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No. 48, 108 pages, 85 figures, 4 plates February 16, 1966

INTRODUCED MOLLUSKS OF WESTERN NORTH AMERICA

By

G Dallas Hanna

Curator
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Introduction

This report has been prepared with emphasis on introductions of mollusks into the Pacific Coast area of western North America. California is covered more thoroughly than any of the other subdivisions of this area because of the number of species introduced into that state and also because of the author's greater familiarity with conditions there. British Columbia and Alaska are treated only briefly because there are few records in the literature. Hawaii is probably the most afflicted with undesirable introduced plants and animals of any area of similar size on earth. No attempt is here made to trace the complete history of molluscan introductions there because the subject has been thoroughly investigated recently by Mead (1961). Notes are included on species, the records of which I have come across incidental to other activities.

Sources of Information

The general literature on Mollusca has been a source of many records contained in this report but probably of greater value, and certainly the most current records, have been found in specialized documents. Most important of these is the mimeograph series "Cooperative Economic Insect Reports" published by the U. S. Department of Agriculture each week. Conchologists may wonder why mollusks should be included in a document primarily devoted to insects and the chief reason may be that no other medium is available for recording the activities of these organisms so destructive to certain branches of agculture. Another reason is that economic insect control has become of great importance and a large and efficient corps of field workers has been established. Most of these workers are trained zoologists and are in a favorable position to detect injurious mollusks and make collections for identification.

The U. S. Department of Agriculture, Plant Quarantine Division, Washington 25, D.C., issues for each fiscal year a *List of Intercepted Plant Pests.* In this all records of forms of known or potential quarantine significance are collected. Mollusks, as well as other groups of animals intercepted, are listed.

Quarantine authority is given to the Department of Agriculture and is repeatedly published in *Plant Regulatory Announcements* issued each year. This authority is as follows:

Regulations governing entry of Mollusks

These regulations, effective October 22, 1952, were promulgated under the Act approved September 22, 1951, entitled, "An Act to prevent the entry of certain mollusks into the United States. The regulations provide that produce, baggage, salvaged war materials, and other goods that might harbor the giant African snail and other destructive mollusks, will be subject to inspection upon arrival in this country from foreign countries and from Guam. Inbound

vessels, vehicles, aircraft, or other conveyances that are found upon inspection to contain such pests may be refused entry or may be allowed to enter after thorough treatment under strict safeguards. Provision is made in the regulations for importation of mollusks for scientific purposes. Those imported for use in medical research may enter under permits issued by the U. S. Public Health Service."

Other sources of information have been communications* from many individuals, specimens in museums, and to some extent field observations of the author and his colleagues. I am especially indebted for assistance to my immediate associates, Allyn G. Smith and Leo G. Hertlein. They have furnished many records which otherwise would have been missed. Mr. Maurice Giles has contributed many photographs used herein. Others who have assisted in various ways have been acknowledged through the text.

Interceptions and introductions

So voluminous are the records of actual interceptions of mollusks at ports of entry and departure, in baggage and mail, that no attempt is made herein to enumerate them all. Ordinarily, if these animals are detected they are destroyed and, therefore, present no special hazard. The likelihood of some shipments slipping by is very great; therefore, it seems pertinent to list the species intercepted at American ports during two late fiscal years 1958 and 1961. (Hunt, 1959, and Mumford, 1962).

NAME	1958	1961	PLACE OF ORIGIN
Achatina fulica	2	5	Morocco, Hawaii, Guam
Bradybaena similaris	-	13	Hawaii and Bermuda
Cochlicella barbara	-	26	Mediterranean countries
Cochlicella conoidea	-	1	Spain
Cochlicella ventrosa	-	10	Azores, Bermuda, Italy, Morocco
Euglandina striata	-	17	Ecuador
Helicella, 10 species	-	41	European countries
Monacha cantiana	-	31	Italy, France, Germany
Monacha carthusiana	-	1	Italy
Porphyrobaphe iostoma	6	8	Ecuador
Rumina decollata	-	1	Italy
Solaropsis monile	-	33	Ecuador
Subulina octona	-	2	Surinam, St. Lucia
Theba pisana	33	64	Mediterranean countries

The above are quoted from the publications cited without further checking.

In addition the same authors cited the following species as having been intercepted but without times of detection or places of origin.

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* In 1960 an unsuccessful attempt to establish *Crassostrea gigas* was made at Sawmill Bay, Prince William Sound, Alaska. Dr. E. L. Bousfield collected six double and three single dead valves there in 1961. This information was received from Dr. Bousfield and Dr. Arthur H. Clark, Jr., of the National Museum of Canada.

1958	1961	
Arion circumscriptus	*Cecilioides acicula*	*Limax marginatus*
Cepaea nemoralis	*Cepaea hortensis (?)*	*Limax maximus*
Deroceras reticulatum	*Helicina strebeli*	*Otala lactea*
Limax marginatus	*Helix aspersa*	*Otala vermiculata*
Limax maximus	*Helix pomatia*	*Oxychilus alliarius*
Milax gagates (?)	*Lamellaxis gracilis*	*Oxychilus draparnaldi*
Oxychilus alliarius		

The extent to which foreign introduction of marine shells can be carried is well illustrated by a report by Bonnot (1935, pp. 1, 2). He found 22 species in addition to the oyster, in 20 boxes of Japanese seed oysters destined for planting in Elkhorn Slough, Monterey County, California (Hanna, 1939, p. 298). The list of species is as follows:

Acmaea concinna (Lischke)
Acmaea heroldi (Dunker)
Acmaea heroldi pygmaea (Dunker)
Alectrion lirata (Dunker)
=*(? A. festiva* Powis)
Anomia laqueata (Reeve)
Balanus amphitrite albicostatus (Pilsbry)
Cellana amussitata (Reeve)
Cellana toreuma (Reeve)
Littorina (Littorivaga) sitchana sitkana (Philippi)
Macoma inquinata (Deshayes)
[Probably a similar but distinct oriental species]
Modiolus atratus (Lischke)
Mytilus dunkeri (Reeve)
Odostomia (Evalea) sp. undet.
Paphia (Ruditapes) japonica (Deshayes)
Pecten (Chlamys) irregularis (Sowerby)
Potamides (Batillaria) multiformis (Lischke)
Septifer rostratus (Dunker)
Siphonaria cochleariformis (Reeve)
Sunetta excavata (Hanley)
Tegula undatella (Gould)
Thais tumulosa clavigera (Küster)
Turbo coronatus (Gmelin)

This lot was collected March 26, 1930, but apparently few survived.

In 1947, Professor Kincaid (pp. 1-3) discussed introduced species in Washington waters. First he mentioned the common, well known ones, *Mya arenaria*, *Crepidula fornicata*, *Urosalpinx cinerea*, *Petricola pholadiformis*, and *Nassarius obsoletus*; then followed with 11 less well known forms brought to Samish Bay in 1924 with seed oysters. The list is as follows:

Ocenebra japonica (Dunker)
Lampania zonale Bruguière
Paphia philippinarum Adams and Reeve
Trapezium japonicum Pilsbry
Turbo marmoratus Linnaeus
Turbo coronatus coreensis Recluz
Monodonta labio Linnaeus
Thais tumulosus or *Thais nodulosa problematica* (Baker)
Acmaea heroldi signata (Dunker)
Modiolus senhausi Reeve
Pododesmus sp.

In September, 1963, I talked with Professor Kincaid about this shipment, and learned that these species had definitely escaped from the seed boxes. Some of them are now well established either from this planting or later ones.

The above names were given to Professor Kincaid by Mrs. Ida S. Oldroyd. It would be very difficult to ascertain now if any of the species became established in Puget Sound as a result of this planting. Professor Kincaid gave the Academy a selection of turban shells and has passed specimens out to several collectors. A few of the species are illustrated in this report, but the names appear only in the list of uncertain status. Of these Dr. Leo G. Hertlein and Mr. Allyn Smith have identified *Littorina brevicula* Philippi and *Tegula turbinatum* A. Adams (or *Omphalius rusticum* Gmelin).

In 1949 Kincaid (p. 1) gave a list of species which he had obtained from boxes of seed oysters from Kumamoto, Japan. Some of these have become well established on the west coast. Dr. Myra Keen has identified them as follows:

Barbatia obtusoides (Nyst)
Volsella senhausi (Benson)
Littorina scabra intermedia Philippi
Littorina brevicula Philippi
Thais bronni (Dunker)
Mitrella pardalina tylerae Griffith and Pidgeon
Nerita japonica Dunker
Cerithidea cingulata Gmelin
Batillaria multiformis (Lischke)
Acmaea heroldi signata Pilsbry

The records indicate that a great many of the interceptions have been snails detected in military cargoes being returned to the United States from foreign countries. Arriving here, the cost of inspection may be very large; and a properly decontaminated cargo may cost up to $40,000. Sometimes the infestation may be discovered after the materials are landed, in which case they may be reloaded aboard ship for treatment. Cognizance of these difficulties has recently been taken by the Department of Defense with the issuance by the Armed Forces Pest Control Board of Technical Information, Memorandum, No. 5, *The Mediterranean Snail Problem, (Adams, 1962).* While this document is especially concerned with *Theba pisana*, *Cochlicella* spp., and *Helicella* spp., the detailed instructions are applicable to many other forms of land snails and other sources of contamination than the Mediterranean area.

The seriousness of the introduction of foreign species is well illustrated by one report, among many, regarding *Theba pisana* Müller. In the Cooperative Economic Insect Report, vol. 11, no. 31, August 4, 1961, p. 747, 14 interceptions of material are recorded which originated in the Mediterranean area. The details of localities are as follows: Detroit, Michigan - 1 interception in stores; New Orleans, Louisiana - 1 interception in cargo for Ohio, 3 interceptions for Charleston, South Carolina, Alaska, and Norfolk, Virginia. Norfolk, Virginia - 5 interceptions, 1 in stores, 4 in cargo for Virginia. New York, New York - 4 interceptions, 1 in cargo, 3 in stores. In many other cases, it is noted that many of the interceptions are in military cargo destined for military posts, a carelessness which is ordinarily inexcusable.

Another illustration taken at random of entry-post interception of *Theba pisana:* "At Charleston, 2 on military cargo; at New Orleans, 4 on old and new autos from France and on military cargo from France and Morocco; at New York, one on *Begonia* cuttings and 2 on military cargo from Morocco; at Norfolk, 1 on motor cannister cargo from France and 3 on military cargo from Morocco," (Coop. Econ. Insect Rept., vol. 9, no. 52, Dec. 25, 1959, p. 1064).

Most introductions of destructive or potentially dangerous mollusks arrive in United States ports in other cargoes through oversight or careless handling from points of origin. Thus Central American snails have been intercepted by quarantine and inspection officers at several west-coast ports. They arrive with bananas and other commodities. No effort has been made in this report to list all of such interceptions because in most cases the species would obviously not be adapted to western climates. Many marine species, however, have arrived and have become established in the introduction of oysters to western waters. Those known to have survived have been listed. Other species come in with nursery stock and other plant material. All of these may be classed as unintentional importations.

In contrast, there are deliberate shipments being made or attempting to be made for commercial purposes. Ingram's finding *Helix lactea* being sold in Ohio as fish bait is a good example. Dealers in aquarium materials like to supply the demands of hobbyists for unusual mollusks as well as fishes and there is a considerable number of persons who would like to raise for commercial purpose species which are used for food in other countries. Lastly, there are people, even conchologists, who derive a certain measure of pleasure in transplanting species from one locality to another just to find if it can be done. This is regrettable but difficult to control.

Probably none of these activities can ever be controlled completely, legally or educationally. There simply cannot be enough inspectors. The ease with which a shipment may be made is indicated by one of my own experiences. A geologist friend travelling in South America stopped in Caracas, Venezuela, saw a number of snails on some plants and at once thought of me. He gathered a mailing tube full and sent them by air mail. Three days later about a hundred cerions arrived in San Francisco, all alive and healthy.

Quarantine and pest-control officials frequently intercept various species of mollusks at ports of entry and elsewhere. In the normal course of events, after identification, the animals are promptly destroyed. Many of the specimens reach museums and are preserved there for future use. They are not properly introduced species and no attempt has been made to record them herein.

In the attempts to establish a commercial supply of oysters in California waters and after it was discovered that *Crassostrea virginica* did not breed there, several attempts were made to introduce Mexican species. *Ostrea corteziana* Hertlein and *Ostrea iridescens* Gray were probably the ones which

formed the basis of the experiments. Townsend (1893, p. 361) has given some details.

Perhaps the greatest instance of "shotgun" style of wilful foreign introduction of animals in west America has been the various activities of the California Department of Fish and Game in connection with the Salton Sea. Linsley and Carpelan (1961, p. 46) have given a list of many invertebrates which have been thus introduced. Among the lot there are 12 forms from California. Also eight molluscan species were listed which had come from Texas. In this case the total number of species introduced was unknown. A thorough account of the Salton Sea work has recently been published by Walker *et al.*

It is a rather rare occasion indeed when it is learned that a native mollusk is considered to be injurious in agriculture or otherwise. Therefore, attention is called to the report of Capizzi (1961, p. 954) of *Monadenia fidelis* a native snail infesting gorse in coastal Lane County, Oregon.

Preservation of Specimens

In the case of slugs we know of no better method of preservation than that given by Messrs. R. W. Harper and H. H. Keifer in a mimeograph sheet issued by the California Department of Agriculture on March 2, 1962.

After stating that these animals contract badly and exude quantities of mucus if placed directly in strong preservatives such as alcohol or formaldehyde, they recommend that killing be done in water. They preferred a 1 per cent solution of a sugar, especially sorbitol, rather than sucrose because of fermentation of the latter. They also recommended that .1 per cent chloral hydrate be added to the water or in the absence of this, a few crystals of thymol as an anesthetizing agent. Containers for drowning should be completely filled so no air pocket remains. The animals should be left in the solution approximately 24 hours. Thus prepared, the material is in a reasonably expanded condition with external characters undistorted and are very suitable for dissection. (Copy furnished by L. J. Garrett, Jr.)

Permanent preservation may be in 75 per cent ethyl alcolol, or 2-4 per cent formaldehyde although Harper and Keifer recommended 50 per cent ethyl alcohol, 1 per cent sugar and 1 per cent formaldehyde. Preparations in the latter formula are excellent.

In most cases shell-bearing mollusks are identified from the shells alone. Thus ordinarily it is sufficient to extract the soft parts and keep the shells dry. In the case of land snails they can be kept for a few days to months (in the case of desert forms) in any ordinary non-metallic containers used for shiping. They contract into the shells and remain dormant in such conditions. If it be desired to preserve the soft parts they can be extracted from the shells by boiling in fresh water for one to a few minutes depending upon size. If de-

sired, the land forms can be drowned as described above for slugs, in which case they will be expanded out of the shells to some degree.

For drowning freshwater snails the solution recommended for slugs is excellent. Thymol crystals are an excellent anesthetizing agent.

Marine snails can be extracted by boiling, but if the shells are heavy and thick as much as five minutes may be required.

In no case should shelled mollusks be preserved in any liquid which contains formaldehyde. This solution attacks the calcite and eventually destroys the shells for taxonomic purposes. A solution of either 40 per cent isopropyl alcohol or 75 per cent ethyl alcohol makes a reliable preservative for these animals.

Methods of Control

There is much literature, European and American, on methods and materials used for the control of slugs and snails destructive to agriculture. Lange and MacLeod (1941, pp. 321-322) have given the best information known at that time. A late series of extensive experiments were conducted over a period of years by Howitt and Cole (1962, pp. 320-325) in Washington. They used sprays and baits in strawberry fields and recommend the sprays if properly applied. Several chemicals are in current use, one of the more popular being metaldehyde.

Burning has been employed in certain areas of California.

L. J. Garrett, Jr., Agricultural Commissioner of Del Norte County, California, advised that after systematic testing of bait materials in that district it was found that a 6 per cent metadehyde bran was most effective for slugs. As a survey trap he recommended a newspaper rolled into a one and one-half inch hollow tube previously moistened with a solution of 10 grams of metaldehyde in 100 ml. of isopropyl alcohol. (Letter to A. G. Smith, March 9, 1962.)

It seems to be axiomatic that when an introduced mollusk becomes well established in western America, no known means has been discovered to completely eradicate it. Except for the land forms there does not seem to be any effective method known for even attacking the problem. This is especially true for marine species.

I do not know of any satisfactory way by means of which all of the small slugs which have been reported from the west can be differentiated either as living or preserved material. A few have characters which in the majority of cases are sufficient for identification of the species. Where this is the case, these characters are noted under the several names. In some cases, differentiation may have been based upon anatomical characters. It is not the purpose of this paper to go into anatomical detail, published or otherwise.

Land Mollusks

Cepaea nemoralis (Linnaeus).

(Plate 3, figures 6-9, 19-22.)

This rather beautifully colored land snail was recorded from western North America by Draycot (1961, p. 164). He noted that some of the snails came to a gardener in Lynn Valley near Vancouver, British Columbia, in 1926 with ornamental plants, but the danger was recognized and the colony was effectively exterminated with sprays and poisons. A more recent introduction from eastern Canada came also with plants to Mrs. L. Pierard of Lynn Valley. Considerable damage had been done before the danger was detected. The identification was made by Dr. A. H. Clarke, Jr., of the National Museum of Canada. Both banded and unbanded shells were present. Mr. Draycot very kindly supplied the specimens illustrated herein.

Hill (1941, p. 31) recorded *C. nemoralis* from nursery stock at Los Angeles and Redondo, California. Collections were made in 1938 and 1940 on four occasions.

Spencer (1961, p. 48) reported the species from his garden in Vancouver, British Columbia.

The only other record for western America is unpublished. H. H. Keifer wrote (letter, November 23, 1940) that: "We are also advised of the establishment of *Helix nemoralis* in Hollywood, California."

From the large collections of European land snails in the California Academy of Sciences, I do not believe it is possible to distinguish *C. hortensis* and *C. nemoralis* on shell characters alone. Pilsbry (1939, pp. 6-12) described and illustrated both species but failed to give shell characters for separation which could be used in the field. Slight anatomical differences were noted. In *C. nemoralis* the outer lip and columella were deep brown in many specimens but in others there is scarcely a trace. The same is true of *C. hortensis*. Ingram (1952, pp. 26-29) has recorded *C. hortensis* from Cincinnati, Ohio, where it was sold as bait, along with *Otala lactea*. In view of the difficulty of distinguishing *C. nemoralis* and *C. hortensis*, we are illustrating one of Dr. Ingram's specimens and two from Denmark furnished by Dr. Hans Schlesch (plate 1, figure 2). Banding in both species is highly variable and many specimens are completely without any bands whatsoever. According to Pilsbry (1939, pp. 6-12) *C. hortensis* is found along the eastern seaboard of the United States, especially on the islands, and since it occurs as fossils in kitchen middens and Pleistocene deposits, it should be considered a North American resident. It is very common in Europe.

Helix aperta Born.

(Plate 3, figures 10-13, 23-26.)

In some mysterious manner this species has become well established at San Ysidro, San Diego County, California. An employee of the gas company, reading meters, saw them in May, 1941, and reported to Mr. Walter Binney, Agricultural Commissioner at Chula Vista, that the local residents informed him the snails were doing much damage to yards and gardens. Mr. Earle Gammon was summoned to investigate and so far as has been determined they are confined to a rather limited area. Several gardens and a small alfalfa patch were found to be well populated. The burrowing habit of the species makes it difficult to eradicate and to determine the extent of the infestation. Many holes were found six inches deep with a spherical cavity at the bottom, lined with dried mucus. A road grader working on a street in the area uncovered many of them. In aestivating, a characteristic very heavy white epiphragm is secreted.

Several writers on European land snails have commented upon the great esteem in which this species is held by epicures. This may have some bearing upon its appearance near San Diego.

The usual methods of combating the introduced helices is to burn the infested areas to the ground wherever practicable. Special oil burning "flame guns" have been developed for the purpose. Also local fire departments often assist in the application of this method. Poisoned baits and attractants are used extensively and especially in the areas where fire cannot be risked. The effectiveness of different types of baits seems to vary in different places, possibly because of the humidity. Moistened bran, poisoned with calcium arsenate, is said to be excellent in some places, particularly in the southern part of the state. Bran, with a small percentage of metaldehyde and some-

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PLATE 1

All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection, unless otherwise stated.

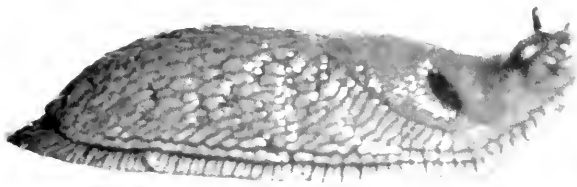
Figure 1. *Arion ater* (Linnaeus). From Crescent City, California; L. J. Garrett, Jr., collector.

Figure 2. *Euglandina rosea* (Férussac). Hypotype no. 12622 (CAS). From Crescent City, California; L. J. Garrett, Jr., collector. Length 58.5 mm.

Figure 3. *Cepaea hortensis* (Müller). Hypotype no. 12623 (CAS). From Denmark. Hans Schlesch, collector. Diameter 19.3 mm.

Figure 4. *Cepaea hortensis* (Müller). Hypotype no. 12624 (CAS). From Denmark. Hans Schlesch, collector. Diameter 19.8 mm.

Figure 5. *Cepaea hortensis* (Müller). Hypotype no. 12625 (CAS). From Cincinnati, Ohio. William Marcus Ingram, collector. Diameter 22.4 mm.



