper one-half or two-thirds of the test a knobby, irregular surface which from test to test, follows no set pattern, the uniserial stage is attained in less than half the specimens, the greater percentage reaching the somewhat cuneate, biserial second stage only with the aperture near or at the inner edge of the last chamber, whereas in the uniserial stage it is a central depression and approximately round with a slightly raised corona in some specimens. Length 1.24 mm ., width, .59 mm .

Holotype no. 12953 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40095 (CAS), sample no. 7 from the lower slope of a south-facing small ridge projecting into Hex Creek from the west causing it to veer to the northeast, about 1150 feet south and 200 feet east of the north quarter corner of Section 31, Township 25 south, Range 18
east, Mouth Diablo base and meridian, Hex Hill area, Kern County, California; C. C. Church collector; early Cretaceous.

The species here described differs from the original description of Gaudryinella in having a more compressed, distinct, biserial stage and appressed uniserial chambers which are only slightly inflated but the overall description best places it in this genus.

This species was found at station no. 15 on Hex Hill and nos. 7 and 8 on Hex Creek where it is one of the most common species.

This species is named in honor of Mr. Alvin A. Almgren of Bakersfield, California.

Superfamily Nodosariacea<br>Family Nodosarididae<br>Subfamily nodosariinae<br>Genus Nodosaria Lamarck, 1812

Nodosaria elegantia Lalicker.
(Plate 5, figures 4, 5.)
Nodosaria elegantia Lalicker, 1950, Univ. Kansas, Paleo. Contrib., art. 2, p. 15, pl. 2, figs. 9 a-d.

The above species occurs typically at stations 3, 5, and 6 at Devils Den with less typical but similar forms at stations 15 of Hex Hill and no. 7 of Hex Creek. It is usually present in small numbers.

The species was originally described from the Ellis group of Kansas of middle and late Jurassic age. It has six straight, round-bottomed, intercostate channels and six sharply keeled, straight costae extending unbroken from the rounded upper end to its bluntly pointed, apiculate initial end. The Devils Den species has a well defined spine at the initial end but this is sometimes broken off giving it the rounded appearance which Lalicker describes as characteristic of the Jurassic species. Length .55 mm ., (fig. 4), .80 mm ., (fig. 5).

## Nodosaria humilis Roemer.

(Plate 7, figure 7.)
Nodosaria humilis Roemer, 1841, Kreidebirges, Hannover, p. 95, pl. 15, fig. 6.
Glandulina humilis Roemer, 1934, Eichenberg, Hauterive, p. 174, pl. 16, fig. 9; pl. 11, fig. 15.
Pseudoglandulina humilis (Roemer), Bartenstein and Brand, 1951, Abh. senckenb, naturf. Ges., no. 485, p. 315, pl. 10, figs. 266-271.

Cushman gave the new generic name Pseudoglandulina to this type of nodosarian previously classed as Glandulina to separate them from the Glandulinas which were derived from the Polymorphinidae. More recently, in the Treatise, Loeblich, and Tappan included the genus under Nodosaria which places it

## Plate 2

All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection.

Figure 1. Pseudoreophax cisounicensis Geroch. Length .53 mm .; side view. Hypotype no. 12958 (CAS). From Locality 40092 (CAS), most easterly deep canyon of Hex Hill, NW. Kern County, California. Page 537.

Figure 2. Bulbophragmium species. Length .59 mm .; side view. Hypotype no. 12959 (CAS). From Locality 40092 (CAS), most easterly deep gully of Hex Hill, NW. Kern County, California. Page 535.

Figure 3. Dorothia cf. D. oxycona (Reuss) var. Length $.37 \mathrm{~mm} . ;$ (a) side view; (b) apertural view. Hypotype no. 12960 (CAS). From Locality 40091 (CAS), sample 8, deep gully, east side of Devils Den, NW. Kern County, California.

Figure 4. Bigenerina antiquissima Bartenstein and Brand. Length .47 mm .; side view. Hypotype no. 12961 (CAS). From Locality 40092 (CAS), most easterly deep gully of Hex Hill, NW. Kern County, California. Page 539.

Figure 5. Dorothia species, Length .71 mm .; side view. Hypotype no. 12962 (CAS). From Locality 40091 (CAS), sample 5, deep canyon, east side of Devils Den, NW. Kern County, California. Page 537.

Figures 6, 7, 8. Identity unknown; side views. Hypotype nos. 12963, 12964, 12965 (CAS). Figure 6. Length .57 mm . Figure 7. Length .55 mm . Figure 8. Length .49 mm . From Locality 40091 (CAS), sample 5, deep gully east side of Devils Den, NW. Kern County, California.

Figure 9. Bigenerina deciusi Church, new species, Length 43 mm .; side view. Holotype no. 12966 (CAS). From Locality 40092 (CAS), most easterly gully of Hex Hill, NW. Kern County, California. Page 539.

Figure 10. Haplophragmium aequale (Roemer). Length .48 mm .; side view. Hypotype no. 12967 (CAS). From Locality 40092 (CAS), most easterly deep gully of Hex Hill, NW. Kern County, California. Page 536.

Figure 11. Trochammina orchardensis Church, new species. Length .59 mm , width .45 mm .; (a) ventral view ; (b) dorsal view ; (c) peripheral view. Holotype no. 12968 (CAS). Locality 40092 (CAS), most easterly deep gully of Hex Hill, NW. Kern County, California. Page 534.


back under its original name. It occurs rather sparingly at station no. 7 of Hex Creek. The species was listed and figured in the paper on the lower Cretaceous of Trinidad, British West Indies by Bartenstein, Bettenstaedt, and Bolli. Length .69 mm .

## Nodosaria mutabilis (Reuss).

Glandulina mutabilis Reuss, 1863, K. Akad. Wiss. Wien, math.-naturwiss. Cl., Sitzungsber, vol. 46, p. 58, pl. 5, figs. 7, ? 8.
Nodosaria (G.) mutabilis Reuss, Chapman, 1893, Jour. Roy. Microsc. Soc. London, no. 4. p. 585, pl. 8, figs. 19, 20.

Pseudoglandulina mutabilis mutabilis (Reuss, 1863), Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 315, pl. 15 C, fig. 10 ; pl. 14 C, fig. 36.

Only a few of this species were found at station no. 7 of Hex Creek. None were found at Devils Den. It is apparently a long range species as it occurs in the upper Cretaceous.

## Nodosaria sceptrum Reuss.

Nodosaria sceptrum Reuss, 1863, Hils u. Gault, p. 37, pl. 2, fig. 3. Bartenstein, Bettenstaedt and Bolli, 1957, Eclog. Geol. Helv., vol. 50, no. 1, p. 35, pl. 7, figs. 150 a, b.

This is one of the rarer species and was found only at Devils Den, stations nos. 1 to 5. It varies somewhat in size but retains the shape and costation typical of the species. It has been figured from the lower Cretaceous of Trinidad, British West Indies, and northwest Germany where it occurs in the Valanginian. It is very similar to $N$. amphioxys Reuss as figured by Helen Tappan from the Grayson formation of north Texas (Albian).

Nodosaria cf. N. tenuicosta Reuss.

(Plate 6, figures 3, 5)
Nodosaria cf. N. tenuicosta Reuss, 1845, Verstein. bohmischen Kreide-formation. Stuttgart, Germ., E. Schweiz., Abth. 1, p. 25, pl. 13, figs. 5, 6.

The present species is almost straight-sided with very little restriction at the sutures to set the chambers apart. There are six continuous costae running the length of the test but they are low and narrow. The megalospheric form has a round proloculus with a short spine. The initial chamber is larger than the succeeding chambers. In the microspheric form the initial chambers are smaller and the additional chambers enlarge very gradually, the costae are very fine and low. The species occurs only at Devils Den at stations 5 and 6. Another form, at first thought to be a separate species, is now thought to be the microspheric form of this species. Length 1.15 mm . (fig. 3), length .92 mm . (fig. 5).

Nodosaria species.
A distinctive but rare species the first two or three chambers are small, straight-sided, and smooth, the following three or four chambers growing much larger but with no restriction at the sutures and no ornamentation. It was found at stations nos. 4 and 5 at Devils Den.

Nodosaria hexensis Church, new species.
(Plate 6, figure 13.)
Test free, multilocular, rectilinear, calcareous, composed of five ovoid chambers each slightly longer than wide, round in cross section, surface smooth, chambers enlarge gradually and regularly from the initial spheroid chamber, aperture small, round, at the end of a short, tube-like neck at the apex of the last chamber, sutures marked by a moderate restriction with a narrow welt at the juncture, chambers with moderate overlap of previous chambers, similar in general appearance to Pseudoglandulina tenuis (Bornemann) but with different aperture, found only at stations 5 and 6 at Devils Den. Length 1.01 mm ., width .24 mm .

Holotype no. 13015 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40091 (CAS), from deep north-south trending V -shaped gully beginning 500 feet south and 700 feet west of the east quarter corner of Section 20, Township 25 south, Range 18 east, Mount Diablo base and meridian, Kern County, California. Station no. 5, east bank of gully approximately 150 feet north of the mouth of the gully; C. C. Church collector; early Cretaceous.

## Dentalina catenula Reuss.

Dentalina catenula Reuss, 1860, Akad. Wiss. Wien, Math.-naturwiss. K1., Sitzungsber., vol. 40, p. 185, pl. 3, fig. 6. Cushman, 1940, Contrib. Cushman Lab. Foram. Res., vol. 16, pt. 4, p. 81, pl. 13, figs. 29-34.

This is a variable and relatively common form at Hex stations nos. 7 and 8. A similar species is present at no. 4 of the Devils Den outcrop.

## Dentalina communis d'Orbigny.

Dentalina commınis d’Orbigny, 1840, Soc. Géol. France, Mém., vol. 4, p. 13, pl. 1, fig. 4. Bartenstein, Bettenstaedt and Bolli, 1957, Eclog. Gcol. Helv., vol. 50, no. 1, p. 34, pl. 7, figs. 144, 145.

One of the more common species of the Devils Den section where it is found in samples from stations nos. 1 to 6 .

Dentalina grahami Church, new species.
(Plate 3, figures $6 \mathrm{a}, \mathrm{b}$.)
Test short, consisting of five chambers, each nearly circular in cross-section, gently arcuate, slight flattening on the inner curved side, chambers somewhat wider than high, sutures almost at right angles in the first three chambers, slightly oblique in the last two, the aperture projects as a tapered, tubular neck flush with the inner curve of the test and forms a continuous arch with the inner edge of the test, sutures slightly depressed, sides of test ornamented with a few, longitudinal, more or less discontinuous, low costae which do not extend over the last chamber, initial chamber large, globular with second chamber slightly smaller but succeeding chambers increasing in width very gently to the last chamber. Length .66 mm ., width .13 mm .

Holotype no. 12974 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40091 (CAS), from deep north-south trending V-shaped gully beginning 500 feet south and 700 feet west of the east quarter corner of Section 20, Township 25 south, Range 18 east, Mount Diablo base and meridian, Devils Den area, Kern County, California. Sample no. 1, east bank of gully near base, approximately 75 feet north of the mouth of the gully; C. C. Church collector; early Cretaceous.

This species was taken at stations nos. 1 and 5 in the Devils Den area, Locality 40091 (CAS).

This species is named in honor of Dr. Joseph J. Graham, Professor of Micropaleontology at Stanford University, Stanford, California.

## Dentalina species.

(Plate 6, figure 2.)
Only one complete specimen of this species was found. The early chambers are compressed but the later ones are rounded in cross section and separated by a small degree of inflation and a restriction at the sutures. The entire test is marked by fine longitudinal, closely spaced costae.

Found only at the most northerly of the Devils Den canyon series which is near the center of the group of hills known as "Devils Den." Length 1.90 mm .

## Genus Vaginulina d'Orbigny, 1826

## Vaginulina recta Reuss.

(Plate 5, figures 1, 3.)
Vaginulina recta Reuss, 1863, Hils u. Gault, Akad. Wiss. Wien, Sitz., vol. 46, p. 48, pl. 3, figs. $14,15$.

A rather rare species at station no. 7 on Hex Creek but more common at station no. 2 in Devils Den. This is a long and narrow species which remains about the same width throughout its growth after the first globular chamber
and the one following, test straight to gently curved, chamber edges raised into a sharp ridge forming an unbroken rim on each side of the test. This is one of the more distinctive species of the fauna but it is believed to range upward into the upper part of the lower Cretaceous. Length .72 mm . (fig. 1), length .57 mm . (fig. 3).

Vaginulina octocostata Church, new species.
(Plate 5, figure 2; plate 6, figure 6.)
Test free, calcareous, rectilinear, gently curved, compressed ovate in section, surface marked by eight vertical, more or less continuous costae two of which are at the outer edges of the test and three equally spaced on each side, all irregularly carinate and extending from the initial end to the edge of the final chamber where they merge around the apertural face, often forming a slight depression and extending to the aperture at the peripheral angle making it more apiculate, chambers enlarge very gradually for the first two or three then continue with little change for the final two or three chambers which are usually five or six in number, initial chamber small and pointed with a short basal spine in the microspheric form and compressed spherical in the megalospheric form, additional chambers compressed to gently inflated and defined by gentle depressions at the sutures. In the more extreme developments, as in figure 6, plate 6, the species has a more rounded final chamber and more restricted suture as in Dentalina. Without the intermediate forms one might easily identify the two extremes as different species or genera. Length .86 mm .

Holotype no. 13009 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40091 (CAS), from deep north-south trending V-shaped gully beginning 500 feet south and 700 feet west of the east quarter corner of Section 20, Township 25 south, Range 18 east, Mount Diablo base and meridian, Kern County, California. Sample from station no. 8, from steep east bank of gully about 20 feet south of junction with first northeast trending branch; this is about 600 feet due west of the east quarter corner of Section 20, Sawtooth Ridge quadrangle, 1953 edition; C. C. Church collector; early Cretaceous.

This species was found at stations 5 and 8 at Locality 40091 (CAS), Devils Den area.

Vaginulina debilis (Berthelin).
(Plate 6, figure 4.)
Marginulina debilis Berthelin, 1880, Soc. Géol. France, Mém., ser. 3, vol. 1, Mem. 5, p. 35, pl. 3, (26) fig. 28.
Vaginulina debilis (Berthelin), Tappan, 1940, Jour. Paleo., vol. 14, no. 2, p. 108, pl. 16, figs. $26 \mathrm{a}, \mathrm{b}$.

The original description is of a smooth form but a similar species from the Grayson formation has both smooth and sparsely costate types. The ones with the costation are very similar to those from the more northerly of the Devils Den samples but smooth forms are present here also. A similar form without the early chambers was figured by Bartenstein, Bettenstaedt and Bolli from the lower Cretaceous of Trinidad. In this instance it was classified as "Dentalina" debilis (Berthelin). The Trinidad species appears to be more sharply angled and flatter on the side. It is also without any vertical costae. Some of the more attenuated and less angled fragments from Devils Den could very readily be considered as Dentalina but where perfect specimens were found, the test was wedge-shaped and compressed. Found only at Devils Den. Length 1.64 mm .

## Vaginulina striolata Reuss.

(Plate 4, figure 9; plate 6, figure 14).
Vaginulina striolata Reuss, 1863, Akad. Wiss. Wien, Sitz., vol. 46, pt. 1, p. 46, pl. 3, fig. 7.
Vaginulina kochii var. striolata Cushman and Alexander, 1930, Cushman Lab. Foram. Res., Contr., vol. 6, pt. 1, p. 4, pl. 1, figs. 10-16.
Vaginulina striolata Reuss, 1863, Bartenstein and Brand, 1951, Abh. senckenb. naturf., Ges., no. 485, p. 294, pl. 6, figs. 161-164.

This may be a variety of Vaginulina kochii as it was considered by Cushman and Alexander and by Helen Tappan. It is a rather rare species here but was found at Stations 5 and 6 of Devils Den and at no. 7 of Hex Creek. Length 1.06 mm . (pl. 4, fig. 9). Length 1.07 mm . (pl. 6, fig. 14).

## Vaginulina kochii Roemer.

(Plate 4, figure 11.)
Vaginulina kochii Roemer, 1840-1841, Verst, norddeutsch. Kreide, p. 96, pl. 15, fig. 10. Tappan, Helen, 1940, Jour. Paleo., vol. 14, no. 2, p. 109, pl. 17, figs. 2-4.

This is one of the more commonly occurring species at both Hex Creek and Devils Den but it is not abundant in any of the samples. It is listed from the lower Cretaceous of Europe, the lower Cretaceous of Trinidad, southeastern United States and the upper Cretaceous of the Sacramento Valley, California. Length .96 mm .

Vaginulina riedeli riedeli Bartenstein and Brand.
(Plate 4, figures 7, 8.)
Vaginulina riedeli riedeli Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 295, pl. 7, figs. 165 a, b, c.

One of the less common but very distinctive species of the Hex Hill fauna. Found at station no. 15, Hex Hill. Length 1.11 mm . (fig. 7), length 1.00 mm . (fig. 8).

## Vaginulina truncata Reuss.

Vaginulina truncata Reuss, 1863, Hils u. Gault. p. 47, pl. 3, fig. 9. Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 293, pl. 12B.

This rare variety may be only a more flaring variation of $V$. kochii as similar species have been described as V. kochii from the German lower Cretaceous by Bartenstein and Brand. Found at stations no. 5 and no. 8 of Devils Den.

Genus Vaginulinopsis Silvestri, 1904
Vaginulinopsis pachynota Ten Dam.
(Plate 4, figure 3.)
Vaginulinopsis pachynota Ten Dam, 1946, Jour. Paleo., vol. 20, no. 6, p. 575, pl. 88, figs. 5, 6 a, b.

A common and variable form at stations nos. 5 and 6 of Devils Den but not found in the Hex Hill samples. This strongly sutured species is similar in many respects to some of the later Eocene forms. Length 1.20 mm .

Genus Marginulina d'Orbigny, 1826

## Marginulina bullata Reuss.

Marginulina bullata Reuss, 1845, Verstein. böhm. Kreideformation, pt. 1, p. 29, pl. 13, figs.
34-38. Cushman, 1937, Cushman Lab. Foram. Res., Contrib., vol. 13, p. 96, pl. 14, figs.
9-15. Cusilman, 1944, Cushman Lab. Foram. Res. Contrib., vol. 20, p. 6, pl. 1, fig. 21.
This species occurs very sparingly in samples nos. 7 and 8 of Hex Creek. Very similar species are, M. curvitura Cushman and M. texasensis Cushman, both from the upper Cretaceous of Texas.

Marginulina cf. M. parkeri (Reuss).
(Plate 3, figure 3.)
Lenticulina parkeri Reuss, 1863, Hils u. Gault, p. 59, pl. 5, fig. 14.
Lenticulina (Marginulinopsis) parkeri (Reuss), Bartenstein and Brand, 1951, Abh. sencken. naturf. Ges., no. 485, p. 288, pl. 6, figs. 136, 137.

This appears, from the figures, to be a much smoother form than the species to which it is compared. The test is without ornamentation and the sutures flush with the surface although very distinctly outlined. Even the initial chambers are clearly displayed showing the half coiled nature of the early chambers which gives to the early portion of the test its distinct but gentle curve. Following the first two or three chambers the oval section continues its growth without appreciable change with parallel, oblique sutures outlining the chambers which are wider than they are high, the test itself gently curved or almost straight with smooth, parallel sides. Length 1.74 mm .

## Marginulina robusta Reuss.

(Plate 4, figure 6.)
Marginulina robusta Reuss, 1863, Hils u. Gault, p. 63, pl. 6, figs. 5, 6.
Lenticulina (Marginulinopsis) robusta (Reuss), 1863, Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 289, pl. 6, figs. 142, 143.
Marginulina robusta (Reuss), Ten Dani 1948, Neocom., Jour. Paleo., vol. 22, no. 2, p. 185, pl. 32, fig. 6.

This species was found sparingly at stations nos. 1, 4, and 5 of Devils Den area but not at Hex Creek or Hex Hill. From a comparison with figures and actual specimens from the European section, it appears to be very close to the species described by Reuss. Length .67 mm .

## Marginulina pyramidalis Koch.

(Plate 6, figure 12.)
Nodosaria pyramidalis Koch, 1851, Palaeontographical, p. 169, pl. 24, fig. 8 .
Marginulina pyramidalis (Koch), Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 307, pl. 9, figs. 221-223.

A common species at station 5 of Devils Den and found from nos. 2 to 6. It is quite variable in size but retains its characteristics of strong, continuous carinate costae and initial spine and prominent, off-center, spout-like aperture, final chamber noticeably larger and more inflated, initial chamber also somewhat larger and more bulbous than those immediately following. It is one of the distinctive species of the Devils Den section but not found in the Hex Hill area. Length 1.09 mm .

Marginulina sigali Bartenstein, Bettenstaedt, and Bolli.
(Plate 6, figure 8.)
Lenticulina (Marginulina) sigali Bartenstein, Bettenstaedt and Bolli, 1957, Eclog. Geol. Helv., vol. 50, no. 1, p. 32, pl. 5, fig. 99 ; pl. 6, figs. 130, 131 a, b.

This is a quite common species at station 5 of Devils Den but was not found in other parts of the section or at Hex Hill. It is a species with distinctive features and appears from Bartenstein, Bettenstaedt, and Bolli, plate 5, figure 99 (see above) to be the same as their Trinidad species. Length .61 mm .

## Marginulina species.

(Plate 4, figure 12.)
This is one of the rarer species of the Hex formation. It was found only at stations no. 7 of Hex Creek and no. 5 of Devils Den but most likely will be found

Plate 3
All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection.

Figure 1. Lingulina tenera Bornemann. Length . 59 mm .; side view. Hypotype no. 12969 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully east side of Devils Den, NW. Kern County, California. Page 560.

Figure 2. Saracenaria spinosa (Eichenberg). Length .94 mm .; side view. Hypotype no. 12970 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 552.

Figure 3. Marginulina cf. M. parkeri (Reuss). Length 1.74 mm .; side view. Hypotype no. 12971 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 548.

Figure 4. Citharina species. Length 1.12 mm .; side view. Hypotype no. 12972 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 557.

Figure 5. Citharina acuminata (Reuss). Length 1.27 mm .; side view. Hypotype no. 12973 (CAS). From Locality 40091 (CAS), sample 5, from deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 556.

Figure 6. Dentalina grahami Church, new species, Length .66 mm .; width .13 mm . (a) side view; (b) side view. Holotype no. 12974 (CAS). From Locality 40091 (CAS), sample 5, from deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 545.

Figure 7. Frondicularia frankei Cushman. Length 1.21 mm .; side view. Hypotype no. 12975 (CAS). An immature specimen from Locality 40091 (CAS), sample 5, deep northsouth gully, east side of Devils Den, NW. Kern County, California. Page 557.

Figure 8. Astacolus perobliqua (Reuss). Length .82 mm .; side view. Hypotype no. 12976 (CAS). From Locality 40091 (CAS), sample 6, deep gully, east side of Devils Den, NW. Kern County, California. Page 556.

Figure 9. Menkenina berryi Church, new species. Length 1.17 mm ; width .37 mm ; (a) dorsal view; (b) ventral view. Holotype no. 12977 (CAS). From Locality 40091 (CAS), sample 6, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 561.

Figure 10. Citharina species " 3 ," (Bartenstein and Brand). Length .83 mm .; side view. Hypotype no. 12978 (CAS). From Localities 27501 (CAS), 47 (FAM). Near central area of Devils Den, NW. Kern County, California. Page 556.

Figure 11. Astacolus perobliqua (Reuss). Length 1.65 mm .; side view. Hypotype no. 12979 (CAS). From Locality 40091 (CAS), sample 6, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 556.

elsewhere in the section. It is almost round in section and with parallel sides and only a suggestion of a beginning coil, chambers few, usually not more than six which indicates the nature of the short, thick species, surface smooth and only slightly indented at the last suture, sutures flush with surface, almost at right angles to dorsal side in later chambers, aperture at dorsal angle of last chamber. Length 1.03 mm .

Genus Marginulinopsis Silvestri, 1904
Marginulinopsis gracillissima (Reuss).
(Plate 6, figure 9.)
Cristellaria gracillissima Reuss, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 64, pl. 6, figs. 9, 10.
Marginulinopsis gracillissima (Reuss), Ten Danr, 1948, Jour. Paleo., vol. 22, no. 2, p. 184, pl. 32, figs. 7, 8.

This species was found sparingly but consistently through most of the Devils Den series from 1 to 8 . Most specimens do not have the pronounced initial coil as figured in the original type, but in all other respects is very similar. In some of the smaller varieties the aperture is drawn out into a distinct neck. Length .49 mm .

Marginulinopsis collinsi Mellon and Wall.
Marginulinopsis collinsi Mellon and Wall, 1956, Res. Council Alberta, Report no. 72, pt. 1, p. 20, pl. 2, figs. 1, 2.

There is a tendency for this species, from the Hex Creek occurrence, to develop the flattened apertural face of a Saracenaria reminiscent of Lenticulina valanginiana Bartenstein and Brand of the lower Cretaceous of Germany. Our Hex Creek, no. 7 occurrence is quite rare but it is possible that it may be less so with further sampling. The species named by Mellon and Wall from Alberta, Canada, is from the basal Clearwater formation, considered to be of middle Albian in age on the basis of its ammonite fauna. A few specimens were also found at station no. 48 (F. A. Menken) of Devils Den which are very similar to the species described by Mellon and Wall.

Marginulinopsis species.
(Plate 4, figure 13.)
This species is similar in general shape and degree of uncoiling to Cristellaria hamata Franke which was described from the Oligocene of Denmark but has fewer and wider chambers and greater inflation in the final chamber. It is one of the more common species found in samples from stations 7 and 8 of Hex Creek, Locality 40095 (CAS) but was not found in the Devils Den samples. Length 1.03 mm .

## Genus Saracenaria Defrance in de Blainville, 1824

## Saracenaria italica Defrance.

(Plate 4, figure 5.)
Saracenaria italica Defrance, 1824, Tableau, p. 176 (vol. 32), pl. 13, fig. 6 (vol. 12). Chapman, 1894, Jour. Roy. Micr. Soc. London, no. 7, p. 653, pl. 10, fig. 10.

This is not one of the commoner species but it was found at station no. 7 of Hex Creek and later more commonly at nos. 2 and 5 of Devils Den. It is a large robust form. Length .78 mm .

Saracenaria spinosa Eichenberg, 1935.
(Plate 3, figure 2.)
Saracenaria spinosa Eichenberg, 1935, Niedersächs. Geol. Ver., Jahesberichts 27 (Mitt. Roemer-Museum, Hildesheim, no. 37, Teil 1, Folge 4), p. 10, pl. 4, fig. 5 a-d. Aptian, Germany. Tappan, Helen, 1962, U. S. Geol. Surv., Prof. Paper 236C, p. 165, pl. 41, figs. 18, 19.

Occurs rather sparingly at station no. 7 of Hex Creek and at station no. 4 of Devils Den. It is much more slender and elongate than S. italica and a sharp spine terminates the base of the chambers at the two side angles where the face and lateral sutures meet. Specimens from the Aptian of northern Germany are very similar to the Hex Hill specimens. The species figured from Alaska is shorter and less spinose. Length .94 mm .

## Genus Lenticulina Lamarck, 1804

## Lenticulina saxonica saxonica Bartenstein and Brand.

(Plate 5, figures $11 \mathrm{a}, \mathrm{b}$.
Lenticulina saxonica saxonica Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485 , p. 284, pl. 5, figs. 115 a, b.

This is one of the common forms at stations nos. 7 and 8 of Hex Creek. It is usually very well preserved as it is large and has a sturdy test. Length 1.29 mm .

## Lenticulina (Lenticulina) münsteri (Roemer).

(Plate 5, figures $7 \mathrm{a}, \mathrm{b}$.)
Robulina münsteri Roemer, 1839, Oolith.-Geb., p. 48, pl. 20, fig. 29.
Lenticulina (Lenticulina) mïnsteri (Roemer), Bartenstein and Brand, 1951. Abh. senckenb. naturf. Ges., no. 485, p. 283, pl. 5, fig. 109.

This is one of the largest and most common of the many species of Lenticulina at stations nos. 7 and 8 of Hex Creek. It varies somewhat in the raised or depressed condition of the suture but in general it is a quite smooth form with
seven to nine chambers, sutures curved, slight depression at the center due to the overlapping of the last few chambers and concealing a possible umbo, outer periphery rather sharply keeled and uniform. Length 1.34 mm .

## Lenticulina species.

(Plate 4, figure 2.)
A few specimens of this unidentified species were found at station no. 7 of Hex Creek. It has seven to nine chambers with prominent, sharp raised sutures which becomes less prominent toward the periphery, each one gently curved, periphery sharply keeled with a thin carina of clear shell material, raised sutures may end abruptly near center without coalescing or blend with the others to form a slightly higher center, height of test from .8 to 1 mm .; width .5 mm . Length .96 mm .

## Lenticulina species.

(Plate 4, figure 1.)
This large, heavily ornamented species is one of the less common of the large lenticulinas at stations nos. 5 and 6 of Devils Den. From among the many at this point the present species may be distinguished by the presence of faint to prominent spiral ridges which generally follow the outer curve of the test, often being higher and noded over the sutures and strongest near the umbonal area, sutures may be raised into welts near the center but usually are flush or depressed near the periphery. In the specimen illustrated the curved welts are strongest between sutures and more regular and prominent than usual. Test large, calcareous, free, thick, lenticular, often reaching a diameter of 1.5 mm . with a height only slightly greater than the width, periphery strongly keeled throughout, surface generally uneven, chambers six to eight in final whorl, sutures gently curved, aperture typically radial. In rare instances the final chamber may depart from the curve and extend out from the test in a straight line resembling a blunt spine in the final chamber. This may be an aberrant form.

The variability of the species suggests that it may be a variation of one of the large species with which it is associated but the smaller number of chambers, the strong peripheral flange and the rugose surface of the test sets it apart. Length 1.46 mm .

Lenticulina kugleri Bartenstein, Bettenstaedt, and Bolli.
Leniiculina kugleri Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Hely., vol. 50, no. 1, p. 27, pl. 5, fig. 95 ; pl. 6, figs. 116 a, b.

This species was found only at station no. 47 (F. A. Menken) where it


Figure 2. Lenticulina eichenbergi Bartenstein and Brand. Hypotype no. 12950 (Calif. Acad. Sci., Dept. Geol. Type Coll.), from the same locality as the specimen shown in figure 3.

Figure 3. Lenticulina cf. L. eichenbergi Bartenstein and Brand. Hypotype no. 12949 (Calif. Acad. Sci., Dept. Geol. Type Coll.), from Locality 27502 (CAS), no. 50, about 600 feet west and 100 feet north of the center of Section 20, Township 25 south, Range 18 east, Mount Diablo base and meridian, Kern County, California.
was not a rare species. It is a compressed species with the sutures thickened and raised and the test longer than broad.

## Lenticulina (L.) eichenbergi Bartenstein and Brand.

(Figure 2.)
Lenticulina (Lenticulina) eichenbergi Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 285, pl. 5, figs. 118, 119.

In the earlier samples from Devils Den this species was found at stations nos. 46 and 50 (F. A. Menken) and later from 5 to 8 of the Devils Den series. Also at Locality 27605 (CAS), south slope of Hex Hill. It is a large, wellpreserved form with considerable variation in the number and arrangement of nodes or bosses in the central area and along the curved sutures where they may at times coalesce to form a welt, both nodes and broken sutures diminish toward the periphery, usually leaving a smooth outer edge, periphery sharply keeled to carinate, number of chambers in outer whorl, seven to ten, average height 1 mm., width .8 mm , length 1.02 mm .

## Lenticulina cf. L. eichenbergi Bartenstein and Brand.

(Figure 3.)
Of the several species of large lenticulinas of the Devils Den 40091 (CAS), station 5 locality, this one is probably a variety of L. eichenbergi Bartenstein and Brand, but in the character of its ornamentation it also has much in
common with a species described by Bartenstein, Bettenstaedt, and Bolli from the lower Cretaceous of Trinidad, British West Indies as L. ouachensis (Sigal, 1952). These authors also described three subspecies of $L$. ouachensis, suggesting a proliferation of varieties of the species at this time or possibly a wide variation in a single species. Regardless of the true or accepted nature of the species, a similar wide variation is evident among the Devils Den specimens. The species and its variations are well represented at station 5 at Localities 40091 and 27502 (CAS), station no. 50 (F. A. Menken) both from Devils Den. Length .88 mm .

Genus Darbyella Howe and Wallace, 1932

## Darbyella species.

(Plate 7, figures $10 \mathrm{a}, \mathrm{b}, \mathrm{c}$.)
A species from the Jackson Eocene described by Howe and Wallace is very similar to the lower Cretaceous species except that, in perfect specimens, the Devils Den species has a typical conical, radiate aperture. The Eocene species has a slit-like aperture with a calcareous lip on either side.

The authors of the Treatise consider Darbyella as an aberrant form of Lenticulina but it is so distinct and constant in its characters that its occurrence here seems worthy of mention. It was found at stations nos. 4 and 5 of Devils Den. Length .69 mm .

Genus Astacolus de Montfort, 1808

## Astacolus grata (Reuss).

(Plate 4, figure 10.)
Cristellaria grata Reuss, 1862, Sitz. Akad. Wiss. Wien, vol. 46, pt. 1, p. 70, pl. 7, figs. 14 a, b. Cushman, 1926, Bull. Amer. Assoc. Petr. Geol., vol. 10, p. 598, pl. 19, figs. 1 a, b.
Marginulina grata (Reuss), Cushman and Jarvis, 1932, Proc. U. S. Nat. Mus., no. 2914, vol. 80 , art. 14 , p. 25 , pl. 7 , figs. 7 a, b; pl. 8 , figs. 3 a, b.

This is a very smooth form but the sutures are very distinct as fine lines. The present species differs slightly from the figured specimen of Cushman and Jarvis in that the last few chambers do not tend to extend down to the initial coil but strike across at a more gentle angle. It is quite common at stations nos. 7 and 8 of Hex Creek. Length 1.36 mm .

Astacolus incurvata (Reuss).
Cristellaria incurvata Reuss, 1863, K. Akad. Wiss. Wien, p. 66, pl. 6, fig. 18.
Lenticulina (Astacolus) incurvata (Reuss), Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Helv., vol. 50, no. 1, p. 30, pl. 3, figs. 57 a, b; pl. 4, fig. 86.

This species occurs at stations no. 7 of Hex Creek and no. 15 of Hex Hill, also at no. 3 of Devils Den. The species is very similar to other uncoiled,
elongate species in these faunas and it is often a question of whether there are a number of species or if they are variants of a single species.

## Astacolus perobliqua (Reuss).

(Plate 3, figures 8, 11.)
Cristellaria (Cristellaria) perobliqua Reuss, 1863, K. Akad. Wiss. Wien, Math., Naturw. Cl., Sitzungsber., vol. 46, pt. 1, p. 67, pl. 7, fig. 3.

There is considerable variation in this species, especially in the initial chambers which may form a sharply curved, pointed, primary part or start with a gentle, rounded curve which emerges quickly into a larger slightly curved but generally parallel sided test with highly oblique sutures and more inflated, slightly wedge-shaped chambers in section, usually seven chambers.

Fairly common at station no. 6 of Devils Den but found also at nos. 4 and 5 of the same section. Length .82 mm . Another specimen (figure 11) was found at station 6 which had a length of 1.65 mm .

Genus Citharina d'Orbigny in de la Sagra, 1839
Citharina acuminata (Reuss).
(Plate 3, figure 5.)
Vaginulina acuminata Reuss, 1863, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzungsber., vol. 46, pt. 1, p. 49, pl. 4, fig. 1.
Citharina acuminata (Reuss), Bartenstein, Bettenstaedt and Bolli, 1957, Eclog. Geol. Helv., vol. 50, no. 1, p. 39, pl. 7, figs. 159 a, b.

One of the rarer species at Devils Den, it was found only at stations nos. 1 and 5. It was not found in the Hex Hill area. Length 1.27 mm .

Citharina species " 3 ," (Bartenstein and Brand).
(Plate 3, figure 10.)
Vaginulina sp. 3, Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 292, pl. 6, fig. 153.

There is considerable variation in this species which corresponds very closely to the species figured by Bartenstein and Brand. It occurs rather commonly at the most northerly of the Devils Den series of samples and F. A. Menke no. 47 and is scarce but present at station no. 8 of Hex Creek. What appears to be a closely related species occurs at station no. 7 on Hex Creek. Length .83 mm .

Citharina kernensis Church, new species.
(Plate 4, figure 4.)
Test small, calcareous, compressed, wedge-shaped in cross section, more compressed in early chambers, becoming slightly inflated in later ones, early
chambers develop a sharp curve, later ones become more oblique and terminate in a more or less straight line at the back, later chambers tend to overlap the previous chambers, extending down almost to the curved initial part of the chambers, aperture a small opening at the apex of the final chamber where the somewhat angular suture and the sharply angled back side of the test converge to form a slight neck for the aperture, sutures of clear shell material may be depressed or raised in a definite welt, in some specimens forming a sharp edge to the more inflated part of the chambers. This species is definitely narrower than Citharina species 3 and more inflated but the wide variation in both species and their general similarities suggests the possibility that they are a single species. If further work and more detailed comparisons of the species should support the above possibility, it is this authors suggestion that the name C. kernensis be retained as the name for both variations. Length .52 mm ., width .15 mm .

Holotype no. 12983 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40095 (CAS), sample no. 7, from the lower slope of a south-facing small ridge projecting into Hex Creek from the west causing it to veer to the northeast, about 1150 feet south and 200 feet east of the north quarter corner of Section 31, Township 25 south, Range 18 east, Mount Diablo base and meridian; C. C. Church collector; early Cretaceous.

Citharina species.
(Plate 3, figure 4.)
This very small species may be a variation of C. acuminata but it is much narrower and the oblique costae are fewer and less continuous than those in C. acuminata. It is very similar in shape and markings to the much larger species from the Duck Creek, lower Cretaceous of Texas, which was referred to as Vaginulina raristriata (Chapman) by Helen Tappan in her paper on the foraminifera of that formation. It is rare in the Devils Den samples having been found only at stations nos. 1 and 5. It probably occurs at other points in the section but its relatively small size and delicate construction renders it more difficult to detect and less likely to be found whole. Length 1.12 mm .

Genus Frondicularia Defrance in d'Orbigny, 1826
Frondicularia frankei Cushman.
(Plate 3, figure 7 ; plate 6, figures 1, 10.)
Frondicularia angusta Reuss, 1860, Akad. Wiss. Wien, Math.-naturwiss. Kl., Sitzungsber., vol. 40, p. 196, pl. 4, fig. 5.
Frondicularia frankei Cushman, 1936, Contrib. Cushman Lab. Foram. Res., vol. 12, pt. 1, p. 18, pl. 4, figs. 6, 7.

Found only at Devils Den in samples from stations nos. 2 to 6. In all of

## Plate 4

All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection.

Figure 1. Lenticulina species. Length 1.46 mm .; side view. Hypotype no. 12980 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 553.

Figure 2. Lenticulina species. Length .96 mm .; side view. Hypotype no. 12981 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 553.

Figure 3. Vaginulinopsis pachynota Ten Dam. Length 1.20 mm .; side view. Hypotype no. 12982 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 548.

Figure 4. Citharina kernensis Church, new species. Length .52 mm ; width .15 mm .; side view. Holotype no. 12983 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 556.

Figure 5. Saracenaria italica Defrance. Length .78 mm .; side view. Hypotype no. 12984 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 552.

Figure 6. Marginulina robusta Reuss. Length .67 mm .; side view. Hypotype no. 12985 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 549.

Figure 7. Vaginulina riedeli riedeli Bartenstein and Brand. Length 1.11 mm .; side view. Hypotype no. 12986 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 547.

Figure 8. Vaginulina riedeli riedeli Bartenstein and Brand. Length 1.00 mm .; side view. Hypotype no. 12987 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 547.

Figure 9. V'aginulina striolata Reuss. Length 1.06 mm .; side view. Hypotype no. 12988 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 547.

Figure 10. Astacolus grata (Reuss). Length 1.36 mm .; side view. Hypotype no. 12989 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 555.

Figure 11. Vaginulina kochii Roemer. Length .96 mm .; side view. Hypotype no. 12990 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 547.

Figure 12. Marginulina species. Length 1.03 mm. ; side view. Hypotype no. 12991 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 549.

Figure 13. Marginulinopsis species. Length 1.03 mm .; side view. Hypotype no. 12992 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 551.

its occurrences it was found sparingly and usually broken. Length 1.21 mm . (pl. 3, fig. 7), length 3.19 mm . (pl. 6, fig. 1). [Specimen illustrated in pl. 6, fig. 10 missing.]

## Frondicularia concinna Koch.

Frondicularia concinna Koch, 1851, Palaeontographica, 1, p. 169, Cassel. Reuss, 1863, Sitz. Akad. Wiss. Wien, p. 54, pl. 4, fig. 13. Hecht, 1938, Abh. senckenb. naturf. Ges. 443, p. 28 (as Frondicularia D.6), pl. 18b, figs. 116-119.

This is a very distinctive species but also very rare as only two imperfect specimens were found. One of these has only the first few initial chambers missing. It was found at station no. 5 of Devils Den.

## Frondicularia species.

(Plate 5, figure 10.)
Frondicularia sp. 2, 1957, Bartenstein, Bettenstaedt and Bolli, Eclog. Geol. Helv., vol. 50 , no. 1, p. 40 , pl. 5 , fig. 109 ; pl. 6, figs. 138 a, b.

This species, from stations 7 and 8 of Hex Creek, is so similar to the species from the lower Cretaceous of Trinidad referred to above, that I have used their names and number. Faint vertical costae are visible on some specimens. It is a large, robust species, some specimens measuring over 1 mm . in length. In the earlier half of the test the edge is flattened and forms a distinct right angle with the two faces. Length 1.22 mm .

## Frondicularia species.

This species is similar in some respects to Frondicularia species 2 and may be a variation of that species. It differs in being flatter and without inflation of the chambers. Also in many of the specimens the first few chambers are uniserial. The test as a whole is quite compressed and thin and the edges at right angles to the sides, the test itself of medium size and the chevron-shaped chambers have a moderate flair.

