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"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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TABLE OF CONTENTS

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Killed in Line of Duty

Byron Sylvester
Arthur Boeke

JOHN OTTERBEIN SNYDER: 1867-1943

By A. C. Taft
Bureau of Fish Conservation
California Division of Fish and Game

The death of Dr. J. O. Snyder at Palo Alto on August 19, 1943, marked the end of a career which was of great significance to all interested in the fish and fisheries of California. When J. O. Snyder came west from his home in Indiana in 1892 to study at Stanford he already had a deep interest in animal life and natural history, and as a student of Dr. David Starr Jordan and Dr. C. H. Gilbert he became particularly qualified as a naturalist of fishes and birds. After graduation he spent a year as a

Fig. 1. John Otterbein Snyder, Stanford University, California.

2—28607

teacher at Pullman, Washington, and then returned to join the staff at Stanford. He remained a member of the faculty until 1932 when he retired as head of the Department of Zoology.

Dr. Snyder joined with Dr. Jordan in trips to Mexico in 1898 and to Japan in 1899 for the purpose of studying the fishes of those countries. These trips resulted in a series of important papers of which most were published jointly by the two authors. It was particularly fortunate for California that shortly after serving as naturalist on the United States Bureau of Fisheries Research Ship "*Albatross*" in 1902, Dr. Snyder's interests in the field of systematic ichthyology became centered on the fishes of California, Oregon and Nevada. Numerous field trips in this area were made by Dr. Snyder accompanied by faculty members and students from Stanford. One of these trips into southeastern Oregon, made in 1904, was by horse and wagon and covered about 1,000 miles. Between 1900 and 1918 these trips under the sponsorship of the United States Bureau of Fisheries resulted in a series of papers by Dr. Snyder which thoroughly described the character and relationships of the freshwater fish fauna of California and has been the foundation on which most subsequent work with the freshwater fishes of the State has been based. The importance and extent of this work can be judged from the following partial list of titles of papers published by Dr. Snyder during that period.

Relationships of the fish fauna of the lakes of southeastern Oregon

Notes on the fishes of the streams flowing into San Francisco Bay, California

Critical notes on *Mylocheilus lateralis* and *Leuciscus caurinus*

The fishes of the coastal streams of Oregon and northern California

The fauna of Russian River, California, and its relation to that of the Sacramento

Description of *Pantosteus-Santa Anae*, a new species of fish from the Santa Ana River, California

Fishes of the streams tributary to Monterey Bay, California

The fishes of the streams tributary to Tomales Bay, California

The fishes of the Lahontan system of Nevada and northeastern California

An account of some fishes from Owens River, California

Fishes of Mojave River, California

Trout of the Sierra San Pedro Martir, Lower California

Notes on some western fluvial fishes described by Charles Girard in 1856

A new species of trout from Lake Tahoe.

In 1919 the April issue of CALIFORNIA FISH AND GAME contained an editorial by N. B. Scofield, then Chief of the Bureau of Commercial Fisheries of the Fish and Game Commission, on the need of more protection for the salmon of the Sacramento and in closing he said, "Investigations which were begun this year by the Fish and Game Commission under the direction of Dr. J. O. Snyder are expected to throw light on this point." Apparently Mr. Scofield had prevailed upon Dr. Snyder to accept an assignment with the Commission to act as a fishery expert and advisor in connection with what was even then becoming the pressing problem of arresting the rapid depletion of the salmon of California's coastal streams. The direct record of Dr. Snyder's work on salmon and steelhead in California as a result of this arrangement is found in a series of brief papers which appeared in CALIFORNIA FISH AND GAME between 1921 and 1928 and in Fish Bulletin No. 34, entitled Salmon of the Klamath River, California, which was published in 1931. This latter, a thorough study of the life history and abundance of the salmon of the Klamath River, summarized the work of about 10 years and became the basis for the conservation of those fishes which has led to the maintenance of the runs of steelhead and salmon at a high level for the enjoyment of thousands of anglers.