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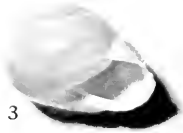

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times with a poison added, is sold under various trade names and is preferred by some in more humid areas. The value of the aldehyde as an attractant is well established, through extensive field use.

Lange and MacLeod (1941, pp. 321-322) have given an account of the preparation, use and effectiveness of these materials with a bibliography.

Campbell (1953, p. 75) related that this species was found to have destroyed the first few rows of a cabbage field adjacent to a pasture in the vicinity of San Ysidro, California. As many as eight snails per plant were found.

Helix aspersa Müller.

(Plate 2, figures 4-9.) 6, 10-12

This, the brown garden snail of popular literature, was the first foreign mollusk to be introduced into western North America. Forbes (1850, p. 53) noted it from Santa Barbara among the shells brought to England by Kellett and Wood during the voyages of the *Herald* and *Pandora*. Carpenter (1856 [1857], p. 239) commented on this record, stating that the species was probably imported.

Stearns (1881, pp. 129-139) did not refer to these records in his extended account of the introduction of the snail by a Mr. A. Delmas near San Jose, California, in 1856. Stearns probably had first hand information and remarked that it was brought in for food purposes.

Since then the species has spread widely throughout most of the western states, except the high mountain country. It is found in desert areas where there are flourishing gardens: Bakersfield (C. C. Church); Chico (Mickey); Coquille, Coos County, Oregon (Capizzi, 1961, p. 232); Holladay, Salt Lake County, Utah (Hutchings, 1961, p. 611); Tucson, Arizona (Mead, 1963, p. 27). The most northern locality for the species of which we have a record is Seaview near Long Beach, Pacific County, Washington, where it was reported to be causing considerable damage to flowers. (Breakey, 1960, Cooperative Economic Insect Report, vol. 10, no. 33, p. 769.) At this and the Coquille, Oregon, locality as well as at Crescent City, California, sea cliff locality, the species is living in essentially wild circumstances. Other than this, there is little, if any, evidence that the species has left the areas of cultivation, but in gardens and orchards it is very destructive.

Effective control on a small scale can be maintained by use of commercially prepared metaldehyde baits, but on a large scale, such as the orchards of southern California, this becomes very difficult. Actual extermination now seems to be hopeless.

Strange to say epicures who like snails for food seem to prefer them from imported cans from Europe rather than picking them from western gardens.

Sinistral specimens of this species are none too common even in Europe. Therefore, attention is called to the fact that Basinger (1931, p. 5) found and recorded one from Anaheim, California, in his general report on the status of the snail in California. The specimen was deposited in the collection of S. S. *Berry*. On June 19, 1941, Mr. Royal Stewart found one alive in his garden, 1230 Glen Avenue, Berkeley, California. This was given to Mr. Allyn G. Smith and placed on exhibition at the Academy soon thereafter. Newspaper notices regarding it resulted in the finding of two more. Mr. William Martin, 114 Grenville Way, San Francisco, found one on the top of Forest Hill near his home, July 5, 1941. This was presented alive to the Academy. A fourth specimen was found by Mr. Albert H. Amon in the garden of Saratoga Inn, Saratoga, California, July 6, 1941. Disposition of this one is not known to me.

Helix pomatia Linnaeus.

(Figure 1.)

Fig. 1. *Helix pomatia*. Diameter 47 mm.

This is the most common food snail of Europe, perhaps, and requests are made from time to time to colonize the species in America. Probably it has been tried, but if so, records have not been found. A shipment of 12 by air, was intercepted at San Francisco on September 12, 1961, by State Plant Quarantine officers. These were for the avowed purpose of having a "snail race," the promotion of which would seem to serve no useful purpose (Galbraith, 1961, p. 2). The shells may be rather strongly banded as in the example shown herewith, down to where there are no perceptible color markings at all. Size also is highly variable.

Otala lactea (Müller).

(Plate 2, figures 1-3, ~~16-12~~ 7-9.)

This striking snail is somewhat larger than *Helix aspersa*. The shell is lighter in color and often spirally banded. It was first reported in western literature by Hill (1941, p. 31) who identified specimens from Elysian Park, Los Angeles. Shells were found by a school boy searching for fossils on Novem-

ber 5, 1940. Dr. Hill notified Mr. Earle T. Gammon of the State Department of Agriculture who was assigned the problem of eradication. The area of infestation was found to cover about 20 acres with a subarea of 5 additional city blocks. Mr. Gammon soon found an additional infestation of about 50 acres near Playa del Rey, south of Venice, California.

On June 21, 1941, Mrs. T. B. Ostick, 741 Chenery Street, San Francisco, brought a living specimen of *Helix lactea* to the Academy for identification. She had found it adhering to a fence across the street from her residence and had kept the snail as a pet for some time. The facts were transmitted to the State Department of Agriculture in Sacramento and Mr. Gammon was detached from his eradication work in the Los Angeles area to make an investigation. I joined him and Mr. H. H. Keifer and on the vacant lot at Chenery and Cliff streets where the original specimen was taken, we found *Otala lactea* in very large numbers; 74 adult specimens were collected in 20 minutes about the roots of plants and under rubbish of various kinds. Within the next few days the infestation was found to be limited to one city block and much effort was expended in eradication. It was learned that this colony had been planted about four years earlier by the Italian owner of the vacant lot and that he used the snails for food to a limited extent. The flavor was reported to be better than that of *Helix aspersa.*

A second infestation of *Otala lactea* was discovered in San Francisco about November 15, 1947, in the vacant area just southwest of Farmers' Market on Alemany Boulevard. The discovery was made by Mr. T. H. Christian, formerly County Inspector but at the time he was the Market Master of this market. He reported the discovery to County Inspector Mr. J. C. Kitchin who passed the information on to Quarantine officials. Mr. Potts of that organization brought specimens to the Academy for verification of the identification.

On November 30, 1947, accompanied by Mr. D. A. McLaren, we visited the Farmers' Market area and in half an hour collected 196 living specimens. They were found in great abundance under papers, boards, rocks, and crawling around in the grass, the day being overcast and moist. Under some boards there were hundreds of young shells. It was found that the species extended far up the hill on the south side of Alemany Boulevard and across to the north among the houses of the war-time assemblage known as "Guam Village." It was noted then that extermination of the species would be extremely difficult, perhaps impossible. No evidence was obtained as to how this colony was started but that it was of long standing was obvious. Many very old dead shells were present. The establishment of the Farmers' Market at this location in 1947 had nothing whatsoever to do with the problem. As late as December, 1959, the species was still present in the vicinity of the Market (A. G. Smith, 1959, p. 19).

The shells of the Los Angeles colonies are fairly uniformly colored with specks or broken bands of dark gray on top with a nearly white background and the usual dark brown to black inside the aperture and on the columella. Very rarely is there a white one. On the contrary, the San Francisco colonies run through the broadest range of color variations we have ever seen in what is obviously a genetically related stock. Many shells are pure white, without a trace of color anywhere. Others are white with various shades of light to dark brown inside the aperture. There are shells with sharp unbroken bands of variable number on a white to dark brown background; and there is every conceivable intergrade between these two basic forms, mentioned only as an illustration, and many others. Truly, there are nearly as many "varieties" or "species" as there are specimens.

PLATE 2

All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection, unless otherwise stated.

Figure 1. *Otala lactea* (Müller). Hypotype no. 12626 (CAS). From Chenery and Cliff streets, San Francisco, California. Earle Gammon, H. H. Keifer, and G. D. Hanna, collectors. Diameter 35.4 mm.

Figure 2. *Otala lactea* (Müller). Hypotype no. 12627 (CAS). From Chavez Ravine, Los Angeles County, California. Earle Gammon, collector. Received from H. H. Keifer. Diameter 33.0 mm.

Figure 3. *Otala lactea* (Müller). Hypotype no. 12628 (CAS). From Chavez Ravine, Los Angeles County, California. Earle Gammon, collector. Received from H. H. Keifer. Diameter 33.1 mm.

Figure 4. *Helix aspersa* Müller. Hypotype no. 12629 (CAS). From San Diego, California. Henry Hemphill, collector. Diameter 31.5 mm.

Figure 5. *Helix aspersa* Müller. Hypotype no. 12630 (CAS). From Funston and Balboa streets, San Francisco, California. A. G. Smith and G D. Hanna, collectors. Diameter 29.5 mm.

Figure 6. *Helix aspersa* Müller. Hypotype no. 12631 (CAS). From Funston and Balboa streets, San Francisco, California. A. G. Smith and G D. Hanna, collectors. Diameter 27.7 mm.

Figure 7. *Otala lactea* (Müller). Same specimen as figure 1.

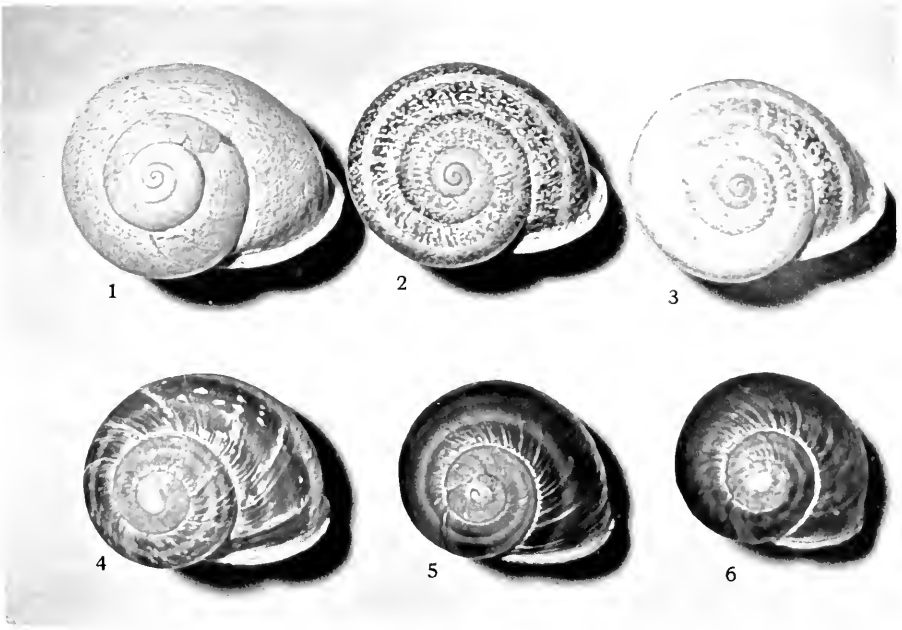
Figure 8. *Otala lactea* (Müller). Same specimen as figure 2.

Figure 9. *Otala lactea* (Müller). Same specimen as figure 3.

Figure 10. *Helix aspersa* Müller. Same specimen as figure 4.

Figure 11. *Helix aspersa* Müller. Same specimen as figure 5.

Figure 12. *Helix aspersa* Müller. Same specimen as figure 6.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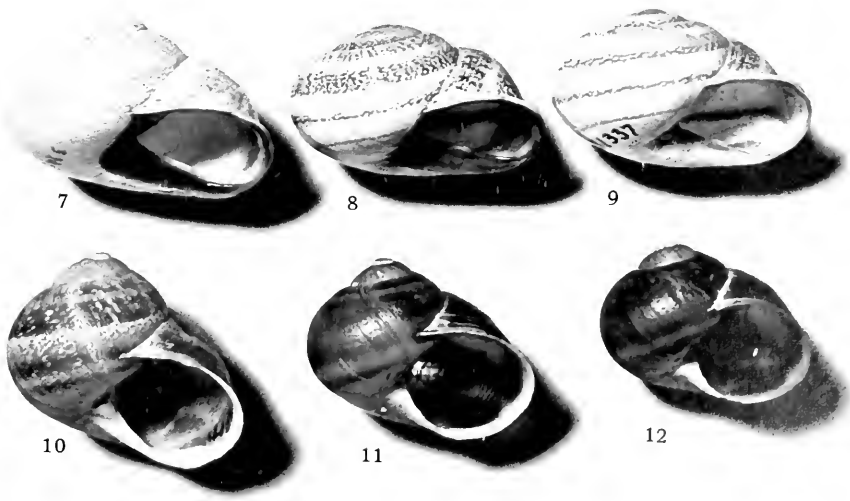
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Ingram (1952, pp. 26-29) called attention to the fact that *Otala lactea* and *Cepaea hortensis* were imported and sold alive for fish bait in Cincinnati, Ohio. Occasionally unused snails were discharged on shore and could become a dangerous pest.

L. J. Garrett, Jr., (letter to A. G. Smith, October 3, 1961) informed us that an extensive colony of the species had been found in Mountain View, Santa Clara County, California. He also stated that the records of his office showed that the species has occurred in Sacramento, Santa Clara, Monterey, Los Angeles and Orange Counties.

Theba pisana Müller [1]

(Plate 3, figures 1-5, 14-18.)

This very dangerous pest was first discovered in California by Mrs. W. E. Ritter in July, 1914, in the garden of a girls' school at La Jolla, according to information given me by E. P. Van Duzee (verbal communication). The specimens were turned over to him and he promptly delivered them to Mrs. Kate Stephens of the San Diego Society of Natural History. Evidently the colony was "found" by several persons at about the same time during 1914, as reported by Chace (Nautilus, 1915, p. 72). The abundance reached is shown by the account of Orcutt (1919, p. 63) when he described bushes literally loaded with snails. Basinger (1923, pp. 522-526) has given an excellent description of the infestation with attempts at eradication. Years of work and much money were required to finally reach what was believed to be stable controlled conditions.

Cockerell received a batch of these early representatives of this species from Basinger and published (1924, pp. 190-192) a list of six varietal names into which the lot could be divided. These were:

Helix pisana pisana Müller
Helix pisana bifrons Moquin-Tandon
Helix pisana alba Shuttleworth
Helix pisana subzonata Bourguinat
Helix pisana interrupta Moquin-Tandon
Helix pisana punctella Moquin-Tandon
Helix pisana sagittifera Taylor

Cockerell did not attach much taxonomic importance to these variations in banding.

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(1) The working out of details of a publication of Férussac by Kennard (1942, pp. 12-14, 105-118) convinced Pilsbry (1948, p. 1091) that the name *Theba* should be replaced by *Helicella* Férussac.

In 1936 an area about 50 acres back of Pacific Beach near La Jolla was found to be infested (E. T. Gammon, personal communication).

Another colony of this snail was discovered in 1932 in Los Angeles and Orange counties, California (Hanna, 1939, p. 303), by officials of the State Department of Agriculture. They were detected in an alfalfa field back of the town of Seal Beach. The hay had been cut, but in the process of curing it had become wet and unfit for stock feed. However, it was widely distributed in the region for orchard and garden mulch and to a lesser extent to dairies and chicken ranches for various purposes. Wherever this hay went a new colony of *T. pisana* was established. Thus it spread to Anaheim Landing, Garden Grove, and 17 orange groves around Santa Ana and Anaheim in Orange County. It evidently spread over most of the San Gabriel River drainage. Specimens were taken in San Pedro in 1935, Long Beach in 1938, and possibly elsewhere in the general area. The difficulties and cost of eradication were very much greater than in the case of the La Jolla colony because there a large part of the infested area was brush-land and could be burned. Nevertheless, in 1940 the task seemed to have been completed.

PLATE 3

All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection, unless otherwise stated.

Figure 1. *Theba pisana* (Müller). Hypotype no. 12632 (CAS). From Orange County, California. H. H. Keifer, collector. Diameter 16.8 mm.

Figure 2. *Theba pisana* (Müller). Hypotype no. 12633 (CAS). From La Jolla, California. G. D. Hanna, collector, July, 1922. Diameter 15.9 mm.

Figure 3. *Theba pisana* (Müller). Hypotype no. 12634 (CAS). From San Pedro, California. E. P. Chace, collector. Diameter 18.7 mm.

Figure 4. *Theba pisana* (Müller). Hypotype no. 12635 (CAS). From La Jolla, California. A. G. Smith, collector, December 31, 1914. Diameter 18.8 mm.

Figure 5. *Theba pisana* (Müller). Hypotype no. 12636 (CAS). From La Jolla, California. G D. Hanna, collector, July, 1922. Diameter 17.0 mm.

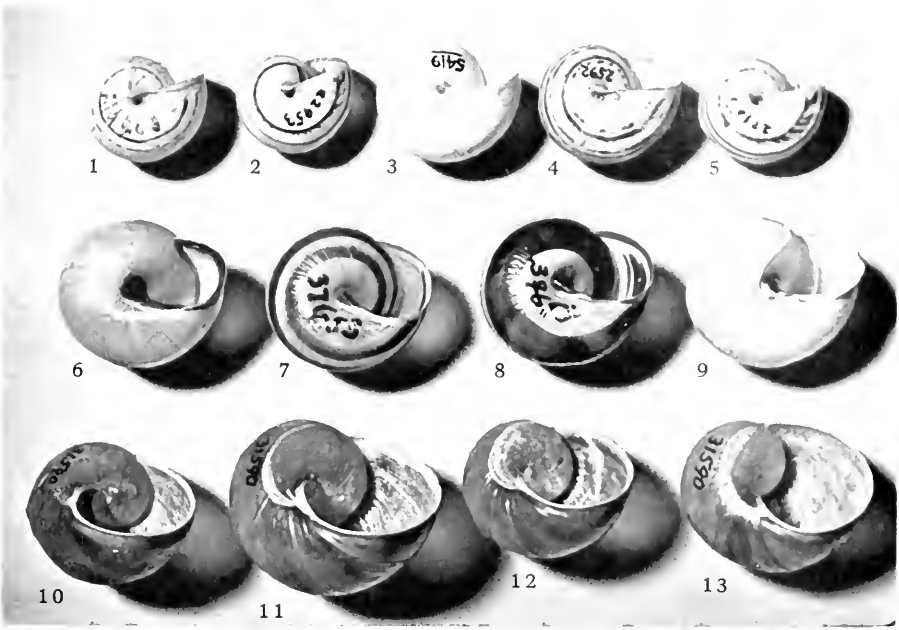
Figures 6-9. *Cepaea nemoralis* (Linnaeus). Hypotypes nos. 12637, 12638, 12639, 12640. From North Vancouver, British Columbia. W. MacKay Draycot, collector. Diameters 22.8, 21.2, 22.5, and 22.5 mm.

Figures 10-13. *Helix aperta* Born. Hypotypes nos. 12641, 12642, 12643, 12644. From San Isidro, San Diego County, California. Earle Gammon, collector. Diameters 23.7, 27.5, 21.6, and 23.8 mm.

Figures 14-18. Same specimens as figures 1-5.

Figures 19-22. Same specimens as figures 6-9.

Figures 23-26. Same specimens as figures 10-13.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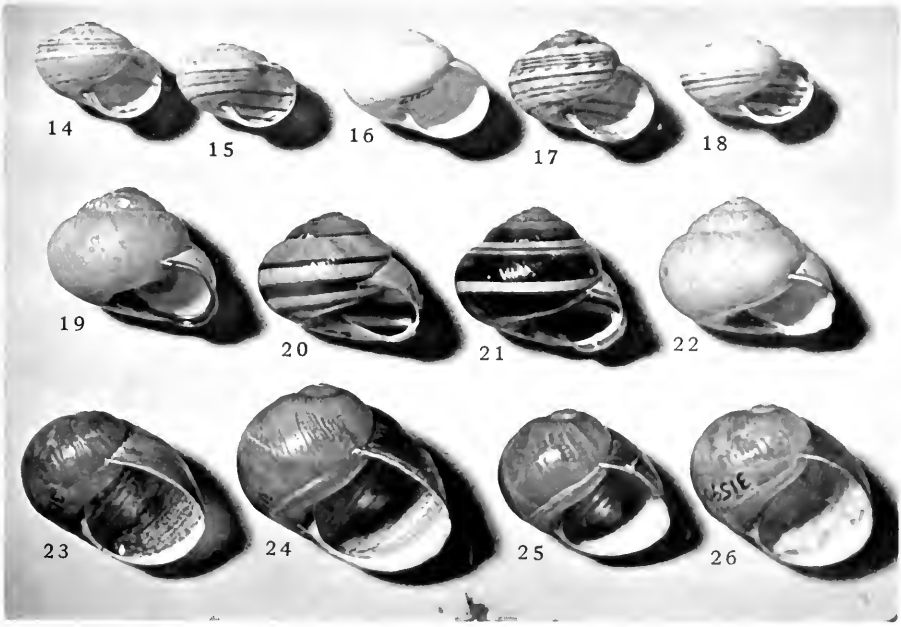
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Along with the colony of *Otala lactea* near Playa del Rey, near Venice, California. Mr. Gammon (verbal communication) found specimens of *T. pisana*. He was uncertain if this might have been an extension of the infestation in the vicinity of Seal Beach.

Numerous references, not cited herein, will be found in the papers by Basinger (1927) and Hanna (1939).

Many published reports show that this destructive snail is constantly being intercepted at ports of entry. A typical record is the following: Six interceptions at Charleston, South Carolina; two at New Orleans, Louisiana; three at Norfolk, Virginia, all in military cargo (Anon., 1960, p. 90). It seems obvious that such operations are due entirely to careless and irresponsible supervision of packing at American military establishments in Europe.

Theba pisana has become established at several east American localities and possibly its ease of distribution is partly due to its habit of crawling up on exposed objects for aestivation.