## Frondicularia species.

(Plate 5, figure 6.)
A very rare species, only two specimens were found and the second one is probably immature. This species is almost parallel sided as it tapers very gently with the addition of each chamber, the cross section is a flattened oval and the edges taper to a thin, narrow carina, the final chamber is attenuated and the aperture at the end of a rather long, narrow neck, the initial chamber
is blunt and rounded and compressed into a flat oval which changes little with growth, surface marked by faint, broken costae. Length .73 mm .

Subfamily lingulininae Loeblich and Tappan, 1961
Genus Lingulina d'Orbigny, 1826

## Lingulina californiensis Trujillo.

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(Plate 6, figure 7.)
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Lingulina californiensis Trujillo, 1960, Jour. Paleo., vol. 34, no. 2, p. 314, pl. 45, figs. 8 a, b.
This is a rare species in the Hex formation and was found only at no. 7 of Hex Creek. It appears to be identical to Trujillo's species from the upper Cretaceous Coniacian of the Sacramento Valley, California. Length .45 mm .

## Lingulina tenera Bornemann.

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(Plate 3, figure 1.)
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Lingulina tenera Bornemann, 1854, Göttingen, p. 38, pl. 3, fig. 24. Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 301, pl. 8, fig. 194 a, b.

Of infrequent occurrence in the Devils Den series from stations nos. 2 to 5. Not found at Hex Hill. Reported from as low as the Lias in Europe. Length .59 mm .

> Subfamily menkeninae Church, new subfamily
> Genus Menkenina Church, new genus

Type Species: Menkenina berryi Church, new species.
The new genus has the usual characters of the uncoiled members of the family. Test calcareous, perforate with a linear arrangement of the chambers, differs from Frondicularia in having rounded sutures with a gentle upward curve on the ventral side and curving upward in a broad, inverted " V " on the dorsal side, test differs from Vaginulina in being compressed dorso-ventrally rather than laterally and in having a rounded aperture at the end of a tapered, tubular neck located at the extreme edge of the dorsal side the trace of which persists as a central welt on the dorsal side, the genus may have evolved from a Vagimutina-like ancestor as suggested by some specimens which are more rounded and inflated on the ventral side, test normally ornamented with a variable number of broken and continuous, longitudinal, carinate carinae extending from the initial end to the penultimate chamber, becoming less prominent
with growth, one of these forming a thin, translucent flange on the edges of the test. The new name is in honor of the late Mr. F. A. Menken ${ }^{1}$ who first brought this fauna to my attention.

Menkenina berryi Church, new species.
(Plate 3, figures 9 a, b.)
Test free, calcareous, perforate, lanceolate, uniserial, compressed from front to back in contrast to Vaginulina, generally flattened on the dorsal side gently rounded on the ventral side, sutures curved upward on the ventral side, gently depressed in last and next to last chambers, flush in earlier ones, chambers lunate on ventral side, chevron-shaped on dorsal side with sutures merging with the trace of the tubular neck of the previous chamber, apertural end drawn out into a short, tapering neck at the extreme edge of the dorsal side, aperture rounded and simple at the end of the tubular neck which is, at least in part, retained in each added chamber and forms what appears to be a continuous tube near the surface, a thin transparent carina extends along each side of the test from the base of the final chamber to the initial end, usually broken and irregular, in the megalospheric form the initial chamber is large and globular followed by six lunate, alightly inflated chambers which increase regularly with growth, the initial chamber of the microspheric form is also spherical but much smaller resulting in a more sharply pointed initial end, several strong, broken to continuous costae extend longitudinally over both sides of the test from the penultimate chamber to the initial end, becoming more prominent and carinate toward the initial end but absent from the final, more inflated chamber, test straight but with a suggestion of a gentle upward curve at the initial end on the ventral side. Length 1.17 mm ., width .37 mm .

Holotype no. 12977 (California Academy of Sciences, Department of Geology Type Collection) from Locality 40091 (CAS), from a deep north-south trending V -shaped gully beginning 500 feet south and 700 feet west of the east quarter corner of Section 20, Township 25 south, Range 18 east. Mount Diablo base and meridian, Devils Den area, Kern County, California. Sample no. 6, east bank of gully near base, approximately 200 feet north of the mouth of the gully; C. C. Church collector; early Cretaceous.

Remarks. This species was found at stations 1, 2, 5, 6, of Localities 40091 (CAS) and no. 49 (F. A. Menken), Devils Den, also at Locality 27605 (CAS), south slope of Hex Hill, Kern County, California. It does not occur in abundance in any of these localities.

The specific name is in honor of Mr. Keith D. Berry of the Standard Oil Company, Oildale, California, author of new stage names for the early Cretaceous of California.

[^33]
## Plate 5

All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection.

Figure 1. Vaginulina recta Reuss. Length .72 mm .; side view. Hypotype no. 12993 (CAS). From Locality 40091 (CAS), sample 6, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 545.

Figure 2. Vaginulina octocostata Church, new species. Length .78 mm ., width .17 mm ; side view. Hypotype no. 12994 (CAS). From Locality 40091 (CAS), sample 8, deep northsouth gully, east side of Devils Den, sample farthest north from mouth, NW. Kern County, California. Page 546.

Figure 3. Vaginulina recta Reuss. Length .57 mm .; side view. Hypotype no. 12995 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 545.

Figure 4. Nodosaria elegantia Lalicker. Length .55 mm .; side view. Hypotype no. 12996 (CAS). From Locality 40091 (CAS), sample 6, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 541.

Figure 5. Nodosaria elegantia Lalicker. Length .80 mm .; side view. Hypotype no. 12997 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 541.

Figure 6. Frondicularia species. Length .73 mm .; side view. Hypotype no. 12998 (CAS). From Locality 40091 (CAS), sample 6, deep north-south gully east side of Devils Den, NW. Kern County, California. Page 559.

Figure 7. Lenticulina (Lenticulina) münsteri (Roemer). Length 1.34 mm .; (a) side view; (b) apertural view. Hypotype no. 12999 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 552.

Figure 8. Quadratina strombecki (Reuss). Length .51 mm .; side view. Hypotype no. 1300 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill. NW. Kern County, California. Page 563.

Figure 9. Tristix acutangulum (Reuss). Length .78 mm .; side view. Hypotype no. 13001 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 563.

Figure 10. Frondicularia species 2, Bartenstein, Bettenstaedt, and Bolli. Length 1.22 mm.; side view. Hypotype no. 13002 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 559.

Figure 11. Lenticulina saxonica saxonica Bartenstein and Brand. Length 1.29 mm .; (a) side view; (b) apertural view. Hypotype no. 13003 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 552.


# Family Glandulinidae Reuss, 1860 <br> Subfamily glandulininae <br> Genus Quadratina Ten Dam, 1946 

Quadratina strombecki (Reuss).
(Plate 5, figure 8.)
Quadratina strombecki (Reuss), 1863, Hils u. Gault, p. 56, pl. 5, fig. 3. Bartenstein and Brand, 1951, Abh. senckenb. naturf. Ges., no. 485, p. 314, pl. 10, figs. 264 a, b, c.

Only a few of this species were found and at one station, no. 7 of Hex Creek. Bartenstein and Brand reported it from the upper Valanginian of northwest Germany. Loeblich and Tappan believe this form to be a quadrate varient of the genus Tristix which it may be as both were found at station no. 7 of Hex Creek and except for the difference in the number of sides, are very similar in size and in being composed of clear shell material. Length .51 mm .

## Genus Tristix Macfadyen, 1941

## Tristix acutangulum (Reuss).

(Plate 5, figure 9.)
Tristix acutangulum (Reuss), Ten Damr, 1948, Jour. Paleo., vol. 22, no. 2, p. 181, pl. 32, figs. 9, 10.

This is one of the rarer species in this fauna but the few found are very well preserved. The angles are sharply carinate with thin transparent flanges extending the length of the test. The sutures are well incised and the chambers moderately inflated. The more mature specimens have six chambers with the greatest width at the fourth chamber. The largest specimens are about 1 mm . in length and .3 mm . in width. The species was found only at station no. 7 of Hex Creek. Length .78 mm .

Family Polymorphinidae d'Orbigny, 1839
Subfamily polymorphininae d'Orbigny, 1839
Genus Guttulina d'Orbigny in de la Sagra, 1839
Guttulina species.
(Plate 7, figures $3 \mathrm{a}, \mathrm{b}$.)
Individuals representative of this family are few in number in the Hex formation and as a rule quite small. Some of the smaller, more rounded species are so similar to the small, Nodosaria-Glandulina-like species that they are difficult to segregate with any assurance. A few specimens were found at station no. 5 of Devils Den and a few at no. 7 of Hex Creek.

## Plate 6

All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection.

Figure 1. Frondicularia frankei Cushman. Length 3.19 mm .; side view. Hypotype no. 13004 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 557.

Figure 2. Dentalina species. Length 1.90 mm .; side view. Hypotype no. 13005 (CAS). From Locality 40091 (CAS), sample 6, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 545.

Figure 3. Nodosaria cf. N. tenuicosta Reuss. Length 1.15 mm .; side view. Hypotype no. 13006 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 543.

Figure 4. Vaginulina debilis (Berthelin). Length 1.64 mm .; side view. Hypotype no. 13007 (CAS). From Locality 40091 (CAS), sample 8, deep north-south gully, east side of Devils Den, sample farthest north from mouth, NW. Kern County, California. Page 546.

Figure 5. Nodosaria cf. N. tenuicosta Reuss. Length .92 mm .; side view. Hypotype no. 13008 (CAS). From Locality 40091 (CAS), sample 8, deep north-south gully, east side of Devils Den, sample farthest north from mouth, NW. Kern County, California. Page 543.

Figure 6. Vaginulina octocostata Church, new species. Length .86 mm .; side view. Hypotype no. 13009 (CAS). From Locality 40091 (CAS), sample 8, deep north-south gully, east side of Devils Den, sample farthest north from mouth, NW. Kern County, California. Page 546.

Figure 7. Lingulina californiensis Trujillo. Length .45 mm .; side view. Hypotype no. 13010 (CAS). From Locality 40081 (CAS), and 27501, 47 (FAM). East-west gully $1 / 2$ mile east of Devils Den, NW. Kern County, California. Page 560.

Figure 8. Marginulina sigali Bartenstein, Bettenstaedt and Bolli. Length .61 mm ; side view. Hypotype no. 13011 (CAS). From Locality 40091 (CAS), sample 5, deep northsouth gully east side of Devils Den, NW. Kern County, California. Page 549.

Figure 9. Marginulinopsis gracillissima Reuss. Length .49 mm .; side view. Hypotype no. 13021 (CAS). From Locality 40091 (CAS), sample 6, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 551.

Figure 10. Frondicularia frankei Cushman. Side view. Hypotype (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 557.

Figure 11. Lingulina species. Length .52 mm .; side view. Hypotype no. 13013 (CAS). From Locality 40091 (CAS), sample 6, deep north-south gully, east side of Devils Den, NW. Kern County, California.

Figure 12. Marginulina pyramidalis Koch. Length 1.09 mm .; side view. Hypotype no. 13014 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 549.

Figure 13. Nodosaria hexensis Church, new species. Length 1.01 mm .; width .24 mm .; side view. Holotype no. 13015 (CAS). From Locality 40091 (CAS), sample 5, deep northsouth gully, east side of Devils Den, NW. Kern County, California. Page 544.

Figure 14. Vaginulina striolata (Reuss). Length 1.07 mm .; side view. Hypotype no. 13016 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 547.


## Genus Globulina d'Orbigny in de la Sagra, 1839

Globulina cf. G. ampulla (Jones).
(Plate 8, figure 4.)
Polymorphina ampulla Jones, 1852, Quart. Jour. Geol. Soc., vol. 8, p. 267, pl. 16, fig. 14.
Polymorphina lactea Plummer, 1927, Bull. 2644, Univ. Texas, p. 121, pl. 6, figs. 7 a-c.
Globulina ampulla (Jones), Cushman and Ozawa, 1930, Proc. U. S. Nat. Mus., vol. 77, art. 6, no. 2829, p. 79, pl. 19, figs. 9 a-c.

There is considerable variation in these lower Cretaceous species. Most specimens are well rounded and globular but some compressed. The lower initial end is distinctly pointed in some but only suggested in most of them. It is a fairly common species at station no. 5 of Devils Den. Length .48 mm .

## Globulina prisca Reuss.

Globulina prisca Reuss, 1862 (1863), Stiz. Akad. Wiss. Wien, vol. 46, pt. 1, p. 79, pl. 9, fig. 8. Cushman and Ozawa, 1930, Proc. U. S. Nat. Mus., vol. 77, art. 6, no. 2829, p. 73, pl. 12, figs. $6 \mathrm{a}-\mathrm{c}$.

This is not a common species here and was found only at station no. 5 of Devils Den.

Genus Pseudopolymorphina Cushman and Ozawa, 1928
Pseudopolymorphina cf. P. leopolitana (Reuss).
Polymorphina leopolitana Reuss, 1851, Haidinger's Nat. Abhandl., vol. 4, p. 28, pl. 4, fig. 11. Pseudopolymorphina leopolitana (Reuss), Cushman and Ozawa, 1930, Proc. U. S. Nat. Mus., vol. 77, no. 2829, art. 6, p. 108, pl. 28, figs. 4 a-c.

This is an extremely rare species as only one was found at station no. 7 of Hex Creek.

Genus Pyrulina d'Orbigny, 1826
Pyrulina species.
(Plate 7, figure 5.)
A single, well preserved specimen of the genus was found at station no. 5 of Devils Den. Length 1.16 mm .

Subfamily ramulininae, Brady, 1884
Genus Ramulina Jones in Wright, 1875

## Ramulina spandeli Paalzow.

Ramulina spandeli Paalzow, 1917, Schwammergel, p. 46, pl. 47, fig. 15. Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Helv. vol. 50, no. 1, p. 42, pl. 5, fig. 106.

This is not an uncommon species at Devils Den stations nos. 1, 2, and 5 but in most of its occurrences it is found in fragments.

# Family Nonionidae Schultze, 1854 Subfamily chilostomellinae <br> Genus Quadrimorphina Finlay, 1939 

Quadrimorphina cf. Q. ruckeri (Tappan).
(Plate 8, figures $1 \mathrm{a}, \mathrm{b}, \mathrm{c} ; 2 \mathrm{a}, \mathrm{b}$. )
Pallaimorphina ruckeri Tappan, 1957, U. S. Nat. Mus., Bull., 215, p. 221, pl. 71, figs. 1-9.
This very small species is very similar to $Q$. albertensis Mellon and Wall but the chambers are much less inflated. It was found rather commonly at stations 4 and 5 of Devils Den but not at Hex Hill. Length .18 mm .

## Family Alabamanidae Hofker, 1951 <br> Genus Gyroidina d'Orbigny, 1826

Gyroidina globosa (Hagenow) Cushman.
(Plate 8, figures $3 \mathrm{a}, \mathrm{b}, \mathrm{c}$.)
Nonionina globosa Hagenow, 1842, Neues Jarb., p. 574.
Rotalia globosa Reuss, 1861, Akad. Wiss. Wien, Math. naturwiss. K1. Sitzungsber., vol. 44, pt. 1, p. 330, pl. 7, figs. 2 a, b.
Gyroidina globosa Cushman, 1931, Jour. Paleo., vol. 5, no. 4, p. 310, pl. 35, figs. 19 a-c.
This long-ranging species is one of the commoner forms at stations nos. 7 and 8 of Hex Creek and no. 15 of Hex Hill. Length .40 mm .

Superfamily Cassidulinacea d'Orbigny, 1839<br>Family Anomalinidae<br>Subfamily anomalininae<br>Genus Gavelinella Brotzen, 1942

Gavelinella barremiana Bettenstaedt.
(Plate 8, figures $6 \mathrm{a}, \mathrm{b}, \mathrm{c}$.)
Gavelinella barremiana Bettenstaedt, 1952, Senckenbergiana, vol. 33, no. 4/6, p. 275, pl. 2, figs. 26-29. Bartenstein, Bettenstaedt, and Bolli, 1957, Eclog. Geol. Helv., vol. 50, no. 1, p. 47 , pl. 7, figs. 168 a-c; 169 a-c.

This is one of the common species in samples 7 and 8 of Hex Creek. It was also found at no. 15 of Hex Hill. The species was described from the middle Barremian of Germany by Bettenstaedt but ranges somewhat higher. It has also been described from the lower Cretaceous of Trinidad, British West Indies. Length .47 mm .

Family Cibicididae Cushman, 1927
Subfamily planulininae Bermudez, 1952
Genus Planulina d'Orbigny, 1826
Planulina andersoni Church, new species.
(Plate 8, figures 7 a, b, c.)
Test trochoid, biconvex, dorsal side gently convex, ventral side compressed but with a slight convexity and central depression, periphery subacute, partially evolute on dorsal side, involute or nearly so on the ventral side, periphery only faintly lobulate, chambers distinct throughout, 12 in final whorl, uninflated and increasing gradually and uniformly as added, sutures broad, strongly recurved and prominent because of lighter color and elevation above the chamber surface near the outer curve of test, sutures tend to merge at outer edge to form a smooth edged keel, wall perforate, smooth, aperture a low arch with narrow bordering lip at the peripheral margin, extending a short distance into the umbilical area on the ventral side. Length .42 mm ., width .33 mm .

Holotype no. 13033 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40091 (CAS), from deep north-south trending V-shaped gully beginning 500 feet south and 700 feet west of the east quarter corner of Section 20, Township 25 south, Range 18 east, Mount Diablo base and meridian, Devils Den area, Kern County, California. Sample no. 5, east bank of gully near base, approximately 150 feet north of the mouth of the gully; C. C. Church collector; early Cretaceous.

Remarks. This species is fairly common where it occurs at the Devils Den locality at stations nos. 1 to 5 but was not found at Hex Hill. It is somewhat similar to Anomalina popenoei Trujillo from the upper Cretaceous of the Sacramento Valley, California and also bears a general resemblance to Planulina spissocostata Cushman from the Taylor marl of Texas, U. S. A. From the former it differs in having more chambers, a smoother periphery and being less sharply keeled and from the latter in having fewer chambers per whorl, a more rounded keel and no buildup of calcite near the umbilicus. Named in honor of the late Dr. F. M. Anderson.

Superfamily Orbitoidacea Schwager, 1876
Family Eponididae Hofker, 1951
Genus Eponides de Montfort, 1808

## Eponides species.

This is one of the rare species in the Devils Den assemblage and the only representative of the genus found in this lower Cretaceous fauna. It is of moderate size, trochospiral, about equally biconvex, four slightly lobed chambers visible on the ventral side, edge smoothly rounded. Found only at stations nos. 4 and 5 of the Devils Den series.

Plate 7
All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection.

Figure 1. Praebulimina species. Length .32 mm .; (a) side view; (b) end view. Hypotype no. 13017 (CAS). From Locality 40091 (CAS), sample 4, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 570.

Figure 2. Globanomalina hexensis Church, new species. Length .28 mm .; width .22 mm .; (a) side view; (b) apertural view. Holotype no. 13018 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 571.

Figure 3. Guttulina species. Length .71 mm .; (a) side view; (b) apertural view. Hypotype no. 13019 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 563.

Figure 4. Hedbergella planispira (Tappan). Length .21 mm .; (a) ventral view: (b) dorsal view; (c) apertural view. Hypotype no. 13020 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 571.

Figure 5. Pyrulina species. Length 1.16 mm .; side view. Hypotype no. 13021 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California, Page 565.

Figure 6. Involutina stinemeyeri Church, new species. Length .44 mm .; width .41 mm.; side view. Holotype no. 13022 (CAS). From Locality 40091 (CAS), sample 6, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 565.

Figure 7. Nodosaria humilis Roemer. Length .69 mm .; side view. Hypotype no. 13023 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 541.

Figure 8. Gubkinella californica Church, new species, Length .19 mm ., width .15 mm ; side view. Holotype no. 13024 (CAS). From Locality 40091 (CAS), sample 6, deep northsouth gully, east side of Devils Den, NW. Kern County, California. Page 573.

Figure 9. Ammodiscus glabratus Cushman and Jarvis, Length .61 mm .; side view. Hypotype no. 13025 (CAS). From Locality 40092 (CAS), west side of most easterly deep gully of Hex Hill, NW. Kern County, California. Page 533.

Figure 10. Darbyella species. Length .69 mm. ; (a) dorsal view; (b) ventral view; (c) apertural view. Hypotype no. 13026 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 555.


# Superfamily Robertinacea Reuss, 1850 <br> Family Ceratobuliminidae <br> Subfamily epistomininae Wedekind, 1937 <br> Genus Epistomina Terquem, 1883 

## Epistomina cf. E. caracolla caracolla (Roemer).

(Plate 8, figure 5.)
Gyroidina caracolla Roemer, 1841, Kreidegeb., p. 97, pl. 15, fig. 22.
Epistomina djaffaensis Sigal, 1952, Crétacé, p. 14, fig. 7.
Epistomina (Hoglundina) caracolla caracolla (Roemer, 1841), Sigal, 1957, Eclog. Geol. Helv., vol. 50, no. 1, p. 46, pl. 5, figs. 113, 114; pl. 6, fig. 142.

In the state of preservation of this species it is difficult to determine internal structure and apertural characters but because of the outer similarity to the species E. caracolla caracolla, it is compared to that species. It is one of the common species of the Devils Den area where it was found at stations nos. 3 to 6. There is quite a range in the size but the largest ones measure up to one millimeter in maximum width. Length .62 mm .

Superfamily Cassidulinacea d'Orbigny, 1839
Family Involutinidae Bütschli, 1880
Genus Involutina Terquem, 1862
Involutina stinemeyeri Church, new species.
(Plate 7, figure 6.)
Test free, calcareous, perforate, lenticular, consisting of a proloculus followed by a nonseptate, planispirally, coiled tubular second chamber, sides of equal thickness and curvatures as a result of the growth of secondary calcite over the primary coil which is slightly thicker over central area and becoming thinner near the edge, surface deeply pitted from the termination of small, calcite pillars which are part of the secondary deposit, the overgrowth covering all coils except the last which may be partially covered, diameter of the tube increases very gradually, most specimens having six coils, the tube being lunate in cross section. Length .44 mm . Width .41 mm .

Holotype no. 13022 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40091 (CAS), from deep north-south trending V-shaped gully beginning 500 feet south and 700 feet west of the east quarter corner of Section 20, Township 25 south, Range 18 east, Mount Diablo base and meridian, Devils Den area, Kern County, California. Sample no. 6, east bank of gully near base, approximately 150 feet north of the mouth of the gully; C. C. Church collector; early Cretaceous.

Remarks. The earlier described species of Involutina were largely from the upper Triassic and lower Jurassic (Lias). I have found only one listed from California and it was from the upper Cretaceous Panoche formation of Fresno

County. It was described by Lewis Martin. This species is finely arenaceous and from the more recent analysis of the history of the genus by Loeblich and Tappan (1961), it would have to be classified as an Ammodiscus. Our species was found rather common at Devils Den Localities nos. 2 and 6. It is a very distinctive species and should prove to be a good marker fossil.

Superfamily Buliminacea Jones, 1875
Family Turrilinidae Cushman, 1927
Subfamily turrilininae Cushman, 1927
Genus Praebulimina Hofker, 1953
Praebulimina species.
(Plate 7, figures 1 a, b.)
The generic assignment of this species is very much in question. As in Bulimina and Praebulimina, it is high spired and triserially arranged, but as the test has been filled with calcite the aperture is not clearly defined. The apertural face is flattened and near the top edge of the final chamber there is a narrow, slit-like channel which follows the curve of the apertural face over a third to one half the distance from the top to its base. This may be the aperture but it could be a growth feature. The only species which I have seen figured which has an aperture somewhat similar to it is Praebulimina seabeensis Tappan from the Seabee formation of the upper Cretaceous of Alaska. The aperture of this species is slit-like but lower down on the face. On the present species there is a darker line which seems to be wider than a suture at the base of the apertural face. It is possible that this feature may have been the aperture rather than the upper facial channel. This species was found only at station no. 4 at Devils Den. Length .32 mm .

Superfamily Robertinacea Reuss, 1850
Family Ceratobuliminidae Cushman, 1921
Subfamily ceratobulimininae Cushman, 1927
Genus Conorboides Hofker in Thalmann, 1952
Conorboides species.
A number of what appears to be this genus were found at sample Locality no. 4 of Devils Den. In its chamber arrangement and shape it is very similar to Conorboides umiatensis (Tappan) from the Grandstand formation of northern Alaska of Albian age. The Devils Den species differs in having a much higher spire, a somewhat flatter and more deeply cleft ventral side. The apertural characters are concealed by a secondary extraneous deposit and the complete crystallization of the test. Length .18 mm .

# Superfamily Globigerinacea Carpenter, Parker and Jones, 1862 <br> Family Hantieninidae Cushman <br> Genus Globanomalina Haque, 1956 

Globanomalina hexensis Church, new species.
(Plate 7, figures $2 \mathrm{a}, \mathrm{b}$.)
Test minute, free, calcareous, planispiral, partially involute, biumbilicate, chambers globose to broadly oval, smooth, finely perforate, sutures depressed, radial, chambers enlarge gradually and evenly with growth, seven in final whorl, aperture a low equatorial arch at base of final chamber with narrow lip which ends abruptly at side of previous whorl with no lateral openings. Diameter . 35 mm ; thickness of final chamber .15 mm . Found only in the Hex Hill area at station no. 7 where it was fairly common and at station no. 15 where it was quite rare. Length .28 mm ., width .22 mm .

Holotype no. 13018 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40095 (CAS), sample no. 7, from the lower slope of a south-facing small ridge projecting into Hex Creek from the west causing it to veer to the northeast, about 1150 feet south and 200 feet east of the north quarter corner of Section 31, Township 25 south, Range 18 east, Mount Diablo base and meridian, Hex Hill area, Kern County, California; C. C. Church collector; early Cretaceous.

## Family Rotaliporidae Sigal, 1958

Subfamily hedbergellinae Loeblich and Tappan, 1961
Genus Hedbergella Brönniman and Brown, 1958

## Hedbergella planispira (Tappan).

(Plate 7, figures $4 \mathrm{a}, \mathrm{b}, \mathrm{c}$.)
Globigerina planispira Tappan, 1943, Jour. Paleo., vol. 17, no. 5, p. 513, pl. 83, fig. 3.
Praeglobotruncana planispira (Tappan), Bolli, Loeblich, and Tappan, 1957, U. S. Nat. Mus., Bull. 215, p. 40, pl. 9, fig. 3.
Hedbergella planispira (Tappan), Loeblich and Tappan, 1961, Micropaleontology, vol. 7, no. 3, p. 276, pl. 5, figs. 4-11. Neagu, 1965, Micropaleontology, vol. 11, no. 1, p. 36, pl. 10, figs. 1-4.

This very small species was found at station no. 7 of Hex Creek in some abundance and at station no. 8 in fewer numbers. At Station no. 15 of Hex Hill they were present but rare. The species was also found at no. 4 of Devils Den but was not of common occurrence. This species is also very similar to Globigerina infracretacea Glaessner. Length .21 mm .

## Plate 8

All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection.

Figure 1. Quadrimorphina cf. Q. ruckeri Tappan. Length . 18 mm .; (a) dorsal view; (b) ventral view ; (c) peripheral view. Hypotype no. 13027 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 566.

Figure 2. Quadrimorphina cf. Q. ruckeri Tappan. Length .18 mm ; (a) dorsal view; (b) ventral view. Hypotype no. 13028 (CAS). From Locality 40091 (CAS), sample 4, deep north-south gully east side of Devils Den, NW. Kern County, California. Page 566.

Figure 3. Gyroidina globosa (Hagenow). Length .40 mm .; (a) dorsal view; (b) ventral view; (c) peripheral view. Hypotype no. 13029 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 566.

Figure 4. Globulina cf. G. ampulla (Jones). Length . 48 mm .; side view. Hypotype no. 13030 (CAS). From Locality 40091 (CAS), sample 8, deep north-south gully, east side of Devils Den, mostly northerly sample from mouth, NW. Kern County, California. Page 565.

Figure 5. Epistomina cf. E. caracolla caracolla (Roemer). Length .62 mm .; dorsal view. Hypotype no. 13031 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 569.

Figure 6. Gavelinella barremiana Bettenstaedt. Length . 47 mm .; (a) dorsal view; (b) ventral view ; (c) peripheral view. Hypotype no. 13032 (CAS). From Locality 40095 (CAS), sample 7, Hex Creek, NW. edge of Hex Hill, NW. Kern County, California. Page 566.

Figure 7. Planulina andersoni Church, new species. Length .42 mm ., width .33 mm .; (a) dorsal view; (b) ventral view; (c) peripheral view. Holotype no. 13033 (CAS). From Locality 40091 (CAS), sample 5, deep north-south gully, east side of Devils Den, NW. Kern County, California. Page 567.


## Family Heterohelicidae Cushman, 1927

Subfamily guembelitrinae Montanaro Gallitelli, 1957
Genus Gubkinella Suleymanov, 1955
Gubkinella californica Church, new species.
(Plate 7, figure 8.)
This species is somewhat similar to G. asiatica Suleyma (1955) except that in the final four chambers of the present species, the chamber size increases very slightly from the first to the fourth of the last four chambers while the change from the first to the second whorl is so great that in some specimens the first whorl appears to be almost a separate individual attached to the four globular chambers. Gubkinella californica also resembles Gümbelitria harrisi Tappan from the Grayson formation of northern Texas, but is shorter and the globular chambers more compact; it also has four chambers to a whorl.

Gubkinella californica Church is very small, having a height of .15 mm . to .2 mm . and a width of .2 mm . In a few specimens the width may be greater than the height, four chambers to a whorl with three whorls, the aperture is a low arch at the base of the last-formed chamber, test calcareous, finely perforate, trochospiral; the inflated chambers suggest that the species was pelagic. It was found only at Devils Den where it was of quite common occurrence at stations nos. 4 and 6 but since the two samples were collected at different times and the first not located by a marker, they may be from the same spot. Length . 19 mm . Width .15 mm .

Holotype no. 13024 (California Academy of Sciences, Department of Geology Type Collection), from Locality 40091 (CAS), from deep north-south trending V-shaped gully beginning 500 feet south and 700 feet west of the east quarter corner of Section 20, Township 25 south, Range 18 east, Mount Diablo base and meridian, Devils Den area, Kern County, California, sample no. 6, east bank of gully near base, approximately 200 feet north of the mouth of the gully; C. C. Church collector; early Cretaceous.

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## PROCEEDINGS

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# THE PLANT GENUS POLYGALA IN THE GALÁPAGOS ISLANDS 

By<br>John Thomas Howell<br>Curator of Botany, Califormia Academy of Sciences<br>and<br>Duncan M. Porter<br>Assistant Professor of Biology, University of San Francisco

The five taxa of Polygala Linnaeus on the Galápagos Islands are endemics and all are similar morphologically. They perhaps represent a radiation from a single past introduction from mainland South America, similar to those radiations postulated for the justly famous Darwin's finches and the plant genus Scalesia. They are members of Polygala section Polygala series Tenues Chodat, and appear to be most closely related to $P$. paludosa St. Hilaire or $P$. paniculata Linnaeus, two widespread species of the New World tropics.

Both authors have had field experience in the Galápagos Islands. Howell was botanist on the Templeton Crocker Galápagos Expedition of the California Academy of Sciences from April to June, 1932, and later was able to examine type material of the taxa in question in several European herbaria. Porter visited the archipelago in January and February, 1967, while assisting Dr. Ira L. Wiggins in a study of its flora under a National Science Foundation grant to the California Academy of Sciences. Both authors wish to express their gratitude to Dr. Wiggins and to the California Academy of Sciences for making this study possible.


Key to the Species and Varieties of Polygala in the Galápagos Islands

1. Stems puberulent; wings $5-7$-nerved; aril $1 / 3$ as long as seed $-\ldots--\quad-\quad-\quad-\quad$ 1. $P$. anderssonii
2. Stems glabrous; wings $3-5$-nerved; aril about $1 / 9$ as long as seed.
3. Apical crest of keel inconspicuous, not showy or petaloid, divisions simple or 2 -lobed, final lobes $6-8$; wings $3.5-5 \mathrm{~mm}$. long, 3-nerved.
4. Leaves linear to oblanceolate-elliptic, acute to cuspidate; racemes becoming elongate, acute, $1.5-12 \mathrm{~cm}$. long; wings $3.5-4$ (or 5) mm. long $\qquad$
2a. P. galapageia var. galapageia
5. Leaves oblanceolate to linear-lanceolate, obtuse to acute; racemes more congested, oblong or rounded, obtuse to subacute, $1-4 \mathrm{~cm}$. long; wings $4-5 \mathrm{~mm}$. long

2b. $P$. galapageia var. insularis
2. Apical crest of keel conspicuous, showy and petaloid, divisions frequently 3lobed, final lobes $12-16$; wings $4-6.5 \mathrm{~mm}$. long, 5 -nerved.
4. Leaves broadly spathulate to rotundate, $6-13 \mathrm{~mm}$. long, $3-8 \mathrm{~mm}$. wide

3a. $P$. sancti-georgii var. sancti-georgii
4. Leaves narrowly to broadly oblanceolate, $8-25 \mathrm{~mm}$. long, $1-4 \mathrm{~mm}$. wide

3b. P. sancti-georgii var. oblanceolata

## 1. Polygala anderssonii Robinson.

Polygala puberula Andersson, Kongliga Vetenskaps-Akademiens Handlingar, 1853, p. 232, 1855. Andersson, Kongliga Svenska Fregatten Eugenies Resa omkring jorden . . .ảren 1851-1853, Botanik, vol. II, p. 100, 1861. Robinson and Greenman, American Journal Science, series 3, vol. 50, p. 145, 1895. Not P. puberula Gray, Plantae Wrightianae Texana -Neo-Mexicanae part I, p. 40, 1852 (Smithsonian Contributions to Knowledge, vol. 3, art. 5).
Polygala galapageia A. W. Bennett in part as a synonym, Journal Botany, vol. 17, p. 204, 1879.

Polygala anderssonii Robinson, Proceedings American Academy, vol. 38, p. 160, 1902. Stewart, Proceedings California Academy Sciences, series 4, vol. 1, p. 85, 1911. Chiristophersen, Nyt Magazin for Naturvidenskaberne, vol. 70, p. 80, 1932.

Suffruticose (perennial?), to 1 m . high, rarely branched basally; stems spreading, puberulent, becoming glabrate below, yellowish or rarely reddish; leaves alternate, linear-lanceolate to oblanceolate, acuminate, puberulent to subglabrate, coriaceous, $4-17 \mathrm{~mm}$. long, $1-1.5 \mathrm{~mm}$. wide; petioles less than 1 mm . long; racemes becoming elongate, 3-9 cm. long, about 1 cm . wide, axis puberulent; flowers white to pale purple; pedicels 1 mm . long, glabrous; bracteoles caducous; outer sepals ovate, acute, glabrous, green, margins white, more or less equal, $1.5-2 \mathrm{~mm}$. long, 1 mm . wide; wings petaloid, obovateelliptic, obtuse, glabrous, 5-7-nerved, $3.5-4.5 \mathrm{~mm}$. long, about 2 mm . wide, longer than capsule; corolla about 3 mm . long; apical crest of keel 12-14-lobed, less than 1 mm . long; capsule oblong, glabrous, equally 2 -loculed, loculicidally dehiscent, $3.5-4 \mathrm{~mm}$. long, about 2 mm . wide; seeds 1 per locule, obconical, apex obtuse and more or less apiculate, base attenuate, dark, shortly lanate, trichomes more or less appressed apically, 2.5-3 mm. long; aril elliptical, 2-lobed, obtuse, white, $1 / 3$ as long as seed.

Specimens examined. Galápagos, Cuming 103 (CGE,K). Isabela: Cowley Bay, not abundant, Stewart 1775 (CAS,K). San Salvador: west of lava flow at James Bay, Howell 9720 (flowers white, more or less tinged with lavender; CAS). Santa Cruz: Andersson (S, type of $P$. puberula Anderssun); north shore, Snodgrass \& Heller 668 (DS) ; north side, abundant in light ashy soil near shore, Stewart 1778 (CAS); northwest side, abundant in tufaceous soil near shore, Stewart 1779 (CAS); in more open spaces in restricted area of Croton forest northwest of Academy Bay, 50 feet, G. Taylor 7 (CAS); south of Conway Bay, Baur 13 (DS,K).

## 2. Polygala galapageia Hooker fil.

2a. Polygala galapageia var. galapageia.
Polygala galapageia Hooker fil., Transactions Linnaean Society, Botany, vol. 20, p. 233, 1847. A. W. Bennett, Journal Botany, vol. 17, p. 204, 1879. Robinson and Greenman, American Journal Science, series 3, vol. 50, p. 145, 1895. Robinson, Proceedings American Academy, vol. 38, p. 160, 1902. Stewart, Proceedings California Academy Sciences, series 4, vol. 1, p. 85, 1911.
Polygala galapageja Andersson, Kongliga Vetenskaps-Akademiens Handlingar, 1853, p. 232, 1855. Andersson, Kongliga Svenska Fregatten Eugenies Resa omkring jorden . . . åren 1851-1853, Botanik, vol. II, p. 100, pl. 10, fig. 1 (m, n, o), 1861.
Polygala galopagensis Chodat, Mémoires Société de Physique et d'Histoire Naturelle, vol. 31, p. 230, 1893.

Suffrutescent perennial, to about 1 m . high, herbage more or less glaucous; stems spreading, glabrous, reddish below, yellowish above; leaves alternate, numerous, linear to oblanceolate-elliptic, acute to cuspidate, glabrous, coriaceous, $5-15 \mathrm{~mm}$. long, $1-1.5 \mathrm{~mm}$. wide; petioles less than 1 mm . long; racemes becoming elongate, acute, $1.5-12 \mathrm{~cm}$. long, about 1 cm . wide; flowers white or whitish; pedicels less than 1 mm . long, glabrous; bracteoles caducous; outer sepals ovate, acute, glabrous, green, margins white, more or less equal, about 1.5 mm . long; wings petaloid, obovate-elliptic, attenuate, glabrous, 3-nerved, $3.5-4$ (or 5) mm . long, 2 mm . wide, more or less equaling capsule; corolla $2-3$ mm . long; apical crest of keel inconspicuous, 4-parted and each part simple or 2-lobed, less than 1 mm . long; capsule oblong, glabrous, equally 2-loculed, loculicidally dehiscent, $3-3.5 \mathrm{~mm}$. long, 1.5 mm . wide; seeds 1 per locule, obconical, apex obtuse and more or less apiculate, base attenuate, dark, shortly lanate, trichomes more or less appressed apically, $2-2.5 \mathrm{~mm}$. long; aril narrowly elliptical, 2 -lobed, white, about $1 / 5$ as long as seed.

Specimens examined. Floreana: Darvin (CGE, type), Edmonston (K), Andersson (S). Isabela: Macrae (CGE,K); Tagus Cove, Crossland 443 (K), Howell 9510 (stems yellow, leaves green, flowers whitish tinged lavender, CAS), Snodgrass \& Heller 142 (DS), Snow 307, 327 (DS), abundant from beach to 600 feet, Stewart 1774 (CAS). Marchena: Snodgrass \& Heller 763 (DS). San Cristóbal: Snodgrass \& Heller 494 (DS); lower region, southwest end,

Baur 9 (K); Puerto Chico, 20 m., Schimpff 172 (CAS); Wreck Bay, bushy plant 2-3 feet high, Howell 8609 (CAS), abundant in sandy soil near shore, Stewart 1777 (CAS).

The type specimens of $P$. galapageia and $P$. obovata Hooker fil. [P. galapageia var. insularis (A. W. Bennett) Robinson] in the University of Cambridge herbarium are very different in appearance, which would account for treating them as distinct species. This difference is due largely to the shapes of the leaves: in var. galapageia linear-oblanceolate or linear-oblong and pungently acute; in var. insularis broader and obtuse. Although the wings in var. galapageia are usually shorter than in var. insularis, the wings in flowers of the type of $P$. galapageia are 5 mm . long, the longest measured in any specimen referable to the typical variety.

## 2b. Polygala galapageia var. insularis (A. W. Bennett) Robinson.

Polygala obovata Hooker Fil., Transactions Linnaean Society, Botany, vol. 20, p. 233, 1847. Andersson, Kongliga Vetenskaps-Akademiens Handlingar, 1853, p. 231, 1855. Andersson, Svenska Fregatten Eugenies Resa omkring jorden . . åren 1851-1853, Botanik, vol. II, p. 99, pl. 10, fig. 2 ( $\mathrm{c}-\mathrm{i}, \mathrm{k}-\mathrm{m}, \mathrm{p}$ ), 1861. Robinson and Greenman, American Journal Science, series 3, vol. 50, p. 146, 1895. Not P. obovata St. Hilaire, Flora Brasiliae Meridionalis, vol. 2, p. 37, 1835.
Polygala obovata fma. angustifolia Andersson, Kongliga Vetenskaps-Akademiens Handlingar, 1853, p. 232, 1855. Andersson, Kongliga Svenska Fregatten Eugenies Resa omkring jorden ...âren 1851-1853, Botanik, vol. II, p. 99, 1861. P. obovata var, angustifolia (Andersson) Riley as a synonym, Kew Bulletin, 1925, p. 219, 1925.
Probably also: $P$. obovata fma. latifolia Andersson, Kongliga Vetenskaps-Akademiens Handlingar, 1853, p. 231, 1855. Andersson, Kongliga Svenska Fregatten Eugenies Resa omkring jorden ... åren 1851-1853, Botanik, vol. II, p. 99, 1861. P. obovata var. latifolia (Andersson) Riley as a synonym of $P$. sancti-georgii, Kew Bulletin, 1925, p. 219, 1925.

Polygala chatamensis Andersson, Kongliga Vetenskaps-Akademiens Handlingar, 1853, p. 232, 1855. Andersson, Kongliga Svenska Fregatten Eugenies Resa omkring jorden . . .åren 1851-1853, Botanik, vol. II, p. 99, pl. 10, fig. 3 (p, q, r), 1861. P. galapageia [var. galapageia] Robinson in part as a synonym, Proceedings American Academy, vol. 38, p. 160, 1902.