Except for one brief period Dr. Snyder continued his association with the work of the Bureau of Commercial Fisheries until October, 1931, when he left Stanford and became Chief of the then Bureau of Fish Culture of the Division of Fish and Game, now known as the Bureau of Fish Conservation. The first-hand experience that he had accumulated over a period of 30 years with the freshwater fishes of California, and trout and salmon particularly, made it possible for Dr. Snyder to take up his new work with a sound background of knowledge. His greatest contribution lay in the emphasis which he gave to the scientific approach to the problems of freshwater fisheries conservation in this State. The broadened program which he instituted in the Bureau of Fish Culture included a number of research projects, and a realistic handling of the problems of fish hatchery work in a more cooperative spirit than sometimes accompanies the application of scientific methods in fields which have developed on a purely practical basis.

During his teaching career many young people were indebted to Dr. Snyder for guidance and leadership and he continued a similar relationship with the many men who came under his supervision in his new work. Starting with a series of meetings of all bureau employees, there soon developed a mutual understanding and a firm belief in Dr. Snyder's fairness and deep interest in the personal welfare of each employee that brought about full cooperation in the changes which he planned in organization and methods.

In 1937 Dr. Snyder retired from work with the Division due to ill health, and it was the hope of his associates that he would be granted the time and energy to do the many things that he had planned, such as travel and writing. Fortunately for the Division of Fish and Game he was able to prepare a revised edition of his paper, "The Trouts of California," which first appeared in the April, 1933, issue of CALIFORNIA FISH AND GAME. For years to come this will be useful to the anglers of the State in learning to identify and understand their favorite game fishes.

THE COMPARATIVE OSTEOLOGY OF THE HERRING-LIKE FISHES *(CLUPEIDAE)* OF CALIFORNIA[1]

By Wilbert McLeod Chapman
California Academy of Sciences

Along the Pacific Coast of North America the herring-like fishes normally yield, by weight of their product, more than all the other fisheries put together. The California sardine alone produces more than any other single fishery of the United States. These species at the same time are perhaps the most important forage fishes for the other denizens of the ocean. Whales, porpoises, fur seals, hair seals, sea-lions, chinook and silver salmon, tuna, shark, sea-gulls and other carnivorous birds and fishes almost without end are dependent upon them for more or less of their food. They therefore occupy an extremely important position in the total economy of the eastern Pacific, both as a direct source of food for man, and as an intermediate link between the microscopic plants and animals of the sea and such important and diverse marine products as canned salmon and tuna, vitamin A, and furs.

By fishing intensively for sardine, herring, shark, salmon and fur seal mankind is working both ends against the middle. At some time it will be necessary to define the point where the herring fishery is damaging the salmon fishery, where the raising of furs on the Pribilof Islands is jeopardizing the sardine fishery of California, where the aesthetic value of seals and sea-lions to nature lovers is overbalanced by the predatory habits of those animals on the herring, sardine, shad, etc.

The seriousness of these problems was recently high-lighted by the Japanese abrogation of the Fur Seal Treaty on the grounds that the fur seals were eating more fish than their furs were worth, and that the increasing size of the fur seal herd in the North Pacific was endangering Japan's marine fisheries. Before any rational approach can be made to the untangling of the intricate web of predatory relationships in the North Pacific it will be necessary to determine accurately the food habits of the various carnivorous fishes, birds and mammals involved, and this will entail the quantitative and qualitative examination of the contents of great numbers of stomachs. In all of them at some period of the studies will appear sardine, herring, shad, or thread-fin herring, or some combination of these, in various stages of disintegration.

The identification of intact Clupeid fishes along this coast is no particular problem, since all four species which are found here differ sufficiently to be placed in separate genera. But when the fins and skin are digested away, if the head and shoulder bones are gone, and if, as is so often the case, nothing is left but a few vertebrae and disarticulated bones, the task becomes most difficult. It is the purpose of the present report to provide the means for the identification, under such conditions, of the sardine (*Sardinops caerulea*), herring (*Clupea pallasii*), shad (*Alosa sapidissima*), and thread-herring (*Opisthonema libertate*). For

[1] Submitted for publication, June, 1943.

a detailed description of the osteology of the sardine, which may be taken as representative of the family, the reader is referred to Phillips (1942). The present report is concerned only with the differences between these species.[2]

Cranium

The median dorsal ridge of the mesethmoid ends anteriorly in two prongs, against which the maxillaries ride and to which they are attached ligamentously. In the shad these processes are enlarged so that the vomer can scarcely be seen in dorsal aspect; in the herring they are even smaller than in the sardine, and the anterior extension of the vomer is much larger than in any of the other genera, so that more of it is visible in dorsal aspect; in the thread-herring the processes are smaller than in the other genera, as also is the anterior extension of the vomer, so that this portion of the cranium is somewhat abbreviated and less strongly constructed than in the other species.