The shells are extremely variable in so far as color banding is concerned. It is difficult to find two alike. Some may be devoid of color altogether, whereas others are beautifully marked with spiral bands of brown. Very often the bands are broken and irregular. The shell is not glossy as in *C. nemoralis*, and lacks the yellowish tinge so often found in that species.

Hawaiia minuscula (Binney).

(Figure 2.)

Fig. 2. *Hawaiia minuscula.* Diameter 2.0 mm.

This native North American zonitid snail was described originally under the genus name *Helix*. At a later date the species was discovered in Hawaii and was thought to be a distinct new genus and species. It was many years before it was discovered that this was the old familiar *H. minuscula* which in some manner had reached Hawaii.

The species is not often found in western America, partly because of its minute size. Capizzi (1961, pp. 791, 809) reported it from the Central Point area in Oregon, identification by John B. Burch. A heavy infestation of a lawn and sidewalk in Napa, California, was reported in "Cal. Coop. Rpt." (Anon-

ymous, 1963, p. 1264). Pilsbry (vol. 2, pt. 1, 1946, p. 421) has cited many records from Alaska to San Diego and pointed out (p. 423) that some of the southern California ones may have resulted from importation with plants. It is left in our list here simply because it must have been accidentally introduced into Hawaii.

Helicodiscus singleyanus (Pilsbry).

(Figure 3.)

Fig. 3. *Helicodiscus singleyanus*. Diameter 2.2 mm.

There is little information on the presence of this snail in western coastal states. It was described (Pilsbry, 1888, p. 84) from New Braunfels, Texas, and has been found native from the east coast, New Jersey to Florida, west to the Rocky Mountains and Arizona. It is a small (diameter 2.4 mm.), flat-whorled species with fine spiral striations. The only California record seems to be the living specimens found once by A. G. Smith on roots and bulbs of iris and daffodils in his garden at 722 Santa Barbara Road, Berkeley, California. No subsequent material was found there. The identification was confirmed by H. B. Baker and the occurrence was noted by Pilsbry (1948, p. 637).

Oxychilus cellarius (Müller)

(Figure 4.)

Oxychilus alliarius (Miller)
Oxychilus draparnaldi (Beck)
Oxychilus helveticus (Blum)
Oxychilus glaber (Studer)
Oxychilus rogersi (Woodward)
Oxychilus lucidus (Draparnaud)
Retinella nitidula (Draparnaud).

Snails of the genus *Oxychilus* are 5-16 mm. in diameter, have four to six rather flat whorls forming a low spire. The umbilicus is small. Shells are

Fig. 4. First vertical row, *Oxychilus cellarius* (Müller), diameter 11.5 mm.; second vertical row, *"Oxychilus draparnaldi"* (Beck), diameter 10.9 mm.; third vertical row, *"Oxychilus alliarius"* (Miller), diameter 9.3 mm.

thin, somewhat translucent, glassy or pale horn color. They prefer a moist habitat such as is provided by greenhouses, gardens and shrubbery, stone walls, and leaf mold. In the west they are almost always found in close association with human activities. Even those found near salt water in Humboldt Bay, California, were not far removed from habitations. They do a certain amount of damage to plants but this apparently is minor compared to the depredations of larger snails and slugs.

They have been recorded from western North America under all of the above names but we know of no constant shell characters which would enable field workers to distinguish one from another. Published descriptions are in very generalized terms making the preparation of a key impossible and large available collections have demonstrated why this is so.

It is believed that we have three species in the west, but they cannot be separated consistently from shell characters. *Oxychilus alliarius* can be

identified in the field by its strong "garlic" or "skunk-like" disagreeable odor. *Oxychilus cellarius* is very similar but lacks this characteristic odor. Bodies of both are a dull lead-gray color. *Oxychilus helveticus* has zigzag dark markings on the body and the mantle margin around the aperture of the shell is black.

Oxychilus cellarius has been known in California since 1888 when Cooper (1888, p. 14) recorded it as *Hyalina cellaria* from gardens near the center of San Francisco (Hanna, 1939, p. 310). In 1946 Mr. Smith and I collected what we thought was this species under logs and boards near a salt water ditch at the north end of Humboldt Bay, California. Pilsbry (1946, p. 249) cited Cooper, 1883, for San Francisco and extended the range to "Oregon." Quick (1952, pp. 181-189) included "Western North America" within the range. Available collections contain what may be the species from many other California localities.

Wood and Raymond (1891, p. 56) listed *Zonites cellarius* from San Francisco, a record which I (1939, p. 310) interpreted to refer to "*Vitrea alliaria.*" The first undoubted record from western North America is that of Berry (1916, p. 37) based upon living specimens collected by A. G. Smith. The species was definitely collected at Crescent City, Del Norte County, California, recently (Anon. 1962, p. 72) and at Newport, Oregon (specimens submitted by Mr. Kenneth Golden). Pilsbry (1946, p. 251) cited both of the above records and Quick (1952, pp. 181-189) gave "Western North America" as part of the range.

The only western record for *O. helveticus* rests on very insecure grounds. Pilsbry (1946, p. 252) cited the species on the authority of Hemphill who had identified specimens from Oakland, California. A search of the Hemphill collections and catalogs fails to reveal the shells recorded under this name from the west. Pilsbry (1946, p. 299) indicated that *O. rogersi* might be a synonym of *O. alliarius*. Quick (1952, pp. 181-189) cited "Western North America" as part of the range without giving details.

Under *O. draparnaldi* there are numerous records from western North America. Hanna (1939, p. 310) cited it from Berkeley, California; and Pilsbry (1946, p. 250) gave San Diego, San Francisco, and Oakland, California; and Portland, Oregon, and Seattle, Washington. Hatch (1949, pp. 141-165) used the name *O. lucidum* for shells found in ten greenhouses in British Columbia but Pilsbry (1946, p. 250) believed this name to be a synonym of *O. draparnaldi*, while others have considered it to be close to or equivalent to *O. cellarius*. *Oxychilus draparnaldi* is sometimes said to be larger than *O. cellarius*, but this is not a very reliable shell character. We know of no way to distinguish it at present. Quick (1952, pp. 181-189) cited *O. lucidus* from "Western North America."

Oxychilus glaber is another name to contend with in this group. Pilsbry (1946, p. 248) stated that the record of the species from a greenhouse in Seattle, Washington, should be checked.

The record of *Retinella nitidula* according to Pilsbry (1946, p. 248) rests upon specimens from gardens in Oakland, California identified by Hemphill. It is probable that he had specimens of *O. cellarius* or *O. alliarius* of more than usual size. A search of Hemphill's collection and catalogs has failed to disclose any information on the record.

An extensive study of the anatomy and natural history of *Oxychilus cellarius* was published by Rigby in 1963.

Vallonia pulchella (Müller).

(Figure 5.)

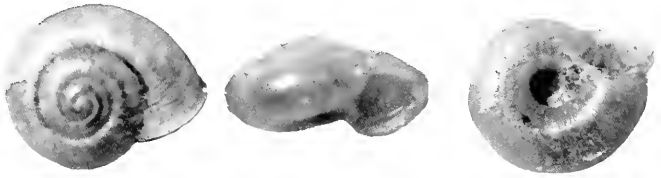


Fig. 5. *Vallonia pulchella* (Müller). Diameter (first figure) 2.3 mm.

While this is a native snail of the United States as well as of Europe, it seems to be a migrant into California. At any rate it was not detected until 1903 when Berry (1909, p. 75) reported it from Redlands, San Bernardino County. Since then it has been found at Berkeley (A. G. Smith, collector) and at Bakersfield, Kern County (C. C. Church, collector), and in many other places. In most cases the shells were found on or beside lawns or in greenhouses and were abundant. A heavy infestation was reported for a dichondra lawn in Riverside County (Anonymous, 1960, p. 71). It is also reported from lawns in Hollister, San Benito County, California (Anonymous, 1960, p. 838). A heavy infestation was reported on *Vinca minor* in Woodside, San Mateo County, California (Anonymous, 1962, p. 1234); and in dichondra lawns in Lakeside, San Diego County, California (Anonymous, 1963, p. 66); and in August, 1963 (Anonymous, p. 18), a subscriber to the *California Farmer* stated that a minute snail identified as *Vallonia pulchella* was eating the leaves of dichondra and killing the lawn. (Information furnished to A. G. Smith by Lucille Zellers.)

Dr. H. H. Crowell of Oregon State University had living material in his vivarium of September 16, 1963. It had come from Medford, Oregon, on May 30, 1963, and had also been seen from the vicinity of Eugene.

Another species of *Vallonia*, *V. cyclophorella* Ancey, is rather widely distributed in the mountains of California.

Vallonia pulchella is readily recognized by its very small size, three to four low rounded whorls, open umbilicus and when adult, a thickened outer periphery.

Achatina fulica "Lam." Bowdich.

(Figure 6.)

Fig. 6. *Achatina fulica*. Diam. 53.5 mm.

The complete history of the dispersion of this extremely destructive African snail will probably never be known because even today it is frequently being intercepted at United States ports of entry by inspectors. The species is firmly established in Hawaii and Guam and some travellers who should know better deliberately try to bring living specimens "home" with them. In most cases, however, the snails are detected in cargos.

According to Abbott (1949, pp. 68-71, 3 figs.) the French naturalist Bosc reported that the species was introduced on Mauritius Island from Madagascar in 1803. From Mauritius it was taken to Calcutta, India, by the conchologist W. H. Benson (1858, pp. 266-268). From there it has spread through Malaya and a great many of the islands of the south seas. It is very destructive on Guam and is now a serious problem in Hawaii. For a most comprehensive account of the strange dispersal of this snail the reader is referred to the book of Albert R. Mead, *The Giant African Snail: A Problem in Economic Malacology*. University of Chicago Press, 1961, 257 pp.

This work contains very extensive information on the distribution, economic importance, eradication attempts, and the bibliography cites over 400 references to literature pertaining to the subject.

So far as our records show, the snail was first intercepted in California early in 1948. On April 19 of that year the *Los Angeles Times* showed photographs of inspectors E. L. Roberts and T. P. Gray with specimens found in inbound cargoes of junk and surplus war goods. Abbott (1949, pp. 68-71) stated

that living adult snails had been found in San Pedro gardens. Fortunately, all escapees seem to have been captured if the report is true.

Ramsay (1954, Cooperative Economic Insect Report, vol. 4, no. 38, p. 877) reported that the species had been intercepted 60 times at United States ports of entry since 1948. Most of these were in California, but others were in Maryland, Oregon, Louisiana, and Texas.

An interception was made in San Diego in 1960 in cargo from Guam destined for Washington, D.C. (Anonymous, 1960, p. 748). Again interceptions were made at Honolulu in mail for California and in baggage for Michigan (Anonymous, August 4, 1961, p. 737). Also, in 1961, the species was intercepted at San Diego in military cargo from Okinawa destined for Barstow, California (Anonymous, November 3, 1961, p. 1028). And as late as July, 1962, one was reported as intercepted from a trailer at San Diego (Anonymous, July 6, 1962, p. 748).

It is obvious that the danger of introduction of this extremely destructive snail into California and areas to the southward is still very great.

Presumably some of the introductions into new areas were in the expectation that here would be a source of protein food. However, no extensive use has been made of it as yet.

Massive attempts at eradication in such places as Hawaii have not yet been successful. Africa has been searched for possible enemies to keep the numbers under control. One of these was *Gonaxis*, but the result has not been successful. The latest attempt of which we have a record was the introduction of the carniverous snail *Euglandina rosea* from Florida which may present a public health problem itself (Mead, Albert R., letter to Allyn G. Smith). Mead (1961, p. 138) stated that 19 invertebrate predators had been introduced into various areas infested with the giant African snail and more were likely to follow.

Robert J. Drake reported (letter to Allyn G. Smith, January 18, 1963) that "A lady in North Vancouver, British Columbia spent the Christmas holidays, 1962-1963 in Hawaii and returned with some 'marine' shells picked up on a beach of Oahu. On January 16, 1963, she telephoned that one was alive and she wished information as to what to feed it." Immediate investigation disclosed that the shell was a healthy giant African land snail. The animal was killed at once. The first interception of the species in British Columbia was in 1946. The snails were found in a cargo of tractors from the Philippines.

This very brief sketch may well be closed by urging anyone who may read it to profit by this sad example set by scattering a species of animal indiscriminately and prior to a thorough understanding of its ecological possibilities.

Euglandina rosea Férussac.

(Plate 1, figure 2.)

This carnivorous snail was introduced in Hawaii in 1955 (Mead, 1961, p. 134). The species is native in southeastern United States and presumably it was transplanted as a prospective control of the giant African snail there.

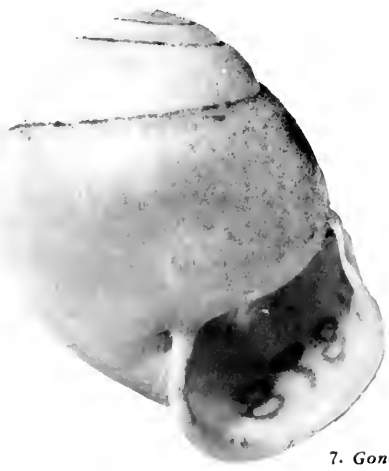
Sometime prior to March 3 1961 releases were made in Riverside County, California, by the University of California Agricultural Experiment Station. It is noted in correspondence that although a variety of sites were selected on the date mentioned the results were not encouraging; however eggs and juveniles had been recovered. Probably the original stock for California came from Hawaii. A published note in 1960 shows that 400 of the snails were liberated in Riverside County to control the European brown snail, *Helix aspersa* (Anonymous, 1960, p. 7)

A shipment of 312 live specimens of *Euglandina rosea* from Hawaii was received at Crescent City on April 26, 1961, and were liberated at seven selected localities. This also was an attempt to control *Helix aspersa*. Inspection a month later disclosed some alive and some dead, mostly larger individuals. The species has also been liberated in two more California counties: Alameda County receiving 145, and Contra Costa County 52 (Anonymous, August, 1961, In both cases the announced purpose was the control of *Helix aspersa*.

Search of the Del Norte County localities a year after liberation failed to locate any living individuals (letter from L. J. Garrett, Jr.).

Gonaxis kibweziensis (E. A. Smith).

(Figure 7.)



7. *Gonaxis kibweziensis*. Diam. 14.2 mm.

For some reason unknown to me, this snail was liberated in 1957 in the San Diego, California area as reported by Clausen (1959, p. 108). The shells were received from the Pacific Science Board and Hawaii Board of Agriculture and Forestry. The origin was stated to be "Agiguan", an island of the Mariana group. Mead (1961, p. 134) stated that 200 snails of this species were introduced into California as a biological control for two introduced helicine snails.

The introduction of *Gonaxis* into Hawaii was one of many such attempts to eradicate the scourge of the giant African snail, *Achatina fulica*.

Gonaxis quadrilateralis (Preston).

This snail was released on Oahu and Maui islands in 1957 (Mead, 1961, p. 134), but it and the related species *Gonaxis vulcani* (Thiele), introduced in 1956, have had little effect as biological control of the giant African snail.

Gulella bicolor Hutton.

This Philippine snail was introduced into Hawaii in 1957 and 1958 in large numbers (Thistle, 1959; Davis, 1959; Mead, 1961, p. 135). It apparently was not effective as a control of *Achatina fulica*, but did prey on *Subulina octona*, a host snail for a poultry fluke.

Gulella wahlbergi (Krauss).

This carnivorous snail was introduced intentionally on Oahu and Maui islands, Hawaii, in 1956-1957, apparently to aid in control of the giant African snail, *Achatina fulica*. The original stock came from Durban, South Africa. Recoveries were made for the first time in 1960 (Anonymous, 1960, p. 1002. Record from Hawaiian Entomological Society Meeting, October 10, 1960.)

Cecina manchurica A. Adams.

(Figure 8.)

According to Morrison (1963, p. 151), J. F. Gates Clark collected this species under drift in a small embayment on the north shore of Chuckanut Bay, Whatcom County, Washington, in 1961. Since then, Mrs. Eleanor Duggan has collected it in abundance about the roots of *Salicornia* along with *Assiminea translucens* and *Phytia myosotis* at Cottonwood Beach, northeast corner of Birch Bay, Whatcom County, Washington. The species may have been brought from Japan with oysters.

On October 4, 1963, we found the species abundant by the breakwater at Nahcotta on the outer peninsula of Willapa Bay. The shells there seemed to be larger than those from Puget Sound. *Phytia myosotis* was abundant at the same place.

Fig. 8. *Cecina manchurica*. Length 6.0 mm.

Cochlicella ventrosa (Férussac).

(Figure 9.)

The shell illustrated is one of the original lot collected by Hemphill in a garden in Oakland, California, in 1899. There is no later information regarding the establishment of the species in west America.

In June 1964, H. H. Keifer reported an infestation of this species in an area of several blocks in Santa Cruz, California.

Fig. 9. *Cochlicella ventrosa* Length 12.3 mm.

Lamellaxis mauritianus Pfeiffer,

(Figure 10.)

This species is recorded on the basis of identification of specimens submitted to Mr. J. P. E. Morrison of the U. S. National Museum by the Oregon State Department of Agriculture in July, 1955. The species was found in large numbers in manure being spread around greenhouses at Hillsboro, Oregon. The species was described from Mauritius but is now so widely distributed that its original habitat is unknown.

Fig. 10. *Lamellaxis mauritianus.* Length 14 mm.

Pupoides albilabris C. B. Adams.

(Figure 11.)

It is inevitable that in the regular operations of commerce and the extensive facilities for travel, many small mollusks are bound to be carried from place to place. The adults and their eggs may be transported with plants, seeds. and soils. Therefore, it may be expected that many more species will be transplanted by human agencies in the future. In the present case these minute snails were found infesting a dichondra and lippia lawn in Brawley, Imperial County, California. J. Taylor and R. A. Flood submitted about 50 specimens for identification in 1963. The species is normally found in the southeastern United States.

Fig. 11. *Pupoides albilabris.* Length 4.8 mm.

Rumina decollata (Linnaeus).

(Figure 12.)

Mead (1952, p. 30) reported a colony of this snail established in Mesa, Arizona and later (1953, pp. 11-12) in Phoenix. It is a European species but has become well established in Texas and other southern states.

Another western locality for the species was reported by Claude M. Finnell to L. J. Garrett, Jr., on November 2, 1961. The snails were first thought to have been found in Imperial County, California, but this was corrected. They were actually taken just across the line to the eastward in Yuma County, Arizona.

The species was reported as a severe infestation in the Phoenix, Arizona, area in 1953 by Brantlinger (1953, Cooperative Economic Insect Report, vol. 3, no. 51, p. 849, December 18.)

Fig. 12. *Rumina decollata*
Length 39.3 mm.

Succinea campestris Say.

(figure 13.)

This species, native of southeastern United States, is not known to be a resident of any of the western states. Therefore, it is interesting to note that Capizzi (1962, p. 1237) found it on orange-tree nursery stock in Portland, Multnomah County, Oregon.

Fig. 13. *Succinea campestris*
Diam. 9.9 mm.

Arion ater (Linnaeus)

(Plate 1, figure 1.)

This is one of the most easily recognized of the foreign slugs introduced into western America. While coloration varies greatly, dark brown is most common. The reticulations on the body are coarse and very well defined. The sole of the foot is often black. The one illustrated is typical of most of the population at Crescent City, California.

Once established, the species multiplies with great rapidity. Under a

board three feet by eight inches, Mr. John W. Anderson showed me 18 individuals in an area which had been heavily poisoned two months earlier. In one yard in Crescent City the owner told him that she had killed over 5,000 in one month. It has been found in wild surroundings by J. W. Anderson and T. Haig near Crescent City (Anonymous, 1962, p. 72).

The report of the species in the Gasquet area of Del Norte County, California (Anonymous, 1962, p. 72), was later (Anonymous, 1962, p. 117) corrected. Attempts to delimit it to the Crescent City area (Anonymous, 1962, p. 197) evidently failed because in March, 1962, (Anonymous, pp. 275, 387) it was found in Humboldt, the next county to the southward at Eureka, and a month later it had reached Fortuna a dozen miles farther south. In October, 1962, Hawthorne reported that this northwest California population had been activated by heavy rains and in some locations there were as many as 25 slugs per square yard. An attempt to find it at Danville in Contra Costa County, California, had negative results (Anonymous, 1962, p. 64). In the records kept in the office of the Agricultural Commissioner of Del Norte County, Mr. L. J. Garrett, Jr., showed me one which stated that the species had been collected in 1954 in the sales building of a nursery at Yucaipa, San Bernardino County, California. The first record for California seems to be that of Doucette (1954) from Del Norte County.

There is a record from Oregon by Thompson in 1942 and Loring reported it at Rockaway, Tillamook County (Cooperative Economic Insect Report, vol. 8, no. 16, April 18, 1958, p. 299), where it was causing considerable damage to flower and vegetable gardens in 1960 (Capizzi, p. 809). It was also found in the Salem area in 1961 (Bock, 1961, Cooperative Economic Insect Report, vol. 11, no. 19, May 12, p. 388).

Probably this slug first appeared in western America in the Puget Sound area of Washington. The Academy has specimens from 3621-43rd Avenue, Seattle, collected by W. P. Thompson and received from Tracy I. Storer on June 24, 1933. It has become a serious pest in northern yards and gardens. Seventy-five per cent of the first picking of strawberries in Washington was damaged by this species, *Agriolimax agrestis* and *Deroceras reticulatum*, in 1960 (Anonymous, p. 167); and heavy damage to strawberries in Puyallup Valley was reported by Howitt in 1958 (p. 541).