Polygala insularis A. W. Bennett, Journal Botany, vol. 17, p. 204, 1879. Robinson and Greenman, American Journal Science, series 3, vol. 50, p. 146, 1895.
Polygala galapageia var. insularis (A. W. Bennett) Robinson, Proceedings American Academy, vol. 38, p. 161, 1902. Stewart, Proceedings California Academy Sciences, series 4, vol. 1, p. 86, 1911.

Differing from var. galapageia in having stems $30-45 \mathrm{~cm}$. high, reddish; leaves oblanceolate to linear-lanceolate, obtuse to acute, more or less apiculate, 6-10 mm. long, 1--2 mm. wide; racemes oblong or rounded, obtuse to subacute, $1-4 \mathrm{~cm}$. long, about 1 cm . wide; wings $4-5 \mathrm{~mm}$. long.

Specimens examined. Galápagos, Andersson (K), Andersson 181 (K). Floreana: "Charles and Chatham," Andersson (S). Marchena: occasional in
tufaceous soil near the shore, Stewart 1776 (CAS,K). Pinta: fairly abundant on lava beds in lower part, Stewart 1773 (CAS). San Cristóbal: Darwin (CGE, type of $P$. obovata Hooker fil.), Andersson (S, type of $P$. chatamensis Andersson, GH, isotype), Andersson 182 (K) ; northern Chatham, Buur 7 (K); Cerro Brujo, north coast, Snow 350 (DS); Sappho Cove, abundant on sand beaches, Stewart 1782 (CAS). Santa Cruz: Academy Bay, common on lower parts, Stewart 1783 (CAS).

Riley (Kew Bull., 1925, p. 219) was probably in error when he referred Andersson's broad-leaved form of $P$. obovata to $P$. sancti-georgii. Neither at Stockholm nor at Kew was an Andersson specimen seen that would be referable to $P$. sancti-georgii. It would seem probable that Andersson was distinguishing by name the two leaf-forms of $P$. galapageia which are represented by his collections. These formal names, however, were not seen on any Andersson collections, a fact that adds to the difficulty of placing them definitely.

The type of $P$. chatamensis Andersson would appear to represent a seedling stage of $P$. galapageia var. insularis, although in general aspect it looks more like var. galapageia. However, in the type of $P$. chatamensis, the leaves, although linear-oblong or linear-oblanceolate, are obtuse, the inflorescence is shortcongested and rounded above, and the wings are over 4 mm . long. These details do not correspond to Andersson's figure of $P$. chatamensis which is more like P. galapageia var. galapageia.

## 3. Polygala sancti-georgii Riley. <br> 3a. Polygala sancti-georgii var. sancti-georgii.

Polygala sancti-georgii Riley, Kew Bulletin, 1925, p. 218, 1925.
Polygala obovata var. latifolia Riley as a synonym, Kew Bulletin, 1925, p. 219, 1925.
Probably not $P$. obovata fma. latifolia Andersson, Kongliga Vetenskaps-Akademiens Handlingar, 1853, p. 231, 1855, basonym of Riley's name.
Herbaceous annual, $15-50 \mathrm{~cm}$. high, herbage glaucous; stems spreading, glabrous, reddish; leaves alternate, usually numerous and crowded, broadly spathulate to rotundate or rarely narrowly spathulate, obtuse, cuspidate, glabrous, coriaceous, blade decurrent into petiole, $6-13 \mathrm{~mm}$. long, $3-8 \mathrm{~mm}$. wide; petioles less than 1 mm . long; racemes $1.5-3.5(-6) \mathrm{cm}$. long, 1.5 cm . wide; flowers purplish to white; pedicels 1 mm . long, glabrous; bracteoles caducous; outer sepals ovate, acute, glabrous, green, margins white, more or less equal, $1.5-2 \mathrm{~mm}$. long, 1 mm . wide; wings petaloid, ovate-elliptic, more or less obtuse, glabrous, 5 -nerved, $6-6.5 \mathrm{~mm}$. long, $2-3 \mathrm{~mm}$. wide, longer than capsule; corolla about 3 mm . long; apical crest of keel conspicuous, petaloid, 14-16-lobed, about 1 mm . long; capsule oblong, glabrous, equally 2 -loculed, loculicidally dehiscent, $3.5-4 \mathrm{~mm}$. long, 2 mm . wide; seeds 1 per locule, obconical, apex obtuse and more or less apiculate, base attenuate, dark, shortly lanate, trichomes more or less appressed apically, $2.5-3 \mathrm{~mm}$. long; aril narrowly elliptical, 2-lobed, white, about $1 /$ as long as seed.

Specimens examined. Galápagos, Mr. Brace (K). Floreana: Hicks 424 (K, type); Cormorant Bay, abundant on sand beaches, Stewart 1780, 1781 (CAS), sand dunes, Wiggins \& Porter 564 (CAS); Post Office Bay, beaches and environs at east end, Wiggins $\mathcal{F}$ Porter 531 (CAS).

As mentioned under $P$. galapageia var. insularis, no specimens of $P$. sanctigeorgii were seen among Andersson's collections either in Stockholm or Kew. Hence, it is believed that his $P$. obovata forma latifolia should be referred to $P$. galapageia var. insularis, not to $P$. sancti-georgii. The epithet, sancti-georgii, is taken from the name of the yacht, St. George, which in 1924 visited the Galápagos Islands on the "St. George Pacific Expedition," under the auspices of the Scientific Expeditionary Research Association of England.

## 3b. Polygala sancti-georgii var. oblanceolata Howell.

Polygala sancti-georgii var. oblanceolata Howell, Leaflets of Western Botany, vol. 10, p. $351,1966$.

Differing from var. sancti-georgii in having stems $25-60 \mathrm{~cm}$. high; leaves narrowly to broadly oblanceolate, obtuse to acute, $8-25 \mathrm{~mm}$. long, $1-4 \mathrm{~mm}$. wide; racemes $2-7(-12) \mathrm{cm}$. long, $1-1.5 \mathrm{~cm}$. wide; flowers light to deep lavender; wings oblanceolate-elliptic, $4-6 \mathrm{~mm}$. long, $2-2.5 \mathrm{~mm}$. wide; corolla 3.5 mm . long; apical crest of keel $12-14$-lobed, about 1.5 mm . long, lobes broad and pink; seeds 2.5 mm . long.

Specimens examined. Rábida: slopes at north end, Howell 9737 (stems and leaves glaucous, flowers light to deep lavender, CAS, type), DeRoy $\mathcal{E}$ DeRoy 31 (DS), Baur 6, 8 (GH), north side, elevation 50 feet, Bowman, 30 July 1957 (CAS). San Salvador: near the shore, Sulivan Bay, Howell 10021 (stems and leaves glaucous, flowers white tinged lavender, CAS). Santa Cruz: Conway Bay, Baur 4 (GH, K), near the shore, Howell 9851 (CAS), sandy patch near the coast, Cheesman 400 (K); 2 miles inland, Cheesman 401 (K).

## PROCEEDINGS

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# A Flora of the san bruno mountains SAN MATEO COUNTY, CALIFORNIA 

By<br>Elizabeth McClintock<br>Califormia Academy of Sciences<br>San Francisco, California<br>and<br>Walter Knight<br>Regional Parks Botanic Garden<br>Berkeley, California<br>In collaboration with<br>Neil Fahy<br>Standard Oil Company<br>San Francisco, Califomia

## INTRODUCTION

The San Bruno Mountains in northern San Mateo County and the hills in San Francisco County, California, constitute the northern outliers of the Santa Cruz Mountains. The San Bruno Mountains have remained relatively undisturbed, except for the City of Brisbane and today constitute an "island" entirely surrounded by metropolitan areas. The covering of vegetation on the San Bruno Mountains contains many of the plants which once were found to the north in San Francisco where only fragmentary remnants of the natural vegetation remain. However, the pressure of metropolitan development is moving toward the San Bruno Mountains and soon some of their sections will undergo changes. This flora records the plants to be found there before these changes occur.


Figure 1. San Bruno Mountains looking north to the City of San Francisco and Mount Tamalpais, showing locations of faults and fault blocks on the San Francisco Peninsula.

## A Bit of History (by Neil Fahy)

When members of the Portolá Expedition discovered San Francisco Bay in 1769, they also were the first Europeans to see San Bruno Mountain, the main ridge of the range. Five years later, 1774, Fernando Rivera and four soldiers climbed the mountain and from its summit watched the sunrise across the bay. The mountain was named the following year by Bruno Hecata for his patron saint.

The San Bruno Mountain region included portions of the five Mexican land grants indicated on figure 2. Rancho Buri Buri was granted to José Antonio Sánchez, who as a child rode mule-back from Sonora, Mexico, to San Francisco with Anza in 1776. Sánchez received the grant in 1827 and had it confirmed in 1835. The rancho extended from the salt flats on the Bay west to San Andreas Valley and from Colma south to Burlingame.

The rancho with the longest name also included most of the mountain and the Crocker Hills. Cañada de Guadalupe, la Visitación y Rodeo Viejo included in its name three identifiable places, Guadalupe Valley, the site of Brisbane and Crocker Industrial Park; the Visitacion Valley district of San Francisco; and the old rodeo grounds along Islais Creek from Daly City to the intersection of Alemany Boulevard and Mission Street. The rancho was requested in 1835 by Miguel Sánchez but his petition was denied. However, it was given in the following year to Jacob P. Leese a naturalized Mexican citizen and a prominent


Figure 2. Mexican land grants of San Bruno Mountains and vicinity.
figure in early Bay Area history. The southern boundary of Leese's rancho is traced approximately by Hillside Boulevard. Leese later traded the rancho to Robert Ridley for one in Sonoma County but Ridley had financial problems and the rancho was divided and sold. Robert Eaton acquired 70 acres and Alfred Wheeler acquired the rest. After American acquisition, the patent of Henry R. Payson to 5473 acres was approved in 1865. The rancho was further subdivided and in 1872 the Visitacion Land Company had the largest holdings. In 1884 Charles Crocker acquired the holdings of the Visitacion Land Company which were 3814 acres of the original land grant. In the following year he acquired the Wheeler parcel comprising 183 acres lying on the shore of San Francisco Bay. When Crocker's estate was distributed in 1891, his lands passed to the Crocker Estate Company, present owners of the San Bruno Mountains.

Three ranchos touched the northern portion of the San Bruno Mountains. The rancho in Visitacion Valley known as Cañada de Guadalupe y Rodeo Viejo was included in Leese's rancho of 1841 but was later separated from it. In 1865 it was granted to William Pierce. The rancho which contained Bernal Heights, Hunters Point, and the area south to San Bruno Mountain was Rincon de las Salinas y Potrero Viejo (which in translation refers to the corner of the salt marsh and the old pasture). This was granted in 1839-1840 to José Bernal, the son of Juan Bernal, a soldier in Anza's expedition of 1776. The San Miguel rancho, including Mt. Davidson and Twin Peaks, was granted to José de Jesus Noé in 1845.

Several cities have grown up surrounding the mountains. On the north is San Francisco. On the northeastern slope of the higher ridge is Brisbane. Formerly known as Visitacion City, the name Brisbane was adopted when the post office was established in 1931. The name was changed to avoid confusion with the Visitacion Valley district of San Francisco. To the south is South San Francisco, the name used from 1849 through the 1880's for the area between Hunters Point and Islais Creek. The present South San Francisco was founded by a subsidiary of G. F. Swift as a meat packing center. The name was adopted when the area was incorporated in 1908. To the west are Colma and Daly City. Originally, Colma was a stop on the San Francisco-San Jose Railroad. It was called Colma in the 1870's and the name was given to the post office in 1891. Daly City was named in 1911 for John Daly, a local property owner.

## Topography (by Neil Fahy)

"The name 'San Bruno Mountains' [is] given to the short range which extends in a direction diagonal to the peninsula from Sierra Point nearly across to the Pacific." On the north it is ". . . separated by a low divide from the group of hills on the San Miguel Ranch, to which the name of San Miguel Hills may be given." This is the extent of the San Bruno Mountains as recorded in 1865 by the Geological Survey of California under the leadership of J. D. Whitney. The "hills on the San Miguel Ranch" culminate in Mount Davidson, 929 feet, the highest point in San Francisco.

San Mateo County contains two distinct, northwest-trending mountain ranges separated by the Merced Valley which lies to the southwest and south of the San Bruno Mountains where part of Daly City, all of Colma, and part of South San Francisco are located. The western range, the backbone of the county, is the northern continuation of the Santa Cruz Mountains. The eastern range is the San Bruno Mountain region, with the highest point, Radio Peak, 1314 feet above the sea (fig. 3, no. 33).

The San Bruno Mountain region is itself composed of two parallel, northwesttrending ranges, separated for over half their length by Guadalupe Valley (fig. 3, no. 43). The ranges are united by the ridge or saddle at the northern end of Colma Canyon (fig. 3, no. 36). The southern range, San Bruno Mountain proper, extends from Sierra Point on San Francisco Bay to near San Diego Avenue in San Francisco. It is the higher range and rises abruptly from Merced Valley about 1000 feet in a horizontal distance of $3 / 4$ of a mile. The northern range, the Crocker Hills (fig. 3, no. 47), extends from Visitacion Point on the bay to the vicinity of the Guadalupe School in San Francisco. Its summit is about 850 feet high.

The region is drained by two main streams and several smaller ones. They are all intermittent. Guadalupe Creek, flowing through Guadalupe Valley, has its headwaters in Wax Myrtle, Dairy, and Romanzoffia ravines (fig. 3, nos. 21,


Figure 3. San Bruno Mountains. Key to numbered location on pages 602 and 603.

22, 23). Colma Creek, the other main stream, has its source below the Flower Garden [in April Brook], and flows westward for a short distance, parallel to Guadalupe Valley Parkway, and then enters Colma Canyon. The canyon of Colma Creek makes a deep cleft in the mountain where it enters Merced Valley (at Market Street in Daly City). The minor streams are mainly in ravines on the southwest flank of the southern range. In the Crocker Hills, Islais Creek which bears the Salinan Indian name for the Hollyleaf Cherry (Prumus ilicifolia), had its headwaters near today's Mission Drive-In Theater. Houses and freeways have altered its course.

The eastern shoreline of the mountain group during the Mission Period had the bay lapping against the sandstone cliffs. Today the shoreline is bay-fill.

## GEOLOGY (by Neil Fahy)

## Rock Types

The great bulk of San Bruno Mountain and the Crocker Hills is composed of late Cretaceous ( 100 million years old) dark greenish-gray graywacke of the Franciscan Formation. This is a poorly sorted sandstone made up of angular rock fragments, detrital chert, and with more than 10 percent feldspar. The angular, unsorted content indicates it was derived from the rapid erosion of the
source area and rapid burial in a subsiding depositional basin. Fossils are rare. The graywacke is exposed in the steep canyons and on the ridge crests but only as isolated knobs on the gentle slopes. Excellent exposures are visible along the Guadalupe Valley Parkway and Radio Road. The Franciscan Formation is the name applied to a group of rock types first described from the San Francisco area.

Small lenses of a hard, brittle, siliceous rock called chert are exposed near Telford and Diamond streets in South San Francisco and at Point San Bruno. The marine origin of the chert is indicated by the abundance of microscopic opaline skeletons of radiolaria, one-celled marine organisms.

Serpentine, the California State rock, outcrops on Point San Bruno, but industrialization has concealed much of it. Two very small serpentine areas are present near Serbian Ravine.

There are areas of poorly consolidated sand at the head of Colma Canyon in The Meadow and along the western base of the mountain. The sand was originally thought to be dune sand but later work has questioned this.

The largest area of recent depositon is in the Guadalupe Valley which contains alluvial deposits eroded from the surrounding hills.

Soil
Because San Bruno Mountain is composed almost entirely of one rock type, there is little variation in the type of soil. It is all derived from the Franciscan graywacke. The varying factor is the soil depth. The graywacke produces a relatively thin soil on the steep slopes and a thicker soil on the gentle slopes.

## Faults

The northern portion of the San Francisco Peninsula is composed of a series of northwest-trending earth blocks bounded by faults or zones of weakness. These blocks are named and indicated on figure 1. They are from north to south: the Telegraph Hill block, the San Miguel Hills block, the San Bruno Mountain block, the Cemetery block, and the Merced Valley block. The two which make up the San Bruno Mountain region are the San Bruno Mountain and the Cemetery blocks.

The City College fault, which extends in an arc from Lands End through the City College of San Francisco to the bay at Visitacion Valley, forms the northern boundary of the San Bruno Mountain block. The Hillside fault forms the southern boundary. At present (1967) no fault evidence has been found to account for the abrupt termination of the San Bruno Mountains at Sierra Point. There are, however, many small faults throughout the mountain. The Cemetery block is bounded by the Hillside fault in the north and the Merced Valley in the south.

## Structure

San Bruno Mountain and the Crocker Hills are part of a great asymmetrical
arch or anticline whose axis roughly coincides with Ridge Road. The dipping strata are visible in most of the earth cuts along Radio Road and the Guadalupe Valley Parkway. It should be noted that the strata generally dip away from the mountain.

## History

The San Bruno Mountain landscape began to develop about 130 million years ago in the Cretaceous Period. At that time the western portion of California was beneath a sea whose eastern shore was lapping against the base of the ancestral Sierra Nevada. Great quantities of sediment were deposited in the Cretaceous sea. Some of these sediments can be seen as the rocks of San Bruno Mountain.

The present Coast Range landforms began to form about a million years ago. A buckling of the earth's crust produced fracture zones along which earth blocks moved relative to one another. One of the elevated fault blocks was San Bruno Mountain.

## Economic Geology

Gold and zinc have been mined from the San Bruno Mountains in past years. The gold occurred in quartz veins in the graywacke. Several uneconomic claims were filed in the Crocker Hills just south of the county line, but little development work was done.

Two veins of zinc ore were discovered near Diamond Avenue in South San Francisco in 1919. A 75 -foot shaft was sunk and a 6 -foot vein was worked for a few years.

The only mineral products from the mountain at present are crushed rock and sand.

## CLIMATE AND WEATHER

Weather data for the San Bruno Mountains which was supplied by the Crocker Land Company ${ }^{1}$ confirmed observations made on our plant collecting forays. The San Bruno Mountains stand alone on the San Francisco Peninsula, unprotected from the atmospheric conditions which bring about their weather pattern (see figure 4).

Wind. Wind on the San Bruno Mountains displays the marked diurnal and seasonal patterns which characterize the San Francisco Peninsula. However, data for March to June 1967, taken from the Crocker Hills Survey (p. 11), show that wind speeds are greater at comparable times at a site on the mountain area than in the nearby City of San Francisco. Wind speeds are less in mornings

[^34]

Figure 4. Aerial view of the San Francisco Peninsula looking west and north with the San Bruno Mountains in the middleground. The San Francisco Airport is in the immediate foreground.
and increase from early to mid-afternoon. Speeds are greater in June than in March. Matched data are given below:

Table 1. Mean Wind Speeds-Crocker Hills vs. San Francisco City (page 11, Crocker Hills Survey).

| 1967 | ${ }_{C H}^{10} \text { A.11. P.S.T. }$ |  | 1 P.M. |  | 4 P. 11. |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| March | 10 | 8 | 13 | 10 | 13 | 12 |
| April | 10 | 9 | 12 | 12 | 13 | 12 |
| May | 11 | 9 | 13 | 14 | 15 | 15 |
| June | 13 | 9 | 15 | 14 | 18 | 16 |

Visitors to the San Bruno Mountains will notice that some sites are more windy than others owing to its irregularity of terrain and the distribution of the several colonies of planted trees. Available data show that some of the windiest sites, obviously those most exposed, are: (1) the 1314-foot summit, (2) the junction of Radio Road and the road to the Nike Base, and (3) the Nike Base. Kamchatka Point which always seemed to us to be very windy and bleak was actually less windy than these three sites.

Data for wind speeds at night on the highest and most exposed points, such
as the 1314 -foot summit and the long ridge to the east, are not available. However, on nights when winds were known to be strong at these sites, it was estimated from known recorded speeds for Mount Tamalpais, in nearby Marin County, that wind speeds on the San Bruno Mountains summit and ridge may have reached to 50 to 80 miles per hour in gusts up until midnight.

Wind direction varies with the time of the day and with the season. During winter the morning to afternoon pattern is frequently north becoming northwest, and a change to a southerly direction indicates that stormy weather can be expected. During summer months wind flow is frequently southwest becoming west.

Fog. An extensive low fog cover is dominant over the San Bruno Mountains during the months of July through August when the summer fog regime prevails along the central California coast. The fog cover, however, does not usually extend over the entire area of the mountains during an entire day, but tends to cover only the western section while the eastern section, with Guadalupe Valley and the City of Brisbane, frequently remain in the sunshine. Data from the Crocker Hills Survey, page 17, comparing the number of foggy days between a site in Guadalupe Valley and a site in the Crocker Hills, show that in the months from March to May the Crocker Hills site was foggier on 30 percent of the days, and in June to July on 79 percent of the days, than at the Guadalupe Valley site. Frequently during afternoons the fog bank has been observed for several hours in a practically stationary position over the western half of the mountain area. During these periods the fog lies so close to the ground that a moisture drip is produced from the trees of Eucalyptus globulus.

Temperature. The generally cool and mild temperatures characteristic of the coastal part of the San Francisco Peninsula prevail on the San Bruno Mountains. "The seasonal range of temperature is small, in keeping with the predominant flow of marine air over the site. Mean daily maximums range from about $56^{\circ} \mathrm{F}$. in winter to about $66^{\circ} \mathrm{F}$. in fall. Mean daily minimums are above freezing during all months. However, several daily minimums below freezing are to be expected during the winter and early spring, particularly on clear, quiet nights when extensive cold-air drift occurs in the gullies and canyons. The lowest minimum temperature likely over the long term is $20^{\circ} \mathrm{F}$.
"The elevation of the site tends to produce lower summer temperatures and warmer winter temperatures on the average than found at nearby sea-level stations. For example, summer fog on the site is associated with afternoon temperatures near $52^{\circ} \mathrm{F}$., while sea level temperatures are frequently 5 degrees higher at the San Francisco airport and 20 degrees higher at Palo Alto ( 20 miles to the south). Warmer winter site temperatures are likely on the slopes and knolls in the morning hours whenever the general wind regime is weak (about $1 / 3$ of the time). Under these conditions the exposed parts of the site are frequently in or near the upper and warmer part of the radiation inversion layer that begins at sea level." (Crocker Hills Survey, Appendix A, page 3.)

Rainfall. "Total yearly rainfall on the site is estimated to be somewhat
greater than at San Francisco or about 22 inches. . . The mean number of days per year with measurable rain (snow is rare) is about 66, mostly during the months November-April." (Crocker Hills Survey, Appendix A, page 3.) Rain is rare during the remainder of the year.

## VEGETATION

The area of the San Bruno Mountains covered by this flora contains about 3000 acres and reaches 1314 feet at the highest point. Although a relatively small area, the topography is sufficiently irregular to provide suitable habitats for four of the plant communities which occur in the Santa Cruz Mountains. These are grassland, coastal scrub, foothill woodland, and salt marsh. Grassland covers the largest portion of the area, all of the Crocker Hills, the entire southeastern slopes, and most of lower western slopes of the taller southern range. A mixture of native and introduced grasses and such associates as Brodiaea laxa, B. pulchella, Sisyrinchium bellum, Ranunculus californicus, Lupinus namus, L. bicolor, Sidalcea malvaeflora, Sanicula arctopoides, Plantago erecta, and Baeria chrysostoma may be found in this plant community.

Coastal scrub occurs in some of the ravines and canyons such as Colma Canyon, the upper part of Buckeye Canyon, and Islay Ravine. Some of the characteristic species are: Anaphalis margaritacea, Achillea millefolium, Artemisia californica, Eriogonum latifolium, Baccharis pilularis var. consanguinea, Diplacus aurantiacus, Rhus diversiloba, and Lupimus arboreus.

Coastal woodland is best developed in lower Buckeye Canyon. Aesculus californica, Quercus agrifolia, and Umbellularia californica make a fairly dense woodland.

The Salt Marsh community occurs at Point San Bruno and Sierra Point but little of it remains today.

## Colma Canyon Watershed

Colma Canyon is accessible from the eastern end of Market Street in Daly City. In late 1964 a paved road called Guadalupe Parkway was completed along the floor of the canyon and from there to the junction with Radio Road. The thoroughfare now continues along the southeast edge of the Crocker Hills and joins old Bayshore Highway north of Brisbane.

The construction of Guadalupe Parkway left the steep slopes of Colma Canyon, with its floristically interesting plant cover, unchanged, but it did change the course of Colma Creek. Originally only a foot trail wound along the creek. Equestrians and hikers would meander through the vegetation along the water's edge. The creek ran all year around and occasional pools would invite youthful swimmers who would be secluded by the overhanging boughs of Coulter and arroyo willows, salmonberry, lady fern, twinberry, snowberry, and creek dogwood which provided shelter from the brisk afternoon winds.

Along the present parkway on the lower slopes of the canyon can still be seen elegant displays of lady ferns, salmonberries, and Coulter willow. Creek dogwood, however, no longer remains due to construction of the parkway. Along the canyon sides from the creek to the ridges, particularly in the vicinity of the rocky outcroppings one can find coast barberry (Berberis pinnata), poison oak (Rhus diversiloba), red berry (Rhammus crocea), holly leaf cherry (Prumus ilicifolia), California polypody (Polypodium californicum), spreading dudleya (Dudleya cymosa), bluff lettuce (Dudleya farinosa), Pacific stonecrop (Sedum spathulifolium), seaside daisy (Erigeron glaucus), rock cress (Arabis blepharophylla), and serviceberry (Amelanchier pallida).

At the mouth of Colma Canyon, especially on the south side, is a sand deposit reminiscent of the former dune areas in the western part of San Francisco. Here are found typical coastal dune plants such as yellow beach lupine (Lupinus arboreus), blue beach lupine (Lupinus chamissonis), sand mat (Cardionema ramosissimum), California whitlowwort (Paronychia franciscana), spine-flower (Chorizanthe pungens var. hartwegii), and dune knotweed (Polygonum paronychia). This dune area continues through the mountain to the southeast and appears again at the mouth of Pig Ranch Ravine. Besides a partial representation of the Colma Canyon dune plants, this odoriferous ravine is the only locality on the mountain for the California croton (Croton californicus).

As one proceeds up Colma Canyon in the areas where the soil has accumulated humus in the decomposed sandstone, the vegetation cover consists of a soft chaparral interspersed with herbs and grasses. This vegetation, which also inhabits the little side ravines fingering out from the canyon, includes buckwheat (Eriogonum latifolium), California sagebrush (Artemisia californica), sticky monkeyflower (Diplacus autantiacus), dwarf chaparral broom (Baccharis pilularis), phacelia (Phacelia californica), pennyroyal (Monardella villosa var. franciscana).

There are no trees in the canyon proper but introduced eucalyptus (Eucalyptus globulus) and cypress (Cupressus macrocarpa) trees are to be seen along Radio Road. Many of the cypresses have their trunks adorned with the leather fern (Polypodium scouleri) growing as an epiphyte as high as 20 feet. This epiphytic habitat is probably subsidized by the extreme moisture from the heavy fogs which roll through the entrance of Colma Canyon. For this reason, the cypress grove has been called the Fog Forest.

The upper part of Colma Canyon opens into a large slightly sloped flat area, which we call the Great Meadow, a grassland punctuated with an occasional dark green prostrate mat of the dwarf chaparral broom (Baccharis pilularis). Along the broad upper slopes draining into the Great Meadow are sheets of dark yellow color in July consisting of lizard tail (Eriophyllum stacchadifolium). In August on adjacent slopes there are spreading white blankets of pearly everlasting, California's most beautiful cudweed (Anaphalis margaritacea).

To the south of the Great Meadow extending gradually uphill for about a mile is April Brook Ravine. April Brook is damp during all the seasons of the year and it empties into Colma Creek near a colony of Coulter willows (Salix coulteri) just below the Great Meadow. The drainage areas of April Brook Ravine are more gradual than the more steep slopes of Colma Canyon.

In the spring, on the eastern slopes of April Brook Ravine, there are sizeable colonies of goldfields (Baeria chrysostoma), which well substantiate the common name. In colonies equally as large are white masses of johnny-tuck (Orthocarpus erianthus). On occasional slopes between Radio Road and April Brook are colonies of both coast iris (Iris longipetala) and Douglas iris (Iris douglasiana). Even though their flowering times partially overlap, there has never been evidence of any interbreeding between the two irises. Also in this area the two native wild strawberries, Fragaria californica and $F$. chiloensis, occur together.

An unusual distributional record in the April Brook drainage area is the occurrence of the dune tansy (Tanacetum camphoratum) at the edge of Radio Road near Summer Seep. In this same watershed are serviceberry (Amelanchier pallida), coffeeberry (Rhammus californica), and Indian hemp (Apocynum pumilum).

The only other sizeable area draining ultimately into Colma Canyon is Cable Ravine. It is accessible from Radio Road about a half mile south of Guadalupe Parkway intersection at a eucalyptus grove. Up this little ravine is the only locality hereabouts of salal (Gaultheria shallon) on a very prominent rocky outcrop which overlooks the lower reaches of the ravine. Progressing up the slope one can see in spring, colorful yellow patches of johnny-jump-up (Viola pedunculata). Nearby is the best display of bearberry manzanita (Arctostaphylos uvaursi) on the entire mountain forming a ground-hugging drape as it clings to the exposed grassy slope.

## The Ridge and its Ravines

A gravel-surface road extends for two miles east of the parking lot along the ridge. Both ends of the ridge are bisected by high voltage transmission lines. In spring on the south-facing slopes at the western end of the mountain are many plants of the bright red Indian paint brush (Castilleja franciscana), and during late spring and early summer crimson sage (Salvia spathacea) displays itself over a considerable acreage.

If one can endure the strenuous descent into the brushy ravines, thickets of poison oak (Rhus diversiloba) can be found with some plants almost arboreal in habit having trunks up to 11 inches in diameter. From the ravines, Ceanothus thyrsiflorus extends in large colonies up to the ridge road and in April its large clusters of blue flowers are a striking contrast against the dark green foliage.

The southeastern section of the mountain is almost exclusively grassland.
The north-facing slopes include ridges and ravines that are brushy in vary-
ing degrees with only a small amount of grassland. Starting near Brisbane and progressing toward the quarry California buckeyes, California laurels, California live oaks, and holly-leaf cherry are found in the ravines. Between the quarry and westward toward the parking lot and Radio Road can be seen a brushy mantle of vegetation consisting of evergreen huckleberry, manzanitas, and other woody plants interspersed with herbaceous perennials such as coast larkspur (Delphinium californicum), coast angelica (Angelica hendersonii), several species of Lomatium and Sanicula, and in the spring Heracleum maximum conspicuously whitens the ravines.

To the west of Lipman School in Brisbane is the base of the densely wooded ravine which we call Buckeye Canyon. California buckeyes occur along the intermittent creek in the lower part of the ravine. Advancing up the slope from the creek are shrubs of chaparral currant (Ribes malvaceum) and above these California laurels (Umbellularia californica) dominate the plant cover of the canyon. On the upper slopes of the canyon particularly around rocky outcropings are low shrubs of the gold-cup oak (Quercus chrysolepis var. nana).

On a windy promontory on the down-side of Radio Road as one approaches the first radio station, there is an area which is frequently so cold and windy that it has been named Kamchatka Point. Among the plants here are two unusual manzanitas, the evergreen huckleberry, and a deciduous huckleberry which we consider to be Vaccinium arbuscula, and another rarity, false lily-of-thevalley (Maianthemum dilatatum).

## Guadalupe Valley

Crocker Industrial Park now covers most of the valley. On the west end of the drainage are the botanically interesting Fern Rock and Wax Myrtle Ravine. Around Fern Rock are coastal wood fern (Dryopteris arguta), leather fern (Polypodium scouleri), western sword fern (Polystichum munitum), bracken fern (Pteridium aquilinum), and chain fern (Woodwardia fimbriata). In the ravine are fine specimens of wax myrtle (Myrica californica), and several herbaceous annuals and perennials including bleeding heart (Dicentra formosa). At the upper part of the ravine below the new Guadalupe Parkway are pitcher sage (Lepechinia calycina), cascading, compact shrubs of redberry (Rhammus crocea), and low dwarf shrubs of gold-cup oak (Quercus chrysolepis var. nana).

At the southwestern end of the valley is a large active quarry forming a wide chasm where it penetrates the main mountain ridge. Recent enlargement of the quarry eliminated a thicket of shrubs in which were creek dogwood (Cornus californica) and caast red elderberry (Sambucus callicarpa).

## Crocker Hills

This area constitutes the range of hills running east to west from the old Bayshore Highway to the spot designated on the aerial photograph as Reservoir Hill (fig. 3). It has a largely introduced and weedy collection of plants ac-
cented here and there by the spiny European gorse (Ulex europaeus). Despite its obnoxious qualities, the prolificly flowering gorse makes a dark yellow expanse of color in spring contrasting with adjacent sky lupine (Lupinus nanus) and two adventive members of the mustard family, wild radish (Raphanus sativus), and field mustard (Brassica campestris). An interesting concentration of plants abounds at Reservoir Hill in the spring and the little area should be visited at that time.

## Point San Bruno

Within the last 5 years much grading and filling has been done on this point of land which extends into the bay. It is a continuation of San Bruno Mountain and extends across the freeway. The interesting plants here were of a coastal strand type with wind-shorn, low-growing buckeye trees and willows along the top of the bluffs. Most of the bay below the bluffs has been filled. Little salt flat coves originally supported pickleweed (Salicornia pacifica), arrowgrass (Triglochin concinna), sea lavender (Limonium californicum), and Jaumea carnosa, but these are disappearing in the path of development.

Regeneration of Plants After Fire
Most plants of chaparral and coastal scrub are characterized by their ability to regenerate after fire by sprouting from root crowns. These basal structures are usually noticeably enlarged at, or just below, the ground level. Other plants not reproducing by crown sprouts sometimes produce abundant seedlings after a fire. During our four years of plant collecting on the mountain there have been fires in different areas. Listed here are the plants which we have observed to regenerate after some of these fires:

Plants stump sprouting after fire:

| Arctostaphylos pacifica | Quercus wislizeni |
| :--- | :--- |
| Baccharis pilularis | Rhamnus californica |
| Ceanothus thyrsiflorus | Rosa gymnocarpa |
| Diplacus aurantiacus | Rubus parviflorus |
| Heteromeles arbutifolia | Salix lasiolepis |
| Holodiscus discolor | Salvia spathacea |
| Monardella villosa var. franciscana | Sambucus callicarpa |
| Osmaronia cerasiformis | Symphoricarpos species |
| Prunus emarginata | Vaccinium ovatum |

Plants seeding abundantly after fire:

| Arctostaphylos imbricata | Grossularia californica |
| :--- | :--- |
| Arctostaphylos montaraensis | Lepechinia calycina |
| Artemisia californica | Ribes malvaceum |

## Plants of San Bruno Mountain Used as Ornamentals

Many of the colorful and attractive California native plants which are used as garden ornamentals may be seen in their native habitats on the San Bruno

Mountains. In the San Francisco Bay region are three botanical gardens where many of the San Bruno plants may be seen growing under garden conditions and where information regarding their culture may be obtained. Tilden Regional Park Botanic Garden, Berkeley, devoted entirely to growing and displaying California native plants, grows all of the plants which are listed here. The University of California Botanical Garden, Berkeley, and the Strybing Arboretum, Golden Gate Park, San Francisco, have sections devoted to California natives and some of the plants listed here may be seen at both gardens:
Allium dichlamydeum
Allium unifolium
Anaphalis margaritacea
Arabis blepharophylla
Arbutus menziesii
Arctostaphylos uva-ursi
Aristolochia californica
Baccharis pilularis
Berberis pinnata
Brodiaea laxa
Ceanothus thyrsiflorus
Clarkia rubicunda
Cornus californica
Delphinium californicum
Dicentra formosa
Diplacus aurantiacus
Dudleya cymosa
Dudleya farinosa
Erigeron glaucus
Erigeron philadelphicus
Erysimum franciscanum
Eschscholzia californica
Fragaria californica
Fragaria chiloensis
Garrya elliptica
Heteromeles arbutifolia
Heuchera micrantha

Allium dichlamydeum
Allium unifolium
Anaphalis margaritacea

Arbutus menziesii
Arctostaphylos uva-ursi
Aristolocha californica

Berberis pinnata
Brodiaea laxa
Ceanothus thyrsiflorus
Clarkia rubicunda
Cornus californica
Delphinium californicum
Dicentra formosa
Diplacus aurantiacus
Dudleya cymosa
Dudleya farinosa
Erigeron glaucus
ergeron philadelphicus

Eschscholzia californica
Fragaria californica
Fragaria chiloensis
Garrya elliptica
Heteromeles arbutifolia
Heuchera micrantha

> Holodiscus discolor
> Iris douglasiana
> Iris longipetala
> Maianthemum dilatatum
> Myrica californica
> Osmaronia cerasiformis
> Physocarpus capitatus
> Potentilla egedii var. grandis
> Prunus demissa
> Prunus emarginata
> Prunus ilicifolia
> Ribes malvaceum
> Romanzoffia suksdorfii
> Rosa californica
> Rosa gymnocarpa
> Rubus parviflorus
> Rubus spectabilis
> Satureja douglasii
> Sedum spathulifolium
> Sisyrinchium bellum
> Thalictrum polycarpum
> Trillium chloropetalum
> Vaccinium arbuscula
> Vaccinium ovatum
> Viola adunca
> Viola pedunculata
> Zauschneria californica

## Plant Collections

The collections on which this flora is based were begun early in 1963. They were made by Walter and Irja Knight (cited in the Catalogue of Plants as K ), E. McClintock (cited as McC), Philip Wheeler (cited as W), Javier Peñalosa (cited as P), Carlyn Halde, Virginia Ryder, J. H. Thomas, Peter Raven, Katherine Toschi, Arthur Menzies, James B. Roof, and Lewis Rose. The cited specimens are deposited in the Herbarium of the California Academy of Sciences except those collected by J. H. Thomas which are in the Dudley Herbarium, Stanford University.

## Place Names

When we began our plant collecting on San Bruno Mountain in early 1963 we found that there were only a few place names in general use for parts of the mountain. Since we needed to designate our collecting localities we assigned our own names to these places. Most place names regardless of their origin are listed here and are located approximately on the aerial photograph of the mountain region (fig. 3).

April Brook
Bitter Cherry Ridge
Blue Blossom Hill
Brisbane
Brisbane Ravine
Buckeye Canyon
Cable Ravine
Colma Canyon
Cow Trough Ravine
Crocker Avenue
Crocker Hills
Crocker Industrial Park
Dairy Ravine
Devil's Arroyo
Eucalyptus Grove
Fern Rock
Flower Garden
Fog Forest
Gladys Ravine
Glen Park Ravine in Brisbane
Guadalupe Valley
Islay Ravine
Juncus Ravine
Kamchatka Point
Manzanita Dike
35
181819
43 Radio Road ..... 37
22 ..... 16

Randolph Ravine, end Randolph Avenue 16
23
Romanzoffia Ravine
Reservoir Hill ..... 41
Ridge Road11
17 Serbian Cemetery ..... 9
Serbian Ravine (serpentine) ..... 8
Sierra Point ..... 45
Summer Seep ..... 42
Tank Ravine ..... 13
Trillium Gulch ..... 31
Wax Myrtle Ravine ..... 21

Monterey Pine 20
Nike Base 32
Olivet Cemetery 10
Olivet Ravine 6
Owl's Canyon 26
Parking Lot at summit 33
Pig Ranch Ravine 7
Point San Bruno 44
Poison Oak Ravine 12
Powerlines, East and West 34
Radio Road 37
-

1 Bitter Cherry Ridge
2 April Brook
3 Flower Garden
4 Kamchatka Point
5 Quarry watershed
6 Olivet Ravine
7 Pig Ranch Ravine
8 Serbian Ravine (serpentine)
9 Serbian Cemetery
10 Olivet Cemetery
11 Sage Ravine
12 Poison Oak Ravine
13 Tank Ravine
14 Juncus Ravine
15 Cow Trough Ravine

26 Owl's Canyon
27 Islay Ravine
28 Buckeye Canyon
29 Brisbane Ravine
30 Gladys Ravine
31 Trillium Gulch
32 Nike Base
33 Parking Lot
34 Powerlines, East and West
35 Devil's Arroyo
36 Colma Canyon
37 Radio Road
38 Ridge Road
39 Cable Ravine
40 Brisbane

| 16 | Randolph Ravine, end Randolph Avenue | 41 | Reservoir Hill |
| :--- | :--- | :--- | :--- |
| 17 | Fog Forest | 42 | Summer Seep |
| 18 | Eucalyptus Grove | 43 | Crocker Industrial Park in Guadalupe |
| 19 | Fern Rock |  | Valley |
| 20 | Monterey Pine | 44 | Point San Bruno |
| 21 | Wax Myrtle Ravine | 45 | Sierra Point |
| 22 | Dairy Ravine | 46 | Crocker Avenue |
| 23 | Romanzoffia Ravine | 47 | Crocker Hills |
| 24 | Manzanita Dike | 48 | Glen Park Ravine in Brisbane |
| 25 | Blue Blossom Hill |  |  |

Table 2. Tabulation of the Vascular Plants.

| $\begin{aligned} & \hline \text { Division } \\ & \text { Class } \\ & \text { Subclass } \end{aligned}$ | Family | Genus | Species Native | Introduced | Total |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Calamophyta | 1 | 1 | 2 |  | 2 |
| Pterophyta |  |  |  |  |  |
| Filicinae | 1 | 8 | 9 |  | 9 |
| Gymnospermae | 2 | 2 |  | 2 | 2 |
| Angiospermae |  |  |  |  |  |
| Monocotyledoneae | 10 | 52 | 69 | 28 | 97 |
| Dicotyledoneae | 64 | 256 | 304 | 128 | 432 |
|  |  |  | $\overline{384}$ | $\overline{158}$ | $\overline{542}$ |
|  |  |  | $71 \%$ | 29\% |  |

Table 3. List of the 10 largest families of vascular plants.

| Family | Number of genera | Number of species |
| :---: | :---: | :---: |
| Compositae | 52 | 90 |
| Gramineae | 27 | 49 |
| Cruciferae | 18 | 25 |
| Rosaceae | 15 | 2.3 |
| Leguminosae | 13 | 42 |
| Umbelliferae | 13 | 18 |
| Scrophulariaceae | 9 | 19 |
| Caryophyllaceae | 9 | 17 |
| Liliaceae | 10 | 15 |
| Labiatae | 10 | 13 |

Table 4. List of the largest genera.

| Lupinus, Trifolium | Number of species in each genus |
| :---: | :---: |
| Juncus | 10 |
| Rumex, Senecio | 8 |
| Carex, Festuca, Gnaphalium, Orthocarpus | 7 |
| Bromus, Lotus | 6 |

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## ANNOTATED CATALOGUE OF VASCULAR PLANTS

In the Flora of the San Bruno Mountains we have, in most instances, used the plant names in the Flora of the Santa Cruz Mountains of California by John Hunter Thomas (in 1961). Keys to the nearly 550 different kinds of plants of the San Bruno Mountains have not been included here since those in the Flora of the Santa Cruz Mountains are applicable. For ease of use by both amateur and professional botanists the sequence of families within their divisions, classes, and subclasses is alphabetical.