Spencer (1961, p. 47) reported vast numbers of the species in his garden in Vancouver, British Columbia, and recommended a poison consisting of calcium arsenate mixed with canned cat food as a control bait. The earliest record for British Columbia, however, may be that of Glendenning, 1952. W. M. Draycot informed me (letter, Jan. 17, 1962) that this slug was one of the worst molluscan pests in southern British Columbia. He further stated that it became so abundant in Abbotsford at one time that a motel owner was forced out of business.

A. G. Smith (1962, p. 215) has assembled information on the general distribution of the species and included distinguishing characters.

Pilsbry (1948, pp. 668, 670) recorded it from Newfoundland, Quebec, Maine, Michigan, and Portland, Oregon. Post later (1959, p. 104) added North Dakota to the list and stated that even in its native habitat, Europe, it does considerable damage to gardens.

Dr. C. O. van Regteren Altena of the Rijksmuseum in Leiden (letter to A. G. Smith, January 13, 1963) dissected some California specimens of this slug and pronounced them to belong to the subspecies *A. a. rufus* Linnaeus, (*sensu* Quick, 1960, p. 145). This, he considered to be a southern and eastern form which "somewhat restricts the possibilities of the country of origin."

Arion circumscriptus Johnston.
Arion fasciatus Nilsson.

(Figure 14.)

This little slug is about 25-30 mm. in length, usually gray in color and the mantle is usually marked by a dark colored ovate band around the border.

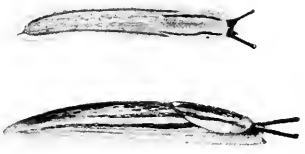


Fig. 14. *Arion circumscriptus* After Pilsbry, 1948, p. 674.

Lange (1944, p. 36) was, I think, the first to report this species. He found it under potted *Eugenia* plants in Golden Gate Park on November 6, 1940.

It was subsequently found by A. G. Smith under dead leaves and boards in Golden Gate Park, San Francisco, just outside the south wall of the California Academy of Sciences. This colony seems to have disappeared.

Quick (1952, pp. 181-189) listed the species from "Western North America" a record too general to be of much value to those interested in details of distribution. He gave the European distribution in greater detail, and in 1960 (p. 127) he put the name in synonymy of *Arion fasciatus* Nilsson (1822).

Dr. H. H. Crowell has found the species widely distributed in the vicinity of Corvallis, Oregon, but never in abundance (letter, September 25, 1963).

Arion hortensis Férussac.

(Figure 15.)

Waste (1940, pp. 55, 56) stated that the most obvious external character for distinguishing this species was the bright orange mucus which often shaded the surface of the body. He found the slug at Niles, California, in July, 1939,

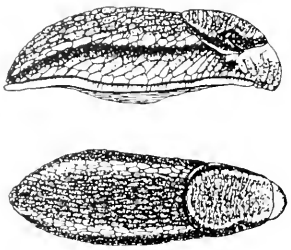


Fig. 15. *Arion hortensis*
After Pilsbry, 1948, p. 672.

in a nursery. The next year he collected it at the same place in February and in an Oakland nursery, March 5, 1940.

It was collected in the wild near Crescent City, Del Norte County, California, in 1962. (Anonymous, p. 72). Specimens from there were identified by T. Kono and verified by A. G. Smith. H. H. Keifer found it in his yard in Sacramento (Anonymous 1962, p. 106) and other California localities are Santa Cruz, San Anselmo, Mill Valley, and San Rafael (Anonymous, 1962, p. 197).

Arion intermedius (Normand).

(Figure 16.)

This slug has been collected at numerous places in the coastal region of California, both north and south (Pilsbry, 1948, p. 676). The species is readily recognized by its lemon-yellow colored slime. Size in preservative has been given as, length 8.5 mm.

Fig. 16. *Arion intermedius*
After Waste, 1940,
pl. 6, fig. 2.

Deroceras caruanae (Pollonera).

(Figure 17.)

The presence of this small European slug was first recorded by Quick (1952, pp. 181-189) who gave "Western North America" among his localities. Apparently it has been located in this country only in California. Pilsbry (1948, p. 507) has given a detailed account of the species with anatomical notes. It has been recorded also as *Agriolimax* [or *Deroceras*] *panormitanum* Lessona and Pollonera by Pilsbry (1944, vol. 58, p. 16) and Gregg (1944, p. 30). It has also been recorded as *Deroceras laeve* (Müller) by Waste (MS. 1940); Gregg (1944, p. 113); and Lange (1944, p. 38).

Fig. 17. *Deroceras caruanae*
× 1 approx.

Deroceras reticulatum (Muller).

(Figure 18.)

Fig. 18. *Deroceras reticulatum*. × 1 approx.

This is another of the small slugs native to Europe. There is no definite information as to how or when it reached western America, but it has found the conditions very suitable for its existence.

The first published record we have is the generalized one "Western North America" by Quick (1952, pp. 181-189). The species has become a very serious pest in parts of Oregon and Washington. Capizzi (1961, p. 67) reported it damaging grain fields in Marion County, Oregon, and in the Willamette Valley it was damaging strawberries, beets, and cauliflower (Anonymous, 1961, p. 166). A year earlier it was feeding on carrots, beans, and strawberries in the same valley and the attack on legumes was reported to be later than expected (Dickason, [Light infestation of *Deroceras reticulatum* on legumes of Willamette Valley, Oregon]. Cooperative Economic Insect Report, vol. 10, no. 20, 1960, p. 378). However a little later, Capizzi (1960, p. 466) found that cool wet weather had increased the infestation on the strawberries, cauliflower and seedling truck crops.

It was found in the Gray's Harbor area of Washington in 1957 by Howitt (p. 372) and near Crescent City, California, in 1962 (Anonymous, p. 72).

Pilsbry (1898, p. 138) recorded it from west-coast sea ports as *Agriolimax agrestis*. He was followed with reports by Keep (1911, p. 266), Storer (1931, pp. 268, 269; 1934, p. 781), and Hanna (1939, p. 298).

Waste (1940, p. 36) stated that the dorsal surface may be gray, brown, or black, but that the chief distinguishing character for use in the field was the milky white slime of the animal when it is touched. He listed it from nine California counties.

It was reported (along with *Arion ater)* to have damaged 75 per cent of the first picking of strawberries in western Washington (Anonymous, 1960, p.167).

The species was reported to be causing heavy damage to strawberries in Puyallup Valley, Washington, in 1958 (Howitt, p. 541; Anonymous, 1960, p. 167), and to vegetable crops in the same area in 1961 (Anonymous, p. 166).

W. M. Draycot (letter to G D. Hanna, January 17, 1962), reported that it was present in gardens at 1521 Draycot Road, Vancouver, British Columbia.

Limax flavus Linnaeus.

(Figure 19.)

This large slug is second in size to *Limax maximus* of the European introduced species. It is readily identified by the yellowish-green margin of the mantle and the yellow slime trail. *Arion ater* is about the same size, but the mantle is quite rough as compared to *L. flavus* and the color is dark, often reddish brown. Also the tentacles of *L. flavus* are blue on all of the living specimens we have seen in California; this is a character apparently no other slug possesses.

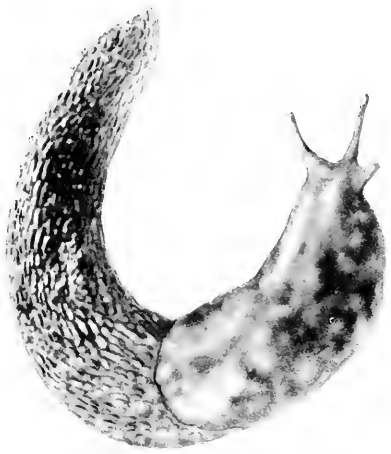


Fig. 19. *Limax flavus* × 1 approx.

The species is widely distributed about gardens, having been recorded from the following counties: San Luis Obispo, Los Angeles, Santa Barbara, San Bernardino, Orange, San Mateo, Ventura, Butte, Alameda, Tulare, and San Francisco (Pilsbry, 1948, p. 528; Waste, 1940; Gregg, 1944, p. 110; Stearns, 1903, p. 133; Berry, 1909, p. 76; Guernsey, 1912, p. 81; Anonymous, 1963, p. 727).

The first record was by Stearns who listed it from Los Angeles. Cockerell (1939, p. 138) found it on Catalina Island; W. M. Draycot (personal communication, January 12, 1962 listed it from gardens at 1521 Draycot Road, Vancouver, British Columbia, and Mead (1963, p. 27) found it in Arizona.

The species has been the subject of some very interesting culture and physiological experiments (Carmichael *et al.*, 1928, 1931, 1932, 1937).

Limax marginatus Müller.

(Figure 20.)

In his study of the slugs of California, Waste (1940, p. 85) found that this species "is probably the most widely distributed" one in the state. He found it from Sutter and Tehama counties on the north to Los Angeles and San

Bernardino counties on the south and through the Sacramento and San Joaquin valleys. Mr. Waste stated that the largest specimens he had collected were about 50 mm. long, but A. G. Smith collected one in 1943 on the University campus at Berkeley which was 68 mm. in overall length.

Fig. 20. *Limax marginatus* × 1 approx.

Cockerell (1939, p. 138) reported the species from Catalina Island and it has been found at Crescent City, Del Norte County, California (Anonymous, 1962, p. 72). It is interesting to note that Quick (1952, pp. 181-189) stated that California specimens probably belonged to the species *Limax poirieri* Mabille.

The best distinguishing character seems to be two or three longitudinal black bands on the back of the mantle; whereas in *Limax maximus* of comparable size, the back is marbled with black.

The species is native in Europe and has spread to New Zealand and Australia.

Hawthorne (1963, p. 1) has proposed that the name for western material be changed to *Lehmannia poirieri*.

Limax maximus Linnaeus.

(Figure 21.)

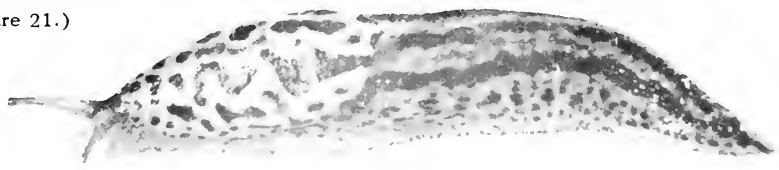


Fig. 21. *Limax maximus*. × 1 approx.

This is the largest of the European "gray" slugs introduced into western America. It is exceeded in size only by the native golden yellow *Ariolimax* which rarely damages gardens. All of the introduced species are highly destructive when conditions are favorable. The species may be distinguished by its marbled or blotchy patches of black on the gray mantle, whereas *Limax marginatus* has two or three black stripes and *Limax flavus* is nearly uniform gray with yellowish green border.

The species is widely distributed in cultivated areas in California, and Gregg (letter to H. A. Pilsbry) found it well established at Arrowhead Lake at an elevation of 5,200 feet. Pilsbry (1948, p. 524) listed it from many counties and from Salem, Oregon. Spencer (1961, p. 47) found it less common than

Arion ater in his garden in Vancouver, British Columbia, and Draycot (personal communication, January 17, 1962) also found it in Vancouver at 1521 Draycot Road.

Our first record for western America is that of Orcutt (1890, p. 68) who listed it from San Diego.

W. M. Wood (1893, p. 382) found the species in San Francisco gardens and Guernsey (1912, p. 81) recorded it from Laguna Beach in southern California. Quick (1952, p. 181) listed the species merely from "Western North America."

Apparently this is a recently introduced species into Hawaii. It was first collected on Oahu Island in Manoa Valley in 1949 and on July 11, 1963, it was first found on Maui Island at Haleakala Acres by Nobuo Miyahira. The identification was by C. E. Pemberton (Chong, 1963, p. 1093).

Fig. 22. *Milax gagates*. × 1 approx.

Milax gagates (Draparnaud).

(Figures 22, 22a.)

This small gray European slug is best distinguished from others of about the same size by the sharp dorsal keel extending from the mantle to the tip of the tail and by the oval or diamond shaped groove centered on the mantle. Waste 1940) traced the distribution, either from the literature or in collections and found it in Tehama, Napa, Alameda, San Francisco, San Mateo, Kern, Ventura, Los Angeles, San Bernardino, and San Diego counties, California. To these may be added Contra Costa, Trinity, and Del Norte counties (Anonymous, 1962, p. 72). The Trinity County specimen was collected on Manzanita Creek, 10-15 miles west of Weaverville and far from human habitation. *Milax hewstoni* (Cooper, 1872, p. 145) is currently considered to be a synonym of *Milax gagates*. In any event the species is one of the more destructive garden pests of California.

Fig. 22a. Eggs of *Milax gagates*. ×5.
Photo by R. J. Waste

Testacella haliotidea (Draparnaud).

(Figure 23.)

Fig. 23. *Testacella haliotidea*. × 1 approx.

This burrowing slug has become well established in the San Francisco Bay region. Naturally, there is no information as to how or when it reached the area. Under the name *Testacella maugerae* (Draparnaud), Orcutt (1915, p. 80) mentioned it as "Introduced in San Francisco, Cal." I do not know the source of his record. It was not detected again until March, 1940, when Mr. T. Paul Maslin collected specimens at three places in Berkeley. Since then it has been found in several more yards and gardens on the east side of San Francisco Bay and also in May, 1958, at the residence of Miss Georgia Holtz, 343 Nevada Street, San Francisco 10.

It has been recorded from Oregon on the basis of a specimen sent from Clackamas County to the University of Michigan by C. J. D. Brown in 1950 (Bruce, p. 59); and Bock (1961, p. 388) has found it in the Salem area.

September 16, 1963, I was shown the specimens Dr. H. H. Crowell has in his vivarium at Oregon State College, Corvallis. These came from the vicinity of Corvallis where they are usually found during plowing operations. Mr. Peter Larson of the Oregon Department of Agriculture has specimens which were collected in the vicinity of Salem.

Probably the species has much wider distribution than the records indicate because much of its life is spent under ground. The food is reported to be earthworms to a large extent. When fully extended the slug may be as much as 60 mm. long, and it is readily distinguished from all others by the small vestigial shell on the tip of the tail.

Freshwater Mollusks

Lymnaea auricularia (Linnaeus).

(Figure 24.)

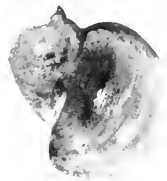


Fig. 24. *Lymnaea auricularia.* Diam. 21.8 mm.

Early records of this pond snail with the widely expanded aperture were confined to small reservoirs and fountain pools (Gregg, 1923, p. 34; Hanna and Clark, 1925, pp. 71, 125). It has since become widely distributed in natural bodies of water and irrigation systems. Thus it is now known from Los Angeles, San Bernardino, Kern, Sacramento, Napa, Santa Clara, Alameda, and Merced counties in California. Draycot (1961, p. 164) reported it from garden pools in North Vancouver, British Columbia, but stated that it had not yet spread to outlying bodies of water; thus far we have no records for Oregon or Washington.

Mr. Hugh Leech of the Department of Entomology, California Academy of Sciences, collected living specimens in a Sierran lake at an elevation of approximately 7,000 feet.

Lymnaea columella Say.

(Figure 25.)

Fig. 25. *Lymnaea columella* Say. Length 15.3 mm.

This rather slender, *Succinea*-like pond snail was reported from Los Angeles by Gregg (1924, p. 34). No other published records have been found but Dr. Gregg informed A. G. Smith, July 7, 1946, that the species "is introduced in Southern California and is quite common in the artificial pools, being distributed with aquatic plants. Several years ago it was very abundant in La Loma Lake, Pasadena, a small body of water formed (or enlarged) by damming a natural stream.

"I have found it here and there in natural streams but generally not in abundance. I first noticed it in 1922 and reported it. I found numerous specimens in Rio Hondo near Montebello which Dr. F. C. Baker identified as *L. columella championi* Von Martens. The aperture is perhaps of slightly different shape from specimens of *columella* from the pond in Exposition Park, Los Angeles, but I am of the opinion that they were introduced from the east." Dr. Gregg was doubtful if a resident of Mexican or Central American waters would survive transport to California by avian means.

Phytia myosotis (Draparnaud).

(Figure 26.)

Fig. 26. *Phytia myosotis* Length 6.2 mm.

This is the name of the species originally described from Europe and although Cooper (1872, p. 143, pl. 3, figs. A-H) described specimens from California as a distinct species "*setifer*", he later (1886, p. 250) decided that only one form was represented; Dall (1921, p. 66), however, in his catalog of west American mollusks, listed "*setifer*" only, thus implying that the European and east American form was not represented. W. O. Gregg (letter, Jan. 4, 1941) stated that he considered material from Terminal Island in the San Pedro area of California to be the native species.

Whether one or more species is represented or not, it seems to be the concensus of most western conchologists that the exotic form *P. myosotis* is present. The shells are somewhat variable, especially in height of spire.

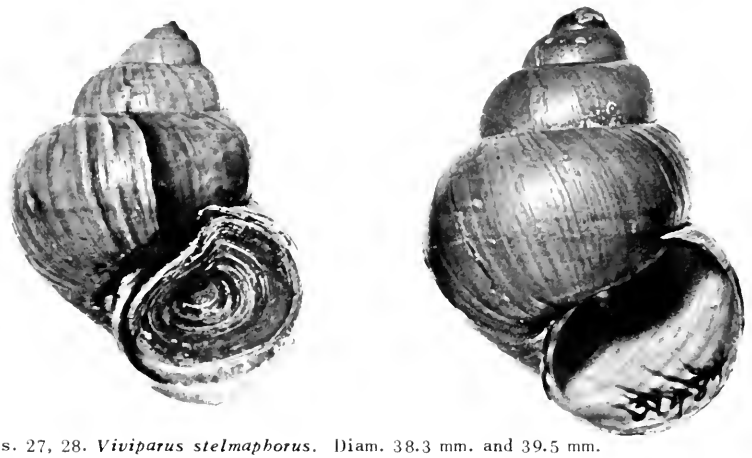
In a late discussion of the proper genus name to be used for this snail, Paulson (1957, pp. 4-7) decided upon *Ovatella*, following Watson (1943, pp. 13-22). Paulson also could not find distinguishing features for more than one species in California and these collections fell well within the variation of material from Europe and eastern North America. Since there is no definite information to indicate that the species was intentionally introduced to the west coast, it seems obvious that it came fortuituously. It has not been reported from kitchen midden and Pleistocene deposits, so far as I have learned, and although this is negative evidence, it does seem to have a bearing upon the introduction being a very late one geologically.

Viviparus stelmaphorus Bourguignat

(Figures 27, 28.)

Vivipara malleata Reeve
Vivipara japonica von Martens
Vivipara iwakawa Pilsbry
Vivipara lecythoides Bensen.

One or more large species of *Viviparus* have become widely distributed in the waters of western America. All of the above names have been applied to the shells, but in a large series of specimens from one locality which I have examined, so much variation is found that separation into more than one species is hardly possible on shell characters alone.



Figs. 27, 28. *Viviparus stelmaphorus*. Diam. 38.3 mm. and 39.5 mm.

The species was first found in a San Francisco market by Williard Wood (1892, p. 114). These are now in the collection of the Academy and on the label (Wood's business card) is the following note: "Bought alive for 10 cents a dozen at a Chinese vegetable store on Wednesday morning, Nov. 18, 1891. Came from China." *Viviparus stelmaphorus* was described from China and it would be much more likely that a *Vivipara* would be brought from there before 1890 than from Japan. Therefore, the name "*stelmaphorus*" seems more applicable to the California species. No attempt has been made to arbitrarily separate the shells under other names.

The species is still sold in the Chinese markets of San Francisco. It is very abundant throughout most of the Delta region of the Sacramento and San Joaquin rivers and in many of the irrigation canals. It is also abundant in Mountain Lake in the Presidio, and Stowe Lake in Golden Gate Park, San Francisco. We have not found it in Lake Merced or the Spring Valley lakes to the southward.

Surprisingly, Walter J. Eyerdam has collected what appears to be the same species in Green Lake in Seattle, Washington. Also Dr. I. McT. Cowan has taken it in a lake on Salt Spring Island, British Columbia, and there are specimens from "Victoria" in the Provincial Museum in that city.

Corbicula fluminea (Müller).

(Figures 29, 30, 31.)

This hardy freshwater clam of Asiatic origin is somewhat rounded in outline with a heavy, almost black periostracum. The outside surface is roughened by low concentric ridges, especially in the upper umbonal portion. The

shell is thick and robust in the adult stage, thinner in the immature ones. It rarely exceeds 50 mm. (two inches) in greatest dimension.

Fig. 29. *Corbicula fluminea* Length 42 mm.

Although of rather recent detection, the species has spread so widely that a full list of localities would be superfluous. It must have been here long before it came into the hands of conchologists. Thus far the only use made of it is for fish bait, although it is probable that some people, especially of oriental origin, occasionally use the clams for food.

This contrasts greatly to conditions in eastern Asia where various nominal species of *Corbicula* form the basis of a large fishery and the items are an important part of the food supply of the people. Miller and McClure (1931) have given a detailed account of the fishery, in the vicinity of Canton, China, together with notes on preparation and marketing of products. Even the shells are used to make a superior quality of lime.

The earliest definite record of this Asiatic clam in the United States is 1938, and is based on a specimen now in the collection of the California Academy of Sciences.

In May, 1947, Gregg stated that the species was "first observed in North America by John Q. Burch who took numerous specimens in 1938 on the north bank of the Columbia River, Pacific County, Washington, about two miles east of Knappton. Later, Marian Shepard and Harold Harry found specimens in the Willamette River near its junction with the Columbia." Also see Burch, 1944, p. 18.

The next record is for 1945 when a specimen in the California Academy of Sciences' collection was obtained from the Sacramento River just north of Pittsburg, California. This specimen was taken by a fisherman whose hook had accidentally touched bottom. It was identified for George Smalley of the Division of Fish and Game by E. P. Chace and John Burch.

The following year I visited the Delta area of the Sacramento-San Joaquin system and found the species to be excessively abundant in some of the irrigation canals. Obviously, it was not a very recent importation. It was not long before the occupied area was found to be very large. The most extensive account of its distribution up to 1959 was given by Ingram (1959, pp. 363-370). He listed many localities from Washington south to Imperial Valley, California and Phoenix, Arizona. Since then it has been found as far east as the Tennessee River (Sinclair and Ingram, 1961) and Ohio River (Fechtner, 1962). Thus it is now (1962) known from Washington, Oregon, Idaho, Nevada, California, Arizona, Illinois, and Tennesee. So far, it has not been determined how living

Fig. 30. Delta Mendota Canal.

material from one drainage system has been transported to another, except that Fitch (1953, p. 9) suggested sport fishermen as likely transplanters. In general, the species seems to prefer rather quiet or slow-moving water.

There is a large pumping plant at Tracy, California, used to raise San Joaquin River water to the Delta-Mendota Canal. In 1952 it was reported that *Corbicula* was causing much interference in the operation of the condenser system which was used to cool the equipment. Living young mollusks lodged in the tubing and continued to grow until they interrupted the flow of water. Those which went through the pumps and screens found the concrete-lined canal an excellent place to live and they multiplied in incredible numbers.

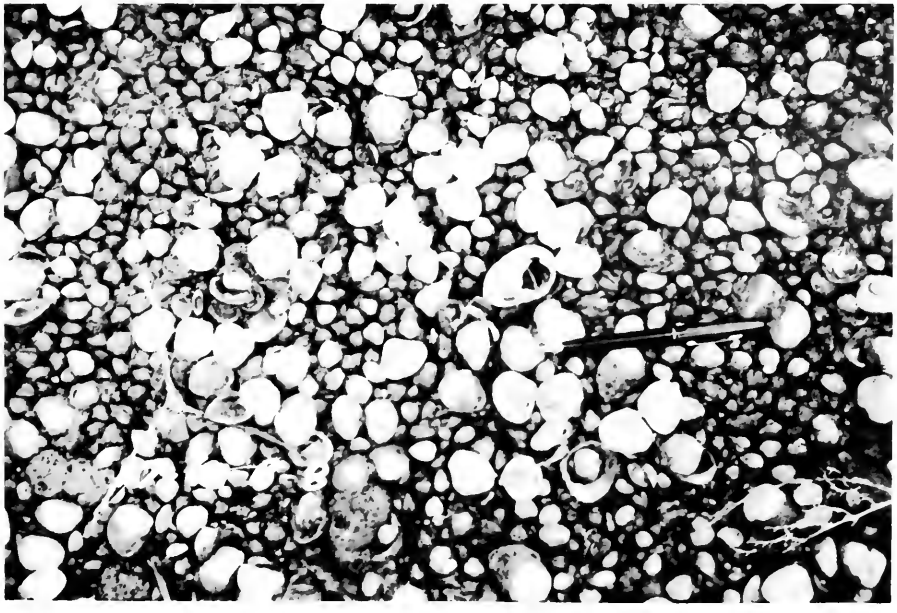
Fitch (1953, p. 9) has described the occurrence of *Corbicula fluminea* in the irrigation system of Imperial Valley, California. He estimated 1½ million clams at just one stand pipe in the Mecca area. This figure is almost infintesimal to that which was made computable when a section of the Tracy Mendota Canal was drained. Some of the extensive beds in a section of the canal were 2-3 feet deep when it was cleaned during the winter of 1960-61. Mr. R.P. Dugan, Regional Director, U.S. Bureau of Reclamation (letter July 13, 1962), has given some details of this operation and furnished the photographs to illustrate this part of the report. Only the north section of the canal, to Mile Post 34.48, was drained at that time. The entire canal is 117 miles long. Extremely fine silt bound by a sort of mucus filled the interstices between the shells. Total volume of clam-bearing material removed from this reach of roughly 30 miles was estimated to exceed 50,000 cubic yards. Sometimes channels had to be cut

through the beds to fully drain the canal. A front end loader and drag-line excavator were used for the greater part of the cleaning.

The question immediately arises as to whether this species has some economic use. Residents of Asiatic origin in the Sacramento-San Joaquin Delta informed me in 1946 that they used the species for food to a limited extent, and that they understood it had been brought from China many years before. In eastern Asia it forms a staple part of the protein diet of the people. Mr. A. G. Smith, who visited Japan in 1958, found huge baskets of the shells in every fish market that he visited. The two halves of the shell close so tightly that individuals can live for a period of days out of water. Their hardiness is shown by finding them exposed or in stagnant pools in the canals which have been drained. Mr. Smith kept three in a small aquarium for an entire summer with no cleaning or replenishment of water except to make up for evaporation. The food of the mollusk has not been investigated but it is suspected to be diatoms. Plankton samples from the Delta Mendota Canal, submitted to the author for identification, contained an extraordinarily rich flora of these microscopic plants.

California is not the only place where *Corbicula* has become more than a nuisance. In a paper entitled "Chokage of Filtered Water Pipe Systems by Freshwater Mollusks," Ray (1962, pp. 20-23) reported that *Corbicula striatella* Deshayes was choking the water filters and meters in a supply system near Trichinopoly in southern India.

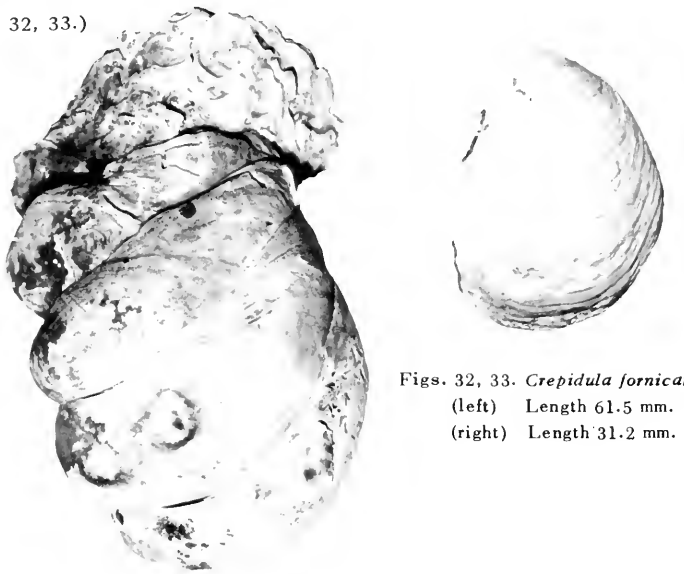
Fig. 31. *Corbicula fluminea* Müller, showing random sample.



Marine Mollusks

Crepidula fornicata (Linnaeus).

(Figures 32, 33.)



Figs. 32, 33. *Crepidula fornicata*
(left) Length 61.5 mm.
(right) Length 31.2 mm.

Evidently this east American slipper shell has been in the Puget Sound area of Washington for many years.

W. M. Chapman (letter to G D. Hanna, February 4, 1948) stated that this species was introduced in Puget Sound with east American oysters in the 1890's; and Vance Tarter (letter to G D. Hanna, April 13, 1948) stated that it was very abundant on the dikes enclosing bays for Olympia oyster culture. E. P. Chace (verbal communication to A. G. Smith) stated, on July 28, 1946, that he had found two or three specimens at Willapa Bay, Washington.

Attempts have been made to use *Crepidula* for chicken feed in Holland. Glud, Tarter, and Tollefson (1946, p. 2) described experiments in the use of *C. fornicata* for human food with the following summary: "It is encouraging that on most counts *Crepidula* ranked well."

Kincaid (1947, p. 2) reported the species to be a great nuisance to persons engaged in the production of the native oyster, *Ostrea lurida*, in Puget Sound.

A series of four nesting specimens attached to one of these oysters was furnished by Mrs. Eleanor Duggan for photography. The length of the group as photographed was 56.5 mm.

Crepidula glauca Say.

(Figure 34.)

Very little information on the distribution of this east American slipper shell has been collected since 1939 when I gave seven literature references (p. 300). At that time it had been reported in San Francisco Bay and a few miles south on the open coast. A. G. Smith (1946, p. 9) pointed out that the name "*glauca*" has page priority over "*convexa*" and that the two names pertain to the same species, "*convexa*" being merely a situs form.

Fig. 34. *Crepidula glauca* Length 17.2 mm.

Crepidula plana Say.

(Figure 35.)

This east American slipper shell could easily be transported with oyster spat and could escape detection for a long time because of difficulty in distinguishing species in the genus.

E. P. Chace collected specimens believed to be this species in Willapa Bay, Washington, on August 14, 1937, one of which became cat. no. 7480 in the collection of A. G. Smith. This specimen is illustrated herein.

Fig. 35. *Crepidula plana* Length, 32.2 mm.

Haliotis rufescens Swainson.

(Figure 36.)

Mr. C. E. Lindsay of the Washington State Shellfish Laboratory informed me on September 18, 1963, that stock of this species had been furnished by Mr. Keith Cox of the California Department of Fish and Game. About 150 individuals were received alive and were planted among the San Juan Islands; 100 went to Long Inlet on Lopez Island. Specimens kept at Point

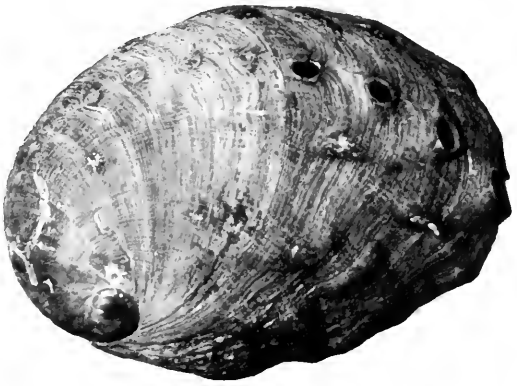


Fig. 36. *Haliotis rufescens*. Length 127.9 mm.

Whitney near the Laboratory spawned.

It was found during SCUBA diving on the San Juan Islands that an octopus had killed and was in the act of eating one of the abalones which had been planted there.

Batillaria zonalis (Bruguière)

(Figures 37, 38, 39.)

Batillaria cumingi (Crosse)
Potamides (Batillaria) multiformis (Lischke)
Batillaria multiformis (Lischke)
Batillaria aterrima (Dunker)
Batillaria attramentaria (Sowerby).

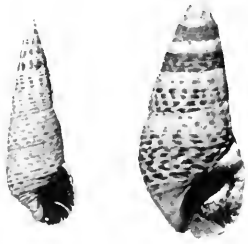


Fig. 38. *Batillaria multiformis*
Length 28.7 mm.

(left) Fig. 37. *Batillaria zonalis*
Length, 26.0 mm.

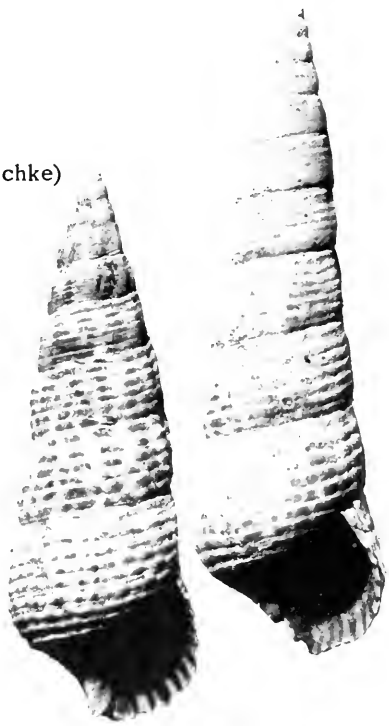


Fig. 39. *Batillaria multiformis*
Length 27.0 mm.

All of the above names have been applied either positively or questionably to a cerithid gastropod which has become widely dispersed on the Pacific Coast. The species seems to be extraordinarily variable as the accompanying illustrations show or else there is more than one species. McLean (letter, Oct. 23, 1963) was of the opinion that the last cited name was correct for the shells which had previously been called *B. cumingi*. Having made a special study of the situation, he also thought that a second species could be recognized under the name of *B. zonalis*, that is, for the ribbed forms. He has also described (1960, pp. 61-63) the great abundance of the species in Elkhorn Slough a few miles north of Monterey, California. It is a common species in Japan and is probably the one recorded by Bonnot (1935, pp. 1-2) and Hanna (1939, p. 299) under the name *Potamides (Batillaria) multiformis* (Lischke).

The species has become extremely abundant in several localities in

Puget Sound. Mrs. Eleanor Duggan has furnished material from Drayton Harbor, Whatcom County, Washington, and Mr. W. J. Meriless found it at Boundary Bay, British Columbia.

Under the name *B. zonalis*, Kincaid (1947, p. 3) recorded a cerithidid in Grays Harbor, Willapa Bay and Samish Bay, Washington. He stated that it was very abundant but did not appear to be harmful. It is recorded as a distinct species in some Japanese literature. The same is true of *Batillaria cumingi* Lischke. However, Pilsbry (1895, p. 57) stated that the last two, together with *Batillaria aterrima* (Dunker), "should be considered varities of *zonalis*."

Ilyanassa obsoleta (Say).

(Figure 40.)

Fig. 40. *Ilyanassa obsoleta* Length 25.5 mm.

This bay mud flat snail probably was brought to San Francisco Bay along with east American oysters. It has been known there for many years (Keep, 1911, p. 162; Packard, 1918, p. 333; Dall, 1921, p. 103; Oldroyd, 1927, p. 269; Hanna, 1939, p. 304). Whether it has spread to other localities by natural means or reached them by separate introductions from the east is not known, but it has been found in Tomales Bay and Humboldt Bay, California; Boundary Bay, Vancouver Island, British Columbia; and Willapa Bay, Washington (A. Myra Keen and E. P. Chace, verbal communication). Kincaid (1947, p. 2) also reported it from Willapa Bay. Moffitt (1941, p. 272) found that *Modiolus demissus*, which is found in the same habitat as *I. obsoleta*, was used extensively as food by the California Clapper Rail, but the snail was seldom eaten. His record was based upon analysis of 18 stomachs of rails. Williams (1929, p. 52-56) found the same to be true at an earlier date.

Nassarius fraterculus (Dunker).

(Figure 41.)

Mrs. Eleanor Duggan has collected this species in abundance in Padilla Bay at Bayview State Park, Skagit County, Washington. The shells were under stones which had a mud substratum and in pools of water left by the receding tide. James McLean was first to identify the species and Mrs. Duggan first found it in 1960 (Veliger, vol. 6, Oct., 1963, p. 112).

Fig. 41. *Nassarius fraterculus*. Length 12.3 mm.

Ocenebra japonica (Dunker).

(Figure 42.)

Fig. 42. *Ocenebra japonica* Length 41.0 mm.

This species was evidently inadvertently transplanted from Japan along with seed oysters and was first detected in Samish Bay, Puget Sound, by Galtsoff in 1929 (Galtsoff, 1932, pp. 14-15, fig. 4; letter from Mr. Vance Tarter to G D. Hanna, April 13, 1948). A detailed account of the distribution of the species in Puget Sound, together with habits and methods of control, was published by the Washington State Oyster Laboratory, Olympia Oyster Bulletin, May 10, 1946, 3 pp., 3 maps. Apparently transfer from locality to locality was effected by moving oysters from one bay to another.

This very destructive oyster drill was reported by Kincaid (1947, p. 3) to be abundant in all oyster-growing areas of Washington north of Grays Harbor.

Bonnot (1935) advised (personal communication) that so far as he could determine, it had not reached California oyster beds. The genus name *Tritonalia* is sometimes used for the species.

The specimen illustrated was furnished by Mrs. Eleanor Duggan who obtained an excellent growth series in Samish Bay, Skagit County, Washington, May 13, 1963.

Thais clavigera (Küster).

(Figure 43.)

Fig. 43. *Thais clavigera.* Length 25.6 mm.

Two specimens of this species were received from Dr. D. B. Quayle of the Fisheries Research Board of Canada. They had been collected at Ladysmith Harbor, British Columbia, July 7, 1951. Two more were received from Mrs. Eleanor Duggan; these had been collected in Willapa Bay and the one illustrated measured 25.6 mm. in height, 17.6 mm. in diameter. The species is common in Japan. Following are names of species also associated with shells Professor Kincaid collected from seed oyster cases and upon which he reported in 1947 (p. 3): *"tumulosus"* (Reeve); *"bronni"* (Dunker); and *"nodulosa problematica"* (Baker).

Urosalpinx cinerea (Say).

(Figure 44.)

Fig. 44.
Urosalpinx cinerea
Length 28.2 mm.

This east American oyster drill evidently was introduced in San Francisco Bay soon after the first oysters were planted because Townsend (1893, p. 349) found it on the flats near Belmont in 1888. Since then it has been collected and recorded from many places.

Kincaid (1947, p. 2) has listed it from Puget Sound and Tartar (letter to G D. Hanna, April 13, 1948) advised that the center of abundance was Oyster Bay, near Olympia. He stated further that it was present in Willapa Bay, Washington, and that it was a relatively unimportant pest

Mr. C. E. Lindsay informed me in October, 1963, that the species was not increasing notably in numbers.

Rapana thomasiana Crosse. [1.]

(Figure 45.)

The first specimen of this species which was made available to me for illustration was furnished by Dr. D. B. Quayle of the Fisheries Research Board of Canada. The shell does not appear to be fully grown. It measures: length 22.4 mm., diameter 16.9 mm. Locality information is not available.

A much larger specimen (length 100.0 mm., diameter 73.4 mm.) was given to Mrs. Eleanor Duggan by Professor Kincaid. It, along with others, was collected in Willapa Bay, Washington, a locality from which Burch (1952, p. 16) recorded it.

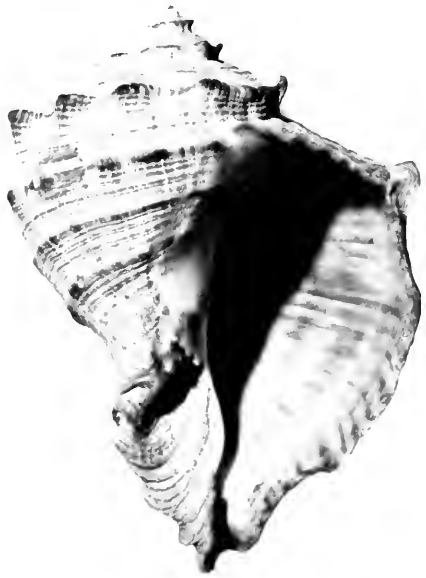


Fig. 45. *Rapana thomasiana*. Length 100.0 mm.

The species is very common in Japan, and as a food it is stated to be delicious (Kira, 1962, p. 63).

1. Attention is called to the fact that *Rapana bezoar* (Linnaeus), another western Pacific species has become a very serious pest in the Black Sea since 1947. (Grossu and Lupu, Archiv für Molluskenkunde, vol. 93, nos. 5, 6, 1964, pp. 215-218, 1 text figure.)

Neptunea arthritica ("Valenciennes" Bernardi).

(Figure 46.)

Fig. 46.
Neptunea arthritica.
Length 87.5 mm.

This large gastropod is included because a single shell 109 mm. long was found in Samish Bay, Puget Sound, by Mr. Charles E. Woelke (1953, p. 11).

He informed me on September 18, 1963, that he had heard of one additional specimen having been found in the same bay. It perhaps bears closer similarity to *Neptunea middendorffiana* of the American Arctic than any other.

The specimen illustrated was obtained from "Fisher" by Henry Hemphill and is possibly a part of the original material.

Busycon canaliculatus (Linnaeus).

(Figure 47.)

Fig. 47.
Busycon canaliculatus
Length 105.3 mm.

This large east American gastropod became known in San Francisco Bay in 1938 through the collection of three specimens by the late F. L. Rogers, at the foot of Gilman Street, Berkeley, California. Subsequently, it has been collected at many places by many people and it seems to be very well established. Stohler (1962, pp. 211-212) has given a history of known museum specimens with much valuable information.

This species was rediscovered living in San Francisco Bay in January, 1948. In the course of his dredging in the Bay for shells (mostly *Ostrea lurida)* for commercial purposes, Mr. Gambetti occasionally secured one of these large gastropods. Being curious as to its identity he took one, with the animal en-

closed, to Dr. Gordon Ferris of Stanford University. Dr. Ferris passed the specimen on to Dr. A. Myra Keen who very kindly transmitted the information on to me through Mr. C. C. Church on January 27, 1948. Mr. Gambetti reported that occasionally he has found enough in his dredge at one time to interfere with his work. He operated in the southern end of the Bay in deeper water off Palo Alto Yacht Harbor.