## DIVISION CALAMOPHYTA <br> Equisetaceae. Horsetail Family

Equisetum arvense Linnaeus. Common Horsetail. Rare, on wet ground. Colma Canyon, K May 30, 1964; Radio Road, W May 23, 1965.

Equisetum telmateia J. F. Ehrhart var. braunii (Milde) Milde. Giant Horsetail. Occasional, along streams and seepages. Colma Canyon, McC, Halde, K June 23, 1963; Cow Trough Ravine, K 341; Devil's Arroyo, McC March 28, 1965; Quarry, K July 14, 1963; Radio Road, K August 5, 1963.

## DIVISION PTEROPHYTA Class Filicinae <br> Polypodiaceae. Fern Family

Adiantum jordani K. Mueller. California Maidenhair Fern. Occasional, in damp protected places. Quarry, K July 14, 1963; Romanzoffia Ravine, McC, Menzies February 16, 1963; Owl's Canyon, K 1049; Colma Canyon, K March 15, 1964; Glen Park Canyon, McC, W May 14, 1967.

Athyrium filix-femina (Linnaeus) Roth. Western Lady Fern. Rare, in wet gullies. Base of Quarry, K July 14, 1963; Colma Canyon, along creek, McC, Halde, K June 23, 1963.

Dryopteris arguta (Kaulfuss) Watt. Coastal Wood Fern. Occasional, brushy, well drained slopes. Buckeye Canyon, $K$ August 5, 1963; Fern Rock, K July 14, 1963; Powerline Ridge, $M c C \mathcal{E} K$ September 2, 1965; 400 feet northeast of Parking Lot, $K$ February 28, 1963; Quarry, K July 14, 1963.

Pityrogramma triangularis (Kaulfuss) Maxon. Goldenback Fern. Rare, shaded well drained slopes. Dies back during winter. Harold Road, Brisbane, W December 30, 1966; Glen Park Canyon above Brisbane, McC April 16, 1967.

Polypodium californicum Kaulfuss. California Polypody. Occasional, rocky slopes. Cable Ravine, $\operatorname{McC}$ March 14, 1965 ; ravine $1 / 2$ mile east of 1314 -foot summit, $P 2700$; Romanzoffia Ravine, McC, Menzies February 16, 1963; Glen Park Canyon, McC April 16, 1967.

Polypodium scouleri Hooker \& Greville. Leather Fern. Occasional, crevices and surfaces of rocks and on tree trunks in Fog Forest. Fern Rock, K August 5, 1963; Fog Forest, on trunk of Monterey cypress, K September 2, 1964; Fog Forest, on trunk of blue gum, McC, Halde June 23, 1963; Cable Ravine, McC March 14, 1965.

Polystichum munitum (Kaulfuss) Presl. Western Sword-Fern. Common, in brushy and rocky areas. April Brook, W July 7, 1965; Colma Canyon, K March 15, 1964; Fern Rock, $K$ August 5, 1963; east facing slope below Parking Lot, McC, Halde June 23, 1963; West Powerline, McC March 28, 1965 (plants growing in an area burned during preceding autumn, were sprouting from crown); Trillium Gulch, McC March 28, 1965.

Pteridium aquilinum (Linnaeus) Kuhn var. pubescens Underwood. Bracken Fern. Widespread in grassland and on brushy slopes. Cable Ravine, McC March 14, 1965; Colma Canyon, McC, Halde, K June 23, 1963; Fern Rock, K August 5, 1963; West Powerline, McC March 28, 1965; slope below Parking Lot, McC June 9, 1963; east of Quarry, W June 19, 1965; Radio Road at Horseshoe Ridge, K August 5, 1965.

Woodwardia fimbriata J. E. Smith. Western Chain Fern. Rare, in moist places. Colma Canyon, W May 18, 1965.

CLASS GYMNOSPERMAE
Cupressaceae. Cypress Family
Cupressus macrocarpa Hartweg. Monterey Cypress. Large trees probably planted many years ago; some young trees spontaneous. Fog Forest along Guadalupe Road, $K$ August 5, 1963.

## Pinaceae. Pine Family

Pinus radiata D. Don. Monterey Pine. Single young tree, probably planted. Cable Ravine, K September 30, 1964.

## CLASS ANGIOSPERMAE <br> SUBCLASS DICOTYLEDONEAE <br> Aizoaceae. Carpet-weed Family

Mesembryanthemum edule Linnaeus. Hottentot-Fig. Planted as a groundcover and occasionally becomes naturalized as along Radio Road. Flowers spring and summer. Ornamental. Useful on banks and roadcuts. Native of South Africa.

Tetragonia tetragonioides (Pallas) Kuntze [Tetragonia expansa Murray]. New Zealand Spinach. Cultivated for food, it escapes and becomes naturalized in disturbed and marshy areas. Point San Bruno, K, McC September 2, 1964; Brisbane Lagoon, W August 14, 1965; trash dumps at west end of mountain, K 1081. Native of southeastern Asia, Australia, and New Zealand.

## Amaranthaceae. Amaranth Family

Amaranthus powellii Watson. Amaranth. Pig-Weed. Weed in disturbed areas. Abandoned quarry, near Hillside Boulevard and School Street, K October 7, 1963.

## Anacardiaceae. Sumac Family

Rhus diversiloba Torrey \& Gray. Poison-oak. Shrub with 3-foliolate leaves. It is variable in habit from subarborescent to shrubby and climbing, and in leaf shape and size. One of the common plants of the mountain, usually occurring with chaparral shrubs but in one locality, on a south facing slope at the base of Blue Blossom Hill, it occurs alone. The foliage turns reddish in autumn and is showy. Contact with any part of the plant may cause a dermititis in those individuals who are susceptible.

Schinus molle Linnaeus. Pepper Tree. Cultivated as an ornamental tree, occasionally becomes naturalized. Old Bayshore Highway, Brisbane, W October 16, 1966. Native of South America.

## Apocynaceae. Dogbane Family

Apocynum pumilum (Gray) Greene. Dogbane. Indian-Hemp. Rare, in grassy or rocky areas. Radio Road at Summer Seep, $K$ August 5, 1963; Radio Road, above Great Meadow, W June 20, 1965.

Vinca major Linnaeus. Periwinkle. Cultivated as a groundcover, escapes and becomes naturalized. Near Bayshore Highway, Brisbane, W June 8, 1965. Native of Mediterranean region.

## Araliaceae. Aralia Family

Hedera helix Linnaeus. English-Ivy. Cultivated as a vine or groundcover, escapes and becomes naturalized. Radio Road, near radio towers, W June 13, 1965. Native of Europe.

## Aristolochiaceae. Aristolochia Family

Aristolochia californica Torrey. Dutchman's Pipe. California Pipe Vine. Rare, grassy slope with scattered shrubs, growing on the ground or scrambling over shrubs. Edge of southern ravine of Glen Park Canyon, McC, W May 14, 1967. Deciduous scandant shrub with characteristically U-shaped flowers, February to May. It is interesting because of the unusual shape of its flowers which in some species are shaped like a pipe. Aristolochia californica is a California endemic from the northern half of the state, San Bruno being its southernmost known locality. Aristolochia, a large genus of about 450 species distributed mainly in tropical and subtropical regions, has pendulous flowers of an extraordinary form, often disagrecable odor, and complicated pollination mechanisms. Several, including A. califormica, are used as garden and greenhouse subjects for their unusual flowers.

## Berberidaceae. Barberry Family

Berberis pinnata Lagasca [Mahonia pinnata (Lagasca) Fedde]. Coast Barberry. Frequent at rock outcroppings. In open windswept habitats it tends to be low-growing. Reservoir Hill, Menzies March 14, 1965 ; Radio Road at Horseshoe Ridge, K August 5, 1963 ; Radio Road near radio towers, McC, Menzies February 16, 1963; Nike Base, K March 15, 1964; Quarry, K982; Colma Canyon, McC, Halde, K June 23, 1963 ; Ridge Road near West Powerline, $M c C, K$ September 2, 1963. Flowers March to May. Attractive evergreen shrub throughout the year; the yellow flowers are showy in the spring and the new foliage which precedes the flowers is glossy and reddish-green. Ornamental.

## Betulaceae. Birch Family

Corylus californica (A. DeCandolle) Rose. California Hazel. Occasional, in ravines or along creeks. Colma Canyon, K March 15, 1964; upper Bitter Cherry Ravine in a thicket, K 1110; Quarry, K June 24, 1963; Owl's Canyon, W June 7, 1965. One of the mountain's interesting deciduous shrubs with flowers in pendant catkins in early spring before the leaves, and small edible nuts in autumn. Ornamental.

## Boraginaceae. Borage Family

Allocarya chorisiana (Chamisso) Greene. Rare, in damp ground. Point San Bruno, K April 24, 1965; Devil's Arroyo, K 1100; Ridge Road at West Powerline, McC, K May 16, 1965; Upper Colma Canyon, McC, W June 11, 1967.

Amsinckia intermedia Fischer \& Meyer. Fiddleneck. Frequent in grassland and disturbed areas. Colma Canyon, McC, Halde, K June 23, 1963; Bitter Cherry Ridge, K May 4, 1964; Romanzoffia Ravine, K May 4, 1964; Devil's Arroyo, K 1089; Owl's Canyon, K 1088; Ridge Road at West Powerline, K April 13, 1964; Ridge Road at Brisbane Powerlines, K March 21, $1965^{\circ}$; Brisbane Ravine, W March 30, 1965.

Cryptantha hispidissima Greene. Rare, in grassland. Devil's Arroyo, K 1124; Quarry, $K$ July 14, 1963. A stiff, bristly herbaceous plant, with small white flowers May to July.

Cryptantha micromeres (Gray) Greene. Occasional, edge of chaparral, sometimes in burned over areas. In a ravine to west of Radio Road, K April 25, 1964; Trillium Gulch, McC March 28, 1965; Devil's Arroyo, McC March 28, 1965; West Powerline, K 1091. Plants often form dense colonies, and have a profusion of small white flowers, April to June

Cynoglossum grande Douglas ex Lehmann. Hound's Tongue. Occasional, in grassland and chaparral, sometimes in burned over areas. Ridge Road, in a ravine $1 / 2$ mile east of Parking Lot, P 2684; Romanzoffia Ravine, K March 21, 1965; Brisbane Ravine, W March 30, 1965; Trillium Gulch, K 1021; Glen Park Canyon, McC, W May 14, 1967. Sometimes used as an ornamental for its attractive basal leaves and blue, forget-me-not-like flowers, February to April.

Myosotis latifolia Poiret. Forget-me-not. An escape from cultivation, grows along roadsides, stream sides and in shaded areas. Guadalupe Road, K August 5, 1963; April Brook, W May 18, 1965; Brisbane Ravine, W May 25, 1965. Flowers in spring and summer. Native of Europe and North Africa.

## Callitrichaceae. Water Starwort Family

Callitriche marginata Torrey. Water Starwort. Rare, floating in water of stream, or on surface of mud at edge of stream. Randolph Ravine, P 2738. The tiny green plants are usually numerous enough to be conspicuous, often forming mats.

## Campanulaceae. Bellflower Family

Triodanus biflora (Ruiz \& Pavon) Greene. Venus' Looking Glass. Rare, in grassland and edge of chaparral. Crystal Cave Canyon, $K 1125$, and $W$ June 19, 1965. The small blue to lavender flowers are axillary and sessile, in June. May become weedy.

## Caprifoliaceae. Honeysuckle Family

Lonicera hispidula Douglas ex Lindley. Honeysuckle. Scandant on adjacent plants or sometimes on ground. Rare. Radio Road, K August 5, 1963.

Lonicera involucrata (Richardson) Banks ex Sprengel [L. ledebourii Eschscholtz]. Twinberry. Rare, along streams and in shade of chaparral. Colma Creek, McC, Halde, K June 23, 1963. (Much of Colma Creek was destroyed by road construction, therefore Twinberry may no longer be growing at this locality.) Bitter Cherry Ravine, K April 4, 1965. Flowers April to June. Ornamental both in flower and fruit.

Lonicera japonica Thunberg. Japanese Honeysuckle. Escape from cultivation, along roadsides and disturbed places. Crocker Avenue near intersection with Guadalupe Road, $K$ September 2, 1964. Native of Japan.

Sambucus callicarpa Greene. Red Elderberry. Rare, brushy ravines, edge of chaparral. Near Olivet Cemetery, W May 18, 1965; base of Devil's Arroyo, McC March 28, 1965 ; Quarry, K June 24, 1963; Ridge Road near West Powerline, McC, K September 2, 1963, and J. Roof March 27, 1966. Flowers March and April. Stump sprouts following fire. Ornamental particularly in fruit.

Sambucus mexicana Presl ex DeCandolle. Blue Elderberry. Rare, brushy ravines, edge of chaparral. Quarry, K June 24, 1963; Buckeye Canyon, K August 5, 1963; Point San Bruno, K 1029; Sierra Point, W May 12, 1965. Flowers April to June. Ornamental for foliage and blue-black glaucous fruits.

Symphoricarpos albus (Linnaeus) Blake var. laevigatus (Fernald) Blake [S. rivularis Suksdorf]. Snowberry. Occasional, brushy slopes, edge of chaparral. Stump-sprouts after a fire. East facing slope below Parking Lot, McC, Halde June 23, 1963; Radio Road, McC, K September 2, 1963; Quarry, K July 14, 1963; Colma Canyon, K May 30, 1964. Flowers May to August. White fruits in late summer and autumn are more conspicuous than flowers. Ornamental, but spreads vigorously by underground rootstocks, therefore must be kept within bounds.

Symphoricarpos mollis Nuttall. Trailing Snowberry. Rare, brushy slopes, edge of chaparral. Quarry, K June 24, 1963; Live Oak Canyon, W April 27, 1965. Flowers April to July followed by showy white berries.

## Caryophyllaceae. Pink Family

Arenaria macrophylla Hooker. Sandwort. Rare, rocky outcrop. Kamchatka Point, McC March 21, 1965; J. Roof April 24, 1965.

Cardionema ramosissimum (Weinmann) Nelson \& Macbride. Sand-Mat. Occasional, sandy soil. Lower Colma Canyon, McC, Halde, K June 23, 1963; Pig Ranch Ravine, K 1082; near Olivet Cemetery, W May 18, 1965; Crocker Hills, W May 17, 1965. Flowers May to Junc.

Cerastium arvense Linnaeus. Mouse-ear Chickweed. Rare, in grassland. Reservoir Hill, McC March 14, 1965; Nike Base, K May 15, 1965. Flowers March to May. A showy spring wildflower.

Cerastium viscosum Linnaeus [C. glomeratum Thuillier]. Mouse-ear Chickweed. Weed of gardens, roadsides, and disturbed places. Ravine to south of Crocker Avenue, $P 2653$; north slope of San Bruno Mountain above Crocker Avenue, Toschi 63:16; above the Quarry, K July 14, 1963; West Powerline, K 948 . Flowers March to July. Native of Europe.

Paronychia franciscana Eastwood. Rare, grassland or rocky slopes. Colma Canyon, McC, Halde, K June 23, 1963; near Nike Base, McC, W May 23, 1965. Mat forming weedy perennial, inconspicuous flowers May to June.

Polycarpon tetraphyllum (Linnaeus) Linnaeus. Weed of sandy soil and disturbed places. Colma Canyon, McC, Halde, K June 23, 1963; Crocker Hills near Cow Palace, W May 17, 1965. Native of Europe.

Sagina apetala Arduino var. barbata Fenzl ex Ledebour. Pearlwort. Inconspicuous weed of disturbed places, often on hardpacked soil. Ridge Road near West Powerline, McC April 25, 1965. Flowers April and May. Native of Europe and Asia.

Sagina occidentalis Watson. Western Pearlwort. Rare, grassland. Ridge Road, near West Powerline, $K$ 945; near Nike Base, $M c C$, $W$ May 23, 1965. Flowers March to May.

Silene gallica Linnaeus. Windmill Pink. Catchfly. Campion. Pinkish petals are twisted simulating the blades of a windmill. Weed of roadsides and disturbed places. Near Nike Base, K 697 ; Flower Garden near April Brook, $K$ 976; Bitter Cherry Ridge, $K$ April 4, 1965; east facing slope below Parking Lot, McC June 9, 1963; Ridge Road about $1 / 1 /$ mile east of Parking Lot, $K 870$; ravine $1 / 2$ mile east of Parking Lot, $P 2696$. Flowers spring and summer. Native of Europe.

Silene scouleri Hooker subsp. grandis (Eastwood) Hitchcock \& Maguire [S. pacifica Eastwood]. Rare, grassland. East facing slope below Parking Lot, McC, Halde June 23, 1963; Quarry, K July 14, 1963. Perennial with long taproot, and pink flowers in June and July.

Silene verecunda Watson. Rare, in grassland. Near summit of mountain below radio towers, W May 11, 1965.

Spergula arvensis Linnaeus. Spurry. Weed of fields and disturbed areas. Crocker Avenue, K August 5, 1963; Crocker Hills, K January 8, 1964; Colma Canyon, McC June 13, 1965; April Brook, McC March 28, 1965; Ridge Road at West Powerline, McC March 14, 1965; ridge above Brisbane, $M c C, K$ September 2, 1963. Flowers in spring and summer. Native of Europe.

Spergularia macrotheca (Hornemann ex Chamisso \& Schlechtendal) Heynhold. Rare, salt-flat bordering San Francisco Bay. Point San Bruno, McC September 11, 1964; Sierra Point, W May 8, 1965; Brisbane Lagoon, W June 19, 1965. Flowers May to September.

Spergularia marina (Linnaeus) Grisebach. Sand Spurry. Rare, salt flat bordering San Francisco Bay or inland. Point San Bruno, K 984; Guadalupe Valley, P 2768. Flowers spring and summer.

Spergularia rubra (Linnaeus) J. \& C. Presl. Sand Spurry. Weed of disturbed places, often in hard-packed soil. Quarry, K July 14, 1963; east facing slope below Parking Lot,

McC, Halde June 23, 1963; Crocker Hills rear Cow Palace, W May 17, 1965; Ridge Road, $K$ April 25, 1964. Flowers spring and summer. Native of Europe.

Stellaria media (Linnaeus) Cyrillo. Chickweed. Weed of gardens, fields, and disturbed areas. Guadalupe Road, K August 5, 1963; Quarry, K July 14, 1963; Crocker Hills, K May 4, 1964; Ridge Road, $1 / \pm$ mile east of Parking Lot, $K 875$; Randolph Ravine, P 2746. Flowers in spring and summer. Native of Europe and Asia.

Stellaria nitens Nuttall. Chickweed. Rare, in grassland. Ridge Road at West Powerline, McC April 25, 1965; Trillium Gulch, McC March 28, 1965.

## Chenopodiaceae. Goosefoot Family

Atriplex patula Linnaeus var. hastata (Linnaeus) Gray [A. hastata Linnaeus]. Occasional, salt marshes or salt flats, along San Francisco Bay shore or inland. Foothill Boulevard at School Street, K October 7, 1963; Crocker Hills, K 2041.

Atriplex rosea Linnaeus. Redscale. Weed, salt flat, Point San Bruno, McC, K September 11, 1964. Native of Eurasia.

Atriplex serenana A. Nelson. Weed, waste ground often forming tangled mats. Brisbane Lagoon, W August 14, 1965.

Bassia hyssopifolia (Pallas) Kuntze [Echinopsilon hyssopifolium (Pallas) Moquin]. Weed of saline waste places. Brisbane Lagoon, McC, K September 11, 1964. Native of Asia.

Chenopodium album Linnaeus. Lamb's-Quarters. Pigweed. Weed of waste ground. Brisbane Lagoon, W June 19, 1965. Native of Europe. The edible young plants are often cooked as greens.

Chenopodium berlandieri Moquin. Weed of waste ground. Brisbane Lagoon, W June 19, 1965. Introduced from southwestern United States and adjacent Mexico. Characterized by an unpleasant odor which is lacking in C. album.

Chenopodium californicum (Watson) Watson. Rare, brushy slopes, becoming weedy in disturbed areas. Lower Colma Canyon, McC, Halde, K June 23, 1963; Pig Ranch Ravine, W May 11, 1965.

Chenopodium murale Linnaeus. Disturbed ground. Crocker Industrial Park, W June 19, 1965. A common weed throughout North America, unpleasantly scented. Native of Europe.

Roubieva multifida (Linnaeus) Moquin [Chenopodium multifidum Linnaeus]. Weed of waste places and roadsides. Lower Colma Canyon, McC, Halde, K June 23, 1963. Native of Chile.

Salicornia pacifica Standley [S. virginica Linnaeus, in part]. Glasswort. Pickleweed. Rare, alkaline and coastal salt flats. Point San Bruno, McC, K September 11, 1964. A perennial forming large colonies, differing from the following which is an annual having individual plants scattered among the perennial plants of S. pacifica.

Salicomia depressa Standley [S. rubra A. Nelson; S. europaea Linnaeus]. Glasswort. Rare, alkaline and coastal salt flats. Point San Bruno, McC, K September 11, 1964.

Salsola kali Linnacus var. tenuifolia Tausch. Russian Thistle. Weed of disturbed ground. Brisbane Lagoon, W June 19, 1965. A common tumbleweed throughout most of California. Native of Eurasia.


Figure 5. Anaphalis margaritacea (Linnaeus) Gray.

## Compositae. Sunflower Family

Achillea millefolium Linnaeus var. californica (Pollard) Jepson [A. californica Pollard]. Yarrow. Milfoil. Frequent, in open grassy or brushy areas. East facing slope below Parking Lot, McC, Halde June 23, 1963; near Crocker Avenue, Toschi 63:15; Randolph Ravine, P 2750; Owl's Canyon, K April 25, 1965; Colma Canyon, K August 5, 1963; Romanzoffia Ravine, K May 4, 1964. Perennial with finely divided, fern-like leaves and white flower heads April to July. Our plant is part of a variable species widespread in the Northern Hemisphere.

Agoseris apargioides (Lessing) Greene. Coast Dandelion. Occasional, in grassland. Colma Canyon, McC June 13, 1965; near Nike Base, McC, W May 23, 1965; West Powerline, $M c C$, $K$ September 2, 1963. Flowers spring and summer.

Agoseris grandiflora (Nuttall) Greene. California Dandelion. Occasional, in grassland. East facing slope below Parking Lot, McC June 9, 1963; near Nike Base, McC, W May 23, 1965; Pig Ranch Ravine, K May 15, 1965; Crocker Hills, K May 4, 1964. Flowers spring and summer.

Anaphalis margaritacea (Linnaeus) Gray. Pearly Everlasting. Frequent, in grassland, sometimes forming sizeable colonies. Lower Colma Canyon, McC, Halde, K June 23, 1963; Flower Garden, McC March 28, 1965 ; near Nike Base, McC, W May 23, 1965 ; upper Radio Road, W May 23, 1965; east facing slope below Parking Lot, McC, Halde June 23, 1963; West Powerline, $M c C, K$ September 2, 1963. Flowers April to September. The pearly-white flower-heads are showy. Ornamental.

Anthemis cotula Linnaeus. Mayweed. Dog-Fennel. Chamomile. A showy weed, occasionally in fields and roadsides. Lower Colma Canyon, McC, Halde, K June 23, 1963; Guadalupe Road, K August 5, 1963; Crocker Avenue, W July 7, 1965 ; Brisbane Lagoon, W June 19, 1965; Old County Road, Brisbane, W June 8, 1965. Flowers spring through autumn. Native of Europe.

Artemisia californica Lessing. California Sagebrush. Frequent, on exposed slopes and ridges. Colma Canyon, McC June 13, 1965; near Olivet Cemetery, W May 18, 1965; slope immediately south of Parking Lot, McC, Halde June 23, 1963; West Powerline, McC, K September 2, 1963; upper Buckeye Canyon, K July 14, 1963; Point San Bruno, McC, K September 11, 1964; Owl's Canyon, seedlings in burned area, McC March 28, 1965. One of the shrubs of the coastal scrub, distinguished by its gray-green foliage and its aromatic sagelike odor. Flowers inconspicuous in summer and early autumn. Regenerates by seeds after fire.

Artemisia douglasiana Besser. California Mug-Wort. Wormwood. Occasional, on grassy or brushy areas, sometimes on disturbed ground. Lower Colma Canyon, McC, Halde, K June 23, 1963; summit of mountain, Raven 1796; Cow Trough Ravine, $K$ October 7, 1963; Brisbane Lagoon, W August 14, 1965. Flowers summer and early autumn.

Aster chilensis Nees. California Aster. Occasional, in brushy areas Cow Trough Ravine, $K$ October 7, 1963; West Powerline, McC, K September 2, 1963; Point San Bruno, K 747. Perennial with flowers July to December. Sometimes used as an ornamental for its late season purplish flowers.

Aster exilis Elliott. Rare, marshy and often alkaline areas. Crocker Hills, K 2037. Annual with small flower heads in autumn.

Aster radulinus Gray. Rough-leaved Aster. Rare, in brushy areas. Quarry, K July 14, 1963; Buckeye Canyon, K August 5, 1963. Perennial with upper surface of leaves rough to the touch, flowers July to December.

Aster subspicatus Nees. Occasional, brushy areas. Lower Colma Canyon, McC, Halde, K June 23, 1963; Radio Road, W May 23, 1965; April Brook, K June 20, 1965; Dairy Ravine near radio towers, $K$ August 5, 1963 ; Romanzoffia Ravine, K May 4, 1964; Quarry, K July 14, 1963. Flowers May to October. Sometimes used as an ornamental.

Baccharis pilularis DeCandolle var. pilularis. Dwarf Chaparral-Broom. Occasional, on exposed slopes and ridges. Lower Colma Canyon, MCC September 29, 1966; Radio Road, $K$ August 5, 1963. In the low-growing form of the species plants are prostrate to decumbent often forming mats scarcely more than 12 inches tall. Occasionally used as an ornamental.

Baccharis pilularis DeCandolle var. consanguinea (DeCandolle) Kuntze. ChaparralBroom, Coyote Brush. Frequent, on open slopes and in ravines, in chaparral. West Powerline, McC, K September 2, 1963; Kamchatka Point, K July 27, 1963; Radio Road, McC, $K$ September 2, 1963; San Bruno Point, $M c C, K$ September 11, 1964. The erect form of the species has plants 5 to 6 feet tall, occurring in the chaparral. Plants near the West Powerline in an area burned in 1964 produced stump sprouts the following spring. The common name, Fuzzy-Wuzzy, is sometimes given to these plants when in fruit because of the abundant dry pappus which blows with the slightest movement of air.

Baeria chrysostoma Fischer \& Meyer subsp. chrysostoma. Goldfields. Rare, open slopes and ridges. Ravine $1 / 2$ mile cast of 1314 -foot summit of mountain, $P 2689$.

Baeria chrysostoma Fischer \& Meyer subsp. hirsutula (Greene) Ferris. Goldfields. Frequent, exposed slopes and ridges. North of Randolph Drive and Hillside Boulevard, $P$ 2727; West Powerline, $K 708$; Brisbane Powerline, $K 964$; Devil's Arroyc, McC March 28, 1965; top of mountain near radio station, McC, Menzies February 16, 1963; east facing slope near top of mountain, McC April 17, 1964. Both subspecies are colorful spring wildflowers which form dense golden-yellow colonies. Flowers March to May.

Bellis perennis Linnaeus. English Daisy. Weed, along roadside and damp fields. Crocker Avenue, $K$ September 2, 1964. A common and attractive, but sometimes troublesome, weed of lawns, where it is in flower almost throughout the year. Native of Europe.

Blennosperma nanum (Hooker) Blake. Rare, in grassland. Owl's Canyon, $M c C, K$ April 25, 1965. A colorful spring wildflower with golden-yellow flowers in March and April.

Carduus pycnocephalus Linnaeus. Italian Thistle. Troublesome weed of disturbed places. Brisbane Lagoon, W June 19, 1965. Flowers May and June. Native of Mediterranean region.

Carduus tenuiflorus Curtis. Troublesome weed of disturbed places. Sierra Point, W April 27, 1965. Flowers May to July. Native of Europe.

Centaurea calcitrapa Linnaeus. Purple Star-Thistle. Troublesome weed of disturbed areas. Crocker Hills, W May 17, 1965; Sierra Point, W June 21, 1965; Brisbane Lagoon, W August 17, 1965; Cow Trough Ravine, $K$ October 7, 1963. Flowers May to October. Native of Eurasia.

Centaurea melitensis Linnaeus. Napa Thistle. Tocalote. Troublesome weed of disturbed places. Quarry at end of School Street near Hillside Boulevard, K October 7, 1963; Colma Canyon, K May 30, 1964. Flowers May to October. Native of Europe.

Centaurea solstitialis Linnaeus. Barneby's Thistle. Troublesome weed of roadsides and disturbed areas. Brisbane Lagoon, $W^{\prime}$ June 19, 1965. Flowers June to December. Native of Europe.

Chaetopappa alsinoides (Greene) Keck. Rare, in grassland. Above Harold Avenue, Brisbane, $M_{C} C, W$ May 14, 1967. Slender inconspicuous annual with few yellowish flowers in head, April and May, ray flowers lacking.

Chrysanthemum coronarium Linnacus. Crown Daisy. Garland Chrysanthemum. Attractive weed of roadsides and disturbed places. Base of Pig Ranch Ravine, K April 24, 1965; Crocker Avenue, K August 5, 1963; Sierra Point, W May 8, 1965. Showy yellow flowers, April to August. Native of Eurasia and Northern Africa.

Chrysopsis villosa (Pursh) Nuttall var. bolanderi (Gray) Gray. Golden Aster. Frequent, in grassland. Cow Trough Ravine, $K$ October 7, 1963; eastern end of Ridge Road, $K$ July 14, 1963. Flowers April to November.

Cichorium intybus Linnaeus. Chicory. Weed with blue flowers particularly showy in mornings, of roadsides and disturbed ground. Crocker Industrial Park, W October 16, 1966. Flowers in summer and autumn. The deep taproot is used as an adulterant or substitute for coffee. Native of Europe.

Cirsium brevistylum Cronquist. Indian Thistle. Occasional, on brushy slopes. Lower Colma Canyon, McC, Halde, K June 23, 1963; top of mountain near Parking Lot, McC, Halde June 23, 1963; Quarry, K July 14, 1963. Flowers April to July.

Cirsium quercetorum (Gray) Jepson. Brownie Thistle. Occasional, in grassland. North of Randolph Avenue at Hillside Boulevard, P 2703; Quarry, K July 14, 1963; near Nike Base, $K$ 588. Low-growing plants with pale flowers, April to July.

Cirsium vulgare (Savi) Tenore. Bull Thistle. Weed, in disturbed areas. Lower Colma Canyon, McC, Halde, K June 23, 1963; Quarry, K July 14, 1963; Brisbane Lagoon, W August 14, 1965. A coarse thistle with upper surface of leaves rough to touch and purplish flowers June to October. Native to Eurasia.

Conyza bonariensis (Linnaeus) Cronquist. Weed, in waste ground and roadsides. Crocker Hills in a marshy area between Geneva Avenue and Guadalupe Parkway, K 2042. Flowers June to September, flower heads larger than those of C. canadensis. Native of South America.

Conyza canadensis (Linnaeus) Cronquist. Horseweed. Weed of waste ground. Hillside Boulevard near Serbian Cemetery, K 390; Radio Road, K August 5, 1963; Colma Canyon, K May 30, 1964. Tall weedy annual with inconspicuous flowers July to October. Widely distributed in North and South America.

Cotula australis (Sieber) J. D. Hooker. Weed, in disturbed places. Ridge Road, $1 / 4$ mile east of Parking Lot, K 876; Ridge Road near West Powerline, K 957; Crystal Cave Canyon, $K$ 1253. Tiny inconspicuous but troublesome annual weed, often forming colonies, common in gardens. Flowers March to October. Native of Australia.

Cotula coronopifolia Linnaeus. Brass-Buttons. Weed of moist places, sometimes in salt flats. Point San Bruno, McC, K September 11, 1964; Sierra Point, W May 8, 1965 ; ravine south of Crocker Avenue, P 2658; near Crocker Avenue, Toschi 63:33. Strong scented perennial with yellow flowers in terminal heads, March to October. Native of South Africa.

Erechtites arguta (A. Richard) DeCandolle [Senecio glomeratus Desfontaines ex Poiret]. New Zealand Fireweed. Weed of disturbed places. Crocker Industrial Park, W June 19, 1965; near Nike Base, McC, IV May 23, 1965. Coarse annual with pale flowers, June to August. Native of New Zealand and Australia.

Erechtites prenanthoides DeCandolle [Senecio minimus Poiret]. Australian Fireweed. Weed of disturbed places. Crocker Hills near Cow Palace, W May 17, 1965; Bitter Cherry Ravine, $K$ 1109. Coarse annual with lance-shaped, toothed leaves which distinguish it from E. arguta in which leaves are deeply divided. Pale flowers, July to September. Native of Australia and New Zealand.

Erigeron foliosus Nuttall. Rare, in grassland. Buckeye Canyon, W July 8, 1965. Flowers June and July.

Erigeron glaucus Ker-Gawler. Seaside Daisy. Frequent, on wind-swept slopes and ridges. East facing slope below Parking Lot, McC, Halde June 23, 1963; West Powerline, McC, K September 2, 1963; Trillium Gulch, K 1016; Pig Ranch Ravine, W May 12, 1965. Attractive low-growing perennial with somewhat thickish smooth leaves, and showy lavender flowers, March to August. Ornamental.

Erigeron philadelphicus Linnaeus. Philadelphia Daisy. Rare, in wet ground. April Brook, where creck joins Colma Canyon, W June 16, 1965; Radio Road, W May 23, 1965. Slender perennial, attractive flower heads with over 150 slender lavender ray flowers, April to June. Ornamental.

Plate 1. Upper. Erigeron glaucus Ker-Gawler.
Lower. Sidalcea malvacflora (DeCandolle) Gray ex Bentham.


Eriophyllum confertiflorum (DeCandolle) Gray. Yellow Yarrow. Occasional, on brushy slopes. East facing slope below Parking Lot, McC, Halde June 23, 1963; Quarry, K July 14, 1963; canyon southwest of radio towers, W May 12, 1965 ; above Olivet Cemetery, McC June 13, 1965. Shrub, usually 1 -foot tall, with narrowly linear leaf divisions and many yellow flower heads in showy clusters, May to November. Ornamental, it stays within bounds when planted and its gray-green finely divided foliage offers a pleasing contrast with its golden-yellow flower heads.

Eriophyllum staechadifolium Lagasca. Lizard-Tail. Occasional, in brushland on western part of mountain. Quarry, K July 14, 1963; Radio Road, McC, K September 2, 1963; slope below Parking Lot, McC June 9, 1963. Shrub usually 2 feet or more tall, with lanceolate leaf divisions and many yellow flower heads in clusters, May to November and often during remainder of year. Distinguished from preceding species by its leaves which have broader divisions and a more coarse appearance than those of E.confertiflorum.

Filago californica Nuttall. Occasional, in grassland and brushy areas. A ridge above Brisbane, $\pm 800$-foot elevation, Raven 1803; South Powerline, McC March 14, 1965. Flowers March and April.

Filago gallica (Linnaeus) Linnaeus. Occasional, in grassland, and disturbed areas. Lower Colma Canyon, McC, Halde, K June 23, 1963; slope below Parking Lot, McC June 9, 1963. Weed of gardens and other disturbed areas. Native of Europe.

Franseria chamissonis Lessing subsp. bipinnatisecta (Lessing) Wiggins \& Stockwell. Beach-Bur. Rare, beaches and salt flats. San Bruno Point, K September 2, 1964, Flowers June to October.

Gnaphalium beneolens A. Davidson. Everlasting. Cudweed. Rare, brushy slopes. Brisbane Ravine, $K$ August 5, 1963. A perennial, flowers July to November.

Gnaphalium californicum DeCandolle. Green Everlasting. California Cudweed. Frequent, on dry brushy slopes and ridges. East facing slope below Parking Lot, McC, Halde June 23, 1963; slopes southeast of 1314 -foot summit, $P$ 2671; West Powerline, McC, K September 2, 1963; Radio Road, K August 5, 1963; Sierra Point, W May 8, 1965. Strongly scented biennial, leaves green not gray, flowers May to August.

Gnaphalium chilense Sprengel. Everlasting. Cudweed. Frequent, brushy areas at margin of chaparral. Colma Canyon, K May 30, 1964; Brisbane Lagoon, W June 19, 1965 ; Pig Ranch Ravine, W May 12, 1965; Crystal Cave Canyon, K Jume 20, 1965; Quarry, K July 14, 1963; Radio Road, K August 5, 1963. Gray woolly annual or biennial, flowers throughout the year.

Gnaphalium luteo-album Linnaeus. Everlasting. Cudweed. Weed of disturbed areas. Crocker Hills, K 2045; Radio Road, K August 5, 1963; Colma Canyon, McC, W June 13, 1965; Guadalupe Valley, P 2763; in coastal scrub, Thomas 1006t. Gray woolly annual or biennial, flowers throughout year. Native of Europe.

Gnaphalium purpureum Linnaeus. Purple Cudweed. Rare, dry disturbed areas. Slope below Parking Lot, McC June 9, 1963; Pig Ranch Ravine, W May 12, 1965. White woolly annual or biennial, flowers April to June.

Gnaphalium ramosissimum Nuttall. Pink Everlasting, Rare, open or brushy slopes. Radio Road, McC, K September 2, 1963; Horseshoe Ridge, K August 5, 1963; Great Meadow
adjacent to upper Colma Canyon, W August 16, 1965. Sweet-scented, green-leaved biennial with pink flowers, June to October. The most attractive of all of the Everlastings.

Grindelia camporum Greene. Gum-Weed. Occasional, on dry open slopes and ridges. North city limits of South San Francisco, McC, K September 11, 1964; Brisbane Lagoon, W August 14, 1965; Radio Road, McC, K September 2, 1963; Quarry, K July 14, 1963; Buckeye Canyon, K July 14, 1963; Ridge Road, W July 8, 1965. Subshrub, leaves resinous, yellow flower heads, June to December.

Grindelia hirsutula Hooker \& Arnott. Occasional, on dry open or brushy slopes. Ravine north of Randolph Drive at Hillside Boulevard, P 2736; Sierra Point, W April 27, 1965; slope southeast of 1314 -foot summit, $P 2666$; Quarry, $K$ June 24, 1963; near radio stations, McC, Menzies February 16, 1963. Flowers April to June.

Grindelia humilis Hooker \& Arnott. Rare, in salt flats. Brisbane Lagoon, W June 19, 1965; near Bayshore Highway north of South San Francisco, K November 8, 1963. Flowers throughout year. Sometimes used as an ornamental; fast growing and large yellow flower heads are showy.

Grindelia maritima (Greene) Steyermark. Rare, in association with coastal scrub, J. H. Thomas 9709. Perennial with yellow flowers August and September.

Haplopappus ericoides (Lessing) Hooker \& Arnott. Mock-Heather. Rare, in sandy soil on brushy slope. Lower Colma Canyon, McC September 29, 1966. Low shrub with heather-like leaves and yellow flower heads September to November.

Helenium puberulum DeCandolle. Sneezeweed. Rosilla. Occasional, moist places or along creeks. Wax Myrtle Ravine, K August 5, 1963; April Brook, K, J. Roof August 4, 1963; Great Meadow, W July 7, 1965. Biennial or shortlived perennial, yellow flower heads with dome-shaped disk surrounded by short, reflexed rays, April to November.

Helianthella castanea Greene. Rare, in grassland. Sierra Point, W April 27, 1965. Perennial herb with large leaves and sunflower-like flower heads, April and May. Superficially resembles Wyethia. Endemic to San Francisco Bay region.

Hemizonia corymbosa (DeCandolle) Torrey \& Gray. Tarweed. Occasional, in grassland. Colma Canyon, McC June 13, 1965; Pig Ranch Ravine, K May 1965; abandoned quarry at end of School Street near Hillside Boulevard, $K$ October 7, 1963; Sierra Point, W April 27, 1965. Annual with lower pinnatifid leaves in spring, leaves becoming entire on older plants, pale yellow flower heads, May to November.

Hemizonia pungens (Hooker \& Arnott) Torrey \& Gray subsp. maritima (Greene) Keck. Spikeweed. Rare. Crocker Avenue, McC September 24, 1967. Erect stiffly branched annual to 12 inches tall, yellow flower heads, late summer to early autumn.

Heterotheca grandiflora Nuttall. Telegraph Weed. Rare, in disturbed places. Crocker Industrial Park, W October 16, 1966. Tall weedy annual or biennial with grayish foliage and yellow flower heads March to October. Native of interior central and southern California, introduced as a weed in our area.

Hypochaexis glabra Linnaeus. Smooth Cat's-Ear. Weed, in disturbed places. Colma Canyon, McC June 13, 1955; north of Randolph Drive at Hillside Boulevard, P 2721. Annual weed with basal leaves and yellow flower heads, February to August. Native of Eurasia and North Africa.

Hypochaeris radicata Linnaeus. Hairy Cat's-Ear. Weed of disturbed places and grasslands. Lower Colma Canyon, $M c C$, Halde, $K$ June 23, 1963 ; east facing slope below Parking Lot, McC, Halde June 23, 1963; Ridge Road at eastern end, K July 14, 1963; near Nike Station, McC May 25, 1965. Perennial with taproot, basal leaves, and yellow flower heads, March to September. Native of Eurasia and North Africa.

Jaumea carnosa (Lessing) Gray. Rare, in salt flat at edge of San Francisco Bay. Point San Bruno, McC, K September 2, 1964. Fleshy perennial with yellow flowers, June to November.

Lactuca saligna Linnaeus. Willow-Lettuce. Weed of disturbed ground. Cow Trough Ravine, $K$ October 7, 1963. Native of Eurasia.

Lactuca serriola Linnaeus. Prickly Lettuce. Weed of disturbed ground. Pig Ranch Ravine, W May 11, 1965. Prickly-leaved annual, flowers May to November. Native of Eurasia and North Africa.

Lactuca virosa Linnaeus. Wild Lettuce. Weed of disturbed ground. Ridge Road near West Powerline, $K$ August 5, 1963. Tall biennial to 6 to 8 feet, with stems hollow at least below, flowers August and September. Native of Eurasia and North Africa.

Lagophylla ramosissima Nuttall. Hareleaf. Rare, known from a single collection in "San Bruno Hills," J. McMurphy June 13, 1909.

Layia chrysanthemoides (DeCandolle) Gray. Rare, known from a single collection in "San Bruno Hills," J. McMurphy June 13, 1909.

Layia gaillardioides (Hooker \& Arnott) DeCandolle. Rare, in coastal scrub, J. H. Thomas 9307. Annual with showy golden-yellow flowers, April to June.

Layia hieracioides (DeCandolle) Hooker \& Arnott. Frequent, in chaparral. Colma Canyon, $K$ August 5, 1963; Radio Road, McC, K September 2, 1963; Dairy Ravine, $K$ August 5, 1963; Quarry, K July 14, 1963; Devil's Arroyo, seedlings in area burned over in previous autumn, McC March 28, 1965. Pungent, hairy annual, with lobed leaves and relatively small flowers, April to August.

Layia platyglossa (Fischer \& Meyer) Gray subsp. campestris Keck. Tidy-Tips. Rare, in grassland and chaparral. Colma Canyon, Raven 1780; Ridge Road at West Powerline, $K$ 636. Hairy annual with pinnately lobed leaves and showy pale yellow flower heads, March to June.

Madia capitata Nuttall. Tarweed. Occasional, in grassland, and disturbed areas. Colma Canyon, K 607 ; April Brook, K May 15, 1965; Pig Ranch Ravine, W May 11, 1965; Radio Road, K August 5, 1963; east facing slope below Parking Lot, McC, Halde June 23, 1963; summit of mountain, Raven 1794. Pungent, glandular-hairy annual with flower heads sessile or shortly stalked, May to September.

Madia exigua (Smith) Gray. Small Tarweed. Rare, in grassland. Ridge Road at West Powerline, $K$ 625. Low growing, branched annual, flowers May and June. The small flower heads with only one or two disk-flowers per head and the slender peduncles distinguish this species.

Madia gracilis (Smith) Keck. Slender Tarweed. Rare, in grassland. Above Olivet Cemetery, McC June 13, 1965. Glandular-viscid annual, flowers May to September.

Madia sativa Molina. Coastal Tarweed. Frequent, in grassland, roadsides, and disturbed areas. Becoming weedy. Lower Colma Canyon, McC, Halde, K June 23, 1963; Radio Road, McC, K September 2, 1963; West Powerline, McC, K September 2, 1963; Quarry, K July 14, 1963; Devil's Arroyo, K 1094. Stout, pungent, glandular-hairy annual with flower heads clustered in upper leaves, June to November.

Matricaria matricarioides (Lessing) Porter. Pineapple-Weed. Weed of disturbed areas, often in dry hard-packed soil. Crocker Hills, K May 4, 1964; Sierra Point, W May 8, 1965; Crocker Industrial Park, W June 19, 1965. Aromatic annual with finely pinnatifid leaves and conical yellow flower heads, March to June.

Micropus californicus Fischer \& Meyer. Slender Cottonweed. Rare, margin of chaparral. Canyon southwest of the National Broadcasting Company radio tower, W May 11, 1965. White woolly annual, inconspicuous flowers, April to June.

Microseris douglasii (DeCandolle) Schultz-Bipontinus subsp. douglasii. Rare, in grassland. Thomas 9259.

Microseris douglasii (DeCandolle) Schultz-Bipontinus subsp. tenella (Gray) Chambers. Rare, in grassland. Buckeye Canyon, W April 27, 1965. Both subspecies are annuals lacking a stem with leaves basal, yellowish to pale apricot-colored flowers on a stalk, April and May.

Picris echioides Linnaeus. Bristly Ox-Tongue. Weed of disturbed places. Quarry, K June 24, 1963; Colma Canyon, K August 5, 1963; Brisbane Lagoon, W June 19, 1965. Rough, bristly annual or biennial, yellow flowers, April to December. Native of Mediterranean region.

Psilocarphus tenellus Nuttall. Slender Woolly-Heads. Occasional, in dry bare, often hard packed, ground, forms colonies and mats, sometimes becomes weedy. Guadalupe Road, McC April 11, 1965; Quarry, K June 24, 1963; Ridge Road, W June 19, 1965. Low-growing grayish annual, flowers March to May.

Rafinesquia californica Nuttall. California Chicory. Occasional, on grassy or brushy areas. Thomas 9294.

Senecio aronicoides DeCandolle. Butterweed. Frequent, in grassland and border of chaparral. Colma Canyon, K March 15, 1964; east slope of mountain below radio station, Toschi 63:68; top of mountain, Raven 1375; 300 yards east of Parking Lot on area burned in autumn 1964, K 869 ; Romanzofia Ravine, K May 4, 1964; ravine $1 / 2$ mile east of 1314 -foot summit, P2690; South Powerline in area burned in autumn 1964, McC March 14, 1965. Tall coarse perennial with yellow flower heads, April to June.

Senecio cruentus (L'Heritier) DeCandolle. Florist's Cineraria. Garden Cineraria. Escapes from cultivation in moist, shaded areas. Top of mountain near KRON radio station, W June 20, 1965. Perennial with large purple ray flowers, summer. Native of Canary Islands.

Senecio elegans Linnaeus. Purple Ragwort. Escape from cultivation. Colma Canyon, W June 16, 1965. Annual with lavender ray flowers, May and June. Native of South Africa.

Senecio mikanioides Otto. German Ivy. Weed of moist areas along roadsides. Crocker Avenue, McC, K January 12, 1964. Evergreen perennial twining on other plants, bright yellow flower heads, winter and spring. Native of South Africa.

Senecio sylvaticus Linnaeus. Weed in brushy areas. East facing slope below Parking Lot, McC, Halde June 23, 1963; Ridge Road about 100 yards east of Parking Lot, K May 19, 1964. Coarse annual weed with pale flower heads, April to June. Native of Europe.

Senecio vulgaris Linnaeus. Common Groundsel. Weed of disturbed areas. East facing slope below Parking Lot, McC April 17, 1964; South Powerline, McC March 14, 1965. Annual with pale flower heads, spring-summer. Black-tipped involucral bracts distinguish it from $S$. sylvaticus. Native of Europe.

Silybum marianum (Linnaeus) Gaertner. Milk-Thistle. Weed of disturbed places and roadsides. Lower Colma Canyon, McC, Halde, K June 23, 1963; Crocker Hills, K May 4, 1964. Coarse annual or biennial with spiny mottled leaves and purple flower heads. Native of Mediterranean region.

Solidago californica Nuttall. California Golden-Rod. Occasional, dry open areas. West Powerline, $M c C, K$ September 2, 1963; Cow Trough Ravine, $K$ October 7, 1963; April Brook, W August 16, 1965. Perennial with creeping rhizome and hairy leaves somewhat rough to touch above, flowers July to November.

Solidago canadensis Linnaeus subsp. elongata (Nuttall) Keck. Meadow Goldenrod. Occasional, on brushy areas. East facing slope below Parking Lot, McC, Halde June 23, 1963; Colma Canyon, K March 15, 1964. Differs from S. californica in its glabrous or only slightly hairy leaves, flowers August to November.

Solidago spathulata DeCandolle. Dune Goldenrod. Frequent, on brushy areas. East facing slope below Parking Lot, McC, Halde June 23, 1963; top of mountain near radio towers, McC, Menzies February 16, 1963; West Powerline, McC September 2, 1963; lower Colma Canyon, McC September 29, 1966; Crocker Hills, K August 5, 1963. Differs from two preceding goldenrods in the shining, more or less glutinous inflorescence, flowers August to October.

Soliva sessilis Ruiz \& Pavon. Weed of roadsides and other disturbed areas. West Powerline, K April 13, 1964; Crocker Hills near Cow Palace, W May 17, 1965; Randolph Avenue, K May 11, 1967. Small depressed annual weed, flowers January to June. Native of Chile.

Sonchus asper (Linnaeus) Hill. Prickly Sow-Thistle. Weed of roadsides and other disturbed areas. East facing slope below Parking Lot, McC, Halde June 23, 1963 ; lower Colma Canyon, McC, Halde, K June 23, 1963; Radio Road, K August 5, 1963. Weedy annual, flowers March to July. Native of Eurasia and North Africa.

Sonchus oleraceus Linnaeus. Sow Thistle. Weed of roadsides and other disturbed areas. Brisbane Lagoon, W June 19, 1965; north of Randolph Drive at Hillside Boulevard, P 2724; Horseshoe Ridge, K August 5, 1963. Weedy annual, flowers March to September. Native of Europe.

Stephanomeria virgata Bentham. Rare, open rocky slope. South side of Ridge Road, about 200 yards south of Parking Lot, McC, K August 1, 1967. Stiff annual with almost leafless stems and inconspicuous pink or white flowers in summer.

Tanacetum camphoratum Lessing. Dune Tansy. Rare, known from only one locality on the mountain. Distribution restricted to the San Francisco area. Radio Road, K August 5, 1963. Herbaceous perennial with gray fern-like leaves and showy yellow flowers, June to October. Ornamental.

Taraxacum laevigatum (Willdenow) DeCandolle. Red-Seeded Dandelion. Weed of disturbed areas. Flower garden adjacent to April Brook, McC March 28, 1965; West Powerline, McC April 25, 1965. Flowers March to July. Native of Eurasia.

Tragopogon porrifolius Linnaeus. Oyster-Root. Salsify. Weed of disturbed areas. Crocker Industrial Park, W June 19, 1965. Perennial with long taproot and purple flowers, March to October. Native of Mediterranean region. Sometimes grown for its edible root called vegetable-oyster.

Wyethia angustifolia (DeCandolle) Nuttall. Mule-Ears. Occasional, in grassland. Crocker Hills, K May 4, 1964; Point San Bruno, K April 24, 1965; Sierra Point, W April 27, 1965; above Harold Avenue, Brisbane, McC, W May 14, 1967; Glen Park Canyon, McC April 16, 1967. Perennial herb with long narrow leaves and showy sunflower-like flower heads April and May. Similar in appearance to Helianthella castanea from which it differs in technical characters of flower and fruit.

Xanthium spinosum Linnaeus. Spiny Clotbur. Spanish Thistle. Weed of disturbed places. Crocker Industrial Park, W June 19, 1965. Coarse spiny annual, inconspicuous flowers, April to November. Nativity doubtful, has been reported from both North and South America, as well as from Europe. Because of the aggressive weedy nature of this plant it is difficult to determine where it may have originated.

## Convolvulaceae. Convolvulus Family

Convolvulus arvensis Linnaeus. Field Bindweed. Orchard Morning-Glory. Deep-rooted, troublesome weed of fields and waste places. Lower Colma Canyon, W June 16, 1965 ; intersection of Radio Road with Guadalupe Parkway, K August 5, 1963; Quarry, W June 8, 1965. Flowers May to October. Introduced from Europe.

Convolvulus occidentalis Gray. Western Morning-Glory. Occasional, on brushy slopes, often scrambling over other plants. Colma Canyon, K May 4, 1964; above Olivet Cemetery, McC June 13, 1965; Randolph Drive at Hillside Boulevard, P 2729 ; east facing slope below Parking Lot, McC, Halde June 23, 1963; upper Buckeye Canyon, K July 14, 1963. Flowers April to July. May be distinguished from preceding by its larger flowers, about $11 / 4$ to $11 / 2$ inches long, whereas, flowers in C. arvensis are about $3 / 4$ inch long.

Convolvulus subacaulis (Hooker \& Arnott) Greene. Occasional, in grassland. Crocker Hills near Cow Palace, W May 17, 1965; Colma Canyon, W June 16, 1965; ravine east of Quarry, W June 19, 1965; Wax Myrtle Ravine, K August 5, 1963; north facing slope south of Guadalupe Parkway close to junction with Radio Road, McC, W June 11, 1967. Flowers April to June. Differs from two preceding morning-glories by its short stem and its larger flowers, from $11 / 2$ to 2 inches long.

Dichondra donelliana Tharp \& Johnston. Rare, known only from a slope above Olivet Cemetery. Above Olivet Cemetery, W May 18, 1965. The gray-green foliage of this species distinguishes it from $D$. micrantha Urban (usually referred to as D. repens Forster) which is cultivated as a ground cover and occasionally escapes to become naturalized. Dichondra donelliana is known from scattered localities in southern Oregon, northern and central California, and Santa Cruz Island off the coast of southern California. Dichondra, a poorly understood genus of about 14 species mostly in North and South America, New Zealand, and Australia, is best known through $D$. micrantha (sometimes called $D$. repens) the much used groundcover. D. donelliana has until recently been known as $D$. repens, a name which applies to a plant in New Zealand and Australia. Its identity was established in 1961 when it was described as a new species and named for the South American botanist, Professor Carlos O'Donell.

## Cornaceae. Dogwood Family

Cornus californica C. A. Meyer. Creek Dogwood. Western Red Dogwood. Rare, in moist canyons and ravines, sometimes forming thickets. Quarry, K July 1f, 1963; lower Colma Canyon along creek, McC, Halde, K June 23, 1963. However, at the present time (1967) it may no longer exist at these localities. Clusters of white flowers, April to June. Leaves turn red in autumn before falling and the slender bare reddish-brown branches are showy in spring before the new leaves appear. Ornamental.

## Crassulaceae. Stone Crop Family

Dudleya cymosa (Lemaire) Britton \& Rose. Bluff Lettuce. Scattered on rocky slopes and ledges. Flowers April to July.

Dudleya farinosa (Lindley) Britton \& Rose. Scattered on rocky slopes and ledges. East facing slope below Parking Lot, McC, Halde June 23, 1963. Flowers July and August. Distinguished from preceding species by the leaves being farinose or white-mealy. Both species of Dudleya are used as ornamental succulent plants.

Sedum spathulifolium Hooker. Stone Crop. Scattered on rocky and grassy slopes and ledges. Ravine east of Quarry, W July 8, 1965; east facing slope below Parking Lot, McC, Halde June 23, 1963. Flowers April to July. Useful as an ornamental succulent plant. Sedum may be distinguished from Dudleya when in flower by its spreading and separate petals. In Dudleya the petals are united to form a short tubular corolla.

Tillaea erecta Hooker \& Arnott. Pigmyweed. Occasional, in open places in grassland and edge of chaparral, often in pure colonies on exposed ground. Slope above Brisbane, Raven 1371; Crocker Hills near Guadalupe Road, McC A pril 11, 1965; on ridge near West Powerline, $K$ 993. A tiny inconspicuous annual, only an inch or two tall. Close examination with a hand-lens, however, reveals its minute but fleshy opposite leaves and tiny, sedum-like flowers April and May.

## Cruciferae. Mustard Family

Arabis blepharophylla Hooker \& Arnott. Coast Rock Cress. Frequent, grassy slopes and rocky outcroppings. Near Crocker Avenue, P 2654; Cable Ravine, McC March 14, 1965 ; Powerlines, K 967 ; Owl's Canyon, $K$ April 25, 1965; Colma Canyon, K 1226; slope southeast of 1314 foot summit, $P$ 2672; slope above Brisbane, Raven 1378. Early spring-flowering perennial with attractive rose-purple flowers, March to May. Ornamental.

Arabis glabra (Linnaeus) Bernhardi. Tower Mustard. Occasional, grassy and brushy slopes. Colma Canyon, K 1217; Flower Garden near April Brook, McC March 28, 1965; West Powerline, Menzies March 14, 1965; summit of mountain, Raven 1799; Quarry, K July 14, 1963; South Powerline Ridge, Mensies March 14, 1965; near radio station, McC, Menzies February 16, 1963. Weedy in appearance with whitish to yellow flowers, February to June.

Barbarea orthoceras Ledebour. American Winter Cress. Occasional, open or brushy areas. Manzanita Dike, K 933; meadow between April Brook and Radio Road, McC March 28, 1965; Eucalyptus grove on Radio Road, $K 861$; east facing slope below radio station, Toschi 63:63; Sierra Point, W April 27, 1965. Pale yellow flowers, March to July.

Barbarea verna (Miller) Ascherson. Early Winter Cress. Weed, in disturbed areas, Colma Canyon, $K$ May 30, 1964; near Crocker Avenue, $P 2651$; east facing slope below summit, McC April 17, 1964; ravine $1 / 2$ mile east of summit, P 2697. Yellow flowers, March to July. Native of Europe.

Brassica campestris Linnaeus. Field Mustard. Weed, disturbed areas. Near Crocker Avenue, $P 2662$; Guadalupe Valley, $P 2766$; Colma Canyon, $K 1236$; Brisbane Lagoon, $W$ June 19, 1965. The bright yellow flowers are colorful in early spring, February to July. Native of Europe.

Brassica geniculata (Desfontaines) J. Ball. Mediterranean Mustard. Summer Mustard. Weed, in disturbed areas. Radio Road, K August 5, 1963; Quarry, K July 14, 1963; Guadalupe Valley, $P$ 2770; Colma Canyon, McC, Halde, K June 23, 1963; Romanzoffia Ravine, K May 4, 1964; base of Owl's Canyon, W June 7, 1965 ; Point San Bruno, K, McC September 11, 1964. Yellow flowers mostly in summer, May to September. Native of Mediterranean region.

Brassica kaber (DeCandolle) L. C. Wheeler. Charlock. Weed along roadsides and in waste ground. Point San Bruno, K April 24, 1964. Flowers March to October. Native of Europe.

Brassica oleracea Linnaeus. Cabbage. Escape from cultivation. Brisbane Lagoon, $W$ June 19, 1965. Sometimes persisting in maritime situations, flowers in spring and summer. Native of western and southern Europe.

Cakile maritima Scopoli. Sea-Rocket. Occasional, as a weed on sand dunes and beaches. Point San Bruno, McC, K September 11, 1964. Flowers lavender to purplish, March to September. Native of Europe.

Capsella bursa-pastoris (Linnaeus) Medicus. Shepherd's Purse. Weed of disturbed areas and on open grassy slopes. West Powerline, K 734. Small whitish flowers throughout year. Native of Europe.

Cardamine oligosperma Nuttall. Bitter Cress. Occasional, in grassland and disturbed areas, sometimes in areas previously burned. Colma Canyon, K May 30, 1964; ravine $1 / 2$ mile east of summit, P 2686; Romanzoffia Ravine, K March 14, 1965; Trillium Gulch, K 1018. Annual with small white flowers and seed pods which open explosively, often becoming weedy, flowers February to June.

Cardaria draba (Linnaeus) Desvaux. Hoary Cress. Weed, in disturbed ground. Crocker Hills near old Bayshore Highway, W May 7, 1967. Erect perennial with numerous tiny white flowers in terminal panicles, March to December. Native of Europe.

Coronopus didymus (Linnaeus) J. E. Smith. Wart-Cress. Weed of waste and cultivated ground and along roadsides, sometimes in hard packed soil. Colma Canyon, K May 30, 1964; Crocker Hills near Cow Palace, W May 17, 1965; Guadalupe Road, McC April 11, 1965 ; east facing slope below Parking Lot, McC, Halde June 23, 1963; Ridge Road east of Parking Lot, K 699. Much branched, strong-smelling annual with tiny flowers, March to November. Native of Europe.

Dentaria californica Nuttall var. integrifolia (Nuttall) Detling. Toothwort. RainBells. Milk-Maids. Occasional, open grassy or brushy slopes. Slope above Brisbane, Raven 1380; Kamchatka Point, K January 8, 1964; Colma Canyon, K March 15, 1964; Radio

Plate 2. Upper. Dudleya farinosa (Lindley) Britton \& Rose.
Lower. Diplacus aurantiacus (Curtis) Jepson.


Road, McC, V. Ryder February 16, 1964; near radio station close to summit, McC, Menzies February 16, 1963; Cable Ravine, McC March 14, 1965; Trillium Gulch, McC March 28, 1965 ; ravine $1 / 2$ mile east of 1314 -foot summit, $P$ 2698. Perennial with an underground thickened stem or rhizome from which in late winter arise 3 -foliolate leaves. The slender erect stems have 3 to 5 -foliolate leaves and pretty white to pink flowers, January to May.

Erysimum franciscanum Rossbach. Franciscan Wallflower. Occasional, open, rocky, or grassy slopes. Quarry, K July 14, 1963, and W July 8, 1965; Buckeye Canyon, K July 14, 1963; below top of mountain, McC June 9, 1963 ; lower Colma Canyon, McC, Halde, K June 23, 1963; Randolph Avenue at Hillside Boulevard, P 2735; South Powerline, McC March 14, 1965. Attractive showy spring wildflower, a biennial or short-lived perennial, leggy in habit, with terminal clusters of pale yellow or cream-white flowers, March to May. Ornamental.

Lepidium nitidum Nuttall. Shining Pepper-Grass. Occasional, open rocky areas and grassland. Side spur of San Bruno Mountain west of Brisbane, Raven 1367; Romanzoffia Ravine, $K$ March 14, 1965 ; West Powerline, K, McC March 14, 1965 ; Crocker Avenue, $K$ 1201; Colma Canyon, K 1248; slope below top of mountain near radio station, McC, Menzies February 16, 1963; Randolph Avenue, South San Francisco, K May 16, 1967. Erect annual with tiny whitish flowers January to May, and small ovate fruits having a peppery taste.

Lepidium pinnatifidum Ledebour. Russian Pepper-Grass. Weed of disturbed ground. Brisbane Lagoon, W June 19, 1965; Randolph Avenue, South San Francisco, K May 16, 1967. Annual or biennial with tiny flowers in spring. Native of southern Russia.

Lobularia maritima (Linnaeus) Desvaux [Alyssum maritimum (Linnaeus) Lamarck. Koniga maritima (Linnaeus) R. Brown]. Sweet Alyssum. Weedy escape from cultivation in disturbed ground. Crocker Avenue, K August 5, 1963; Reservoir Hill, McC March 14, 1965. Low much branched perennial with often a profusion of small white flowers throughout the year. Native of Europe.

Lunaria annua Linnaeus. Moonwort. Honesty. Money-Plant. Weedy escape from cultivation in moist shaded areas. Radio Road, Thomas 10632. Erect branched annual or biennial with attractive purple flowers, March to June, followed by rounded to oval paperthin fruits resembling a silver coin and used in dry arrangements. Native of Europe.

Raphanus sativus Linnaeus. Wild Radish. Weed of disturbed areas. Guadalupe Road, $K$ August 5, 1963; ravine south of Crocker Avenue, $P 2663$; ridge above Brisbane, Mc®, $K$ September 2, 1963. Tall branched annual or biennial with showy clusters of flowers in varying shades of white, yellowish, to pale and darker lavender, February to May. Native of Europe. The edible radishes are selected forms of the species.

Rorippa nasturtium-aquaticum (Linnaeus) Schinz \& Thellung [Nasturtium officinale R. Brown]. Water Cress. Occasional, in shallow water or margins of streams. Cow Trough Ravine, $K$ October 7, 1963; Crocker Avenue, $K$ August 5, 1963; Quarry, K July 14, 1963; lower Colma Canyon, McC, Halde, K June 23, 1963; Devil's Arroyo, McC March 28, 1965; Sierra Point, $W$ April 27, 1965. Leafy aquatic perennial with white flowers March to November. Native of the Old World. Cultivated for its edible leaves.

Sisymbrium officinale (Linnaeus) Scopoli. Hedge Mustard. Weed of waste ground. Crocker Avenue, K August 5, 1963; Colma Canyon, K May 4, 1964; Romanzoffia Ravine, K May 4, 1964; Crocker Hills, K May 4, 1964. Coarse stiffly branched annual with clusters of small yellowish flowers, February to August, and elongate fruits closely appressed to stem. Native of Europe.


Figure 6. Marah fabaceus (Naudin) Greene.

Sisymbrium orientale Linnaeus. Weed of waste ground. Guadalupe Road, K April 11, 1965. Coarse, branched annual or biennial, distinguished from Sisymbrium officinale by its spreading fruits. Native of Europe.

Thelypodium lasiophyllum (Hooker \& Arnott) Greene var. inalienum Robinson. Occasional, open and brushy slopes in undisturbed areas. Crocker Hills, K May 4, 1964; South Powerline, Menzies March 14, 1965 ; Devil's Arroyo, K 1090, and K 1103; Guadalupe Road, McC April 11, 1965. Tall, erect, annual which in this form of the species has the slender fruits spreading away from the stem.

Thysanocarpus curvipes Hooker. Fringe-Pod. Rare, in grassland. Owl's Canyon, K May 1, 1967. Slender, branched annual with tiny whitish flowers, March to May, and a small rounded fruit sometimes with perforate margin.

## Cucurbitaceae. Gourd Family

Marah fabaceus (Naudin) Greene. Manroot. Wild Cucumber. Occasional, in brushland climbing on shrubs or trailing over the ground. Slope above Crocker Avenue, Toschi 63:27; Colma Canyon, K May 30, 1964; lower Colma Canyon, McC, Halde, K June 9, 1963; above the Quarry, K July 14, 1963; ravine east of West Powerline, McC March 28, 1965; slope below summit of mountain, MCC June 9, 1963. Flowers cream-white, corolia more or less rotate, that is having a lube and spreading lobes, February to May, and mature fruits with many stiff spines. This species and the following, Marah oregonus, are similar in appearance. Both have herbaceous stems arising annually from a large perennial tuber, hence the common name of Manroot. They may be distinguished by the shape of their corollas and the number and stiffness of the spines on the fruits.


Figure 7. Arctostaphylos imbricata Eastwood.

Marah oreganus (Torrey \& Gray) T. J. Howell. Manroot. Wild Cucumber. Occasional, in brushland climbing on shrubs or trailing over the ground. Dairy Ravine, K August 5, 1963; west facing slope below summit of mountain, McC April 17, 1967; slopes southwest of Brisbane, P 2760 ; Devil's Arroyo, $K 1060$. Flowers whitish, corollas more or less campanulate, March to May, and mature fruits with few weak spines.

## Dipsacaceae. Teasel Family

Dipsacus fullonum Linnaeus [ $D$. sativus Honckeny]. Fuller's Teasel. Weed along roadsides and in disturbed areas. Crocker Industrial Park, W March 27, 1966. Tall stout biennial herb with terminal oblong flower clusters, of which the spine-like bracts are conspicuous and surpass the flowers, which appear in spring and summer. Has been cultivated in Europe for fulling in textile mills, hence the common name. Native of Europe.

Scabiosa atropurpurea Linnaeus. Pincushion Plant. Escape from cultivation along roadsides. Humboldt Road, Brisbane, $K$ November 8, 1963. Attractive garden annual with terminal flower heads, flowers in whites, pinks, to purples throughout most of the year.

## Ericaceae. Heather Family

Arbutus menziesii Pursh. Madroño. Madrone. Rare, on eastern end of mountain, dry rocky ground. Brisbane Canyon (to east of Buckeye Canyon), W May 25, 1965; on frontage road to south of Brisbane, $M c C, K$ September 11, 1964. One of the important broadleaved evergreen trees of the Pacific Coast region with clusters of small white bell-shaped flowers in spring followed by red fruits looking much like those of its relative, the European strawberry tree, Arbutus unedo. Ornamental.

Arctostaphylos imbricata Eastwood. Manzanita. Occasional, brushy slopes and ridges forming dense low colonies. Summit of mountain, northwest of lowermost radio tower, McC, Menzies February 16, 1963; West Powerline, McC, K September 2, 1963. Also reported by W. Knight and J. Roof from Kamchatka Point, Blue Blossom Hill and Manzanita Dike. Known only from San Bruno Mountain. The low-growing, much branched plants form mat-like colonies, flowers February to May. Plants regenerate by seed following fire.

Arctostaphylos montaraensis J. Roof. Montara manzanita. Rare, adjacent to a rocky outcrop about 300 yards east-northeast of Parking Lot, Menzies, February 5, 1963. Only one shrub known prior to 1964 fire. The fire destroyed the shrub but since the fire approximately a hundred seedlings have appeared. Erect shrub to about 6 feet at maturity with sessile leaves. Flowers in March. Known only from the San Bruno Mountain locality and on Peak Mountain in Montara Range about 15 miles airline to south.

Arctostaphylos pacifica J. Roof. Rare, one rocky outcrop. Only in one locality, Ridge Road about 300 yards northeast of Parking Lot on a prominent rocky outcrop, $M c C$, Menzies February 16, 1963. Known only from San Bruno Mountain. Plants have a basal burl and stump-sprout after fire. Flowers in February. Ornamental.

Arctostaphylos uva-ursi (Linnaeus) Sprengel. Bear-berry. Kinnikinnick. Occasional, on west end of mountain on uppermost ridges. West Powerline, McC, $K$ September 2, 1963; Cable Ravine, about 30 yards from the Monterey pine, largest colony on mountain, K 864 ; Kamchatka Point, McC, Menzies February 16, 1963 ; northern end of West Powerline Ridge, K May 4, 1964. San Bruno Mountain represents one of the southernmost stations known in California for this manzanita which has a wide circumboreal distribution in North America, Asia, and Europe. Low growing, mat-forming shrubs, flowers February and March. Ornamental.

Although one of the smaller genera on San Bruno Mountain the genus Arctostaphylos is one of the most interesting. Arctostaphylos imbricata, an endemic, is a prostrate sessileleaved shrub which forms sizeable colonies and has been found at five locations. It is making a good recovery from the fire of 1964 due to the large amounts of seed which lay on the ground at the time of the fire. Arctostaphylos pacifica, a small-leaved burl-forming creeping manzanita is also making a comeback after the fire due to regeneration from root sprouts. It is found only at one rocky outcrop a couple of hundred yards below the parking lot and is distinguished by its reticulate leaf surfaces and serrulate leaf margins. Just adjacent and downhill a few yards was a six foot high shrub of A. montaraensis which was killed outright by the fire in 1964 but is being perpetuated nicely by the appearance of numerous seedlings. A cross section of this original shrub showed growth rings which indicated its age to have been about thirty years. The largest and only other colony of A. montaraensis is at its type locality on Montara Mountain Range, within sight, and about 15 airline miles to the south.

Arctostaphylos uva-ursi usually occurs on the north-facing slope of the mountain except for the colony previously mentioned near Cable Ravine. On Kamchatka Point there is a low-growing form with small suborbicular leaves borne on assurgent branchlets coming off of cord-like branches which are absolutely prostrate. It has been introduced to cultivation under the cultivar name of 'Miniature' and seems to be suitable as a ground cover. Arctostaphylos uva-urrsi, in some of its localities along the Pacific Coast, hybridizes with adjacent species. Some of its plants on San Bruno Mountain, however, are characteristic of the species and do not appear to be of hybrid origin as they do farther to the south in Monterey County.

Gaultheria shallon Pursh. Salal. Rare. Known from only one locality on San Bruno Mountain. Brushy slope above Radio Road about $1 / 4$ mile from Eucalyptus grove, Menzies

January 12, 1964, and $K$ 863. Evergreen spreading shrub of medium height with small urnshaped flowers in spring followed by black berry-like fruits. Ornamental.

Vaccinium arbuscula (Gray) Merriam. Huckleberry. Rare, known only from two exposed rocky outcrops. Kamchatka Point, McC, Menzies February 16, 1963; Huckleberry Ridge, $K$ September 2, 1964. Deciduous shrub to about 2 feet tall, flowers sparsely in ? March and April. The occurrence of Vaccinium arbuscula if indeed our material belongs to this species, is unexpected on San Bruno Mountain since it is a huckleberry of forested and montane areas to the north as far as British Columbia and east to the Sierra Nevada and the Rocky Mountains.

Vaccinium ovatum Pursh. Evergreen Huckleberry. Frequent, on exposed often rocky slopes, ridges, and ravines on upper part of mountain. Shrubs stump sprout in spring following fire. In two of its localities it occurs close to Vaccinium arbuscula from which it is distinguished by its evergreen, thickish and leathery leaves. Kamchatka Point, Menzies May 17, 1964; Quarry, K June 24, 1963; ravine $1 / 2$ mile east of 1314 -foot summit, $P 2693$; West Powerline, McC, K June 2, 1963; top of Dairy Ravine, K August 5, 1964; Huckleberry Ridge, K May 4, 1964. Erect, much branched, evergreen shrub with small bellshaped white, pink tinged flowers, March to May, followed by black edible huckleberries.

## Euphorbiaceae. Euphorbia Family

Croton californicus Mueller-Argoviensis. Rare, in sandy soil. Pig Ranch Ravine, W July 7, 1965, and K 1028. Silvery-leaved perennial, inconspicuous flowers, June to November. Used by California Indians for stupefying fish.

Euphorbia crenulata Engelmann. Chinese Caps. Wartweed. Occasional, on grassy or brushy slopes, or disturbed areas. Near Crystal Cave Canyon, W June 20, 1965 ; Colma Canyon, K March 15, 1964; Pig Ranch Ravine, W May 12, 1965, and K 1113; Olivet Cemetery, W May 18, 1965. Green-leaved annual or biennial with milky juice, and inconspicuous flowers February to November. Becomes weedy.

Euphorbia lathyris Linnaeus. Gopher Plant. Caper Spurge. Weed, escaping from cultivation in waste places. Hillside Boulevard near Cypress Hill Golf Course, K October 7, 1963. Coarse, blue-green, annual or biennial, with milky juice, upper leaves clasping the stem, and inconspicuous flowers, February to November. Native of Europe.

Euphorbia peplus Linnaeus. Petty Spurge. Weed, waste places. Crocker Avenue, McC September 24, 1967. Erect usually branched annual, to about 10 to 12 inches tall, small greenish flowers almost anytime. Native of Europe.

## Fagaceae. Oak or Beech Family

Quercus agrifolia Née. Coastal Live Oak. California Live Oak. Occasional, in woodland of canyons and ravines. Quarry, K July 14, 1963; Buckeye Canyon, K August 5, 1963; Point San Bruno on a bluff near shoreline, $M c C, K$ September 11, 1964. Also reported from the ridge to west of lower part of Owl's Canyon. Spreading, much branched evergreen oak, flowers in catkins, February and March. The leaves of this oak tend to be convex, sharply toothed, and to have tufts of hairs in the axils of the veins on the lower surface.

Quercus chysolepis Liebmann. Maul Oak. Canyon Oak. Gold-cup Oak. Occasional, open rocky outcroppings on open slopes and in ravines. Crocker Hills, McC, $K$ September 2, 1963; near Guadalupe Road, K August 5, 1963; Quarry, K July 14, 1963, and June 24, 1963; Buckeye Canyon, W May 25, 1965, and K 722; Bitter Cherry Ridge, K May 4, 1964. On San Bruno Mountain this oak tends to be a low shrub or small tree 6 to 8 feet tall.

The most dwarf of these low growing shrubs have been designated as Quercus chrysolepis Liebmann var. nana Jepson. This is an evergreen oak in which the leaves are thick and leathery, more or less brown hairy on lower surace, flowers in catkins in May and June. The acorns have scales more or less covered by golden-brown felt-like hairs, hence the common name, Gold-cup Oak.

Quercus moreha Kellogg. Oracle Oak. Rare, only on one ridge toward eastern end of mountain. Brisbane Powerline, J. Roof April 25, 1965. Quercus moreha originated as a hybrid between the deciduous $Q$. kelloggii and the evergreen $Q$. wislizeni and tends to be semi-deciduous. At its one locality on the mountain it is low growing to about 18 inches tall and spreading to several feet across. Has been called Quercus morehus.

Quercus wislizeni A. DeCandolle. Interior Live Oak. Occasional, in ravines and rocky open slopes. Plants regenerate by stump sprouts after fire. Quarry, K July 14, 1963; Buckeye Canyon, K August 5, 1963; about 100 yards east of Parking Lot near Ridge Road, K 1107. Quercus wislizeni is an evergreen oak with thick, toothed, parallel-veined leaves. Plants on San Bruno Mountain are low growing, a form which has been designated as $Q$. wislizeni A. DeCandolle var. frutescens Engelmann.

## Frankeniaceae. Frankenia Family

Frankenia grandifolia Chamisso \& Schlechtendal. Alkali Heath. Rare, salt flats and alkaline areas. Beach at Point San Bruno, $K$ September 2, 1964; salt flat at Point San Bruno, McC, K September 11, 196t; Brisbane Lagoon, W August 14, 1965. Perennial sometimes exuding crystals of salt, with heath-like leaves, and rose-purple flowers, May to November.

## Fumariaceaf. Fumitory Family

Dicentra formosa (Haworth) Walpers. Pacific Bleeding Heart. Rare, in moist shaded areas. Creek in Colma Canyon, K May 30, 196t; Fern Rock near Guadalupe Creek, K 1024. In both localities it is sparse in occurrence. Although the creek in Colma Canyon was mostly covered for the Guadalupe Parkway bleeding heart may still be found in one p'ace. Attractive perennial with much divided, fern-like leaves and attractive pale to deep lavender flowers in March and April. Ornamenta!.

## Garryaceae. Silk Tassel Family

Garrya elliptica Douglas. Coast Silk Tassel. Silk Tassel Bush. Quinine Bush. Occasional, brushy slopes, in chaparral. Regenerates after fire by stump sprouting. Colma Canyon, K May t, 196ł; Sierra Point, W April 27, 1965; Quarry, K June 27, 1963; Bitter Cherry Ridge, $K$ April 4, 1965; slope above Trillium Gulch, McC April 27, 1965; ravine just below top of mountain, McC, Mensies February 16, 1963. Evergreen shrub with stiff, leathery, undulate-margined leaves which are gray hairy on the lower surface, flowers are in long tassels, January to March. Plants are either male or female and both staminate and pistillate flower tassels are showy although the stamirate hang more gracefully. Ornamental.

## Gentianaceae. Gentian Family

Centaurium davyi (Jepson) Abrams. Centaury. Rare, in grassy areas, occurring sparsely. On fire trail west of Quarry, W June 19, 1965. Both this species and Centaurium floribundum are rather inconspicuous anna's with pink flowers in spring and summer.

Centaurium floribundum (Bentham) Robinson. Centaury. Rare, in grassy and disturbed areas, occurring sparsely: Crocker Industrial Park, W March 27, 1966.

## Geraniaceae. Geranium Family

Erodium botrys (Cavanilles) Bertoloni. Long-beaked Filaree. Common, weed in grassland and disturbed areas. Abandoned quarry at end of School Street, near Hillside Boulevard, K October 7, 1963; Ridge Road near Brisbane Powerline, McC May 16, 1965, and $K 958$; Crocker Avenue, P 2637, and Toschi 63:32; Hillside Boulevard, P 2709. Long-beaked filaree has simple but pinnately lobed leaves with relatively large flowers (petals to nearly $1 / 2$ inch long) in spring. Native of Mediterranean region.

Erodium cicutarium (Linnaeus) L'Heritier. Red-stemmed Filaree. Common, weed in grassland and disturbed areas. Colma Canyon, K March 15, 1964, and McC June 13, 1965 ; abandoned quarry at end of School Street near Hillside Boulevard, K October 7, 1963; Quarry, K July 14, 1963; Ridge Road, McC May 16, 1965, and K 970; Radio Road near radio stations, McC, Menzies February 16, 1963. Red-stemmed filaree has pinnately compound leaves with each leaflet finely divided, and relatively small flowers (petals about $1 / 4$ inch long) late winter into autumn. Native of southern Europe.

Erodium moschatum (Linnaeus) L'Heritier ex Aiton. White-stemmed Filaree. Musk Filaree. Weed in grassland and disturbed areas. Crocker Avenue, P 2636, and Toschi 63:40; ravine north of Randolph Avenue, $P 2747$; Guadalupe Valley, $P 2767$; Romanzoffia Ravine, K May 4, 1964. White-stemmed filaree has pinnately compound relatively long leaves ( $21 / 2$ to 12 inches long) with each leaflet coarsely serrate or cleft and relatively small flowers, about the same size as the red-stemmed filaree. Flowers late winter into autumn. Native of Mediterranean region.

Erodium obtusiplicatum (Maire, Weiler \& Wilczek) J. T. Howell. Rare, weed in grassland and disturbed places. Romanzoffia Ravine, K May 4, 1964; Ridge Road near Brisbane Powerlines, McC May 16, 1965. This filaree which has no common name was long confused with Erodium botrys which it resembles in its simple but lobed leaves, its relatively large flowers and long beak of fruit. Flowers in spring and summer. Native of North Africa.

Geranium carolinianum Linnaeus. Carolina Geranium. Rare, on brushy or grassy slopes. Near Nike Base, McC, W May 23, 1965. Branched annual with pinkish flowers, April to October. A widely distributed plant from the Pacific to the Atlantic states.

Geranium dissectum Linnaeus. Cut-leaved Geranium. Occasional, weed in grassland and disturbed areas, often in partial shade. Colma Canyon, $K$ May 4, 1967; Crocker Avenue, P February 23, 1963. Annual with leaves more deeply divided than Geranium carolinanum and small pink flowers, April to October. Native of Europe.

Geranium molle Linnaeus. Crane's-bill Geranium. Occasional, weed in grassland and disturbed areas, sometimes in shade of other plants. Colma Canyon, McC, Halde, K June 23, 1963; Nike Base, K 1199; Radio Road, W May 23, 1965. Annual or biennial with rosepink flowers, February to June.