There is no information to my knowledge as to how or when the species reached the west coast. It might be surmised that this species was brought to to San Francisco Bay along with oysters, but other animals have been planted repeatedly in attempts to get them established. Many shipments of lobsters have been made for which there are no records. Also, *Venus mercenaria* has been brought to the west coast on several occasions. The time of arrival is especially difficult to determine. During the years 1912-1914 the U. S. Bureau of Fisheries, in cooperation with the Department of Zoology of the University of California, made a very elaborate survey of the bottom of San Francisco Bay. The facilities of the U. S. S. *Albatross* were made available for the work. Dredging was done at close intervals throughout the area. An interesting form of *Arca*, among other things, was found in about the same locality from which this species of *Busycon* came, but the latter was not found. If it were present it would be expected that it would have been collected, but this does not necessarily follow. Since 1924 there had been some opportunity for the species to have been planted but oyster shipments from the east were then tapering off and ceased completely soon afterward. The responsible parties, whether governmental or private, might well take heed of so large a species being carried from one ocean to another unintentionally. Its egg cases are very large and could not pass without detection. Only carelessness on the part of someone now unknown is responsible.

For many years the shells of this genus were referred to the genus *Fulgur* Monfort, 1810. *Busycon* Röding, 1798, gradually replaced that name in the literature and lately *Busycotypus* Wenz, 1943, seems to be preferred to either of the above in some quarters. To avoid subgeneric questions, it seems best for purposes of the present work to retain the introduced species in *Busycon*.

Arca transversa Say.

(Figure 48.)

There is no additional information in regard to this species to add to that reported by Packard (1918, p. 250) and Hanna (1939, p. 300). There is no known reason to doubt the authenticity of the report since the species was collected at three separate places in the south end of San Francisco Bay by trained zoologists of the U.S.S. *Albatross*

Fig. 48.
Arca transversa
Length 23.0 mm.

investigations. It should be added, however, that little if any work of a similar nature has been conducted in that area since the original discovery of the of the species. It could have come to the Bay incidental to the introduction of east American oysters which was a thriving industry in that section for many years.

Anomia lischkei Dautzenberg and Fischer.

(Figure 49.)

This species has become established in Willapa Bay, Washington, and probably in Samish Bay, Skagit County, Washington. It was found by Professor Kincaid who furnished to Mrs. Eleanor Duggan the specimen illustrated in exchange for Puget Sound shells. Burch (1952, p. 16) also received specimens from Willapa Bay.

Fig. 49. *Anomia lischkei*. Diameter 49.2 mm.

Ostrea cucullata Born.

Galtsoff and Smith (1932, p. 371) mentioned that they had made experiments in attempting to cross fertilize this species with *Ostrea virginica*, but without success. The latter were from stock established in Honolulu, Hawaii, and it may be presumed that the Australian species had been brought to that locality although it was not specifically so stated. No other published information regarding the introduction of *O. cucullata* has been found.

Ostrea edulis Linnaeus.

(Figures 50-53.)

This European oyster has been introduced into Puget Sound and has been grown at Whitney Point, Dabob Bay, by the State Shellfish Laboratory. The specimen illustrated was presented to Mrs. Eleanor Duggan who made it available for this report. Mr. C. E. Lindsay of the Laboratory informed me on September 18, 1963, that the first planting, of which a record had been found, was in Case Inlet, Puget Sound, in 1951. Results were negative in so far as reproduction was concerned. Another attempt was made in 1961 at Fisherman's Bay.

Fig. 50.

Fig. 51.

Length 75.5 mr

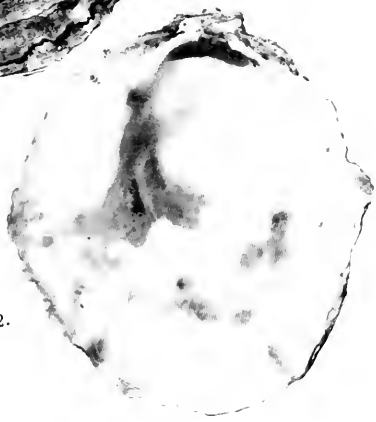


Fig. 52.

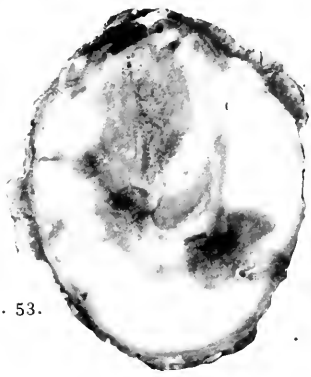


Fig. 53.

Figs. 50-53. *Ostrea edulis*

In May, 1956, a shipment of European flat oysters, the common name for this species, was received from Japan by the California Department of Fish and Game. The planting was made in Tomales Bay. A protective fence was provided and in two years a length of 76 mm. had been attained. A storm destroyed the fence and silt, crabs and drills destroyed the oysters. In a later experiment (1962) shipments of these oysters were received by the U. S. Fish and Wildlife Service from Milford, Connecticut, and Arcachon, France. The oysters were put out in trays and on ground plots. Survival was very high and growth rapid. About two inches was added to length in one year (information from Mr. H. G. Orcutt, December, 1963).

According to Mr. Orcutt, the Department of Fish and Game received additional shipments in May and November, 1963. The May shipment was put in trays in Drake's Estero and Tomales Bay; survival was high. The November shipment of 900 oysters was planted in Morro Bay.

According to a newspaper account (San Francisco Examiner, June 16, 1963, sec. 1, p. 23), Dr. Victor L. Loosanoff of the U. S. Bureau of Commercial Fisheries planted 800 European oysters in Tomales and Drake's bays, California, in 1962. The notice stated that the oysters were doing very well.

Crassostrea gigas (Thunberg).

(Figure 54.)

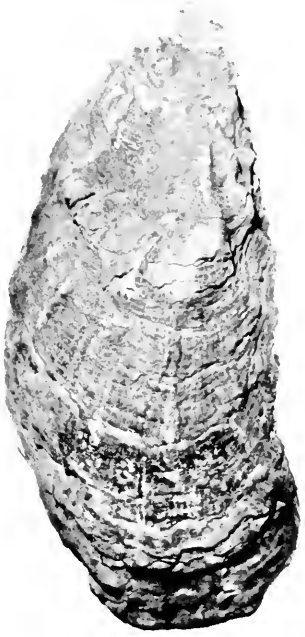


Fig. 54. *Crassostrea gigas* Length 211.0 mm.

The Pacific oyster (sometimes referred to as "giant" oyster and Japanese oyster) has been planted in many places along the American west coast and has become the basis for a thriving industry. The name "*laperousii*" Schrenck is sometimes applied to it because of a prior use of the name "*gigas*" in *Ostrea* by Meuschen, 1781. However, the work of Meuschen has been rejected for nomenclatural purposes by the International Commission on Zoological Nomenclature, Opinion no. 261.

Kincaid (1951) indicated that the first introduction of the species from Japan was in 1902. However, Stearns (1884, pp. 219-220) had suggested the introduction was long before that. Kincaid also stated that commercial development did not take place until 1928. Chapman and Esvelt (1943) stated that the first planting in California took place in 1932.

This species has been grown in Japan for about 300 years. Shape of the shells is variable but in America, if crowded, they assume a strap-like form with a few heavy radial flutes on the lower (attached) valve; but in uncrowded situations they grow in oval shape with well developed flutes. Several varieties are recognized commercially in Japan depending, it seems, upon the bays from which the oysters are obtained. Custom has dictated that a marketable oyster should be about three or four inches in length, a size reached by the Pacific oyster in two or three years. If allowed to develop to maturity, the total length may reach ten or twelve inches. The mantle border is a narrow, almost black line, a character which the consumer can use to distinguish the meat from the east American *Crassostrea virginica.*

If temperature conditions be just right on the few necessary days, natural propagation can be expected in some favorable places. It has been reported from Hood Canal, Willapa Bay, Washington, and Newport Bay, California, by Burch (1946, p. 54), but some western waters are a few degrees too cold. This makes it necessary for a continuing supply of spat to be brought from Japan. An elaborate system for growing and transporting this has been developed.

Mr. C. E. Lindsay of the Washington Shellfish Laboratory informed me on September 18, 1963, that the species has become well established in Puget Sound and now reproduces regularly.

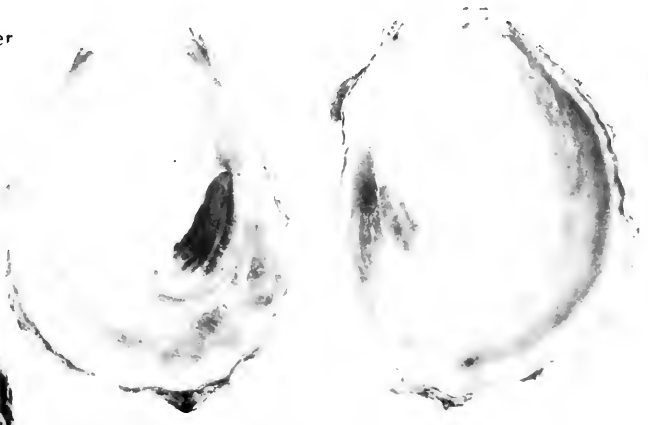
Extensive precautions are taken to prevent the introduction of other organisms, destructive or otherwise. These measures were not in effect in the early stages of the industry and this has resulted in the establishment of many Japanese mollusks on the American coast as well as members of other zoological groups. One clam, *Paphia philippinarum*, thus introduced, has become a commercially important product.

Plantings of spat have been made in a great many places along the coast from Vancouver Island to San Diego, California. A small race of this oyster from Kumamoto Prefecture, Japan, has been introduced on a rather extensive scale in Washington in an endeavor to produce a form suitable for "cocktails." The original planting consisted of "10,000" individuals. They survived transit and planting, but there is no information available at this date (December 1963) as to whether reproduction has been successful (Linsley and Carpelan, 1961, p. 46). The same small form was put in Drake's Estero, Elkhorn Slough, Morro Bay, and Salton Sea in California in May, 1953. By June, 1954, when the experiment was terminated, it was learned that all plantings had survived and had produced good, firm, tasty meats. Those in Elkhorn Slough attained the greatest size, 58 mm., and were the fattest (H. B. Orcutt, personal communication, December, 1963).

Ostrea lurida Carpenter

(Figures 55, 56, 57.)

Figs. 55. Length 54.0 mm.



Figs. 56, 57. Length 53.0 mm.

In 1893, John F. Colburn of Honolulu imported 3,000 individuals of *Ostrea lurida* for planting in a private fish pond. Three months later no living ones were found (letter, R. A. Coleman to G D. Hanna, April 28, 1922).

Crassostrea rivularis (Gould).

(Figures 58-61.)

A specimen of this large oyster was supplied by Mrs. Eleanor Duggan. She understood that the species was grown by the Olympic Oyster Company at Totten Inlet, Mason County, Washington. The shell was given to her by Dr. Stein of the Rayonier Paper Company Laboratory.

Mr. C. E. Lindsay told me on September 18, 1963, that the introduction of this oyster was apparently accidental, the seed having come along with that of *O. gigas*. It was first observed about 1950, so the introduction must have been a few years earlier. It is being experimented with at the Washington Shellfish Laboratory.

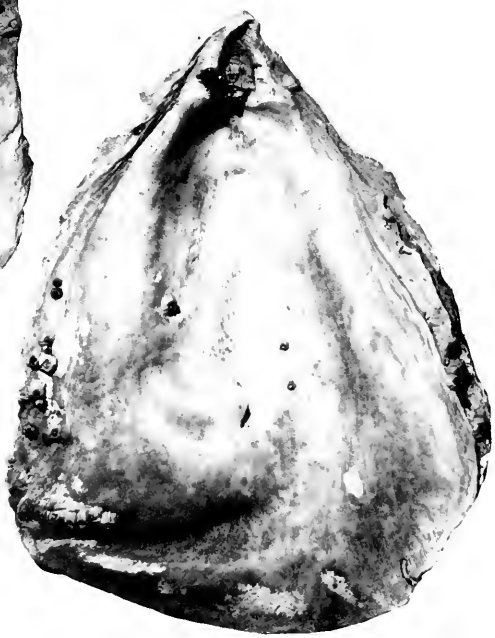


Fig. 58. (above). Fig. 59. (right).
Crassostrea rivularis.
Distance, beak to margin, 217 mm.

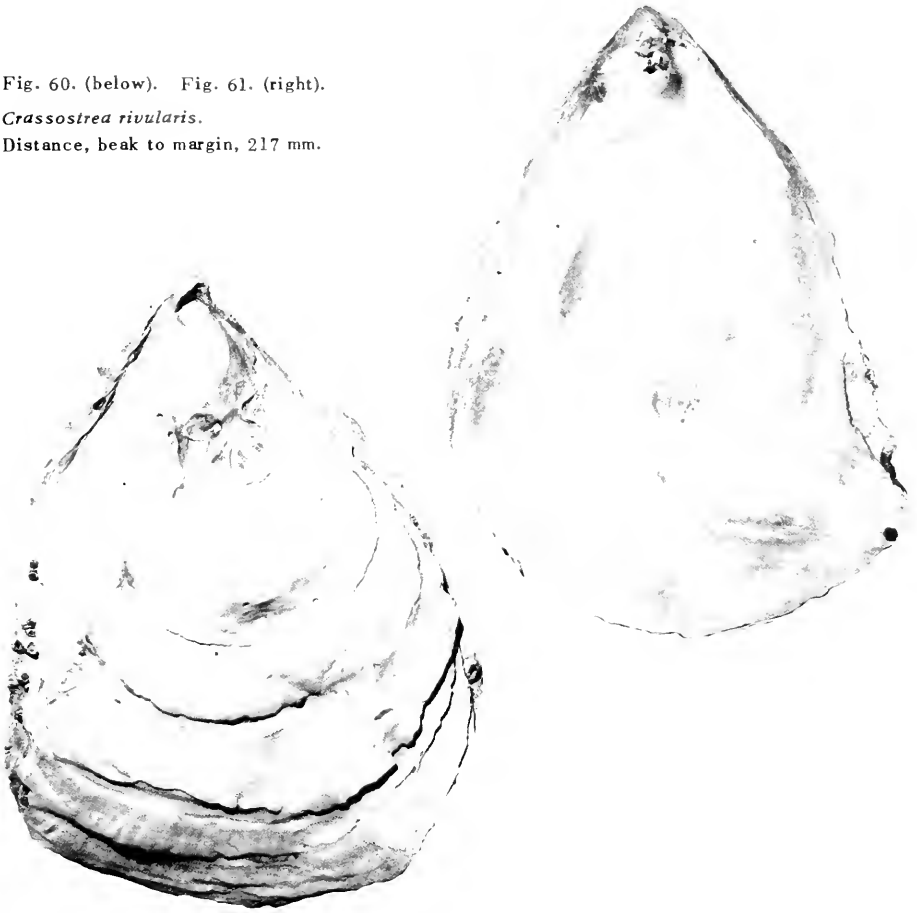


Fig. 60. (below). Fig. 61. (right).
Crassostrea rivularis.
Distance, beak to margin, 217 mm.

Ostrea sinuata Lamarck.

(Figures 62, 63.)

On November 29, 1962, 110 oysters of this species were received by the California Department of Fish and Game and were placed in holding trays at Redwood City, San Francisco Bay. On December 1, 1962, the lot was transferred to Tomales Bay and set out at the site of the Jensen Oyster Company. By July 26, 1963, only 60 were still alive and none survived to December of that year. These oysters were received from Foveaux Strait, New Zealand.

This is the "mud oyster" of south Australian estuaries.

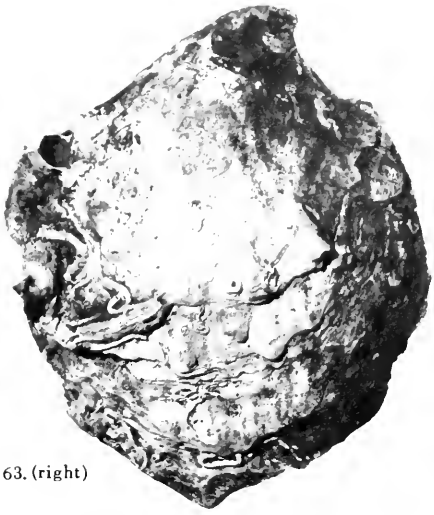
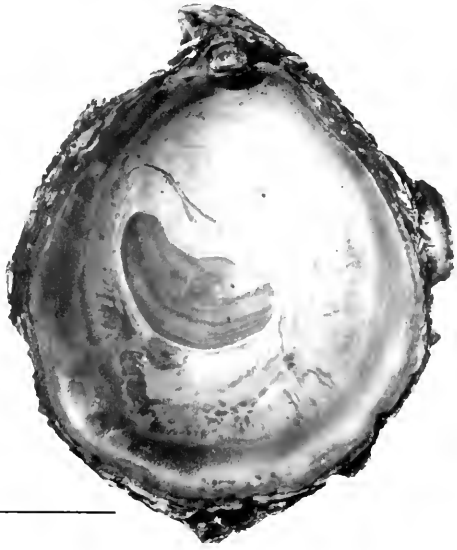


Fig. 62. (left); Fig. 63. (right)
Ostrea sinuata,
Length 99.7 mm.



Crassostrea virginica (Gmelin).

(Figures 64, 65.)

The complete history of the transplanting of east American oysters to western waters cannot be learned at this late date. However, there is an extensive literature in which much important information has been recorded. The earliest published record we have found is that of Throckmorton in 1874, but this gives no essential details. Collins (1892) on the other hand, in a long re-

port on the fisheries of the Pacific Coast, attributed the first planting to an accident. According to this version, transcontinental rail service was established about 1869, "...the firm of A. Booth & Co. brought to San Francisco three car loads of live eastern oysters of large size. It is said that this was the first shipment of live oysters from the Atlantic coast. But, according to the traditions of the trade, the market was overstocked by even this small invoice; consequently, to avoid loss, the shippers had to plant in San Francisco Bay all that could not be promptly sold. This experiment, the first attempt at planting oysters on the Pacific Coast that we have any record of, resulted favorably. The oysters lived and thrived, and those interested gained valuable experience from the enforced experiment, while the financial result gave them confidence to enter more extensively into the business."

Figs. 64, 65.
Crassostrea virginica
Length 97.0 mm.

Gilbert (1891) collected data on the introduction of oysters in southern California and this was followed by Townsend (1893) who described the procedure in detail. The same author, in 1896, gave details regarding the transplantings to Willapa Bay, Washington. These early records are followed by few accounts which give details as to localities, dates, and other information a biologist desires but there are many brief citations. A list of these was given by Hanna (1939) and will not be repeated here.

Evidently an effort was made to establish the species in nearly all bays and inlets from Puget Sound to San Diego, and it was hoped that propagation would result. However, although there are a few reports of spawning, the species never really established itself in western waters. Presumably this was because of the temperature being too low.

After it was found that the spat of *Crassostrea gigas* could be brought from Japan, and that rapid growth to commercial size resulted, live shipments from Atlantic localities ceased. The last shipment of which we have a record came in 1935 and was planted in Humboldt Bay, California (Paul Bonnot, personal communication, March 1, 1936).

The first attempt to introduce oysters to Hawaii was in 1883 by Albert Herbert (letter, R. A. Coleman to G D. Hanna, April 28, 1922; see also, U. S. Bureau of Fisheries, Bull., Vol. 23, pt. 1, pp. 528-529 and Ann. Rept., 1897, pp. CLXIX - CLXXL). He obtained 300 live individuals in San Francisco and they were planted at Kahili. They were destroyed by a freshet. In 1893 John F. Colburn obtained 3 cases of oysters from San Francisco for a private fish pond. Three months later, 50 per cent had survived and were spawning. This en-

couraged Colburn to secure another lot of 38,614 oysters, the fate of which seems not to have been recorded.

In May, 1921 (letter, R. A. Coleman to G D. Hanna) the U. S. Bureau of Fisheries shipped 5,000 (5 barrels) oysters to H. L. Kelly of the Hawaiian Fish and Game Commission. The shipment arrived safely and was planted in Pearl Harbor. The next year two more barrels of oysters were sent over, the result of which has not been traced.

According to Galtsoff and Smith (1932, p. 371-372) and Higgins (1932 [1933] , p. 231), *Crassostrea virginica* interbreeds with *C. gigas*.

Modiolus demissus (Dillwyn).

(Figure 66.)

Fig. 66. *Modiolus demissus* Length 84.5 mm.

This bay mussel is usually black or very dark brown, and has conspicuous radial ridges posteriorly. It is very common on the mud flats of San Francisco Bay where it is presumed to have been unintentionally "planted" during the many futile attempts to establish eastern oysters. It was first detected by Stearns (1899, p. 86) from specimens collected in the south end of the Bay by N. F. Drake in 1894. Nine published records were cited by Hanna (1939, pp. 305-306). The species may be found under *Modiolus*, *Modiola*, *Volsella*, *Mytilus*, or *Brachydontes* and may have the name "*demissus*" or "*plicatula.*" Lately (Poel, 1959), the species has been made the type of the genus *Geukensia.*

It is common knowledge among local ornithologists that this mussel sometimes closes its shell on the toes of birds feeding on the mud flats of San Francisco Bay. Clapper Rails are said to be especially susceptible to capture, and when the tide rises the birds are drowned (De Groot, 1927, pp. 266-267). However, the destruction of the birds has been shown by Moffitt (1941, p. 272) not to be entirely one sided. He found, by examining contents of numerous stomachs of rails that this mussel furnished over 66 per cent of the animal food consumed.