Geranium retrorsum L'Heritier ex DeCandolle. New Zealand Geranium. Occasional, weed in grassland and disturbed areas, sometimes in shaded areas. Radio Road, McC, K September 2, 1963; Cable Ravine, K 860; April Brook, K 980. Perennial with a taproot, plant covered with retrorse whitish hairs, flowers purple, March to September. Native of Australia and New Zealand. The four species of Geranium on San Bruno Mountain are inconspicuous annuals or perennials with small flowers and are not to be confused with the garden geraniums which belong to the South African genus Pelargonium.

## Haloragidaceae. Water Milfoil Family

Myriophyllum brasiliense Cambessèdes. Parrot Feather. Rare, growing in water. Crocker Industrial Park, W March 27, 1966. Aquatic perennial, stems supported by water, leaves finely dissected and appearing feathery, tiny flowers June to August. Cultivated as an aquarium plant but escapes. Native of South America.

## Hippocastanaceae. Horse Chestnut or Buckeye Family

Aesculus californica (Spach) Nuttall. California Buckeye. Horsechestnut. Rare, part of woodland in ravines or slopes, often windswept and low in stature. Buckeye Canyon, McC May 27, 1967; Point San Bruno, McC, K September 11, 1964. Deciduous tree with round crown, leaves characteristically palmately 5 -lobed and appear before the showy white and pinkish flowers borne on thick spike-like clusters, April to June. The leaves fall early even before the summer is over. The pear-shaped fruits usually have one glossy brown seed which contains poisonous substances. The Indians used the seeds for food after leaching with boiling water, and for stupefying fish.

## Hydrophyllaceae. Waterleaf or Phacelia Family

Eriodictyon californicum (Hooker \& Arnott) Torrey. Yerba Santa. California Mountain Balm. Rare, in chaparral. Buckeye Canyon, K July 14, 1963; Owl's Canyon, W June 17, 1965; West Powerline, K May 4, 1964. Evergreen shrub with small pale blue flowers, April to July. Regenerates after fire both by root sprouts and by seeding itself.

Nemophila heterophylla Fischer \& Meyer. Rare, moist brushy slope. Devil's Arroyo, McC March 28, 1965. Weak-stemmed annual with pale blue to white flowers, January to April.

Nemophila menziesii Hooker \& Arnott. Baby-Blue Eyes. Occasional, moist open grassland or in chaparral, often coming up among other plants. Reservoir Hill, K 879, and McC March 14, 1965; Bitter Cherry Ravine, K 1006. Weak-stemmed, diffusely branched annual with showy pretty blue flowers, February to April. A favorite spring wild flower, its name commemorates Archibald Menzies, the early Scottish explorer of the Pacific coast who was with the Vancouver Expedition.

Nemophila parviflora Douglas ex Bentham. Rare, moist brushy slope. Devil's Arroyo, $K$ April 26, 1965. Weak-stemmed annual with small inconspicuous flowers, March to June.

Phacelia californica Chamisso. One of the most common perennials on mountain, in grassland and chaparral. Lower Colma Canyon, McC, Halde, K June 23, 1963; Colma Canyon, $K$ 1197, K1214, K 1222; ravine north of Randolph Avenue at Hillside Boulevard, $P 2739$; east facing slope below radio station, Toschi $63: 67$; slope south of 1314 -foot summit, $P 2667$; ravine $1 / 2$ mile east of 1314 -foot summit, $P 2691$; exposed slopes below summit, McC June 9, 1963; Quarry, K July 14, 1963; Romanzoffia Ravine, K May 4, 1964; Huckleberry Ridge, K May 4, 1964; Cable Ravine, McC March 14, 1965; Bitter Cherry Ravine, K 1010; Glen Park Canyon, McC A pril 16, 1967. Gray hairy perennial with blue to purplish flowers, March to September.

Phacelia distans Bentham. Wild Heliotrope. Occasional, rocky, sandy, and brushy slopes. South facing slope near West Powerline, McC March 14, 1965; Pig Ranch Ravine, W May 11, 1965, K May 15, 1965. Weak-stemmed annual with blue flowers, March to June.

Phacelia malvaefolia Chamisso. Stinging Phacelia. Occasional, on brushy slopes. Colma Canyon, McC, Halde, K June 23, 1963 ; Romanzoffia Ravine, K May 4, 1964, McC March

28, 1965. Weak stemmed annual with coarse conspicuous hairs, and dull white inconspicuous flowers, April to July.

Pholistoma auritum (Lindley) Lilja ex Lindblom. Fiesta Flower. Climbing Nemophila. Rare, under shade in wooded slopes. Sierra Point, W April 27, 1965; Gladys Canyon, W June 16, 1965. Weak stemmed annual with coarse hairs, short recurved prickles, and blue flowers, March to June.

Romanzoffia suksdorfii Greenc. Mist-Maiden. Occasional, on shaded or open moist rocky areas. Romanzoffia Ravine, K May 4, 1964, McC March 28, 1965; Buckeye Canyon, W May 8, 1965. Reported in Owl's Canyon by James Roof. Attractive, dainty, tuberousrooted perennial with mostly basal leaves and small white flowers, March to May. Ornamental.

## Hypericaceae. St. John's Wort Family

Hypericum anagalloides Chamisso \& Schlechtendal. Creeping St. John's Wort. Tinkers Penny. Rare, along seepages or stream sides. Cow Trough Ravine, K October 7, 1963; stream in Colma Canyon, W June 16, 1965. Perennial with prostrate and a few erect stems and small yellow flowers, March to July.

## Labiatae. Mint Family

Lepechinia calycina (Bentham) Epling [Sphacele calycina Bentham]. Pitcher Sage. Occasional, in brushy areas. Regenerates by seedlings after a fire. Crocker Hills, K, McC September 2, 1963; Guadalupe Road, $K$ August 5, 1963; ravine west of Crystal Cave Canyon, W June 20, 1965. Low-growing, aromatic shrub with somewhat woolly leaves and showy white flowers, April to July. Ornamental.

Marrubium vulgare Linnaeus. White Hoarhound. Rare, weed of waste ground. Along Bayshore Highway, South San Francisco, W March 20, 1966. White woolly perennial with small white flowers in dense heads, February to July. Native of Europe.

Mentha spicata Linnaeus. Spearmint. Escape from cultivation in wet ground. Crocker Avenue, $W$ July 7, 1965. Pleasantly fragrant perennial with lavender flowers in a spike-like inflorescence, July to October. Native of Europe.

Monardella villosa Bentham. Coyote Mint. Pennyroyal. Common, on brushy and rocky areas. Regenerates after fire by root sprouts. Quarry, K July 14, 1963, and K June 4, 1963; lower Buckeye Canyon, McC September 29, 1966; lower Colma Canyon, McC, Halde, K June 23, 1963; slope above April Brook, McC August 1, 1965; lower area of Quarry, McC August 1, 1965; West Powerline, McC March 25, 1965; east facing slope below Parking Lot, McC, Halde June 23, 1963; canyon east of Quarry, W June 19, 1965; Dairy Ravine, $K$ August 5, 1963. An erect perennial, 12 to 18 inches tall, with lavender flowers in compact heads, June to August. Two forms are described which may sometimes be distinguished on San Bruno Mountain. Var. villosa has "thin" nearly glabrous leaves, and is mostly on the eastern side of the mountain. Var. franciscana (Elmer) Jepson has "thickish" usually densely hairy leaves, and is mostly on the western side of the mountain.

Pogogyne serpylloides (Torrey) Gray. Rare, moist grassy and brushy places. South Powerline near summit, McC April 25, 1965; fire trail west of Quarry, W June 19, 1965. Slender aromatic annual with small lavender flowers, April to June. Grows in shade of surrounding plants and is easily overlooked.

Prunella vulgaris Linnaeus subsp. lanceolata (Barton) Hultén. Rare, on grassy or semi-shaded slopes. Upper Colma Canyon near Radio Road, W July 7, 1965; Colma Canyon, $K$ August 5, 1963. Perennial with lanceolate leaves, and light purple flowers, April to December.

Salvia spathacea Greene. Crimson Sage. Pitcher Sage. Common, open grassy or rocky slopes. Lower Colma Canyon, McC, Halde, K June 23, 1963; Colma Canyon, K 1218, Raven 1787; slope southeast of 1.314 -foot summit, $P$ 2681; West Powerline, McC, K September 2, 1963; Brisbane Powerline, K 953; Trillium Gulch, McC March 28, 1965. Coarse, gray hairy, aromatic perennial with reddish flowers in showy heads, March to June.

Satureja douglasii (Bentham) Briquet [Micromeria douglasii Bentham]. Yerba Buena. Frequent, in grassland and brushy areas, creeping on ground at base of surrounding p'ants. Slope above April Brook, McC August 1, 1965; Ridge Road at Saddle Camp, K August 5, 1963; east facing slope below Parking Lot, McC, Halde June 23, 1963; West Powerline, McC, K September 2, 1963; Point San Bruno, K March 13, 1964. Fragrant, evergreen trailing perennial, rooting at the stem tips, small whitish flowers, May to August.

Scutellaria tuberosa Bentham. Skull-cap. Rare, on brushy slopes, under shade of surrounding plants. Glen Park Canyon, McC April 30, 1967. Low growing, fragrant perennial with tubers on the root-stocks and dainty blue flowers, March to May.

Stachys ajugoides Bentham. Hedge Nettle. Rare, low often wet ground and waste places. Colma Canyon, $K$ August 5, 1963; Radio Road, $K$ August 5, 1963. Coarse perennial, flowers May to October.

Stachys bullata Bentham. Hedge Nettle. Occasional, edge brushy areas and shaded slopes. Lower Colma Canyon, McC, Halde, K June 23, 1963; Quarry, K July 14, 1963; Cow Trough Ravine, October 7, 1963. Coarse perennial, flowers April to September.

Stachys chamissonis Bentham. Coast Hedge Nettle. Rare, in moist places and ravine creek bottoms. Devil's Arroyo, McC March 28, 1965, K 1101; near source of Guadalupe Creek, K 988. Rather tall coarse perennial, flowers March to May.

Stachys rigida Nuttall ex Bentham subsp. quercetorum (Heller) Epling. Hedge Nettle. Frequent, on open grassy slopes and brushy hillsides, often in colonies. East facing slope below Parking Lot, McC, Ha'de June 23, 1963; Bitter Cherry Ridge, K 1012; near Nike Base, McC, W May 23, 1965; Point San Bruno, K 1063; Crocker Hills, K May 4, 1964; Glen Park Canyon, McC Ápril 16, 1967. Coarse perennial, flowers March to July.

## Lauraceae. Laurel Family

Umbellularia californica (Hooker \& Arnott) Nuttall. California Laurel. California Bay. Oregon Myrtle. Woodland in Buckeye Canyon, McC September 29, 1966. Evergreen tree with pungently aromatic, coriaceous leaves and clusters of small yellow-green flowers, January to March. A relative of the Mediterranean laurel, Laur us nobilis, its leaves may be used as a seasoning, but since its leaves are more pungent than the Mediterranean tree it should be used with discretion. Its hard wood takes a fine polish and is used for making small ornaments.

## Leguminosae. Pea or Bean Family

Acacia decurrens Willdenow. Green Wattle. Escape from cultivation and occasionally naturalized. Crocker Avenue, MCC K Jannary 12, 1963. Tree with finely divided leaves and yellow flowers, January to March. Native of Australia.

Acacia melanoxylon R. Brown. Blackwood Acacia. Black Acacia. Escape from cultivation and occasionally naturalized. Cable Ravine, McC March 14, 1965; Horseshoe Ridge, K August 5, 1963. Tree with leaves reduced to 2 to 5 nerved phyllodia, yellow flowers, February and March. Native of Australia.

Acacia retinodes Schlechtendal. Everblooming Acacia. Escape from cultivation and occasionally naturalized. Crocker Avenue, McC, K January 12, 1964, W July 7, 1965. Tree with leaves reduced to 1-nerved phyllodia, yellow flowers January to August. Native of Australia.

Albizia distachya (Ventenat) Macbride [A. lophantha (Willdenow) Bentham]. Stink Bean. Plume Albizia. Escape from cultivation and occasionally naturalized. Bayshore Highway, $W$ June 8, 1965. Tree with finely divided leaves and yellow flowers in a spike-like plume, late winter and spring. Native of Australia.

Astragalus nuttallii (Torrey \& Gray) J. T. Howell var. virgatus (Gray) Barneby Locoweed. Occasional, in grassland, and in the open on sandy soil. Flower Garden near Radio Road, W June 20, 1965, W August 16, 1965 ; south of Pig Ranch Ravire, W July 7, 1965 ; near Olivet Cemetery, W May 18, 1957; April Brook, J. Roof July 17, 1963. Robust but weak-stemmed perennial with greenish-white fowers, April to October.

Cytisus maderensis Masferrer. Broom. Escape from cultivation and naturalized in disturbed places. Radio Road, K August 5, 1963. Evergreen shrub with yellow flowers in spring. Native of Madeira.

Cytisus monspessulanus Linnaeus. French Broom. Escape from cultivation and is naturalized in disturbed places.

Cytisus scoparius (Linnaeus) Link. Scotch Broom. Escape from cultivation and naturalized in disturbed places. Brisbare, W April 27, 1965; Sierra Point, W April 27, 1965. Nearly leafless shrub with large yellow or sometimes yellow and brown flowers, spring.

Lathyrus odoratus Linnaeus. Sweet Pea. Escape from cultivation, occasionally becoming established in disturbed places. Point San Bruno, W May 8, 1965. Annual with fragrant flowers in different colors, spring. Native of Italy.

Lathyrus vestitus Nuttall ex Torrey \& Gray. Pacific Pea. Common, on brushy areas, climbing on adjacent shrubs or spreading on the ground. Lower Colma Canyon, McC, Halde, K June 23, 1963; Colma Canyon, W June 13, 1965, K March 15, 1964; slope southwest of Brisbane, P 2759; South Powerline, McC March 1t, 1965; Reservoir Hill, McC March 14, 1965; Devil's Arroyo, McC March 28, 1965; West Powerline, McC March 10, 1965. Perennial with well developed tendrils, pink to pale purplish flowers usually fading with age, March to July. A variable species divided into two or more subspecies on the basis of height of plant, internode length, and amount of pubescence.

Lotus corniculatus Linnaeus. Bird's Foot Trefoil. Weed of roadsides and other disturbed areas. Crocker Industrial Park, McC July 29, 1966; West Powerline, W May 18, 1966. Prostrate perennial with yellow flowers, June to August. Native of Europe.

Lotus micranthus Bentham. Bird's Foot Trefoil. Frequent, in grassland and edge of brushy areas. Colma Canyon, K May 30, 196t; April Brook, McC March 28, 1965; Bitter Cherry Ridge, $K$ April 4, 1965 ; Buckeye Canyon, W March 30, 1965; Crocker Hills, McC April 11, 1965. Slender-stemmed annual with small salmon-colored flowers, March to June.

Lotus purshianus (Bentham) Clements \& Clements. Spanish Clover. Rare, in grassland. Sierra Point, W May 8, 1965. Low-growing annual, sometimes forming mats, with small pinkish-white flowers, April to October.

Lotus scoparius (Nuttall) Ottley. Deerweed. Frequent, in many habitats, in grassy and brushy areas. Lower Colma Canyon, McC, Halde, K June 23, 1963; Radio Road, McC, K September 2, 1963; Owl's Canyon, W June 7, 1965; near Olivet Cemetery, W May 18, 1965; Crocker Hills, K May 4, 1954. Brushy perennial with erect to spreading green virgate stems and flowers yellow tinged with red, May to October.

Lotus subpinnatus Lagasca. Frequent, in grassland and brushy slopes, sometimes in disturbed places. Crystal Cave Canyon, K 1252; Devil's Arroyo, K May 9, 1965; Pig Ranch Ravine, K May 15, 1965; Crocker Industrial Park, McC March 28, 1965. Low growing, weak-stemmed annual with small, yellowish, solitary, sessile flowers, March to June.

Lupinus affinis Agardh. Rare, in grassland. Colma Canyon, McC, W June 13, 1965. Annual with blue flowers, April to June.

Lupinus albifrons Bentham ex Lindley. Silver Bush Lupine. Common, open rocky slopes. Colma Canyon, K May 4, 1964; Randolph Drive at Hillside Boulevard, P 2725; Sierra Point, W April 27, 1965; Motorcycle Ridge, K August 5, 1963; west facing slope below top of mountain, McC April 17, 1964; ravine $1 / 2$ mile east of summit, P 2685; Glen Park Canyon, McC April 16, 1967. Attractive shrub or subshrub with silvery-gray foliage and blue flowers April to June. This lupine is variable in habit and two forms may sometimes be recognized. Plants erect and up to 3 to 4 feet tall may be called var. albifrons and those lax and spreading with stems less than 18 inches may be called var. collinus Greene.

Lupinus arboreus Sims. Bush Lupine. Yellow Beach Lupine. Occasional, mostly in sandy areas or disturbed places. Colma Canyon, McC June 13, 1965; Sierra Point, W May 8, 1965; top of mountain near radio station, MCC, Halde June 23 1963. Attractive shrub with yellow flowers, March to September. Occurring commonly in sandy soil along the coast of northern and central California.

Lupinus bicolor Lindley. Frequent, in grassland. Slopes southwest of Brisbane, P 2757; Bitter Cherry Ridge, K 1008; Ridge Road, K March 14, 1965; Guadalupe Road, McC April 11, 1965; Flower Garden adjacent to April Brook, K 975 ; Crocker Industrial Park, W June 19, 1965. Annual with small blue flowers, March to June. This common spring wildflower is a variable species with several forms separated on the basis of technical characters of the flowers.

Lupinus chamissonis Eschscholtz. Blue Beach Lupine. Rare, in sandy soil. Colma Canyon, K 973. Shrubby, with blue flowers, March to August. Frequently seen in sandy soil along the coast of central and southern California.

Lupinus formosus Greene. Rare, dry open often sandy areas. Sierra Point, W June 21, 1965. Perennial with lavender flowers, May and June.

Lupinus micranthus Douglas ex Lindley. Occasional, in grassland. Guadalupe Valley, $P$ 2764; West Powerline, $K$ 709. Annual with small blue flowers, March to May. Resembles Lupinus bicolor from which it usually may be distinguished by the glabrous or sparsely hairy upper leaf surfaces.

Lupinus nanus Douglas ex Bentham. Frequent, in grassland, often forming showy colonies. Colma Canyon, McC, W June 13, 1965; Crocker Industrial Park, W May 1,

1966; Sierra Point, W April 27, 1965. Annual with dark blue or rarely white flowers, March to June.

Lupinus succulentus Douglas ex Koch. Rare, in disturbed ground. Point San Bruno, K March 30, 1964. Stout, hollow-stemmed annual with blue flowers.

Lupinus variicolor Steudel. Frequent, in grassland or open gravelly places. Colma Canyon, K May 4, 1964; east facing slope below top of mountain, McC April 17, 1964; West Powerline, $K$ 1042. Perennial, often decumbent, with flowers of varying shades of blues, pinks, yellows and whites.

Medicago polymorpha Linnaeus var. vulgaris (Bentham) Shinners [M. hispida Gaertner]. Bur Clover. Weed of disturbed places. Randolph Drive at Hillside Boulevard, P 2718; Colma Canyon, K May 30, 1964; Point San Bruno, K 1033. Weak-stemmed annual with small yellow flowers, March to June, and a coiled spiny pod. Native of Europe.

Medicago sativa Linnaeus. Alfalfa. Lucerne. Weed of roadsides and waste ground, an escape from cultivation. Frontage road at north city limits of South San Francisco, McC, K September 11, 1964 ; Brisbane Lagoon, W June 19, 1965. Perennial with small blue flowers, spring to autumn. An important forage plant, native of the Old World.

Melilotus albus Desrousseaux ex Lamarck. White Sweet Clover. Weed, waste places. Crocker Avenue, McC September 24, 1967. Tall erect annual or biennial with tiny white flowers, spring to autumn. Native of Eurasia.

Melilotus indicus (Linnaeus) Allioni. Indian Sweet Clover. Weed of waste ground and disturbed places. Point San Bruno, McC, K September 11, 1964; Sierra Point, W May 8, 1965. Erect annual with small yellow flowers, April to October. Native of Old World.

Melilotus officinalis (Linnaeus) Lamarck. Weed of roadsides and disturbed places. Crocker Industrial Park, W June 8, 1965. Erect annual with small yellow flowers, May to August. Native of Europe.

Pisum sativum Linnaeus. Garden Pea. Weed of disturbed places. Cow Palace area, W May 17, 1965. Annual, flowers in spring. An edible plant which occasionally escapes from cultivation. Native of the Old World.

Trifolium amplectens Torrey \& Gray. Sack Clover. Occasional, in grassland. Point San Bruno, K 1078; Bitter Cherry Ravine, K May 15, 1965; West Powerline, McC March 28, 1965. Annual with purple or sometimes pale flowers in small heads, March to June. At maturity the flowers become inflated, like tiny sacks, hence the common name.

Trifolium bifidum Gray. Rare, in grassland. Radio Road, W May 23, 1965; April Brook, K May 15, 1965. Annual with pale pink flowers, April and May, on slender recurved pedicels.

Trifolium dubium Sibthorp. Shamrock. Weed of waste places, lawns, and other disturbed areas. Near Cow Palace, W May 18, 1965. Annual with small yellow flowers, May and June. Native of Europe.

Trifolium gracilentum Torrey \& Gray. Occasional, in grassland and disturbed areas. North of Randolph Drive at Hillside Boulevard, P 2719; Pig Ranch Ravine, K May 15, 1965; Crocker Hills near Guadalupe Road, McC April 11, 1965. Slender-stemmed annual with small heads of little pink flowers, March to May.

Trifolium microcephalum Pursh. Occasional, in open grassland. Slope above Quarry, McC August 1, 1965 ; Devil's Arroyo, K May 9, 1965; West Powerline, McC March 28, 1965. Slender-stemmed annual with pinkish flowers in small heads, April to June.

Trifolium microdon Hooker \& Arnott. Occasional, in open grassland or rocky slopes. Pig Ranch Ravine, K May 15, 1965; West Powerline, McC March 28, 1965. Slenderstemmed annual with pinkish flowers, March to July.

Trifolium repens Linnaeus. White Clover. Escapes from cultivation, sometimes used in lawns, and naturalized. West Powerline, W May 18, 1965; Radio Road, K August 5, 1965. Perennial with whitish flowers in showy heads, April to October. Native of Europe.

Trifolium tridentatum Lindley. Tomcat Clover. Occasional, in grassland, sometimes forms colonies. Pig Ranch Ravine, K May 15, 1965; Nike Base, K May 15, 1965; Devil's Arroyo, K May 9, 1965 ; Ridge Road, May 16, 1965. Annual with erect to decumbent stems and red-purple flowers in showy heads, March to May.

Trifolium wormskjoldii Lehmann. Occasional, in wet or marshy places. April Brook, W May 18, 1965; Crocker Industrial Park, W May 17, 1965. Creeping perennial with decumbent stems and light purple flowers in showy heads, April and May.

Ulex europaeus Linnaeus. Gorse. Furze. Escape from cultivation, becoming weedy in disturbed areas. North of Crocker Avenue, Toschi 63:37; Crocker Hills, McC, K September 2, 1963. Spiny shrub with yellow flowers, February to July. Native of Europe.

Vicia americana Muhlenberg ex Willdenow. American Vetch. Frequent, in grassy and brushy areas, often scrambling over other plants. Colma Canyon, K May 4, 1964; Nike Base, K 1232; Kamchatka Point, K March 21 1965; South Powerline, McC March 14, 1965. Trailing perennial with purplish flowers, March to May. Resembles Lathyrus vestitus.

Vicia angustifolia Linnaeus. Common Vetch. Weed of roadsides and waste places. Crocker Hills, K May 4, 1964. Trailing perennial with fairly large purple flowers, April to June. Native of Europe.

Vicia benghalensis Linnacus. Vetch. Weed of roadsides and disturbed areas. Vicinity of Cow Palace, W May 17, 1965. Pubescent annual with rose-purple flowers, April to June. Native of Mediterranean region.

Vicia gigantea Hooker. Giant Vetch. Occasional, in moist open or brushy places, rampant climber on adjacent shrubs. Colma Canyon, K May 30, 1964; base of Quarry, K July 14, 1963; Radio Road, W May 23, 1965; April Brook, McC March 28, 1965; Wax Myrtle Ravine, $K$ August 5, 1963. Perennial with stout trailing stem and reddish-purple flowers, March to August.

Vicia sativa Linnaeus. Spring Vetch. Weed along roadsides and disturbed areas. Upper Colma Canyon, $M C C$, Wune 11, 1967. Annual with sessile, light and dark purple flowers March to July. Native of Europe.

## Linaceae. Flax Family

Linum usitatissimum Linnaeus. Flax. Escape from cultivation and becoming weedy along roadsides and disturbed places. San Bruno Hills, Vincent Jones April 1921. Slender, branched annual with pretty blue flowers, March to July. Native of Europe. Not reported from our area within recent years.

## Lythraceae. Loosestrife Family

Lythrum hyssopifolia Linnaeus. Loosestrife. Occasional, in moist places as damp creek beds, and meadows. Crocker Hills, McC September 2, 1963; Radio Road, K August 5, 1963; fire trail west of Quarry, W June 19, 1965; Sierra Point, W August 8, 1965 ; Crocker Industrial Park, W June 8, 1965. Slender annual with small linear leaves and pale purple flowers, April to October. Widely distributed in the northern hemisphere from North America to Europe.

## Malvaceae. Mallow Family

Lavatera arborea Linnaeus. Tree Mallow. Escape from cultivation along roadsides, becoming spontaneous. Bayshore highway, Brisbane, W June 8, 1965. Shrubby with redpurple flowers, May to July.

Lavatera assurgentiflora Kellogg. Malva-Rose. Escape from cultivation, used as a windbreak, and occasionally becoming spontaneous. Hillside Boulevard near Cypress Hill Golf Course, $K$ October 7, 1963. Shrubby, sometimes a small tree, showy rose-purple flowers almost throughout the year. Native of the Channel Islands.

Lavatera cretica Linnaeus. Weed of waste places, fields, and roadsides. Point San Bruno, K 1032; lower Pig Ranch Ravine, K April 4, 1965; Crocker Hills, K 2043; Colma Canyon, $M c C$, Halde, $K$ June 23, 1963. Annual with small pinkish flowers, spring through autumn. Native of Mediterranean region.

Malva nicaeensis Allioni. Bull Mallow. Weed of roadsides, waste places, and around habitations. Crocker Hills, W May 17, 1965. Annual with pale lavender flowers, spring through summer. Native of Europe.

Malva parviflora Linnaeus. Cheeseweed. Weed of waste ground, fields, and around habitations. Crocker Industrial Park, W October 16, 1966. Annual with pale pinkish flowers, spring through summer. Native of Europe. The small disk-shaped fruits or "cheeses" are edible.

Sidalcea malvaeflora (DeCandolle) Gray ex Bentham. Checker Bloom. Wild Hollyhock. Common, on open grassy areas. Crocker Avenue, P 2633; Randolph Drive, P 2710; Colma Canyon, McC, Halde, $K$ June 23, 1963; Radio Road, K 1245 ; Flower Garden adjacent to April Brook, McC March 28, 1965; top of mountain near radio station, McC, Menzies February 16, 1963; slope southeast of summit, P 2674. Attractive perennial with pink flowers, February to June.

## Myricaceae. Wax Myrtle or Bayberry Family

Myrica californica Chamisso \& Schlechtendal. California Wax Myrtle. Rare, in moist ravines. Wax Myrtle Ravine, K August 5, 1963; canyon south of Pig Ranch Ravine, IV July 7, 1965. Evergreen tree with inconspicuous flowers, April to June. Ornamental.

## Myrtaceae. Myrtle Family

Eucalyptus globulus Labillardière. Blue Gum. Spontaneous with planted trees. Fog Forest along old Guadalupe Road, K January 15, 1964; Horseshoe Ridge, K August 5, 1965. Tall tree with peeling bark and white flowers, January to May. Native of Tasmania and Victoria, Australia.


Figure 8. Camissonia ovata (Nuttall ex Torrey \& Gray) Raven.

## Nyctaginaceae. Four-o'Clock Family

Mirabilis jalapa Linnaeus. Four-o'Clock. Marvel of Peru. Escape from cultivation and occasionally spontaneous. Marshy area near Bayshore Freeway, K October 4, 1966. Perennial with showy flowers in shades of rose-pink to purple and white, opening in late afternoon, August to October. Native of tropical America.

## Onagraceae. Evening Primrose Family

Camissonia dentata (Cavanilles) Reiche [Oenothera contorta Douglas ex Hooker var. strigulosa (Fischer \& Meyer) Munz]. Rare, open areas in deep sandy soil. Mouth of Colma Canyon, K April 15, 1965; Pig Ranch Ravine, K May 16, 1967. Annual with small yellowish flowers, April to July.

Camissonia micrantha (Hornemann ex Sprengel) Raven [Oenothera micrantha Hornemann ex Sprengel]. Rare, in grassland or sandy areas. Pig Ranch Ravine, K April 24, 1965; K May 16, 1967. Annual with small yellow flowers, April to July.

Camissonia ovata (Nuttall ex Torrey \& Gray) Raven [Oenothera ovata Nuttall]. Suncup. Frequent, in grassland. Flower Garden near April Brook, McC March 28, 1965 ; near Nike Base, McC May 23, 1965 ; eastern side of mountain about $1 / 4$ mile east of Brisbane Powerlines, $K$ 952; Glen Park Canyon, McC April 16, 1967. Perennial with deep taproot, basal rosette of leaves, and bright yellow flowers, February to June.

Clarkia davyi (Jepson) Lewis \& Lewis. Occasional, grassy slopes. Crystal Cave Canyon,

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K June 20; 1965; Buckeye Canyon, W May 25, 1965. Annual, stem sometimes stout, leaves ovate and more or less crowded, flowers pinkish, petals sometimes spotted, May and June.

Clarkia purpurea (Curtis) Nelson \& Macbride. Occasional, in grassland. Above Harold Avenue, Brisbane, $M c C, W$ May 14, 1967. Slender annual with dark red-purple flowers, the petals lacking spots, April to July.

Clarkia rubicunda (Lindley) Lewis \& Lewis. Farewell-to-Spring. Frequent, in grassland. Sierra Point, W June 21, 1965; Colma Canyon, McC, Halde, K June 23, 1963; Crystal Cave Canyon, K June 20, 1965; Quarry, K July 14, 1963; Buckeye Canyon, W June 7, 1965; above Olivet Cemetery, McC June 13, 1965. Showy annual often branched above, with pink flowers, petals often with red spot at base, April to August. Ornamental.

Epilobium adenocaulon Haussknecht. Northern Willow-Herb. Occasional, in moist places. Quarry, McC August 1, 1965; Sierra Point, W May 8, 1965; Radio Road, McC, K September 2, 1963; Cow Trough Ravine, K October 7, 1963; Crystal Cave Canyon, K June 20, 1965. Perennial with pale to dark pink flowers, June to October.

Epilobium franciscanum Barbey. San Francisco Willow-Herb. Occasional, in moist places. Guadalupe Road, K August 5, 1963; Wax Myrtle Ravine, K August 5, 1963; slope below top of mountain, McC June 9, 1963; Colma Canyon, K May 30, 1964; Radio Road, K June 20, 1965; Crystal Cave Canyon, K June 20, 1965. Perennial with pink flowers, April to June.

Epilobium paniculatum Nuttall. Willow-Herb. Occasional, in open usually dry disturbed areas. Crocker Avenue, $K$ August 5, 1963; Cow Trough Ravine, K October 7, 1963; Radio Road, McC, K September 2, 1963; Great Meadow near Radio Road, W August 16, 1965; Quarry, K July 7, 1963. Annual, stem of mature plants almost woody and with exfoliating epidermis, small pinkish flowers, May to October.

Epilobium watsonii Barbey. Willow-Herb. Occasional, in moist areas. Radio Road, $M c C, K$ September 2, 1963; Cow Trough Ravine, $K$ October 7, 1963; Crystal Cave Canyon, K June 20, 1965. Perennial with dark pink flowers, June and July.

Oenothera hookeri Torrey \& Gray. Rare, in a seepage area. Upper Colma Canyon, $M c C$, W June 11, 1967. Coarse biennial, 3 to 4 feet tall with large yellow showy flowers, June to October.

Zauschneria californica Presl. California Fuchsia. Occasional, dry rocky or brushy areas. South Powerline, Menzies March 14, 1965; Pig Ranch Ravine, K 1112, W July 7, 1965. Suffrutescent, decumbent, grayish perennial with showy red flowers, July to November. Ornamental.

## Orobanchaceae. Broomrape Family

Orobanche uniflora Linnaeus. Broomrape. Rare, on rocky ledges, parasitic on Sedum spathulifolium. Owl's Canyon, $K, M c C, W$ April 25, 1965. Stems fleshy, colorless, and leafless, flowers purple, March and April.

## Oxalidaceae. Oxalis Family

Oxalis pes-caprae Linnaeus. Bermuda Buttercup. Cape Oxalis. Weedy escape from cultivation in grassland and disturbed areas. Crocker Avenue, K January 15, 1964; Reservoir Hill, $K$ February 28, 1965 ; South Powerline, Menzies March 14, 1965. Stemless perennial, leaves all basal, bright yellow showy flowers February to June. Native of South Africa.

This attractive weed is undesirable because the scaly bulbs on its rootstocks make it difficult to eradicate.

Oxalis pilosa Nuttall. Hairy wood sorrel. Occasional, grassland. Colma Canyon, $M c C$, Halde, K June 23, 1963; Guadalupe Road, McC, Ryder February 16, 1964; Nike Base, K 1239; Ridge Road near Powerlines, McC April 25, 1965; Glen Park Canyon, McC April 16, 1967. Low growing perennial with small yellow flowers, April to June.

## Papaveraceae. Poppy Family

Eschscholzia californica Chamisso. California Poppy. One of the mountain's commonest spring wildflowers, in grassland and disturbed areas. Cable Ravine, McC March 14, 1965; rocky slope near Parking Lot, McC, Halde June 23, 1963; Randolph Avenue, $P 2706$; Ridge Road on summit of mountain, $K 632$. Usually a biennial with gray-green much divided leaves and showy orange colored flowers, March to October or occasionally other times during the year.

Meconella californica Torrey. Rare, wet rocky slopes and grassland, sometimes in small colonies. Ravine east of Brisbane Powerlines, McC March 21, 1965; Devil's Arroyo, McC March 28, 1965; Glen Park Canyon, McC April 16, 1967. Slender glabrous annual with obovate to spathulate basal leaves, and small white flowers, February to April.

Meconella linearis (Bentham) Nelson \& Macbride. Known only from a collection made in "San Bruno Hills" by A. D. E. Elmer (no. 4594) in June, 1903. Differs from preceding species by its linear basal leaves and spreading hairs on flowering stems.

Papaver somniferum Linnaeus. Opium Poppy. Escape from cultivation. Pig Ranch Ravine, K May 15, 1965. Coarse, gray-green annual with milky juice, upper leaves clasping the stem and large, white, pink or purplish flowers. Native of Old World. Sometimes cultivated for its large flowers. Opium is obtained from milky juice of fruit.

Platystemon californicus Bentham. Cream-Cups. Occasional, grassland and brushy areas. Colma Canyon, $\boldsymbol{M c} \subset$, Halde, $K$ June 23, 1963; above Harold Avenue, Brisbane, W March 30, 1965 ; Devil's Arroyo, McC March 28, 1965 ; Quarry, W July 8, 1965. Annual with spreading hairs, entire leaves, and cream-colored flowers, March to June.

Stylomecon heterophylla (Bentham) Taylor. Wind Poppy. Rare, moist shaded often grassy slopes, sometimes appearing in abundance after a fire. Devil's Arroyo, K 1017; Owl's Canyon, K 1072; lower slopes of West Powerline, W May 12, 1965. Glabrous annual with divided leaves and scarlet flowers, March to May.

## Plantaginaceae. Plantago Family

Plantago coronopus Linnaeus. Weed, on salt flats. Sierra Point, W May 8, 1965 ; Brisbane Lagoon, W June 19, 1965. Annual (sometimes a perennial) with coarsely toothed leaves and flowers in spikes 2 to 3 inches long, March to August. Native of the Old World.

Plantago erecta Morris [ $P$. hookeriana Fischer \& Meyer var. californica (Greene) Poel. California Plantain. Frequent, open slopes at edge of chaparral and in grassland, sometimes forming sparse to dense colonies. Randolph Avenue, P 2732; Colma Canyon, K March 15, 1954; Glen Park Canyon, McC April 16, 1967; Devil's Arroyo, K 1106; Crystal Cave Canyon, W June 20, 1965; slope below Parking Lot, McC June 9, 1963. Slender annual with entire linear leaves and flowers in spikes to as much as 1 inch long, January to June.

Plantago hirtella Humboldt, Bonpland \& Kunth var. galeottiana (Decaisne) Pilger. Mexican Plantain. Rare, in damp areas and in places where water seeps. Radio Road adjacent to radio station near top of mountain, McC, Halde, June 23, 1963, W June 20, 1965 ; Colma Canyon, $K$ August 5, 1963. Perennial with broadly ovate leaves and flowers in spikes 5 to 6 (or more) inches long.

Plantago lanceolata Linnaeus. Ribgrass. English Plantain. Buckhorn. Weed of roadsides and other disturbed areas, and in grassland. South of Crocker Avenue, $P 2644$; Quarry at end of School Street and Hillside Boulevard, K October 7, 1963; frontage road at northern city limits of South San Francisco, McC, K September 11, 1964; Crocker Industrial Park, W June 8, 1965; Glen Park Canyon, McC April 16, 1967. Perennial with slender lanceolate leaves and flowers in spikes to 3 inches long, April to October. The flowers of this species have much exerted anthers. Native of Europe.

## Plumbaginaceae. Plumbago Family

Limonium californicum (Boissier) Heller. Marsh Rosemary. Sea Lavender. Rare, salt flats along San Francisco Bay. Point San Bruno, K 1047. Perennial with a basal tuft of leaves and small purplish flowers at the ends of a branched inflorescence, July to November.

## Polemoniaceae. Polemonium Family

Gilia achilleaefolia Bentham. California Gilia. Occasional, open rocky slopes and brush covered areas. Pig Ranch Ravine, W May 12, 1965; Crystal Cave Canyon, K June 20, 1965. Erect branched annual with slender stems and blue-violet flowers, February to July.

Gilia clivorum (Jepson) V. Grant. Occasional, open rocky slopes and grassland. Crocker Hills, K 1003; Ridge Road near West Powerline, K 1036; Owl's Canyon, K 1067; Buckeye Canyon, $W$ A pril 2, 1967; Crystal Cave Canyon, K June 20, 1965. Erect branched annual, blue-violet flowers, March to June; similar to preceding species from which it differs by its generally shorter corollas and more numerous seeds in the capsules.

Linanthus androsaceus (Bentham) Greene. Occasional, open grassy slopes, often in colonies. Colma Canyon, Raven 1793; Glen Park Canyon, McC, W May 14, 1967; Owl's Canyon, $K$ 1068. Slender, attractive annual with clusters of pink to white flowers, April to July.

Navarretia squarrosa (Eschscholtz) Hooker \& Arnott. Skunkweed. Occasional, dry open slopes in often hard-packed soil, sometimes in grassland. Colma Canyon, K August 5, 1963; Quarry, K July 14, 1963; Brisbane Lagoon, W June 19, 1965. Annual with skunklike odor and heads of small blue flowers, June to October.

Phlox gracilis (Hooker) Greene. [Gilia gracilis Hooker; Microsteris gracilis (Hooker) Greene]. Occasional, in grassland, sometimes recurring after fire. Two ravines east of Brisbane Powerlines, McC March 21, 1965; Owl's Canyon, K 1044; Devil's Arroyo, McC March 28, 1965; Glen Park Canyon, McC April 16, 1967; Quarry, W April 2, 1967. Diminutive annual with small pink flowers, February to April.

## Polygonaceae. Buckwheat Family

Chorizanthe pungens Bentham var. hartwegii (Bentham) Goodman. Spine-flower. Rare, sandy areas. Lower Colma Canyon, McC June 13, 1965. Prostrate annual with inconspicuous flowers in spiny heads, April to June.

Eriogonum latifolium Smith. Wild Buckwheat. Frequent, open rocky slopes, grassy and brushy areas. Quarry at end of School Street near Hillside Boulevard, K October 7, 1963; adjacent to Olivet Cemetery, W May 18, 1965; Randolph Avenue at Hillside Boulevard, P 2717; Guadalupe Road, McC April 11, 1965; Point San Bruno, K September 2, 1964; Quarry, K July 14, 1963; above Harold Avenue, Brisbane, McC, W May 14, 1967. Perennial with mostly basal leaves densely hairy on lower surface and small flowers in dense heads, June to October.

Eriogonum nudum Douglas ex Bentham. Rare, dry open or rocky areas. Sierra Point, W June 21, 1965. Similar in appearance to preceding except that stem is glabrous, flowers June to August.

Eriogonum vimineum Douglas ex Bentham. Rare, rocky slopes. Canyon south of Pig Ranch Ravine, W July 7, 1965. Annual branched above with few flowers in small clusters, July to September.

Polygonum aviculare Linnaeus. Dooryard Knotweed. Weed of dry packed soil in disturbed areas. Crocker Avenue, $K$ August 5, 1963. Prostrate annual, stems and leaves gray-green, small whitish flowers along stems, May to October. Native of Eurasia.

Polygonum paronychia Chamisso \& Schlechtendal. Dune Knotweed. Rare, in sandy soil. Colma Canyon, McC June 13, 1965. Prostrate perennial, stems and leaves gray-green, small whitish flowers in terminal clusters, May to July.

Pterostegia drymarioides Fischer \& Meyer. Occasional, on open and rocky or brushy slopes, scrambling under the adjacent shrubs. Rocky slopes below summit, McC June 9, 1963; Bitter Cherry Ridge, K May 4, 1964; South Powerline, Menzies March 14, 1965 ; Crystal Cave Canyon, K June 20, 1965; Colma Canyon, K 1216. Delicate prostrate, twining annual with tiny inconspicuous flowers, March to June.

Rumex acetosella Linnaeus. Sheep Sorrel. Weed, frequent on open and brushy areas or grassland. Glen Park Canyon, McC April 16, 1967; Colma Canyon, McC, Halde, K June 23, 1963; meadow between April Brook and Radio Road, McC March 28, 1965 ; Sierra Point, W May 8, 1965 ; south of Crocker Avenue, P 2642. Perennial with hastately lobed leaves and small reddish flowers in terminal panicles, March to September. Native of Eurasia.

Rumex californicus Rechinger f. California Dock. Rare, in grassland. Lower Buckeye Canyon, K September 2, 1964; near Bayshore Freeway, Brisbane, W June 8, 1965. Coarse perennial with lanceolate leaves and small greenish flowers on terminal branches, May to August.

Rumex conglomeratus Murray. Green Dock. Weed of low moist areas. Colma Canyon, K August 5, 1963; April Brook, W August 16, 1965. Tall coarse perennial. Flowers April to October. Native of Europe.

Rumex crispus Linnaeus. Curly Dock. Weed of low moist places. Ravine south of Crocker Avenue, P 2656; Guadalupe Road, K August 5, 1963; Point San Bruno, W March 23, 1965. Perennial with somewhat undulate leaf margins and small flowers, April to July. Native of Eurasia.

Rumex obtusifolius Linnaeus. Bitter Dock. Weed of low moist places. Guadalupe Road, $K$ August 5, 1963. Stout perennial with often large leaves (to 12 inches long), small flowers, May to September. Native of Europe.

Rumex pulcher Linnaeus. Fiddle Dock. Weed of waste places. Colma Canyon, $M c C$, Halde, K June 23, 1963; above Randolph Avenue at Hillside Boulevard, P 2728; ridge above Buckeye Canyon, K July 14, 1963. Perennial with divaricately branched stem, and small flowers, May to July. Native of Mediterranean Region.

Rumex transitorius Rechinger f. [ $R$. salicifolius Weinmann forma transitorius (Rechinger f.) J. T. Howell]. Rare, in moist disturbed areas. Crocker Hills, McC, K September 2, 1963.

## Portulacaceae. Portulaca or Purslane Family

Calandrinia ciliata (Ruiz \& Pavon) DeCandolle var. menziesii (Hooker) Macbride. Red Maids. Occasional, open places and disturbed areas, sometimes bordering grassland. Glen Park Canyon, McC April 16, 1967; lower Colma Canyon, McC, Halde, K June 23, 1963; Flower Garden adjacent to April Brook, McC March 28, 1965; Pig Ranch Ravine, W May 12, 1965 ; slope above Crocker Avenue, Toschi 63:36. Somewhat fleshy annual with small but conspicuous magenta flowers, February to May.

Montia perfoliata (Donn ex Willdenow) Howell. Miner's Lettuce. Frequent, in moist areas and grassland. Colma Canyon, K May 30, 1964; Glen Park Canyon, McC April 16, 1967; near Nike Base, McC, W April 23, 1965; Bitter Cherry Ridge, K May 4, 1964; Ridge Road, K February 28, 1965. Glabrous annual with stem leaves opposite and connate, small white flowers, February to May.

Portulaca oleracea Linnaeus. Purslane. Weed of disturbed areas. Hillside Boulevard, K October 7, 1963. Prostrate, fleshy, glabrous annual with small yellow flowers, May to October. Native of Europe.

## Primulaceae. Primrose Family

Anagallis arvensis Linnaeus. Scarlet Pimpernel. Weed of disturbed areas and in grassland. Lower Colma Canyon, McC, Halde, K June 23, 1963; Sierra Point, W April 27, 1965 ; near Nike Base, McC, W May 23, 1965 ; West Powerline, McC, K April 13, 1964. Diffusely branched, slender annual with dainty salmon-colored flowers at most times throughout the year. Native of Europe.

Dodecatheon hendersonii Gray subsp. cruciatum (Greene) Thompson. Shooting Star. Occasional, on grassy slopes, but sparse at all localities on San Bruno Mountain. Radio Road, McC,V.Ryder, February 16, 1964; Cable Ravine, K 865; West Powerline, K 951; Glen Park Canyon, McC April 16, 1967. Perennial with basal rosette of leaves and flower stalk terminated by several magenta flowers, February to April. One of our most attractive early spring wildflowers. The strongly reflexed corolla lobes indicate the relationship of this genus to the European Cyclamen which we know as a florist's and garden plant. Ornamental.

## Ranunculaceae. Buttercup Family

Aquilegia formosa Fischer var. truncata (Fischer \& Meyer) Baker. Columbine. Rare, moist, partially shaded brushland, only a few plants in each locality. Bitter Cherry Ridge, K May 4, 1964; Columbine Gulch, W March 28, 1965. Attractive perennial with divided leaves and nodding salmon-red flowers, April to June. Ornamental.

Delphinium californicum Torrey \& Gray. Coastal Larkspur. Occasional, moist, partially shaded brushland. Colma Canyon, McC, W June 13, 1965 ; Owl's Canyon, K 1048; Romanzoffia Ravine, K May 4, 1964. Perennial to 4 to 5 feet tall, racemes densely flowered, flowers dull bluish or lavender, April to July.

Delphinium decorum Fischer \& Meyer. Blue Larkspur. Occasional, in grassland. Colma Canyon, K March 15, 1964; Bitter Cherry Ridge, K May 4, 1964; Owl's Canyon, McC April 25, 1965; grassy meadow between April Brook and Radio Road, McC March 28, 1965; above Harold Avenue, Brisbane, McC, W May 14, 1967. Perennial to about 12 inches tall, with deep blue flowers, March to May. A very attractive spring wildflower.

Ranunculus californicus Bentham. California Buttercup. Frequent, in moist grassland. Slope above Parking Lot, McC February 16, 1964; Kamchatka Point, McC June 9, 1963; above Harold Avenue, Brisbane, McC May 14, 1967; Randolph Drive north of Hillside Boulevard, P March 30, 1963; near Nike Base, McC, W May 23, 1965. Perennial with fibrous roots, stems more or less hairy, sparsely branched, usually 1 to 2 feet tall, bright yellow flowers, February to June, smooth achenes.

Ranunculus muricatus Linnaeus. Prickle-fruited Buttercup. Weed of wet ground and seepage areas. Near Olivet Cemetery, W May 18, 1965; Colma Canyon, W June 16, 1965. Annual or perennial with fibrous roots, stems glabrous, to about 12 inches tall, yellow flowers February to June, achenes roughened with sharp points. Native of Europe.

Thalictrum polycarpum (Torrey) Watson. Meadow Rue. Occasional, in moist places on brush covered slopes. Lower Colma Canyon, McC, Halde, K June 23, 1963; Bitter Cherry Ridge, $K$ April 4, 1965; Romanzoffia Ravine, K May 4, 1964. Perennial with attractive fernlike leaves, much branched panicles with dainty yellowish flowers, March to May. Ornamental.

## Rhamnaceae. Buckthorn Family

Ceanothus thyrsiflorus Eschscholtz. Blue Blossom. Frequent, on brushy slopes, seedlings sometimes appear after fire. Near West Powerline, McC, K September 2, 1963; Quarry, K June 24, 1963; Ridge Road, $1 / 2$ mile east of summit, P 2695. Evergreen shrub to 15 feet or more, with leaves 3 -veined from base and blue flowers, March to May. Ornamental.

Rhamnus californica Eschscholtz. California Coffee Berry. Frequent, on brushy slopes. Regenerates by crown sprouts after fire. Base of mountain adjacent to Olivet Cemetery, W May 18, 1965; Pig Ranch Ravine, K 1108 ; above April Brook and east of Nike Base, McC April 23, 1965; Huckleberry Ridge, K May 4, 1964; Buckeye Canyon, K July 14, 1963; West Powerline, $M c C, K$ September 2, 1963; north-facing slope south of Guadalupe Parkway and west of its junction with Radio Road, McC, W June 11, 1967. Evergreen shrub with inconspicuous flowers, May to July, and black berries. Ornamental, especially the more compact low-growing plants.

Rhamnus crocea Nuttall. Redberry. Occasional, on brushy slopes and rocky outcrops. Ridge south of Parking Lot, K May 4, 1964; Guadalupe Road, K August 5, 1963; Colma Canyon, McC June 13, 1965. Small leaved, prostrate, compact, evergreen shrub with inconspicuous flowers February to May, and red berries. Ornamental.

## Rosaceae. Rose Family

Acaena californica Bitter. Frequent, grassland and rocky slopes. Above Harold Avenue, Brisbane, McC, W May 14, 1967; near Nike Base, K March 15, 1964; Flower Garden, MACC March 28, 1965; slope below Parking Lot, McC, Halde June 23, 1963; South

Plate 4. Left. Rhamnus californica Eschscholtz, stump sprouting after fire. Right. Baeria chrysostoma Fischer \& Meyer.



Figure 9. Fragaria chiloensis (Linnaeus) Duchesne.

Powerline, McC March 14, 1965. Perennial with basal, pinnately divided leaves and inconspicuous flowers in clusters on flower stalks usually 12 to 18 inches tall, March to June.

Alchemilla occidentalis Nuttall ex Torrey \& Gray. Western Lady's Mantle. Occasional, on rocky and brushy slopes. Because of its small size easily overlooked. South Powerline, McC March 14, 1965; West Powerline, K 949. Inconspicuous annual with tiny flowers lacking petals, February to May.

Amelanchier pallida Greene. Service Berry. June Berry. Occasional, on rocky and brushy slopes. Stump sprouts after fire. Slope just below summit, McC June 9, 1963; Horseshoe Ridge, $K$ August 5, 1963 ; above Harold Avenue, Brisbane, McC, W May 14, 1967 ; April Brook, W June 16, 1965. Deciduous shrub with white flowers April and May. Ornamental.

Cotoneaster pannosa Franchet. Rare, an escape from cultivation. Colma Canyon, W June 10́, 1965. Evergreen shrub, lower leaf surface gray hairy, small pinkish flowers, June, reddish fruits later in season. Native of China.

Crataegus monogyna Jacquin. Hawthorn. Rare, an escape from cultivation. North of Crocker Avenue, W July 7, 1965; in eucalyptus forest, Crocker Avenue near Guadalupe Road, K September 2, 1964. Deciduous small tree, with lobed leaves, pink flowers in spring, red fruits later in season. Native of Europe and western Asia.

Fragaria californica Chamisso \& Schlechtendal. California Strawberry. Frequent, in grassland and on brushy and rocky slopes. Growing with Fragaria chiloensis along Radio Road. Colma Canyon, K March 15, 1964; below Nike Base, McC, W May 23, 1965 ; Radio Road, McC, W May 23, 1965; April Brook, McC March 28, 1965; Cable Ravine, McC March

14, 1965 ; ravine west of Radio Road, K 700; Kamchatka Point, McC May 1, 1966; below summit in vicinity of radio station, McC, Menzies February 16, 1963. Attractive perennial, spreading by runners, leaves thin, dull green above and with silky hairs beneath, white flowers $1 / 2$ to $3 / 4$ inch across, January to June, fruit edible. Ornamental.

Fragaria chiloensis (Linnaeus) Duchesne. Beach Strawberry. Occasional, in sandy and rocky areas. Radio Road, K August 5, 1963; ravine west of Radio Road, K 688; April Brook, McC March 28, 1965. Similar to Fragaria californica in habit, leaves leathery, shining and silky hairy beneath, flowers usually $3 / 4$ inch or more across, February to August, fruit edible. Ornamental, probably superior to Fragaria californica because of its thicker and more glossy leaves and larger flowers.

Heteromeles arbutifolia (Aiton) Roemer [Photinia arbutifolia (Aiton) Lindley]. Toyon. Christmas Berry. California Holly. Frequent, in chaparral and wooded ravines, or sometimes occurring as single individuals in open areas. Stump sprouts after fire. Colma Canyon, McC June 13, 1965; Quarry, K June 24, 1963; Bitter Cherry Ravine, K 1015; Guadalupe Road, K 1001; Cable Ravine, McC March 14, 1965. Evergreen shrub or small tree; leaves leathery, mostly glabrous, margins toothed; small white flowers in large clusters, June and July, red holly-like fruits in winter. Ornamental.

Holodiscus discolor (Pursh) Maximowicz. Cream Bush. Ocean Spray. Frequent, in chaparral and brushy areas. Stump sprouts after fire. Colma Canyon, McC, Halde, K June 23, 1963; Radio Road near summit of mountain, K September 2, 1964; Horseshoe Ridge, K August 5, 1963; Quarry, K June 24, 1963; Romanzoffia Ravine, K 1019; Trillium Gulch, McC March 28, 1965; Buckeye Canyon, McC, W May 14, 1967. Deciduous shrub with small white flowers in showy panicles, April to July. Ornamental.

Horkelia californica Chamisso \& Schlechtendal. Occasional, in grassland. Colma Canyon, McC June 13, 1965 ; Quarry, K July 14, 1963; Radio Road, McC, K September 2, 1963; Pig Ranch Ravine, W May 11, 1965; slope below Parking Lot, McC, Halde June 23, 1963. Herbaceous perennial, leaves mostly basal, pinnately compound; stems to 2 feet or more with small white flowers, June to October. Similar in appearance to Potentilla glandulosa and often confused with it.

Osmaronia cerasiformis (Torrey \& Gray ex Hooker \& Arnott) Greene. Oso-Berry. Frequent, in chaparral and in moist wooded ravines. Stump sprouts after fire. Colma Canyon, K March 13, 1964; Cable Ravine near Eucalyptus grove, McC March 14, 1965 ; Quarry, K July 14, 1963; Devil's Arroyo, McC March 28, 1965; Bitter Cherry Ravine, $K 1011$; ravine near Parking Lot, P 2701; Buckeye Canyon, W May 7, 1965, and McC April 16, 1967. Deciduous shrub or small tree with small white flowers in nodding racemes, February to April, and fruit berry-like, red at first and black when mature. The soft wood of this shrub has the pith divided into transverse chambers. Ornamental.

Physocarpus capitatus (Pursh) Kuntze. Ninebark. Rare, on wooded slopes. Quarry, K June 24, 1963. Deciduous shrub with exfoliating bark, small white flowers in capitate clusters, May to Junc. The shrubs at this locality on San Bruno Mountain vary in height from about 7 to 8 inches to 5 feet, the taller shrubs being toward the lower part of the ravine in more protected places and the lower ones where it is more open and windswept. Ornamental.

Potentilla egedii Wormskjöld var. grandis (Torrey \& Gray) J. T. Howell. Cinquefoil. Occasional, in scepages and other wet places. Colma Creek in Colma Canyon, McC April 11, 1965; Guadalupe Road, $K$ August 5, 1963; Radio Road, W May 23, 1965. Low perennial
with runners, silvery pinnately compound leaves in basal rosettes, and yellow flowers, April to June. Ornamental for its silvery foliage and yellow flowers.

Potentilla glandulosa Lindley. Sticky Cinquefoil. Occasional, on grassy or brushy slopes. Crocker Avenue, P 2634; Colma Canyon, $K$ 1224; Cow Trough Ravine, $K$ October 7, 1963; Quarry, K July 7, 1963; Flower Garden, K 978; Devil's Arroyo, McC March 28, 1965; above Harold Avenue, Brisbane, McC, W May 14, 1967; slopes below summit of mountain, McC June 9, 1963. Herbaceous perennial with mostly basal pinnately compound leaves, stems to 2 feet or more, and small yellowish flowers, March to July. Similar in appearance to Horkelia californica from which it is distinguisheed by technical characters of flowers.

Prunus demissa (Nuttall) Walpers. Western Choke Cherry. Occasional, in chaparral and wooded ravines. Upper Colma Canyon, $K$ April 11, 1965; lower Colma Canyon, McC, Halde, K June 23, 1963; Devil's Arroyo, Roof April 25, 1965; Sierra Point, W May 12, 1965. Deciduous shrub with small white flowers in showy racemes, April to June. Ornamental.

Prunus emarginata (Douglas) Walpers. Bitter Cherry. Rare, on brushy slopes. Stump sprouts after fire. Bitter Cherry Ridge, $K$, Roof May 15, 1965; Glen Park Canyon, McC, W May 14, 1967. Deciduous shrubs with small white flowers in showy umbellate clusters, April and May. Ornamental.

Prunus ilicifolia (Nuttall ex Hooker \& Arnott) Walpers. Holly-leaved Cherry. Islay. Occasional, brushy and wooded ravines. Crocker Hills, McC, K September 2, 1963; Dairy Ravine, $K$ August 5, 1963; Wax Myrtle Ravine, $K$ August 5, 1963; between Devil's Arroyo and Buckeye Canyon, W June 7, 1963; Buckeye Canyon, K July 14, 1963; Sierra Point, W May 12, 1965. Evergreen shrub with holly-like leaves and small white flowers in showy racemes, March to June. Ornamental.

Rosa californica Chamisso \& Schlechtendal. California Wild Rose. Occasional, on brushy areas. Stump sprouts after fire. Point San Bruno, K September 2, 1964; Romanzoffia Ravine, $K$ May 4, 1964; Buckeye Canyon, W June 7, 1965. Deciduous shrub with stout flattened usually recurved prickles, attractive pink flowers in corymbs, April to October, petals usually $1 \times 2$ to 1 inch long.

Rosa gymnocarpa Nuttall ex Torrey \& Gray. Wood Rose. Frequent, on brushy slopes. Stump sprouts after fire. Colma Canyon, K May 30, 1964; Quarry, K June 24, 1963; Bitter Cherry Ridge, K May 4, 1964; Owl's Canyon, Roof April 25, 1965; Romanzoffia Ravine, K May 4, 1964; Buckeye Canyon, W June 7, 1965; east facing slope below Parking Lot, McC, Halde June 23, 1963. Slender-stemmed deciduous shrub with many terete mostly straight prickles, dainty pink flowers, April to September, usually solitary, petals less than $1 / 2$ inch long. Ornamental.

Rubus parviflorus Nuttall var. velutinus (Hooker \& Arnott) Greene. Thimble Berry. Occasional, on moist brushy slopes. Stump sprouts after fire. Colma Canyon, K May 30, 1964; Romanzoffia Ravine, K May 4, 1964; Columbine Gulch, McC March 28, 1965; Quarry, K June 24, 1964. Deciduous shrub lacking prickles, leaves 5 -lobed, flowers white to pink, March to August, fruit an edible red thimble-berry. Ornamental.

Rubus procerus P. J. Mueller ex Boulay. Himalaya Berry. Aggressive weedy shrub forming roadside thickets. Colma Canyon, $K$ August 5, 1963; Guadalupe Road, $K$ September 2, 1964; Crocker Avenue, $W$ July 7, 1965. Robust, more or less evergreen, sprawling, prickly shrub, with 5 leaflets white hairy beneath, white or pink flowers, June to August, in large
terminal panicles, edible blackberries. Native of Europe. Its rampant growth makes this shrub undesirable but its berries are delicious.

Rubus spectabilis Pursh var. franciscanus (Rydberg) J. T. Howell. Salmon Berry. Occasional, on moist brushy slopes forming thickets. Colma Canyon, K April 11, 1965; ravine to west of summit of mountain, $K 692$. Deciduous shrub, young stems with prickles and 3-foliolate leaves, flowers single, red-purple, March to May, edible fruits reddish to salmoncolored. Ornamental.

Rubus ursinus Chamisso \& Schlechtendal. California Blackberry. Pacific Blackberry. Frequent, forming brushy thickets by trailing on ground and over and among other shrubs, Crocker Avenue, McC, K January 12, 1964; Colma Canyon, K May 30, 1964; ravine west of Radio Road, K 696 ; near Nike Base, McC, W May 23, 1965; Owl's Canyon, McC April 25, 1965. Scandent shrub with prickles, leaves white hairy at least when young, 3 -foliolate on young stems, mostly 3-lobed on flowering stems, flowers white in small clusters March to August, edible blackberries. Cultivated for its excellent edible fruits and has entered into the development of the Loganberry, the Youngberry, and the Boysenberry.

## Rubiaceae. Madder Family

Coprosma repens J. D. Hooker. Mirror Shrub. Escapes from cultivation and persists in waste places. Crocker Avenue, McC September 24, 1967. Evergreen shrub to 8 to 10 feet tall with shining leaves, inconspicuous flowers and orange berry-like fruits, late summer to autumn. Native of New Zealand.

Galium aparine Linnaeus. Bedstraw. Goose Grass. Cleavers. Frequent, scrambling over other plants, mostly in brushy and shaded areas. Buckeye Canyon, McC April 16, 1967; Colma Canyon, K May 30, 1964; near Nike Base, McC, W May 23, 1965; April Brook, McC March 28, 1965; ravine west of Radio Road, K April 25, 1964; Quarry, K July 14, 1963; east facing slope below Parking Lot, McC, Halde June 23, 1963; Reservoir Hill, McC March 14, 1965; Randolph Drive at Hillside Boulevard, P 2748; South Powerline, McC March 14, 1965. Weak stemmed annual with usually linear leaves more than $1 / 2$ inch long, 6 to 8 in a whorl, white flowers, March to August, dry fruits with hooked bristles. Nativity is doubtful, may be introduced from Europe.

Galium californicum Hooker \& Arnott. California Bedstraw. Occasional, shaded slopes and brushy areas. East facing slope below Parking Lot, McC, Halde June 23, 1963; canyon below radio towers, W May 12, 1965; East Powerline, K March 21, 1965. Perennial, stems more or less erect but intertwining and clumping together, leaves mostly ovate and longer than $1 / 4$ inch, in 4's, yellow-green flowers May to July, fruits fleshy, glabrous or hairy.

Galium nuttallii Gray. Climbing Bedstraw. Frequent, clambering over adjacent plants, mostly on dry brushy slopes. Randolph Drive at Hillside Boulevard, P 2722; Reservoir Hill, McC March 14, 1964; lower Colma Canyon, McC, Halde, K June 23, 1963; near Nike Base, K 1230; east of Brisbane Powerlines, K 965; above Harold Avenue, Brisbane, McC, W May 14, 1967. Perennial, more or less woody at base, with stems to as much as 6 feet long, leaves mostly oval and less than $1 / \pm$ inch long, in 4's, yellow-green flowers March to August, fruit fleshy, glabrous.

## Salicaceae. Willow Family

Salix coulteri Andersson. Coulter Willow. Occasional, streams and seepage areas. Colma Canyon, K August 5, 1963 ; junction of Colma Creek and April Brook, K March 28, 1965; ravine south of Crocker Avenue, P 2640; Crocker Industrial Park, W October 16, 1966;
northern South San Francisco, McC, $K$ September 11, 1964. Small tree with entire leaves which are densely silvery hairy on lower surfaces, flowers in catkins, March to May.

Salix lasiolepis Bentham. Arroyo Willow. Common, streams and seepage areas. Crown sprouts after fire. Lower Colma Canyon, McC March 30, 1963; Radio Road at Summer Seep, $K$ 862; above the Quarry, $K$ July 14, 1963; Cow Trough Ravine, $K$ October 7, 1963; Devil's Arroyo, McC March 28, 1965 ; northern South San Francisco, McC, K September 11, 1964; Guadalupe Valley along a creek bank, $P$ March 30, 1963. Small tree with leaves nearly entire and somewhat revolute on the margins, glaucous and more or less glabrous beneath, flowers in catkins March to May.

Salix lasiolepis and S. coulteri hybridize occasionally and plants apparently of hybrid origin with varying amounts of tomentum on the lower leaf surface are found in Colma Canyon and at the junction between April Brook and Colma Creek.

## Saxifragaceae. Saxifrage Family

Grossularia californica (Hooker \& Arnott) Coville \& Britton [Ribes californicum Hooker \& Arnott]. California Gooseberry. Hillside Gooseberry. Occasional, on shrubby or wooded areas. Seedlings appear after fire. Guadalupe Road in Crocker Hills, $K$ January 15, 1964; above the Quarry, K July 14, 1963; Devil's Arroyo, McC March 28, 1965; Buckeye Canyon, W May 5, 1963. Deciduous shrub with nodal spines, reddish-green flowers January to April, and prickly fruits.

Grossularia divaricata (Douglas) Coville \& Britton [Ribes divaricatum Douglas]. Rare, on shrubby slope. Colma Canyon, K May 4, 1964. Differs from Grossularia californica in its mostly greenish and rather inconspicuous flowers February to May, and fruits lacking prickles.

Grossularia leptosma Coville [Ribes menziesii Pursh var. leptosmum (Coville) Jepson]. Bay Gooseberry. Canyon Gooseberry. Buckeye Canyon, K August 5, 1963; above the Quarry, K July 14, 1963. Deciduous shrub with nodal spines, leaves glandular hairy beneath, reddish flowers March to June, and prickly fruits.

Heuchera micrantha Douglas ex Lindley. Alum Root. Occasional, shaded and brushy slopes. Bitter Cherry Ravine, K May 15, 1965; Quarry, K July 14, 1963; Romanzoffia Ravine, K May 4, 1964; Owl's Canyon, K 1051; Dairy Ravine, K August 5, 1963. Perennial herb with mostly basal leaves, small greenish-white flowers, May and June, having five shortly exerted stamens. Ornamental.

Lithophragma affinis Gray. Woodland Star. Occasional, in moist wooded or open rocky areas. Romanzoffia Ravine, $K$ March 14, 1965; between Romanzoffia Ravine and Trillium Gulch, K 969 ; Flower Garden, McC March 28, 1965 ; Bitter Cherry Ravine, $K$ April 4, 1965. Slender perennial with basal leaves and white flowers, February to May, having petals about $1 / 1$ inch long and 10 stamens.

Ribes malvaceum Smith. California Black Currant. Chaparral Currant. Rare, wooded ravine. Buckeye Canyon, $K$ 944. Deciduous shrub with rose-pink flowers in racemes, October to March, fruits purple-black. The stems of the currants lack the nodal spines which are present in the gooseberries, sometimes the two are united into a single genus.

Saxifraga californica Greene. California Saxifrage. Occasional, in moist grassland or brushy or rocky areas. Colma Canyon, K 1247; Cable Ravine, Menzies March 14, 1965; Devil's Arroyo, McC March 28, 1965 ; ravine $1 / 4$ mile east of Brisbane Powerlines, McC March 21, 1965. Slender perennial with mostly basal leaves, flowering stems about 12 inches tall, small flowers, February to April, petals white, $1 / 8$ inch long, 10 stamens.

Tellima grandiflora (Pursh) Douglas ex Lindley. Fringe Cups. Occasional, in moist shrubby areas, seepage and stream banks. Creek bank in Colma Canyon, McC April 11, 1965; Romanzoffia Ravine, K April 25, 1964; north facing slope south of Guadalupe Parkway near junction with Radio Road, McC, W June 11, 1967. Stout perennial with mostly basal cordate leaves, cup-shaped flowers, March to June, petals whitish then turning red, margins laciniate or fringed, hence the common name.

## Scrophulariaceae. Figwort Family

Bellardia trixago (Linnaeus) Allioni. Weed of roadsides and disturbed areas. Randolph Avenue, K May 16, 1967; Crocker Industrial Park, Brisbane, W June 19, 1965; junction of Radio Road and Crocker Avenue, W June 16, 1965; Sierra Point, W April 27, 1965. Coarse annual, but attractive, weed with rose-pink and white flowers. Native of Mediterranean region.

Castilleja affinis Hooker \& Arnott. Indian Paint Brush. Occasional, in brushy or open grassy and rocky areas. Randolph Drive at Hillside Boulevard, P 2740; near Nike Base, McC, W May 23, 1965; Flower Garden near April Brook, McC February 28, 1965. Perennial with red bracts, flowers March to September. Differs from Castilleja franciscana by having the lower lip of the corolla not exerted.

Castilleja franciscana Pennell. Franciscan Paint Brush. Occasional, in grassland and rocky areas. South side of Ridge Road near powerlines, K 921; Colma Canyon, Raven 1775; Guadalupe Road in Crocker Hills, K 1098; near Olivet Cemetery, McC June 13, 1965 ; near Cow Palace in Crocker Hills, W May 17, 1965. Perennial with more or less hairy but not glandular-hairy stems and leaves, and red bracts, flowers March to September, slender yellow-green lower lip of corolla much exerted.

Castilleja wightii Elmer. Wight's Paint Brush. Frequent, grassland, brushy and rocky areas. Colma Canyon, Raven 1778; Quarry, K July 14, 1963; Flower Garden near April Brook, McC March 28, 1965; near Nike Base, McC, W May 23, 1965; Trillium Gulch, McC March 28, 1965; slope below Parking Lot, McC June 9, 1963; West Powerline, McC, K September 2, 1963; South Powerline, K 947; Guadalupe Road in Crocker Hills, K 1013. This is the most commonly seen of the paint-brushes on San Bruno Mountain. It differs from the two preceding species in being glandular-hairy especially in the inflorescence and somewhat viscid to the touch. Its bracts are either yellow or dull reddish, flowers March to October.

Collinsia franciscana Bioletti. Chinese Houses. Occasional, in open grassy, or brushy areas. Colma Canyon, K May 4, 1964; Bitter Cherry Ravine, K 1014; Devil's Arroyo, McC March 28, 1965; ravine east of Brisbane Powerlines, McC March 21, 1965; above Harold Avenue, Brisbane, McC, W May 14, 1967. Annual with whorls of sessile, violet-blue and whitish flowers, March to May.

Collinsia heterophylla Buist ex Graham. Chinese Houses. Rare, in shaded grassland. Buckeye Canyon, W May 7, 1965. Annual with whorls of sessile lavender and white flowers, April to July.

Collinsia sparsiflora Fischer \& Meyer var. solitaria (Kellogg) Newsom. Chinese Houses. Occasional, in grassland. Ravine east of Brisbane Powerlines, McC March 21, 1965 ;

Plate 5. Upper. Artemisia californica Lessing, on slope in Owl's Canyon. Lower. Eschscholzia californica Chamisso.

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Owl's Canyon, $K 1069$; Buckeye Canyon, W April 2, 1967. Annual with mostly single small blue flowers, March to May, borne on pedicels.

Diplacus aurantiacus (Curtis) Jepson. Sticky Monkey Flower. Bush Monkey Flower. Common, in dry brushland and open areas. Regenerates by crown sprouts after fire. Cow Trough Ravine, $K$ October 7, 1963; Dairy Ravine below radio tower, K August 8, 1963; Pig Ranch Ravine, W May 12, 1965; ridge above Owl's Canyon, W June 7, 1965; Quarry, K June 14, 1963; east facing slope below Parking Lot, McC, Halde June 23, 1963; Gladys Canyon, Brisbane, W June 14, 1965; above Harold Avenue, Brisbane, McC, W May 14, 1967. Evergreen shrub with large and showy yellow-orange flowers March to July. Ornamental.

Linaria texana Scheele [L. canadensis (Linnaeus) Dumont de Courset var. texana (Scheele) Pennell]. Blue Toad Flax. Occasional, sandy soil in open areas. Colma Canyon, K April 11, 1965; west of Pig Ranch Ravine, W May 11, 1965; Manzanita Dike, K 971. Slender annual with violet-blue flowers, March to May, spur on the corolla. Linaria texana has a wide distribution outside of California, it goes northward to British Columbia and eastward to the southeastern states.

Mimulus guttatus DeCandolle. Monkey Flower. Occasional, in seepage and wet areas. Lower Colma Canyon, McC, Halde, K June 23, 1963; Radio Road at Summer Seep, K 1105 ; Quarry, W June 19, 1965; Devil's Arroyo, McC March 28, 1967; Glen Park Canyon, McC April 16, 1967; ravine north of Randolph Drive and Hillside Boulevard, P 2744. Perennial herb with showy bright yellow flowers, March to August.

Orthocarpus densiflorus Bentham. Owl's Clover. Frequent, grassy and brushy areas. Colma Canyon, Raven 1776; Flower Garden, K March 28, 1965; April Brook, K May 15, 1965; near Nike Base, W May 23, 1965; Pig Ranch Ravine, W May 11, 1965 ; summit above Owl's Canyon, K 1045; Romanzoffia Ravine, K March 13, 1965; above Harold Avenue, Brisbane, $M c C, W$ May 14, 1967. Annual with purple flowers in terminal clusters, March to May.

Orthocarpus erianthus Bentham var. erianthus. Butter-and-eggs. Johnny Tuck. Rare, in grassland. CoIma Canyon, W June 13, 1965. Annual often forming colonies, with yellow flowers, March to May.

Orthocarpus erianthus Bentham var. roseus Gray. Frequent, in grassland, usually forming colonies. Ravine south of Crocker Avenue, P 2657; Pig Ranch Ravine, K 1030; Flower Garden, K 977; ravine west of Radio Road, K 1244; Crocker Industrial Park, W March 27, 1966. Annual with whitish flowers aging rose-pink, March to May.

Orthocarpus faucibarbatus Gray var. albidus (Keck) Howell. Rare, in sandy soil. Sierra Point, W May 2, 1965. Annual with whitish flowers, April to June.

Orthocarpus floribundus Bentham. Rare, in moist grassland. Ravine north of junction of Randolph Drive and Hillside Boulevard, P 2734 ; Point San Bruno, K April 25, 1965. Annual with whitish flowers, April and May. Orthocarpus floribundus occurs only in Marin, San Francisco and San Mateo counties.

Orthocarpus purpurascens Bentham var. latifolius Watson. Escobita. Frequent, in grassland and open fields. Quarry, K June 24, 1963; Colma Canyon, McC June 13, 1965; near Nike Base, K 1234; Radio Road, K August 5, 1963; slope below Parking Lot, McC June 9, 1963; Kamchatka Point, K May 15, 1965; Ridge Road near West Powerline, K 968 ; above Harold Avenue, Brisbane, $M c C$, W May 14, 1967. Annual, stems and leaves hairy, stems usually purplish and branched, flowers purplish March to May.

Orthocarpus pusillus Bentham. Occasional, in open and grassy areas, sometimes in hard packed soil and then somewhat depauperate. West Powerline, K 876; Glen Park Canyon, McC April 16, 1967. Small slender annual with foliage brownish tinged, tiny inconspicuous flowers, April and May.

Scrophularia californica Chamisso \& Schlechtendal. California Bee Plant. Frequent, in brushland and bordering it. Lower Colma Canyon, McC July 18, 1967; Quarry, McC August 1, 1965; east facing slope below Parking Lot, McC April 17, 1964; West Powerline, MIC C March 28, 1965. Coarse perennial to as much as 5 to 6 feet tall with small insignificant reddish-brown flowers February to July. Tends to become weedy.

Veronica americana (Rafinesque) Schweinitz ex Bentham. American Brooklime. Occasional, in seepages and other wet areas. Colma Canyon, W June 16, 1965 ; north facing slope south of Guadalupe Parkway, McC, W June 11, 1967; west of Radio Road, K June 20, 1965; canyon east of Quarry, W June 8, 1965; April Brook, W May 18, 1965. Erect perennial with small bright blue flowers, May to October.

Vexonica persica Poiret. Rare, in disturbed sandy soil. Lower Colma Canyon, McC, K, Kasapligil July 18, 1967. Procumbent annual with small blue flowers, March to September. Native of Eurasia.

## Solanaceae. Nightshade Family

Solanum furcatum Dunal. Nightshade. Weed in disturbed areas. Crocker Hills, McC, K September 2, 1963; Pig Ranch Ravine, W May 11, 1965; adjacent to Olivet Cemetery, W May 18, 1965; on summit near Parking Lot, McC, Halde June 23, 1963. Weak-stemmed, straggling perennial, with insignificant white to pale lavender flowers April to October, corolla about $3 / 8$ inch or more across. Native of South America.

Solanum nodiflorum Jacquin [has been called S. nigrum by some authors but it is not S. nigrum Linnaeus]. Nightshade. Weed in disturbed areas. Guadalupe Road, $K$ August 5, 1963; Wax Myrtle Ravine, K August 5, 1963; near Olivet Cemetery, W August 18, 1965. Weak stemmed straggling annual or perennial, with small insignificant pale lavender or whitish flowers, March to December, corolla about $1 / 1$ inch across. Nativity uncertain, but it is probably South America.

Solanum umbelliferum Eschscholtz. Blue Witch. Frequent, on brushy slopes. Slopes southeast of 1314-foot summit, P 2678; Quarry, K June 24, 1963; South Powerline, Menzies March 14, 1965. Subshrub, more or less rounded in habit, hairy, with blue flowers January to September.

## Tropaeolaceae. Tropaeolum Family

Tropacolum majus Linnaeus. Garden Nasturtium. Escape from cultivation and persisting in waste places. Crocker Avenue, McC September 24, 1967. Trailing annual or perennial with peltate leaves and attractive yellow-red flowers during most of the year. Native of South America

## Umbelliferae. Carrot or Parsley Family

Angelica hendersonii Coulter \& Rose. Occasional, in brushland. Regenerates after fire by sprouting from rootstocks. Quarry, K July 14, 1963; Romanzofiia Ravine, McC March 28, 1965. Also in Colma Canyon. Stout perennial to 3 to 4 feet tall with large pinnately compound leaves, each leaflet more or less ovate and pinnately veined, white flowers April


Figure 10. Heracleum maximum Bartram.
to July. Superficially resembles Heracleum maximum but may be distinguished by the shape of the leaves.

Anthriscus caucalis Bieberstein [A. scandicina (Weber) Mansfeld]. Bur-chervil. Weed of disturbed areas. Guadalupe Road, K August 5, 1963; Sierra Point, W May 12, 1965. Annual or biennial with finely divided leaves, small white flowers April to June, and fruits with little hooks. Native of Europe.

Apiastrum angustifolium Nuttall. Wild Celery. Rare, in sandy soil. Pig Ranch Ravine, K 1200. Annual with finely divided leaves, small white flowers February to May, and fruits with inconspicuous ribs.

Bowlesia incana Ruiz \& Pavon. Occasional, in grassy and brushy areas. Devil's Arroyo, K 1099; Trillium Gulch, K 1107. Delicate, weakly trailing, prostrate annual with tiny inconspicuous flowers, March to May. Superficially resembles Pterostegia drymarioides, another weakly trailing annual.

Caucalis microcarpa Hooker \& Arnott. California Hedge Parsley. Rare, on open grassy slopes. South Powerline, $K$ 1215. Hispid annual, leaves finely divided, flowers small, white, April to June, and fruits with numerous hooks.

Conium maculatum Linnaeus. Poison Hemlock. Spotted Hemlock. Weed of disturbed areas. Crocker Hills, $M_{c} C, K$ September 2, 1963. Also in upper Colma Canyon. Tall biennial, stems purple spotted, leaves pinnately divided, flowers white, small, April to August, fruits with prominent ribs.

Native of Europe. The plant is poisonous, more so when fresh than when dry, and by it "criminals and philosophers were put to death at Athens." It was said to have been used to execute Socrates.

Daucus pusillus Michaux. Rattlesnake Weed. Common, in grassland. Quarry, K July 14, 1963; Devil's Arroyo, K April 25, 1965; Guadalupe Road, McC April 11, 1965; Radio Road in eucalyptus area, $M c C$, W June 11, 1967; Nike Base, K April 25, 1964; Colma Canyon, McC June 13, 1965. Annual, leaves finely divided, flowers small white or pinkish, April to June, fruits with stout hooks.

Foeniculum vulgare Miller. Sweet Fennel. Weed in disturbed areas. Guadalupe Road, $K$ August 5, 1963; Brisbane Lagoon, W August 14, 1965. Biennial or perennial with aniselike odor, leaf divisions linear, flowers yellow, May to October, fruits smooth, angled. Native of Europe where cultivated edible forms have been selected and used as a vegetable especially in Italy.

Heracleum maximum Bartram [H. lanatum Michaux]. Cow Parsnip. Occasional, on open slopes and in bases of ravines. Romanzoffia Ravine, K May 4, 1964; top of mountain near radio station, McC, Menzies February 16, 1963; Crocker Avenue, P 2660; southwest of Brisbane, P 2761; Colma Canyon, $K$ May 30, 1964. Stout coarse perennial, to 5 to 6 feet tall, leaves ternately lobed with broad leaflets palmately veined and lobed, flowers white in large flat-topped clusters April to July, fruits with narrow wings. See Angelica.

Ligusticum apiifolium (Nuttall) Gray. Lovage. Occasional, on open and exposed grassy or brushy areas. Sometimes root sprouts after fire. Quarry, K June 24, 1963; Kamchatka Point, McC March 21, 1965 ; Nike Base, K 690 ; east facing slope below Parking Lot, McC, Halde June 23, 1963; West Powerline, McC March 28, 1965. Perennial, leaves pinnately divided, flowers whitish, April to June, turning rusty in age, fruits smooth but ribbed.

Lomatium caruifolium (Hooker \& Arnott) Coulter \& Rose. Alkali Parsnip. Occasional, in grassy areas. Radio Road, McC, Ryder February 16, 1964; Randolph Drive at Hillside Boulevard, P 2731; above Harold Avenue, Brisbane, McC, W May 14, 1967. Acaulescent perennial with ternately divided leaves, yellow flowers, March and April, fruits broadly winged.

Lomatium dasycarpum (Torrey \& Gray) Coulter \& Rose. Lace Parsnip. Frequent, in grassy and rocky areas. Colma Canyon, Raven 1789; ravine north of Randolph Avenue at Hillside Boulevard, P 2745; ravine south of Crocker Avenue, P 2647; Quarry, K July 14, 1963; top of mountain on slope above Parking Lot, McC, Ryder February 16, 1964; Radio Road near radio station, McC, Menzies February 16, 1963; Guadalupe Road, McC April 11, 1965; above Harold Avenue, Brisbane, McC, W May 14, 1967. Perennial differing from $L$. caruifolium by its woolly fruits.

Lomatium utriculatum (Nuttall) Coulter \& Rose. Bladder Parsnip. Occasional, on open grassy slopes and ridges. Radio Road near radio station, McC, Menzies February 16, 1963; Reservoir Hill north of Colma Canyon, K 878; Cable Ravine, McC March 14, 1965; Brisbane Powerlines, K 954; Guadalupe Road in Crocker Hills, K April 11, 1965; meadow between April Brook and Radio Road, McC March 28, 1965. Perennial, differs from two previous species by the thin wings of the fruit being broader than the main body of the fruit.