Modiolus demissus is used for human food to a limited extent and is occasionally obtainable in San Francisco markets. A set of specimens in the California Academy of Sciences was obtained at the Washington Market March 13, 1913, by the *Albatross* survey of San Francisco Bay. There is apparently no record to indicate that the species has been responsible for any human mussel poisoning in California. For extensive accounts of this dangerous malady, and for which warnings against the gathering of the animals are issued each year, see Sommer, Whedon, Kofoid, and Stohler (1937, pp. 537-539) and Sommer and Meyer (1937, pp. 560-598).

The species has become exceedingly abundant in the south end of San Francisco Bay and could be harvested in large tonnages. In fact, it has been proposed to do this in preparation of biological products for poultry and animal food (Applin, verbal communication, May, 1963).

Modiolus senhousei (Benson).

(Figure 67.)

Fig. 67. *Modiolus senhousei.* Length 27.7 and 22.4 mm.

This beautiful little mussel has been reported under various names. The first record seems to be by A. G. Smith (1944, p. 18) who found it in Bolinas Bay, California. It has also been taken in San Francisco Bay and Tomales Bay. Kincaid (1947, p. 3) found it in abundance in Samish Bay, Puget Sound, Washington, and it is probably more widely distributed than these records indicate. Kira (1962, p. 127, pl. 46, fig. 1) stated that it was very common in Japan and China and that it made byssal nests on mud flats.

In 1949, Messrs. C. C. Church, David Church, and Allyn G. Smith, and I found specimens living and attached to piling with no nests at the yacht harbor at San Mateo Point in San Francisco Bay.

I have seen the following names used for this interesting species:

Modiola senhousia Benson
Modiolus senhousea Benson
Volsella senhausi Reeve
Modiolus senhousea Reeve
Modiola senhusi Benson
Musculus (Musculista) senhousia (Benson)
Modiolus senhausi Reeve
Volsella (Arcuatula) senhausii Reeve

Benson's (1842, p. 489) original spelling was "*Modiola senhousia*" but Dr. L. G. Hertlein informs me that a preferable rendition under *Modiolus* would be *senhousei*, following Lamy.

Mya arenaria Linnaeus.

(Figure 68.)

The first western collection of this important food clam was made in San Francisco Bay in 1874 by Henry Hemphill. Newcomb (1875, p. 415) described the material as a new species *Mya hemphillii* and it was so recognized by Stearns (1881, p. 362-366). Soon thereafter, the identity of the bay shells with the east American *Mya arenaria* was recognized and since then this de-

Fig. 68. *Mya arenaria.* Length 113.3 mm.

termination has been accepted generally. Hanna (1939, p. 306) cited 15 references to the west coast introduction. No record has been found of any intentional shipment of live clams from the Atlantic Coast for planting; therefore, it is supposed that the stock must have been brought in with oysters. Subsequent plantings at Santa Cruz and Tomales Bay, California; Coos Bay, Oregon; and the coast of Washington were said by Stearns to have been successful. Dall (1921, p. 53) reported the range to be from Vancouver Island, British Columbia, to San Diego, California. Specimens were collected by me at Ketchikan, Alaska, in 1946; these appear to be identical with those from California.

Kincaid (1947, p. 2) noted that the species was not as abundant in some places along the Pacific coast as it had been formerly.

R. A. Coleman, U. S. Bureau of Fisheries (letter to G Dallas Hanna, April 28, 1923), advised that two shipments of *Mya arenaria* were made from San Francisco to Honolulu in May, 1922, but that there was 100 per cent loss of both in the refrigeration room of the ship.

It may be of interest to note here that *Mya* was present in late Pliocene waters of the San Joaquin Valley, and members of the genus are abundant along the Arctic coast of Alaska.

Petricola pholadiformis Lamarck.

(Figure 69.)

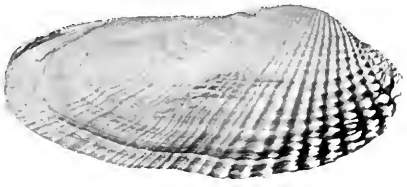


Fig. 69. *Petricola pholadiformis* Length of hinge line, 54.0 mm.

This east American clam has been known in San Francisco Bay since 1934 when Baily reported it from Lake Merritt, Oakland. It has also been found on the mud flats between South San Francisco and Burlingame (Hanna, 1939, p. 308). Kincaid (1947, p. 1) reported it as having become established in Willapa Bay, Washington.

Pteria sterna (Gould).

(Figure 70.)

Fig. 70. *Pteria sterna* Length of hinge line, 83.0 mm.

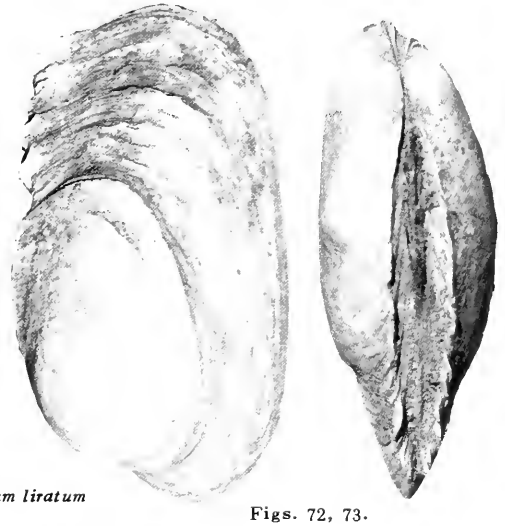
Dall (1921, p. 17) gave the range of this species as San Diego to Panama. Baker (Hanna, 1939, p. 308) stated that the presence of the species in San Diego waters was almost certainly due to it having been brought there from the south on the bottoms of ships and barges. On June 12, 1946, Mr. John Q. Burch advised us that about 1938, Mr. P. M. Connelly had found the species on piling in Newport Bay, Orange County, California. At best, the species is not often found north of Mexico.

Trapezium liratum (Reeve)

(Figures 71 - 73.)

Trapezium liratum

Fig. 71. (left). Length 28.4 mm.



Figs. 72, 73.

Two specimens of this species from Ladysmith Harbor, British Columbia, were loaned for photography by Dr. D. B. Quayle of the Fisheries Research Board of Canada. They are obviously fully grown shells and bear a strong superficial resemblance to *Hiatella arctica*. These two shells measure as follows: length, 25.4 mm. and 24.7 mm.; height, 14.2 mm. and 13.4 mm. Mrs. Eleanor Duggan furnished a specimen which she had collected at Nahcotta, Willapa Bay, Washington. Its measurements were: length 28.4 mm., height 15.0 mm., thickness, 11.3 mm.

Apparently the species has become established in most of the Pacific oyster-growing localities. Solem (1954, p. 73) listed it from many places in Japan and repeated Bonnot's record for Elkhorn Slough, California. Some la-

bels have been seen which called the shells *T. japonicum*, but apparently the name was given to material which is not too well differentiated.

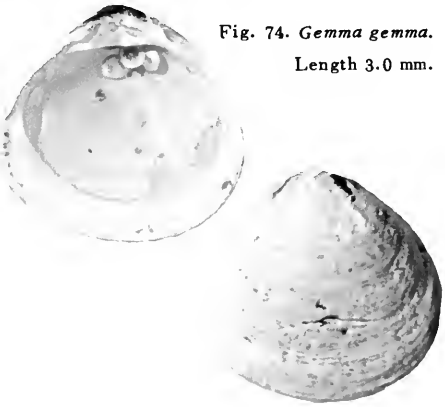


Fig. 74. *Gemma gemma.* Length 3.0 mm.

Gemma gemma (Totten).

(Figure 74.)

This minute marine clam, supposedly introduced from the Atlantic Coast with oysters, has an extended range from Puget Sound to San Diego. Nine references to the literature were given by Hanna (1939, p. 301).

Meretrix lusoria (Röding).

(Plate 4, figure 1.)

In some of the records, this species is referred to as *Meretrix meretrix* Linnaeus. According to Mr. C. E. Lindsay of the State Shellfish Laboratory at Quilcene, Washington, a commercial planting was made in Grays Harbor about 1959. Apparently there has been no reproduction.

The small highly colored shell was received from Mrs. Eleanor Duggan who obtained it at the Shellfish Laboratory in 1962 where an attempt was being made to grow the species.

Mr. Walter J. Eyerdam of Seattle, Washington, sent me a good series of shells from the same place, Quilcene on Hood Canal, Puget Sound. No two are alike in coloration.

The Academy has a specimen of this species collected by C. G. Harold at Nash Harbor, Nunivak Island, in 1927. This locality is so far removed from the natural range that the probability of the species living there seems very remote. Possibly it may have been brought there on a Japanese schooner

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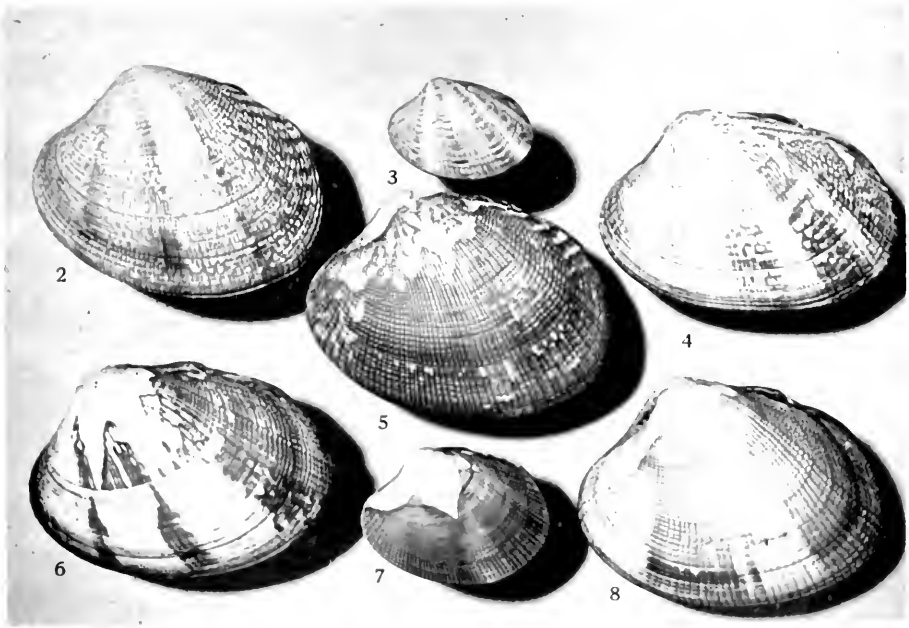
PLATE 4

All specimens illustrated on this plate are in the California Academy of Sciences, Department of Geology Type Collection, unless otherwise stated.

Figure 1. *Meretrix lusoria* (Röding). From Shellfish Laboratory, Whitney Point, Jefferson County, Washington. Specimen is in the collection of Mrs. Eleanor Duggan. Length 40.0 mm.

Figures 2-8. *Paphia philippinarum* (Adams and Reeve). Hypotypes nos. 12693-12699 from Coyote Point, San Mateo County (San Francisco Bay), California. Length of uppermost specimen on left, 50.0 mm.


1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which was wrecked on the island a few years earlier. The specimen is 50 mm. long and 40 mm. high.

A small shipment of *Meretrix* was received by the California Department of Fish and Game from Tokyo Bay in 1957. The clams were planted in Humboldt (Arcata) Bay but it is believed they were destroyed by crabs (information from Mr. H. G. Orcutt).

Paphia philippinarum (Adams and Reeve).

(Plate 4, figures 2 - 8.)

Although positive proof cannot be cited, it is practically certain that this clam was accidentally introduced with oyster spat from Japan. In any event, it became widely dispersed and commercially important before it was detected as a species distinct from the native *Paphia staminea* by taxonomists. Eyerdam (1943) found some of the shells among some *P. staminea* which he purchased in a Seattle fish market in 1943, and soon thereafter he published the note it was found far to the southward. Kincaid (1944) stated that it "has developed on a great scale in the lower section of the Puget Sound district and is coming into the market along with *P. staminea.*" A little later (1947, p. 3), he made the interesting observation that: "It seems to cross freely with the related local species and all sorts of intergrades have appeared. Either in its pure or crossed form it has become a conspicuous element in the catch of the local clam digger." He also stated that the species was first detected in Willapa Bay, Washington, in 1947.

On April 24, 1946, Henry Trost obtained a set of specimens of the species in a San Francisco restaurant and brought them to the California Academy of Sciences. On May 2, 1946, C. C. Church collected a large series of fine live shells on the north side of San Mateo Point, San Francisco Bay. These were living in sand and among loose rocks in large numbers, and showed almost every conceivable color variation from plain white to plain purple. In this respect the shells agree fairly well with the eastern *P. grata*, but that species and all of the true "*staminea*" we have examined are slightly shorter and rounder than *P. philippinarum*. The extreme range of coloration makes this one of the most beautiful of the west American clams, and its delicious flavor makes it commercially valuable. If all intentional introductions of plants and animals turned out as well as this unintentional one, there would be less criticism of public agencies engaged in such traffic.

In 1955, the California Department of Fish and Game transplanted the species from San Francisco to Morro Bay and the Salton Sea. The clams survived and grew well at Morro Bay, but excessive silt destroyed them at Salton Sea (information received from Messrs. H. G. Orcutt and Keith Cox, December, 1963).

In northern areas the common name "Manila clam" seems to be gaining

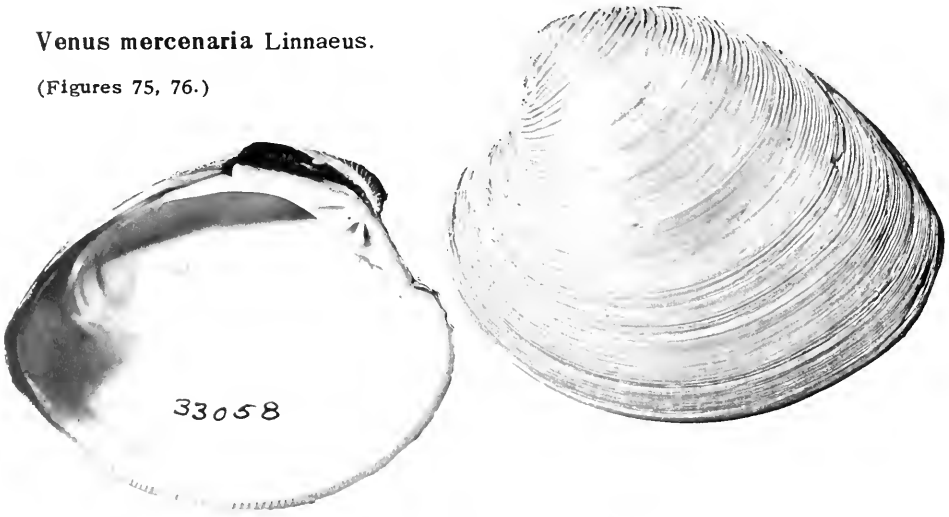
over "Japanese little neck clam." It is quite likely that the common name will become more stable than the scientific one. Taxonomists have assigned many names to this fine clam. The genus to which it was originally referred was "*Venus*." Since then it has been transferred at one time or another to all of the following: *Tapes*, *Paphia*, *Venerupis*, *Protothaca*, *Ruditapes*, and *Cytheraea*, and probably to others. The name "*philippinarum*" implies that the species came originally from the Philippine Islands. A similar shell from Japan has been given the name "*semidecussata*," and this specific name has been applied to our shells at times. The uncertainty of origin and Kincaid's statement regarding free interbreeding with the native species, leads us to use the name by which the species is best known on the west coast.

It is interesting to note that before this was recognized as a Japanese species, it was described as new under the name *Paphia bifurcata* by D. B. Quayle, Jr. (1938; 1952, p. 139) from Ladysmith Harbor, British Columbia.

Carl and Guiguet (1958, p. 69) stated that the species occurs throughout Georgia Strait and Barkley Sound, British Columbia. Seymour Narrows seemed to them to be a possible temperature barrier to farther northward spread. Carl and Guiguet (1958, p. 68) used the specific name "*japonicus*" (Deshayes) for the species.

Venus mercenaria Linnaeus.

(Figures 75, 76.)



Figs. 75, 76. *Venus mercenaria*. Length 77.3 mm.

The records of this east coast clam being found on the west coast date back to 1901 when Keep (p. 114) stated that several dead valves from the Alameda shore of San Francisco Bay had been brought to him. He was not

sure that it had become established in these waters. On May 15, 1940, Mr. Howard McCulley of the State Division of Fish and Game informed me verbally that he had taken a living specimen from the San Francisco region. Attempts may have been made at that time to introduce the species to San Francisco Bay, but if this was accomplished published records have not been found to substantiate it.

It is known, however, that an attempt was made to plant the species in Newport Bay, California, on March 31, 1940 (McCulley, letter dated July 31, 1941 to G D. Hanna). Two sacks of the clams from New Jersey were liberated under the observation of Paul Bonnot. Presumably the attempt failed.

Details of the early planting of the species in Humboldt Bay, California, have not been found, but the experiment was moderately successful. A bed is located near the end of the causeway where Highway 101 leaves Eureka going northward (specimens received from Dale Goodwin).

In 1956, the Coast Oyster Company made small experimental plantings of the quahog, the common name of *Venus mercenaria*, in Drake's Estero and Tomales Bay. There was no fencing, and it is believed there was no survival. The same company also made a small planting in Catalina Harbor in 1959. Bat rays are supposed to have destroyed the mollusks.

In October, 1960, the California Department of Fish and Game received a shipment from Milford, Connecticut. The planting was made in Humboldt Bay ("Arcata Bay") and survival has been good; and in May, 1963, clams came by air from the same place but were planted in Drake's Estero and Tomales Bay. Survival has been good. Also in November, 1963, 20,000 more were received and planted in Morro, Drake's, and Tomales bays (information received from Messrs. H. G. Orcutt and Keith Cox, December, 1963).

It is reported that 2,000 quahogs were planted in San Francisco Bay in May, 1963, by V. K. Loosanoff and Walter Dahlstrom (North, 1963, p. 23).

It was learned at the Washington State Shellfish Laboratory that experiments were being made there toward the establishment of the species in Puget Sound. However, up to September, 1963, the work had been confined to the Laboratory.

Mollusks of Uncertain Status

Acanthochitona achates (Gould).

One specimen of this well known Japanese chiton was collected by Professor Trevor Kincaid on the oyster beds of Puget Sound, Washington, in 1948. It was sent to Dr. A. Myra Keen who in turn sent it to Mr. Allyn G. Smith for identification. After considerable study of Japanese literature, it was decided that the species is the one described by Gould (1859, p. 165) from Kikaia and Hakodate Bay, Japan. Introduction into Puget Sound waters was undoubtedly with imported seed oysters.

The most extensive discussion of the species that we have found is that of Taki (1938, pp. 360-362, pl. 15, fig. 2; pl. 23, figs. 7-11, pl. 24, figs. 3-7) and to which reference is made for details of distribution and anatomy. Taki stated that *A. achates* was scarcely distinguishable from *A. rubrolineata* Lischke (1873), which also has wide distribution in Japan.

The specimen is entered in the collection of the California Academy of Sciences as catalogue no. 33329.

Acmaea heroldi signata Pilsbry.

Kincaid (1947, p. 3) included this Japanese shell among those which were found near Bellingham, Washington, where seed oysters had been planted.

Anadara nipponensis (Pilsbry).

(Figure 77.)

An adult shell of this species was collected at Quilcene on Hood Canal, Puget Sound, Washington, by Walter J. Eyerdam who furnished the specimen for illustration. Much of the epidermis is present on one valve.

I was informed by Dr. C. E. Lindsay, of the State Shellfish Laboratory near Quilcene, that this specimen may have been originally among some shells brought from Japan by State inspectors and later discarded. He knew of no specimens of the species having been found living in Puget Sound or Willapa Bay waters.

Fig. 77. *Anadara nipponensis* Length 63.6 mm.

"Arion echinopus"

This name appeared in California literature in the California Insect Pest Report dated February 9, 1962, and was repeated a little later in the U.S. Department of Agriculture Report (Anonymous, 1962, p. 85). The statement indicated that it had been collected in Golden Gate Park under boards and stones. H. H. Keifer of Sacramento advised (letter, March 5, 1962) that the record was an error due to transposition of copy in the original report.

Astralium triumphans (Philippi).

(Figure 78.)

Fig. 78. *Astralium triumphans* Diam. 62.0 mm.

This Japanese gastropod was dredged just outside of San Francisco Bay during the exploration of that body of water prior to World War I. It was reported by Packard (1918, p. 309) and again by Hanna (1939, p. 300). Extensive dredging operations off central California were conducted by the California Academy of Sciences in 1951-1952, but *A. triumphans* was not found. The same is true of a long series of trawling hauls made by the California Department of Fish and Game. In spite of these failures, there is no evidence to indicate that the record is not authentic. One of the original shells was living when collected. A vague report of a beach shell having been picked up by an amateur collector on the coast of Humboldt County has not been confirmed.

Cochliopa rowellii (Tryon).

This species was originally stated to have come from Clear Lake, California, and later Bolinas Bay was cited. Pilsbry (1905, p. 91) cast doubt on these records and believed that the specimens may have come from Central America. Some of the original collection, made by Rev. J. G. Rowell, were given to Wm. Gabb, who sent the shells to Tryon. Rowell's main collection was given to the University of California; Mr. Allyn G. Smith has examined a set of specimens labeled *C. rowellii* there, and was of the opinion then that they belonged to the species which passed under the name *"Paludestrina stearnsiana."*

Conus flavidus Lamarck.

Dall (1910, p. 277) reported this species as having been picked up at San Diego, California, by a correspondent who sent it to him, but he stated that it was "without doubt exotic."

Drymaeus californicus (Reeve).

Bulimus californicus Reeve, Conch. Icon., vol. 5, December, 1848, pl. 56, f. 378. "California; Hartweg."

Drymaeus ziegleri (Pfeiffer), Pilsbry, Man. Conch., vol. 12, 1898, pp. 39, 40, pl. 9, fig. 34.

This species was cited from California or Lower California several times on the basis of Reeve's statement, but Pilsbry doubted the record and referred the name to *D. ziegleri* from Mazatlan and Altata, northwest Mexico.

Euglandina albersi (Pfeiffer).

Achatina albersi Pfeiffer, Proc. Zool. Soc. London, 1864, p. 295.

Glandina albersi (Pfeiffer), Binney and Bland, Land and fresh-water shells of North America, Smithsonian Misc. Coll., no. 194, pt. 1, 1869, p. 18, figs. 9, 10. "California."

Euglandina albersi (Pfeiffer), Pilsbry, Man. Conch., serv. 2, vol. 19, 1908, pp. 198, 201.

Pilsbry was not certain where this species may have come from originally, and he cited Mazatlan, Mexico, questionably.

Helicodiscus salmonaceus Hemphill.

The recent description of *Speleodiscoides spirellum* by A. G. Smith (1957, p. 33) has clarified this record. It now seems certain that all of the previous records of snails under the names "*salmonaceus*" or "*lineatus*" should be referred to the new species. The references are as follows: Binney, 1878, p. 185; Binney, 1885, p. 75; Cooper, 1886, p. 249; Binney, 1886, p. 35; Cooper, 1888, pp. 13, 19; Binney, 1890, p. 220; Keep, 1935, p. 293; Hanna, 1939, p. 301; Pilsbry, 1946, p. 632.

Helisoma antrosum (Conrad)

This species was placed among the doubtfully resident species by Hanna (1939, p. 313) but it is now believed that colonies of it exist in western North America. It is a common species east of the Rocky Mountains. It was found in a Pleistocene deposit near Soap Lake, Washington, several years ago by Olaf P. Jenkins.

Helix heligmoidea d'Orbigny.

Helix heligmoidea D'ORBIGNY, Voy. Amer. Merid., p. 237, pl. 23, figs. 1-3. BINNEY, Man. American Land Shells, Bull. U.S. Nat. Mus., no. 28, 1885, p. 251.
Polygyratia (Entodina) heligmoidea (d'Orbigny), PILSBRY, Man. Conch., vol. 9, ser. 2, 1894, p. 83.

Binney stated that the species "is said to have been found by Mr. H. Moores in 1849 in the foothills of the west slope of the Sierra Nevada, about five miles south of Coloma and about a quarter of a mile south of Weber Creek under an old log; a single old specimen. Certainly very doubtful. The species was described from Guayaquil, Colombia, South America." [Ecuador].

Helix mazatlanica Pfeiffer.

Zonites mazatlanica (Pfeiffer), BINNEY, Man. Amer. Land Shells, Bull. U.S. Nat. Mus., no. 28, 1885, p. 87.
Punctum conspectum (Bland), PILSBRY, Monog. 3, Acad. Nat. Sci. Philadelphia, vol. 2, pt. 2, p. 651, fig. 357.

Shells bearing the above name were sent to Binney by Mr. Rowell and were stated to have come from "Lone Mountain," San Francisco. He further indicated that the shells belonged to *Zonites conspectus* Bland, a well known west American species.

Helix sagraiana d'Orbigny.

Helix sagraiana D'ORBIGNY, Moll. Cuba, vol. 1, p. 145, pl. 7, figs. 4-6. BINNEY, Land and fresh-water shells of North America, Smithsonian Misc. Coll., no. 194, pt. 1, p. 186.
Cepolis sagraiana (d'Orbigny), PILSBRY, Man. Conch., vol. 9, ser. 2, 1894, p. 180.

Binney stated that this is "...a Cuban species erroneously attributed to California (on the authority of Sowerby) by Pfeiffer (Mon. I, p. 324) and Carpenter (Report, 1856 [1857] p. 314)."

Helix sandiegoensis Lea.

Helix sandiegoensis LEA, Gould, Pac. Railroad Reports, vol. 5, 1856, p. 331.

The name appeared in a table published by Gould and the locality was cited as "Point Reyes." Apparently no description was published.

Littorina brevicula (Philippi).

(Figures 79, 80.)

Two fine specimens of this species were made available for this report by Mrs. Eleanor Duggan who had obtained them from Professor Kincaid, March 27, 1963, in exchange for Puget Sound shells. They were obtained from a ship-

Littorina brevicula. Fig. 79. (left). Height 14.5 mm. Fig. 80. (right). Height 13.7 mm.

ment of Japanese seed oysters at Willapa Bay, Washington in 1947. Their measurements are: height 14.5 and 13.7 mm., diameter 13.4 and 13.0 mm. And in 1963 Professor Kincaid gave the Academy several specimens from the same lot. There is no evidence that the species has become established.

Littorina littorea Linnaeus.

(Figure 81.)

E. P. Chace collected this species at Deception Pass, Puget Sound, Washington, in 1937. Five specimens were presented to the California Academy of Sciences collection. Length 17.9 mm.

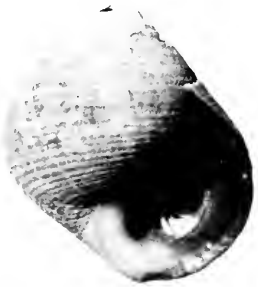


Fig. 81. *Littorina littorea* Diameter 15.3 mm.

Lymnaea bombycina de Lunge.

Limnaea bombycina Lunge, WOOD and RAYMOND, Nautilus, vol. 5, 1891, p. 56. BAKER, F. C., Chicago Acad. Sci. Spec. Publ., no. 3, 1911, p. 462.

Baker considered this name a *nomen nudum* and he quoted Raymond to the effect that it was inserted in the San Francisco list on the authority of Wood. In the list it was stated to be "introduced." de Lunge's shells were apparently deposited in the University of California.

Monodonta labio Linnaeus.

Kincaid (1947, p. 3) stated that this Japanese species was abundant in Samish Bay, Washington, near where seed oysters had been planted. He did not find evidence of survival.

Mytilus dunkeri (Reeve).

Hill (1951, p. 4) reported this Japanese species from southern California but Coe (1946, p. 97) described the same thing as *Mytilus edulis diegensis* and considered it a native species.

Mytilus recurvus Rafinesque.

The record of this species by Dall (1921, p. 21) is based upon a specimen obtained at Newport Bay, California, by "Dr. Tremper" many years ago. It has not been found since and it is generally believed that an error is involved in the record (Burch, 1944, p. 11).

Netastomella japonica (Yokoyama).

(Figure 82.)

Fig. 82. *Netastomella japonica* Length 20.0 mm.

This species is included on the basis of a specimen furnished by Mrs. Eleanor Duggan. It was collected at the mouth of Watun River, Graham Island, Queen Charlotte Island, British Columbia, by Mr. P. Hanson, May 23, 1960. Mrs. Duggan received the specimen from Dr. I. McT. Cowan of the University of British Columbia, July 20, 1962, in exchange for trawled mollusks. Dr. Cowan stated that the species differed from the native one by its greater length of rostrum. He doubts if it has been introduced by man because of the location far north of where Japanese oysters have been planted. Probably it just happens not to have been detected previously.

Octopus sp.

An unsigned item in Desert Magazine (vol. 26, no. 7, July, 1963, p. 5) contained the following information:

"A lot of things have turned up in the Salton Sea, but for the first time an octopus made its appearance. There can be no doubt that the creature was transplanted in Salton, probably a visitor from one of the Pacific Coast towns. The Salton octopus, 18 inches in diameter was captured by a 12 year old boy."

The most likely source of the original introduction of such animals as this can probably be assigned to the California Department of Fish and Game. This organization has made some extensive transplantations of marine organisms from the Gulf of California to the Salton Sea and without apparently keeping (or at least publishing) an inventory of species involved. The most complete information on the subject seems to be that which was assembled by Walker and associates (1961).

Pododesmus sp.

Kincaid (1947, p. 3) stated that some of the shells taken in Samish Bay, Washington, do not appear to belong to the local species, *P. macroschisma*. He referred to some material which had come from Japan in boxes of seed oysters in 1924.

Polygyra monodon Rackett.

The record by Gratacap (1901, p. 378) as *Stenotrema monodon* is believed to have been a misidentification of *P. germana* for this common east American shell.

Rhodea californica (Pfeiffer).

Achatina californica Pfeiffer, Sym. Hist. Heliceorum, sec. 3, 1846, p. 89. "Monterey, California. Coll. Cuming."

Rhodea californica (Pfeiffer), Pilsbry, Man. Conch., vol. 18, 1906, p. 235, pl. 38, figs. 1-6, 10. "Colombia = Bogota; Marmato."

The recording of this South American species from California was an obvious error. It has been placed in the genus *Columna*.

Tegula lischkei (Tapparone - Canefri).

(Figure 83.)

Among the shells which were collected by Professor Kincaid in 1924 at Samish Bay, Puget Sound, were young of a species identified by Mrs. I. S. Oldroyd as *Turbo marmoratus*. These were associated with a shipment of seed oysters of the species *Crassostrea gigas*, and apparently none survived. This turban shell subsequently appeared in a shipment destined for Willapa Bay, Washington. A specimen is here illustrated and the identification was made by Dr. Takashi Ino.

Fig. 83. *Tegula lischkei* Diameter 30.4 mm.

Teredo navalis Linnaeus.

This was recorded as an exotic species in California in my 1939 report, (p. 308). Undoubtedly it arrived here sometime but since it is so widely distributed in the oceans of the world it seems doubtful if the first came within historical time.

Thais lapillus (Linnaeus).

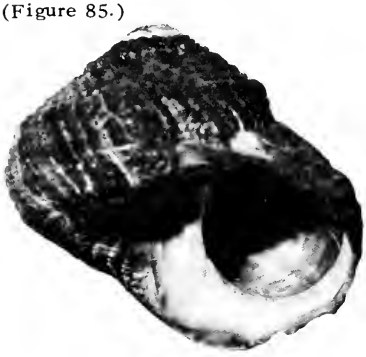
(Figure 84.)

E. P. Chace collected a species of *Thais* at Deception Pass, Puget Sound, Washington, which he identified as *T. lapillus*. It was taken along with *Littorina littorea*, an easily identified east American species. *Thais lamellosa* Gmelin is abundant in Puget Sound and there is a possibility that there is confusion in the identity because of the extreme variability of species of *Thais*.

Fig. 84. *Thais lapillus*
Height 28.3 mm.

Turbo coronatus coreensis Recluz.

(Figure 85.)



This is one of the species which Professor Kincaid detected in 1924 in a shipment of seed oysters from Japan. The shells escaped in Samish Bay, but it does not appear that any survived. Identification, according to Professor Kincaid (verbal communication, 1963), was by Mrs. I. S. Oldroyd.

Fig. 85. *Turbo coronatus coreensis*
Diameter 20.7 mm.

Veronicella olivacea Stearns.

This species was described by Stearns in 1871 with the locality given as "Habitat - Nicaragua (Occidental Department) where several specimens were collected by Mr. J. A. McNeil. Also found in Upper California, a specimen having been collected by me near Lobitos in the year 1866."

The original description and Stearns' remarks were quoted by Binney in 1878 (pp. 243-244) and 1885 (pp. 160-161). In both cases he referred to the Proceedings of the Boston Society of Natural History without a definite citation. In one case he stated that the original description was taken from that publication and in the other he cited the year as 1871. I have not been able to locate any mention of the species in the Boston Proceedings. Furthermore, in the 1885 publication, Binney stated that the species was found in Lower California, a record which has apparently not been verified to date. Stearns original description of the species and his California record were contained in a

one page private publication called "Conchological Memoranda, VIII, Oct. 14, 1871."

Cockerell (1895, p. 141) reached the conclusion that the California record was accidental or doubtful although Stearns was known as a very careful worker.

Mr. W. H. Lange, Jr. has done a great deal of detailed work in the area of San Mateo County, California, where the slug was "collected," but has failed to find anything like it. Mr. C. C. Church and I have searched the vicinity of Lobitos and in Lobitos Creek and we also failed to find the species. Therefore, it is included in the unverified records of introduced forms.

"Zonites" limatulus Ward.

It is suspected that Binney's record of this species from San Mateo County, California, is based upon an accidental mixing of shells. It is found living in the middle west.

Zachrysia auricoma Férussac

This Cuban snail was transplanted to Little River, Florida, by C. T. Simpson (Clapp, 1919, p. 104).

Pilsbry (1939, p. 412) stated that no subsequent records had been published regarding its having become established although Clapp remarked that it was abundant at the time of his visit. It is interesting to note that a shell of this species was intercepted at Los Angeles in 1961 on nursery stock from Miami, Florida. (Letter H. H. Keifer to A. G. Smith, December 11, 1961.) The determination was made by L. G. Hertlein.

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FRESHWATER MOLLUSKS

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Figure 31. *Corbicula fluminea* (Müller). From Delta-Mendota Canal, San Joaquin County, California. Photograph furnished by Mr. R. P. Dugan, Regional Director, U. S. Bureau of Reclamation.

MARINE MOLLUSKS

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Figure 48. *Arca transversa* Say. Hypotype no. 5832 (CAS). From Punta Rassa, Florida; Henry Hemphill, collector.

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Figures 50-53. *Ostrea edulis* Linnaeus. Hypotype no. 12685 (CAS). From Whitney Point, Dabob Bay, Jefferson County, Washington. Mrs. Eleanor Duggan, collector. Donated by Washington State Shellfish Laboratory.

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Figures 62, 63. *Ostrea sinuata* Lamarck. Hypotype no. 12684 (CAS). From Foveaux Strait, New Zealand, then transferred to Tomales Bay, California. Specimen furnished by H. G. Orcutt and Keith W. Cox of the California Department of Fish and Game.

Figures 64, 65. *Crassostrea virginica* (Gmelin). Hypotype no. 5841 (CAS). From Cedar Keys, Florida; Henry Hemphill, collector.

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Records of Uncertain Status

Figure 77. *Anadara nipponensis* (Pilsbry). Hypotype no. 12686 (CAS). From Quilcene, Hood Canal, Puget Sound, Washington; W. J. Eyerdam, collector.

Figure 78. *Astralium triumphans* (Philippi). Hypotype no. 5838 (CAS). From Japan.

Figures 79, 80. *Littorina brevicula* (Philippi). Hypotypes nos. 12675, 12675a (CAS). From Willapa Bay, Washington; Trevor Kincaid, collector, and furnished by Mrs. Eleanor Duggan for illustration.

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Figure 83. *Tegula lischkei* (Tapparone-Canefri). Hypotype no. 12677 (CAS). From Willapa Bay, Washington; Trevor Kincaid collector. Received for illustration from Mrs. Eleanor Duggan.

Figure 84. *Thais lapillus* (Linnaeus). Hypotype no. 12667 (CAS). From Deception Pass, Puget Sound, Washington; E. P. Chace, collector.

Figure 85. *Turbo coronatus coreensis* Recluz. Hypotype no. 12670 (CAS). From Willapa Bay, Washington; Trevor Kincaid, collector. Received for illustration from Mrs. Eleanor Duggan.

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ANONYMOUS

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1959b. [*Theba pisana* and *Cochlicella ventrosa* intercepted at San Diego, California, June 8, in cargo from Italy.] Cooperative Economic Insect Report, vol. 9, no. 46, p. 1000, November 13.

1960a. [Release of *Euglandina rosea* in Riverside County, California.] Cooperative Insect Pest Report for California, p. 7, October.

1960b. [*Vallonia pulchella* in Riverside County, California.] Cooperative Economic Insect Report, vol. 7, no. 6, p. 71.

1960c. [Interceptions of *Theba pisana* at ports of entry in military cargo.] Cooperative Economic Insect Report, vol. 10, no. 7, p. 90.

1960d. [*Arion ater, Agriolimax agrestis* and *Deroceras reticulatum* very damaging to vegetables and strawberries in western Washington and Oregon.] Cooperative Economic Insect Report, vol. 10, no. 11, p. 167.

1960e. [*Vallonia pulchella* in lawns at Hollister, San Benito County, California. August 19.] Cooperative Economic Insect Report, vol. 10, no. 36, p. 838.

1960f. [*Gulella wahlbergi* received in Nuuanu Valley, Oahu, Hawaii from 1956-1957 plantings.] Cooperative Economic Insect Report, vol. 10, no. 43, p. 1002.

1960g. [*Achatina fulica* intercepted at San Diego, California in cargo from Guam.] Cooperative Economic Insect Report, vol. 10, no. 48, p. 1106.

1961a. [White garden snail, *Theba pisana* (Muller) intercepted at New Orleans with military cargo from the Mediterranean and destined for various bases in the United States.] Cooperative Economic Insect Report, vol. 11, no. 5, p. 50, February 3.

1961b. [*Agriolimax agrestis* and *Arion ater* damaging vegetable crops in Puyallup Valley, Washington. *Deroceras reticulatum* in Willamette Valley, Oregon, damaging strawberries, beets and cauliflower.] Cooperative Economic Insect Report, vol. 11, no. 11, p. 166, March 17.

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1961e. [*Euglandina rosea* released in Alameda and Contra Costa Counties, California.] Cooperative Insect Pest Report for California, p. 10, August.

1961f. [*Achatina fulica* Bowditch) intercepted at Honolulu, Hawaii in mail for California and baggage for Michigan.] Cooperative Economic Insect Report, vol. 11, no. 31, p. 737, August 4.

1961g. [Brown garden snail, *Helix aspersa,* recorded for the first time in Washington where it caused considerable damage to flowers in Pacific County.] Cooperative Economic Insect Report, vol. 11, no. 43, p. 1001, October 27. ["Garden slugs" were also reported destructive in some areas in Alaska. Species and localities not given.]

1961h. [White garden snail *Thebapisana* (Müller) intercepted nine times at east coast ports destined for various eastern and southern localities. Also *Achatina fulica* intercepted in cargo from Okinawa at San Diego and destined for Barstow, California.] Cooperative Economic Insect Report, vol. 11, no. 44, p. 1028, November 3.

1962a. [*Achatina fulica* reported to be eradicated on the island of Hawaii but a new colony became established at Poipu, Kauai.] Cooperative Economic Insect Report, vol. 12, no. 6, pp. 76, 77, February 9.

1962b. [*Arion ater* in the Crescent City, California area.] Cooperative Economic Insect Report, vol. 12, no. 11, p. 197, March 16. Recorded also in Cooperative Insect Pest Report for California.

1962c. [*Arion ater* at Smith River, Del Norte County, California.] Cooperative Economic Insect Report, vol. 12, no. 14, p. 314, April 6. (From Cooperative Insect Pest Report for California.)

1962d. [*Arion ater* recorded for both Del Norte and Humboldt Counties, California.] Cooperative Economic Insect Report, vol. 12, no. 17, p. 423, April 27. (From Cooperative Insect Pest Report for California.)

1962e. [*Arion ater* at Eureka, Humboldt County, California.] Cooperative Economic Insect Report, vol. 12, no. 13, pp. 275, 287, March 30. Recorded also in Cooperative Insect Pest Report for California.

1962f. [*Arion circumscriptus* at Crescent City, Del Norte County, California.] Cooperative Economic Insect Report, vol. 12, no. 13, p. 287, March 30. (From Cooperative Insect Pest Report for California.)

1962g. [*Arion hortensis* in Santa Cruz, San Anselmo, Mill Valley and San Rafael, California.] Cooperative Economic Insect Report, vol. 12, no. 11, p. 197, March 16. Recorded also in Cooperative Insect Pest Report for California.

1962h. [*Arion hortensis* in Sacramento, California.] Cooperative Economic Insect Pest Report, vol. 12, no. 8, p. 106, February 23.

1962i. [*Deroceras reticulatum* and *Arion ater* damaging nurseries and gardens in western Oregon.] Cooperative Economic Insect Report, vol. 12, no. 14, p. 326, April 16.

1962j. [Gray garden slug *Deroceras reticulatum,* heavy population feeding in Ladino clover in Sonora area, Tuolumne County, California.] Cooperative Economic Insect Report, vol. 12, no. 22, p. 552, June 1. (From Cooperative Insect Pest Report for California,)

1962k. [Heavy population of *Vallonia pulchella* on *Vinca minor* at Woodside, San Mateo County, California.] Cooperative Economic Insect Report, vol. 12, no. 49, p. 1234, December 7.

1962m. [*Helix aspersa* in Oregon and Utah.] Cooperative Economic Insect Report, vol. 12, no. 11, p. 209, March 16. The records of Capizzi, 1961 and Hutchings, 1961, are repeated.

1962n. [Interception of *Achatina fulica* at San Diego, California.] Cooperative Insect Report, vol. 12, no. 27, p. 748, July 6.

1962o. [Slugs in California.] Cooperative Economic Insect Report, vol. 12, no. 7, p. 85. (Report *Deroceras reticulatum, D. caruanae* and *Arion echinopus* from Golden Gate Park, San Francisco, under boards and stones.) (From Cooperative Insect Pest Report for California.)

1962p. [Slugs in California.] Cooperative Economic Insect Report, vol. 12, no. 5, p. 64, February 2. [Populations of *Limax marginatus, L. flavus, Arion hortensis* and *Deroceras laeve* heavy in nursery soil in Danville, Contra Costa County. Survey for *Arion ater* negative.]

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