Oenanthe sarmentosa Presl. Occasional, in sluggish streams and marshy areas. Colma Canyon, $K^{K}$ August 5, 1963; Pig Ranch Ravine, K May 30, 1964; Guadalupe Creek, K April 11, 1965; April Brook, K 982. Perennial with pinnately compound leaves, each leaflet toothed or lobed, white flowers May to October, fruits with corky ribs.

Sanicula arctopoides Hooker \& Arnott. Footsteps-of-spring. Yellow mats. Snake-root. Common, on open grassy slopes and windswept ridges. Above Harold Avenue, Brisbane, McC, W May 14, 1967; Radio Road, McC, Ryder February 16, 1964; Cable Ravine, McC

March 28, 1965; meadow between April Brook and Radio Road, McC March 28, 1965 ; Radio Road near radio station, $M c C$, Menzies February 16, 1963; Kamchatka Point, McC May 1, 1966; Crocker Avenue, P 2646. One of the mountain's colorful spring wildflowers. Prostrate perennial, entire plant a chartreuse-yellow color when in flower, flowers small, in rounded clusters, February to May, surrounded by conspicuous bracts, seeds with few hooks.

Sanicula bipinnatifida Douglas ex Hooker. Purple Sanicle. Occasional, in grassland and open slopes. Above Harold Avenue, Brisbane, McC, W May 14, 1967; Owl's Canyon, K 1065; Randolph Avenue, $P$ 2726. Stout perennial with pinnately compound leaves, usually purple flowers in a tight head without bracts, February to May, seeds with hooks,

Sanicula crassicaulis Poeppig ex DeCandolle. Pacific Sanicle. Common, on open or shaded and wooded slopes. Colma Canyon, K1220; east facing slope below Parking Lot, $M c C$, Halde June 23, 1963; west facing slope below mountain summit; $K 694$; Quarry, $K$ July 14, 1963; West Powerline, K 707; Trillium Gulch, K 1020; Owl's Canyon, K 1050; Bitter Cherry Ridge, $K$ April 15, 1965. Perennial with palmately lobed leaves, yellow flowers in tight heads with tiny bracts, February to June, seeds with hooks.

Sanicula laciniata Hooker \& Arnott. Coast Sanicle. Rare, on open exposed slope. Below top of mountain near Parking Lot, McC June 9, 1963. Perennial with palmately lobed leaves, leaf divisions laciniate, flowers yellow in tight heads with small bracts, April to June, seeds with hooks.

## Urticaceae. Nettle Family

Soleirolia soleirolii (Requien) Dandy. [Helxine soleirolii Requien]. Baby's Tears. Weed in shaded disturbed areas. Crocker Avenue under Monterey cypress, K September 2, 1964. Delicate creeping mat-forming perennial with inconspicuous flowers during most of the year. Native of Corsica and Sardinia.

Hesperocnide tenella Torrey. Rare, in moist shaded areas. Colma Canyon, McC, Halde, $K$ June 23, 1963. Weak-stemmed but erect annual with stinging hairs and inconspicuous flowers, March to May. Nettle-like in appearance.

Urtica holosericea Nuttall. Nettle. Rare, along banks of creeks. Buckeye Canyon, K 725; Guadalupe Creek, McC, K September 11, 1964. Stout coarse perennial with stinging hairs and inconspicuous flowers, May to October.

## Valerianaceae. Valerian Family

Centranthus ruber (Linnaeus) DeCandolle. Jupiter's Beard. Red Valerian. Weed in disturbed ground. Brisbane Lagoon, W August 14, 1965. Attractive perennial with white, pink, and rose-pink flowers from late winter into autumn. A garden plant which escapes from cultivation. Native of the Mediterranean region.

Plectritis congesta (Lindley) DeCandolle. Occasional, in grassland and moist brushy areas, sometimes forms small colonies. Meadow between Radio Road and April Brook, McC March 28, 1965; Romanzoffia Ravine, $K$ April 24, 1964; Devil's Arroyo, McC March 28, 1965; Owl's Canyon, K 1095; Glen Park Canyon, McC April 16, 1967. Annual with small pink flowers, February to May, in spike-like inflorescences.

## Violaceae. Violet Family

Viola adunca Smith. Blue Violet. Frequent, in grassland. Colma Canyon, K March 15, 1964; Flower Garden adjacent to April Brook, K 978; Cable Ravine, McC March 14,

1965; west facing slope below top of mountain, McC April 17, 1964. Low growing perennial with violet flowers, February to April. This attractive violet resembles the cultivated English violet of gardens.

Viola pedunculata Torrey \& Gray. Johnny-Jump-Up. California Golden Violet. Frequent, in grassland. Point San Bruno, K 1026; Randolph Drive at Hillside Boulevard, P 2716; Glen Park Canyon, $M c C$ April 16, 1967; above Harold Avenue, Brisbane, $M c C, W$ May 14, 1967; Cable Ravine, McC March 14, 1965; Flower Garden, McC March 28, 1965; ridge above Great Meadow, W June 20, 1965. Perennial with yellow flowers, March and April, the two upper petals are marked with red-brown on the back. An attractive spring wildflower.

# SUBCLASS MONOCOTYLEDONEAE 

## Araceae. Calla Family

Zantedeschia aethiopica (Linnaeus) Sprengel. Calla. Calla-Lily. An escape from cultivation in damp sandy soil. Pig Ranch Ravine, K April 25, 1965; W May 14, 1965. Native of South Africa.

## Cyperaceae. Sedge Family

Carex barbarae Dewey. Occasional, wet grassy ground. Colma Canyon, McC, K June 23, 1963; Radio Road, W May 23, 1965; north city limits of South San Francisco in seepage area with Salix coulteri and S. lasiolepis, McC, K September 11, 1964.

Carex brevicaulis Mackenzie. Rare, on exposed slopes. J. T. Howell 13774.
Carex densa (Bailey) Bailey. Rare, in seepages. Crocker Hills, K May 4, 1964.
Carex obnupta Bailey. Rare, wet ravines. Crystal Cave Canyon, W June 19, 1965; Cow Trough Ravine, $K$ October 7, 1963.

Carex subbracteata Mackenzie. Rare, in wet ravine. Crystal Cave Canyon, K June 20, 1965.

Carex tumulicola Mackenzie. Rare, on grassy slope. Olivet Cemetery, W May 18, 1965.
Cyperus eragrostis Lamarck. Occasional, in marshy places and roadside ditches. Buckeye Canyon, K September 2, 1964; Cow Trough Ravine, K October 7, 1963; Crocker Avenue, K August 5, 1963; Crocker Hills, K October 4, 1966; Crocker Industrial Park, Brisbane, W June 19, 1965; Sierra Point, W May 8, 1965.

Scirpus californicus (C. A. Meyer) Steudel. California Tule. Rare, in marsh, growing with cattails. Near Bayshore Freeway, K October 4, 1966.

Scirpus cernuus Vahl var. californicus (Torrey) Beetle. Rare. Edge of creek in Colma Canyon, K May 30, 1964.

Scirpus microcarpus Presl. Rare, in wet and marshy places. Meadow adjacent to April Brook, W May 18, 1965; Colma Canyon, K May 30, 1964.

Scirpus robustus Pursh. Rare. Moist roadside ditch. Crocker Hills, K 2047.

## Gramineae. Grass Family

Agrostis diegoensis Vasey: Rare, open grassy slope. Near Quarry, W June 8, 1965.

Agrostis exarata Trinius. Rare, in low moist places. Pig Ranch Ravine, W May 11, 1965.

Agrostis hallii Vasey. Occasional, on brushy slopes. East facing slope bclow Parking Lot, McC, Halde June 23, 1963; Quarry, K July 14, 1963; Crystal Cave Canyon, W June 19, 1965.

Agrostis semiverticillata (Forskal) C. Christensen. Moist disturbed ground. Crocker Industrial Park, Brisbane, W June 8, 1965. Introduced from Europe and Asia.

Aira caryophyllea Linnacus. Silvery Hair Grass. Delicate graceful annual. Well distributed on grassy or brushy slopes. Crocker Hills, near Cow Palace, W May 17, 1965; Devil's Arroyo, K May 9, 1965; near Nike Station, McC, W May 23, 1965; Owl's Canyon, K April 25, 1965; Pig Ranch Ravine, W May 11, 1965; east facing slope below Parking Lot, McC, Halde June 9, 1963; south of West Powerline, K March 14, 1965. Introduced from Europe.

Avena barbata Brotero. Slender Wild Oat. Weed of waste places and grassy slopes, Colma Canyon, McC, Halde, K June 23, 1963; Crocker Avenue, Toschi February 23, 1963; Quarry, K July 14, 1963. Native to Mediterranean region.

Briza maxima Linnaeus. Rattlesnake Grass. Big Quaking Grass. Attractive weedy grass of waste ground. Sierra Point, W April 27, 1965. Introduced from Europe.

Briza minor Linnaeus. Little Quaking Grass. Occasional, on grassy areas and waste ground. Guadalupe Valley, P March 30, 1963; near Olivet Cemetery, McC June 13, 1965; Colma Canyon, McC, Malde, K June 23, 1963; Pig Ranch Ravine, W May 11, 1965; Romanzoffia Ravine, K May 4, 1964; Point San Bruno, K 1027. Introduced from Europe.

Bromus carinatus Hooker \& Arnott. Common, on exposed or shaded habitats. Plants mostly biennial. Randolph Ravine, P 2711; Colma Canyon, K March 15, 1964; near Nike Base, K April 25, 1964; McC,W May 23, 1965 ; Radio Road, below radio stations, Toschi March 3, 1963; Owl's Canyon, K April 25, 1965.

Bromus diandrus Roth [B. rigidus sensu auct. Amer.]. Rare, in disturbed soil. Guadalupe Valley, P 2765a. Introduced from Europe.

Bromus marginatus Nees von Esenbeck. Occasional, open grassy slopes. North facing slope above Crocker Avenue, Toschi 63:29; West Powerline, K April 13, 1964; Owl's Canyon, K 1052.

Bromus mollis Linnaeus. Soft Chess. Occasional, waste places and in grassland. West Powerline, K April 13, 1964 ; Pig Ranch Ravine, K May 15, 1965 ; Colma Canyon, W July 7, 1965 ; Sierra Point, W April 27, 1965. Introduced from Europe.

Bromus rubens Linnaeus. Foxtail Chess. Rare, in disturbed dry soil. Pig Ranch Ravine, K May 15, 1965 ; Sierra Point, W May 8, 1965. Introduced from Europe.

Calamagrostis nutkaensis (Presl) Steudel. Large clumping perennial, occasional, near summit of mountain. Colma Canyon, McC, Halde, K June 23, 1963; Dairy Ravine, K August 5, 1963; east facing slope below Parking Lot, McC June 9, 1963.

Cortaderia selloana (Schultes) Ascherson \& Graebner. Pampas Grass. Tall perennial planted as an ornamental but occasionally naturalized. Brisbane Lagoon, W August 14, 1965. Native of South America.

Danthonia californica Bolander. Rare, open brushy or grassy slopes. East facing slope below Parking Lot, McC June 9, 1963; Crocker Hills, K May 4, 1964.

Deschampsia caespitosa (Linnaeus) Beauvois subsp. holciformis (Presl) Lawrence. California Hair Grass. Rare, clumps on grassy slopes, a tufted perennial. Crocker Hills, K May 4, 1964.

Distichlis spicata (Linnaeus) Greene. Salt Grass. Rare. Salt marsh near edge of bay. Brisbane Lagoon, W August 14, 1965.

Elymus glaucus Buckley. Blue Wild Rye. Western Rye Grass. Common, in grassland and on brushy hillsides. East facing slope below Parking Lot, McC, Halde June 23, 1963; upper Buckeye Canyon, K July 14, 1963; Bitter Cherry Ridge, K May 15, 1965; Quarry, W June 17, 1965.

Elymus triticoides Buckley. Rare, disturbed areas. Brisbane Lagoon, W August 14, 1965.

Festuca californica Vasey. Tall clumping perennial. Frequent, on somewhat shaded brushy hillsides. Colma Canyon, K May 4, 1964; Bitter Cherry Ridge, K May 4, 1964; near Parking Lot, McC April 17, 1964; Romanzoffia Ravine, K May 4, 1964; Owl's Canyon, K April 25, 1965.

Festuca dertonensis (Allioni) Ascherson \& Graebner. Common, on brushy and grassy slopes or flats. Near Crocker Avenue, P 2648; Randolph Ravine, P 2712; slope above Parking Lot, McC April 17, 1964; Ridge Road, $1 / 2$ mile east of Parking Lot, P 2604. Introduced from Europe.

Festuca idahoensis Elmer. Blue Bunch Grass. Rare, rocky grassy slope at summit of mountain. East facing slope below Parking Lot, McC, Halde June 23, 1964.

Festuca megalura Nuttall. Occasional, mostly in disturbed areas, sometimes on grassy slopes. Crystal Cave Canyon, K June 20, 1965; ridge southwest of Brisbane, P 2756; near Nike Station, McC, W May 23, 1965; Sierra Point, W April 27, 1965.

Festuca myuros Linnaeus. Weed, in disturbed areas and grassy slopes. Ravine $1 / 2$ mile east of Parking Lot, P March 9, 1963; Crystal Cave Canyon, K June 20, 1965. Introduced from Europe.

Festuca rubra Linnaeus. Rare, on brushy slope below summit. Near Parking Lot, McC June 9, 1963.

Holcus lanatus Linnaeus. Velvet Grass. Occasional, moist places and grassy slopes. Lower part of Colma Canyon, McC, Halde, K June 23, 1963; Crocker Avenue, K September 2, 1964; Crocker Industrial Park, Brisbane, W June 8, 1965. Introduced from Europe.

Hordeum brachyantherum Nevski. Meadow Barley. Rare, in grassland and brushy areas. Crocker Hills, W May 17, 1965; Randolph Avenue, at Hillside Boulevard, P 2733.

Hordeum geniculatum Allioni [H. hystrix Roth]. Mediterranean Barley. Rare, in grassland, Crocker Hills near Cow Palace, W May 17, 1965. Introduced from Europe.

Hordeum leporinum Link. Farmer's Foxtail. Disturbed or grassy areas, Guadalupe Valley, $P$ 2765; Randolph Avenue at Hillside Boulevard, $P$ 2741; West Powerline, $K$ April 13, 1964; Colma Canyon, W August 16, 1965. Introduced from southern Europe.

Koeleria macrantha (Ledebour) Sprengel [K. gracilis Persoon; K. cristata (Linnaeus) Persoon]. June Grass. Frequent, on brushy and often rocky slopes. Sierra Point, W April 27, 1965 ; near Nike Station, McC, W May 23, 1965 ; upper Buckeye Canyon, K July 14, 1963; Owl's Canyon, K 1053; east facing slope below Parking Lot, McC, Halde June 23, 1963.

Lolium multiflorum Lamarck. Italian Rye Grass. Occasional, in waste places and grassy slopes and flats. Lower part of Colma Canyon, McC, Halde, K June 23, 1963; Guadalupe Road, $K$ August 5, 1963. Introduced from Europe.

Melica californica Scribner. Occasional, in grassland. Ridge southwest of Brisbane, P 2754; Randolph Avenue at Hillside Boulevard, P 2720; near Olivet Cemetery, W May 18, 1965; Owl's Canyon, K April 25, 1965; Pig Ranch Ravine, K May 15, 1965.

Mclica imperfecta Trinius. Delicate perennial. Rare. Brushy slope, Colma Canyon, K May 30, 1964.

Melica torreyana Scribner. Frequent, on brushy slopes and grassland. Near Olivet Cemetery, W May 18, 1965; Huckleberry Ridge, K May 4, 1964; Owl's Canyon, K April 25, 1965; Buckeye Canyon, K May 24, 1966; slope southeast of summit, P 2676; West Powerline, McC March 14, 1965.

Panicum capillare Linnaeus. Witch Grass. Rare. Disturbed area, Brisbane Lagoon, W June 19, 1965. Introduced from eastern North America.

Parapholis incurva (Linnaeus) C. E. Hubbard. Sickle Grass. Rare. Salt flat, Sierra Point, W May 8, 1965. Native of Europe.

Phalaris californica Hooker \& Arnott. California Canary Grass. Common, in moist areas and on grassy ridges. Randolph Avenue at Hillside Boulevard, P 2737; Colma Canyon, K May 30, 1964; Quarry, K July 14, 1963; Bitter Cherry Ridge, K May 4, 1964; Crystal Cave Canyon, K June 20, 1965; Pig Ranch Ravine, K May 15, 1965.

Phalaris canariensis Linnaeus. Canary Grass. Rare. Disturbed ground. Brisbane Lagoon, W June 19, 1965. Introduced from Europe. Used in bird-seed mixtures.

Poa annua Linnaeus. Annual Bluegrass. Occasional, in grassland. Randolph Avenue, K May 16, 1967 ; Crocker Avenue between Templeton Avenue and Scenic Way, J. H. Thomas May 2, 1967.

Poa pratensis Linnaeus. Kentucky Blue-Grass. Disturbed area along Radio Road, W May 23, 1965. Probably introduced from Europe and often used in lawn grass mixtures.

Poa unilateralis Scribner. Occasional, open grassy or rocky slopes. Ridge southwest of Brisbane, $P 2755$; east facing slope below Parking Lot, McC April 17, 1964; Owl's Canyon, K April 25, 1965; Brisbane Powerlines, K March 21, 1965.

Polypogon monspeliensis (Linnaeus) Desfontaines. Rabbit-foot Grass. Occasional, in wet or damp areas. Point San Bruno, McC, K June 8, 1965; Sierra Point, W May 8, 1965; Crocker Industrial Park, W June 15, 1965; lower Colma Canyon, McC, Halde, K June 23, 1963. Introduced from Europe.

Secale cereale Linnaeus. Cereal Rye. Rare. Disturbed ground, Point San Bruno, K 1038. Tufted annual, frequently cultivated and becoming naturalized. Native of southwest Asia.

Sitanion jubatum J. G. Smith. Big Squirrel-tail Grass. Rare, dry open often rocky places or waste places. Sierra Point, W June 20, 1965; Brisbane Ravine, W May 25, 1965.

Sorghum halepense (Linnaeus) Persoon. Johnson Grass. Rare. Disturbed ground, Point San Bruno, W June 19, 1965. Native of Mediterranean region.

Stipa cernua Stebbins \& Love. Rare. Rocky grassland. Pig Ranch Ravine, K May 15, 1965.

Stipa lepida Hitchcock. Rare. Rocky open grassland, Raven 1783; near Olivet Cemetery, W May 18, 1965.

Stipa pulchra Hitchcock. Rare, grassland and rocky slopes. Randolph Avenue, at Hillside Boulevard, P 2613; slope southeast of summit, P 2670.

Triticum aestivum Linnaeus. Wheat. Spontaneous in waste places, may not persist. Point San Bruno, K 1037 ; Brisbane Lagoon, W June 19, 1965. Widely cultivated, introduced from Old World.

## Iridaceae. Iris Family

Chasmanthe aethiopica (Linnaeus) N. E. Brown [Antholyza aethiopica Linnaeus]. Head of Buckeye Canyon, persisting. Planted in 1965 by Philip Wheeler. Native of South Africa.

Freesia refracta Klatt. Freesia. Slope below radio station on Radio Road. Toschi 63:64. Native of South Africa.

Iris douglasiana Herbert. Douglas Iris. Frequent, open grassland and meadows. Point San Bruno, K March 16, 1964; Colma Canyon, McC, Halde, K June 23, 1963; Nike Base, K March 15, 1964; Meadow between April Brook and Radio Road, McC March 28, 1965; Cable Ravine, McC March 14, 1965; Horseshoe Ridge, K August 5, 1963; Pig Ranch Ravine, $W$ August 11, 1965. Showy flowers in various shades of cream-white to blue, March to May. Ornamental.

Iris longipetala Herbert. Frequent, open grassland and meadows. Occurs in same habitat as preceding iris and in at least one locality (the Flower Garden) the two are growing together. Colma Canyon, K 508 ; near Crocker Avenue, $P$ 2655; north of Randolph Drive at Hillside Boulevard, P 2707; Point San Bruno, K March 16, 1964; east end of ridge near Brisbane Powerlines, K 956 . Flowers in various shades of blue, April and May. Petals to 3 inches long, often longer than petals of Douglas Iris. In the absence of flowers the two irises may be distinguished by their leaves which in Iris douglasiana are dark green and shining on upper surface and dull grayish-green on lower surface while in I. longipetala the leaves have the same color on both surfaces.

Sisyrinchium bellum Watson. California Blue-eyed Grass. Widely distributed, open grassland. Colma Canyon, McC, Halde, K June 23, 1963; east facing slope below Parking Lot, McC April 17, 1964; Cable Ravine, McC March 14, 1965; Manzanita Dike, K 932 ; Olivet Cemetery, McC June 13, 1965; Sierra Point, W May 21, 1965; north of Randolph Drive at Hillside Boulevard, P2705; Glen Park Canyon, McC April 16, 1967.

Sisyrinchium californicum (Ker) Dryander. Yellow-eyed Grass. Rare, in boggy places or edge of water. Colma Creek, in water, W June 15, 1965.

Tritonia crocosmaeflora Lemoine. Montbretia. Rare, an escape from cultivation. In shade of eucalyptus trees, Radio Road, McC September 24, 1967. Perennial, growing from a corm, 3 to 4 feet tall, sword-shaped leaves, showy orange flowers, August and September. A garden hybrid between two South African plants, T. pottsii Baker and T. aurea Planchon.

## Juncaceae. Rush Family

Juncus balticus Willdenow. Baltic Rush. Rare. Salt flat, Point San Bruno, $K, M c C$, September 11, 1964.

Juncus bufonius Linnaeus. Toad Rush. Occasional, in wet places or seepage areas. Quarry, K July 7, 1963; Colma Canyon, K May 30, 1964; between Nike Base and April Brook, McC, W May 23, 1965; Point San Bruno, K 1040.

Juncus effusus Linnaeus var. brunneus Engelmann. Bog Rush. Occasional, in wet places. Lower Colma Canyon, McC, Halde, K June 23, 1963; Quarry, K July 14, 1963; Buckeye Canyon, K September 2, 1964; Crocker Avenue, K August 5, 1963.

Juncus leseurii Bolander. Salt Rush. Rare, wet places, in both fresh water and salt flats. Creek in lower Buckeye Canyon, K September 2, 1964; Point San Bruno, K September 11, 1964.

Juncus mexicanus Willdenow. Mexican Rush. Rare. Dry ground, Point San Bruno, K September 11, 1964.

Juncus occidentalis (Coville) Wiegand [J. tenuis Willdenow var. congestus Engelmann]. Western Rush. Rare. Sierra Point, W May 8, 1965.

Juncus phaeocephalus Engelmann. Rare. Sierra Point, W May 8, 1965 ; north facing brushy slope south of Guadalupe Parkway and near its junction with Radio Road, McC, W June 11, 1967.

Juncus xiphioides E. Meyer. Rare. Sierra Point, W May 8, 1965.
Luzula multiflora (Retzius) Lejeune [L. subsessilis (Watson) Buchenau]. Wood Rush. Common, in grassland and seepage areas. Bitter Cherry Ridge, K April 4, 1965; Radio Road below transmitting towers, McC, Menzies February 16, 1963; east facing slope below Parking Lot, McC March 17, 1964; Crocker Hills, K January 8, 1964; Crystal Cave Canyon, K June 20, 1965; Randolph Drive at Hillside Boulevard, P 2677; Glen Park Canyon, McC April 16, 1967; Sierra Point, W May 8, 1965.

## Juncaginaceae. Arrowgrass Family

Triglochin concinna Davy. Slender Arrowgrass. Rare. Salt flat, Point San Bruno, K 1084.

## Lemnaceae. Duckweed Family

Lemna minima Philippi. Duckweed. Rare, floating in water. Cow Trough Ravine, K October 23, 1963; April Brook, K June 20, 1965; Crocker Hills, in a marsh between Geneva Avenue and Guadalupe Parkway, $K$ October 4, 1966.

## Liliaceae. Lily Family

Allium dichlamydeum Greene. Coastal Onion. Occasional, grassland and rocky slopes. Colma Canyon, McC, Halde, K June 23, 1963; Bitter Cherry Ridge, K 1094; near Nike Base, McC May 23, 1965; Flower Garden, W June 20, 1965; east facing slope below Parking Lot, McC, Halde June 23, 1963; Sierra Point, W May 8, 1965. Attractive rose-purple flowers, May and June. Ornamental.

Allium triquetrum Linnaeus. A weed in gardens and disturbed places. Crocker Industrial Park, W March 27, 1966. Native of southern Europe.


Flicur 11. Allium dichlamydeum Greene.

Allium unifolium Kellogg. Rare, in moist areas. Colma Creek, W May 18, 1965 ; April Brook, W May 24, 1965 ; north facing slope south of Guadalupe Parkway near its junction with Radio Road, McC, W June 11, 1967. Attractive rose-pink flowers, May.

Brodiaea elegans Hoover. Harvest Brodiaea. Rare, in grassland. Sierra Point, W June 21, 1965.

Brodiaea laxa (Bentham) Watson. Grass-Nut. Ithuriel's Spear. Frequent, in grassland. Colma Canyon, McC, Halde, K June 23, 1963; Crocker Hills, W June 8, 1965; grassland along Radio Road, W June 16, 1965 ; east facing slope below Parking Lot, McC, Halde June 23, 1963; Sierra Point, W May 8, 1965. Attractive robust plant with blue-purple flowers in umbels which look like a miniature agapanthus, May and June. Ornamental.

Brodiaea pulchella (Salisbury) Greene [B. capitata Bentham]. Blue-Dicks. WildHyacinth. Frequent, in grassland or in brush. Colma Canyon, K May 30, 1964; Devil's Arroyo, K 1023; Bitter Cherry Ravine, K April 4, 1965; Crystal Cave Canyon, W June 19, 1965; east facing slope below Parking Lot, McC April 17, 1964; Randolph Avenue at Hillside Boulevard, South San Francisco, P 2730. The congested heads of flowers on weak stems distinguish this species from the other three brodiaeas in our area.

Brodiaea terrestris Kellogg [ $B$. coronaria (Salisbury) Engler var. macropoda (Torrey) Hoover]. Rare, on western section of mountain. Near Quarry, W June 19, 1965; Radio Road in Eucalyptus area, $M c C, \boldsymbol{W}^{\dagger}$ June 11, 1967. The corms of the species of Brodiaea are edible and were used as food by California Indians.

Chlorogalum pomeridianum (DeCandolle) Kunth. Amole. Soap-Plant. Occasional, in grassland. Colma Canyon, K May 4, 1964; Trillium Gulch (where there had been a fire during previous autumn), McC March 28, 1965; east facing slope below Parking Lot, McC June 9, 1963; Sierra Point, W June 23, 1965. The wavy-margined leaves appear in winter and spring before the tall flowering branches. The star-like flowers open in the evening or on gray foggy or overcast days. The large underground bulb is covered with old fibrous coats from previous seasons. The bulb which contains a saponin was used by Indians and early settlers for its saponifying effect. The Indians roasted the bulb and used it for food.

Disporum hookeri (Torrey) Nicholson. Rare, in damp ground. Devil's Arroyo, McC March 28, 1965. Ornamental.

Fritillaria lanceolata Pursh. Checker-Lily. Mission Bells. Occasional, grassland and rocky or brushy slopes. Sierra Point, W June 21, 1965; Radio Road, east facing slope below radio station, Toschi March 17, 1963; near Parking Lot at summit, K $630 ; 1 / 2$ mile east of Parking Lot at summit, P 2702; Cable Ravine, McC March 14, 1965; Trillium Gulch, K 990. Brownish-purple flowers are nodding. Ornamental.

Maianthemum dilatatum (Wood) Nelson \& Macbride. False Lily-of-the-Valley. Rare. Rocky outcrop. Kamchatka Point, McC June 9, 1963; Thomas 9288. Maianthemum dilatatum occurs in eastern Asia and western North America and reaches its southernmost known American distribution in San Mateo County. It belongs to a small genus of three species known from the north temperate regions of Eurasia and North America.

Muilla maritima (Torrey) Watson. Rare, in grassland. Guadalupe Road, L. Rose March 25, 1965. Muilla is an agram of Allium. This yellow-flowered species has an onionlike appearance but its plants lack the odor or taste of onion and the underground part is a corm and not a bulb as in Allium.


Figure 12. Fritillaria lanceolata Pursh.


Figure 13. Trillium chloropetalum (Torrey) T. J. Howell.

Smilacina racemosa (Linnaeus) Desfontaines var. amplexicaulis (Nuttall) Watson. Fat Solomon. Occasional, in grassy and brushy areas. Colma Canyon, W June 13, 1965; Devil's Arroyo, K 1055; Romanzoffia Ravine, K May 4, 1964; Trillium Gulch, McC March 28,1965 . Ornamental, with numerous white flowers in a panicle.

Smilacina stellata (Linnaeus) Desfontaines var. sessilifolia (Baker) Henderson. Slim Solomon. Occasional, on grassy or brushy areas, sometimes with Fat Solomon, from which it is distinguished by its fewer flowers in a raceme. Colma Canyon, McC, Halde, K June 23, 1963; Trillium Gulch, McC March 28, 1965 ; Bitter Cherry Ridge, K May 4, 1964; Devil's Arroyo, K 1056; Crystal Cave Canyon, W June 20, 1965. Ornamental.

Trillium chloropetalum (Torrey) T. J. Howell. Wake-Robin. Rare, in brushy areas under Baccharis and Heracleum. Devil's Arroyo, McC March 28, 1965; Trillium Gulch, K March 21, 1965; Colma Canyon, McC April 11, 1965. Flowers March and April. The pale purple flowers are sessile and surrounded by the mottled whorled leaves. Ornamental.

Zigadenus fremontii (Torrey) Torrey ex Watson var. minor (Hooker \& Arnott) Jepson. Zygadene. Rare, in grassland. Point San Bruno, K March 16, 1964. Attractive white flowers, February to April. In some species of Zigadenus, especially. Z. venenosus, the deathcamas, all parts of the plants are poisonous. Bulbs of all species are suspect.

## Orchidaceae. Orchid Family

Habenaria unalascensis (Sprengel) Watson var. maritima (Greene) Correll [H. elegans (Lindley) Bolander var. maritima (Greene) Ames]. Rein Orchis. Rare, grassland or brushy slopes. April Brook, W August 16, 1965; Horseshoe Ridge along Radio Road,


Figure 14. Fog over top of ridge above the quarry on north side.

K August 5, 1963. Flowers small, greenish in a spike, August and September, each flower with a basal spur. Neither the small flowers of this orchid nor of the following orchids have any ornamental value.

Habenaria unalascensis (Sprengel) Watson var. elata (Jepson) Correll. Rein Orchis. Rare. Grassy slope above April Brook, McC August 1, 1965.

Habenaria unalascensis (Sprengel) Watson var. unalascensis. Rein Orchis. Rare. Quarry, K July 14, 1963.

Spiranthes romanzoffiana Chamisso \& Schlechtendal. Ladies-Tresses. Rare, in grassland. Radio Road near radio towers, Marsh Pitman 482. Small greenish-white flowers in June occur in a spike and lack the spur of the rein-orchis.

## Typhaceae. Cattail Family

Typha domingensis Persoon. Rare, marshy area in Crocker Hills between Geneva Avenue and Guadalupe Road, K October 4, 1966.

Typha latifolia Linnaeus. Broad-leaved Cattail. Soft Flag. Rare, marshy area in Crocker Hills between Geneva Avenue and Guadalupe Road, K October 4, 1966. Both of these cattails grew together in the same area which has now been filled for industrial development. With phasing out of this habitat these two species probably no longer exist in our area.

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## ERRATA

Page 50. Line 10 from bottom: for (Polyastrea) read (Polyastra).
Page 132. Line 22 from top: for sikkimensis read sikkimense.
Page 231. Line 20 from bottom: for Cladocera read Cladocora.
Page 235. Line 3 from bottom: for mexicana read mexicanus.
Page 245. Line 13 from top: for Tetraelita read Tetraclita.
Page 443. After line 11 from top, in center of page add: LITERATURE CITED.
Page 451. Line 18 from top: for Silas read Silis.
Page 627. Line 5 from bottom: for chysolepis read chrysolepis.

## PROCEEDINGS

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Robert C. Miller<br>California Academy of Sciences



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[^0]:    1. Based on studies aided by National Science Foundation grant G19006
[^1]:    2. We wish to thank Mr. Maurice Giles for preparing the three black-and-white prints from our kodachromes for use as illustrations in this paper.
[^2]:    3. We are indebted to Dr. William J. Hamilton of the California Academy of Sciences for referring us to some of this literature and also for lending us certain reprints from his personal files.
[^3]:    1. Work supported by National Science Foundation grant G17564, under direction of Dr. Willard H. Whitcomb, Department of Entomology, Agricultural Experiment Station, University of Arkansas.
    2. Mrs. Don L. Frizzell, Rolla, Missouri.
[^4]:    1. Work supported by National Science Foundation Research grant (i-10221, 1959-1961.
[^5]:    "Conger" sanctus Frizzell and Lamber, new species.
    (Figures 1 a-b, 7 a-d.)

[^6]:    1．Research Associate，Department of Herpetology，California Academy of Sciences

[^7]:    2. Many of Günther's records (between 1858 and 1864) noted in the following checklist were based on collections made by Brian Hodgson. Most of the specimens probably came from the vicinity of Katmandu, but it is known that Hodgson employed collectors to obtain specimens from elsewhere in the country. Unless otherwise noted, all of Günther's records are presumed to have been based on collections from central Nepal, from in and about the capital city of Katmandu.
    3. Nepal has been divided into Western, Central, and Eastern portions based on the major river systems of the country. See map, pages $120-121$, fig. 1 .
    4. The spelling of locality names has been corrected to follow the Survey of India Eight Mile Map of Nepal (1934) and the 1 inch to 4 mile map sheets of Nepal (1955).
[^8]:    5. Aelurophryne mammata was recently shown to be congeneric with Scutiger sikkimmensis (Myers and Leviton, 1962).
[^9]:    1. Swaine and R. Hopping (1928, p. 38) synonymized Ortholeptura Casey under Anoplodera Mulsant, but Linsley ( 1942, p. 51) raised it to generic status again.
[^10]:    2. Not appreciably margined in only four specimens of a total of 1061 studied; these are all females from Washington and California.
[^11]:    3. Centrodera autumnata flies later in the season, when fewer collectors are in the field, and the two may actually have more localities in common than museum records indicate.
[^12]:    4. There is still no universally accepted opinion as to the homologies of the wing venation of the Coleoptera. The anal veins of Forbes (1923) and of Swaine and Hopping are the cubitals of Saalas. The wedge-cell of Forbes, significant in Centrodera, is the anal cell of Swaine and Hopping, and the Cubitalzelle of Saatas.
[^13]:    5. In life the integument of $C$. spurca and $C$. autumnata (I have not seen $C$. dayi alive) is remarkably transparent. The underside of the abdomen is so transparent that in a gravid female the individual egge are clearly visible, while if the antennae are held against even a moderate light the contents of the basal four or five segments can be seen.
[^14]:    7. In early April, 1959, Ir. E. S. Ross dug up several adults of C. spurca at his property in Mill Valley, an additional record.
[^15]:    8. This figure does not tally with the totals from tables I, II, and III. This is because of specimens which were adequate for study but lacked data as to month of collection, or were from places which I could not find in any gazetteers.
[^16]:    9: Reference not seen by H. B. L.

[^17]:    1. Molina, 1851 (p. 27), mentioned that Cocos Island belonged to Costa Rica.
[^18]:    2. According to Murphy (1936, p. 317), "The central hills rise to an altitude of 518 meters, which is much less than is commonly credited to them."
[^19]:    1. See Generic Position, p. 324, and Nomenclature, p. 328.
[^20]:    3. In the original diagnosis of the genus Quinquarius, Jordan (1907, p. 238) stated that there are "no teeth on vomer . . . ," but in his key to the genera of the Quinquariinae (ibid., p. 236), he stated that there are "teeth on vomer" in Quinquarius. In a $154-\mathrm{mm}$. specimen of Quinquarius ( $=$ Pentaceros) japonicus (Stanford University no. 18191), which we have examined, teeth are present on the head of the vomer, but not on its shaft.
[^21]:    5. Data from HeCCulloch (1915).
[^22]:    4. The vernacular "porgy," used for species of this family by Jordan (1907), has been adopted for certain species of the Sparidae by the American Fisheries Society Committee on Names of Fishes (1960, p. 32).
[^23]:    *This elevation is given in Sailing Directions for the west coasts of Mexico and Central America. United States Naval Oceanographic Office, H.O. No. 26. p. 26, January, 1962.

[^24]:    Figure 1. Acrial view of Año Nucvo Island with Año Nuevo Point in the distance.

[^25]:    Bartholonew, George A., and Richard A. Boolootlan
    1960. Numbers and population structure of the pinnipeds on the California Channel Islands. Journal of Mammalogy, vol. 41, pp. 366-375.
    Bartholomew, George A., and Carl L. Hubbs
    1952. Winter population of pinnipeds about Guadalupe, San Benito, and Cedros islands, Baja California. Journal of Mammalogy, vol. 33, pp. 160-171.
    1960. Population growth and seasonal movements of the northern elephant seal, Mirounga angustirostris. Mammalia, vol. 24, pp. 313-324.
    Bonnot, Paul
    1928a. The sea lions of California. California Fish and Game, vol. 14, pp. 1-16.
    1928b. Report on the seals and sea lions of California. California Division of Fish and Game, Fish Bulletin no. 14, pp. 1-62.
    1931. The California sea lion census for 1930. California Fish and Game, vol. 17, pp. 150-155.
    1937. California sea lion census for 1936. California Fish and Game, vol. 23, pp. 108-112.
    1951. The sea lions, seals and sea otter of the California coast. California Fish and Game, vol. 37, pp. 371-389.

[^26]:    * Present address, University of California, Davis, California.

[^27]:    . . carry their young until they are in an advanced trochophore stage. These, to the number of about 200 in the case of Trachydermon $[=$ Cyanoplax $]$, are held

[^28]:    ${ }^{1}$ Heath mentions his success in raising the young of Cyanoplax denticns and Nuttallina thomasi to sexual maturity by removing adults to isolated tide pools where the development of the young could be observed with facility over a considerable period of time. Christiansen used the method followed by Grave (1937) to induce larval development, moving the larvae to clean dishes with filtered sea water. Seven days after fertilization the larvae were supplied with the diatom Nitschia closterior as food, but her efforts to continue development of the young chitons after metamorphosis were unsuccessful.

[^29]:    Median part of dorsal plate not emarginate

[^30]:    $\leftarrow$
    Figures 13-21. Male genitalia; ventral, lateral, and dorsal views, arranged in that order from left to right.

    Figure 13. Silis (Silis) tenuata Green, holotype.
    Figure 14. Silis (Silis) carbo Van Dyke.
    Figure 15. Silis (Silis) oregonensis Green, holotype.
    Figure 16. Silis (Silis) striatella Green, holotype.
    Figure 17. Silis (Silis) difficilis LeConte.
    Figure 17a. Silis (Silis) difficilis occidens Green, holotype.
    Figure 17b. Silis (Silis) difficilis subspecies?
    Figure 18. Silis (Silis) atra LeConte.
    Figure 19. Silis (Silis) egregia Green, holotype. Diagram of posterior orifice of tegmen inserted.
    Figure 20. Silis (Silis) singularis Green, holotype. Diagram of posterior orifice of tegmen inserted.
    Figure 21. Silis (Silis) eximia Green, holotype. Diagram of posterior orifice of tegmen inserted.

[^31]:    $\leftarrow$
    Figures 32-41. Male genitalia; ventral, lateral, and dorsal views, arranged in that order from left to right.
    Figure 32. Silis (Silis) crucialis Green, holotype.
    Figure 33. Silis (Silis) thermalis Green, holotype.
    Figure 34. Silis (Silis) acuta Green, holotype.
    Figure 35. Silis (Silis) cava LeConte, Cave Junction, Josephine County, Oregon. Dorsal view omitted.
    Figure 35a. Silis (Silis) cava complex, Miami Ranger Station, Mariposa County, California. Dorsal view omitted.
    Figure 35b. Silis (Silis) cava complex, Jackson County, Oregon. Dorsal view omitted.
    Figure 36. Silis (Silis) arizonica Van Dyke.
    Figure 37. Silis (Silis) fenestrata Van Dyke.
    Figure 38. Silis (Silis) californica Fender. Dorsal view omitted.
    Figure 39. Silis (Silis) reversa Green, paratype, Keen Camp, California. Dorsal view omitted.
    Figure 40. Silis (Silis) solitaria Green, holotype. Dorsal view omitted.
    Figure 41. Silis (Silis) recta Green, holotype. Dorsal view omitted.

[^32]:    $\leftarrow$
    Figures 42-52. Male genitalia; ventral, lateral, and dorsal views, arranged in that order from left to right.
    Figure 42. Silis (Silis) angelica Green, holotype. Dorsal view omitted.
    Figure 43. Silis (Silis) latestyla Green, holotype. Dorsal view omitted.
    Figure 44. Silis (Silis) fabulosa Green, holotype.
    Figure 45. Silis (Silis) divaricata Green, holotype.
    Figure 46. Silis (Silis) montanica Green, holotype.
    Figure 47. Silis (Silis) lecontei Green, holotype.
    Figure 48. Silis (Silis) dentigera Green, holotype.
    Figure 49. Silis (Silis) disjuncta Green, holotype.
    Figure 50. Silis (Silis) triplicata Green, holotype.
    Figure 51. Silis (Silis) protracta Green, holotype.
    Figure 51a. Silis (Silis) sp. near protracta?
    Figure 52. Silis (Silis) simulata Green, holotype.

[^33]:    ${ }^{1}$ Geologist and later Vice President in charge of Exploration for Tidewater Oil Company. Died in San Francisco, California, May 4, 1965.

[^34]:    ${ }^{1}$ Climate Survey of San Bruno Mountain. Phase 2: On-site Survey of Crocker Hills Climate. Aerosol Laboratory, Metronics Associates, Inc., Stanford Industrial Park, Palo Alto, California. October 20, 1967. Prepared for Crocker Land Company, San Francisco, California, and used with their permission.

[^35]:    Plate 3. Upper. Clarkia rubicunda (Lindley) Lewis \& Lewis.
    Lower. Castilleja zuightii Elmer.