The frontals of the thread-herring are considerably wider over the eyes than in the other genera, and they taper in sharply over the mesethmoid so that the bones form a distinct heart-shaped structure when viewed from above.

In all the genera the vomer bears a small, longitudinal crest anteriorly. In the sardine, shad and thread-herring the bone does not bear teeth, but in the herring this crest is enlarged and bears 10 or 11 small, recurved teeth in an irregularly double longitudinal series.

The orbitosphenoid in the sardine sends a strong anterior wing to the prefrontals and the cartilage between those bones. In the shad this wing is heavier and larger than in the sardine. In the herring the wing is proportionately much reduced in size, but is approximately the same width throughout its length. In the thread-herring the anterior wing is of about the same width anteriorly as in the sardine, but where it leaves the posterior part of the bone it is not one-half so wide as it is anteriorly.

The posterior edge of the prootic in the sardine is deeply indented by the large auditory foramen, as shown by Phillips' Figures 2 and 3, but in the shad, herring and thread-herring this edge is nearly straight and merely forms the anterior side of the foramen.

The socket of articulation of the hyomandibular to the cranium is in all genera somewhat separated into pterotic and sphenotic parts, although in the sardine, herring and thread-herring the two parts are always more or less confluent. In the shad only, the pterotic and sphenotic sockets of hyomandibular articulation are completely separate.

In all four genera the anterior temporal foramen is larger than the pre-epiotic fossa. In the herring it is only a little larger, but in the thread-herring it is fully twice as large. The pterotic bulla (containing a diverticulum of the air-bladder) is enlarged in the sardine and nearly closes the pre-epiotic fossa, but in the herring it is small.

Circumorbital Bones

There are seven bones in the circumorbital series in all genera (Figs. 2, 3, and 4), two of which lie over the dorso-anterior edge of the orbit

[2] It should be pointed out that the technical terms herein, while they may present difficulties to the lay reader, must be used if the descriptions are to be sufficiently accurate and complete for practical application in this potentially highly important field.—Ed.

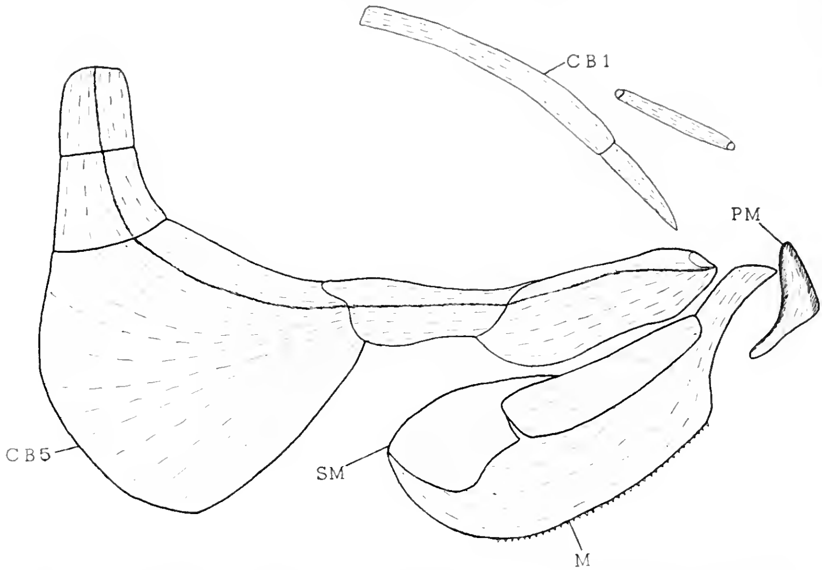

FIG. 2. Circumorbital bones and upper jaw of the sardine, *Sardinops caerulea*, ×5.

and extend laterally the protection afforded by the frontal (to which the first and largest is securely bound for its full length), and the other five of which surround the orbit ventrally. The bones are quite distinctive in shape in the different genera, regardless of the size of the specimen. The third bone (lachrymal) is more slender in the sardine than in the shad or herring. In the herring it is shorter and distinctly broader than in the other genera. In the thread-herring it is also slender, but it is more heavily ossified than in the sardine, and is somewhat sculptured by

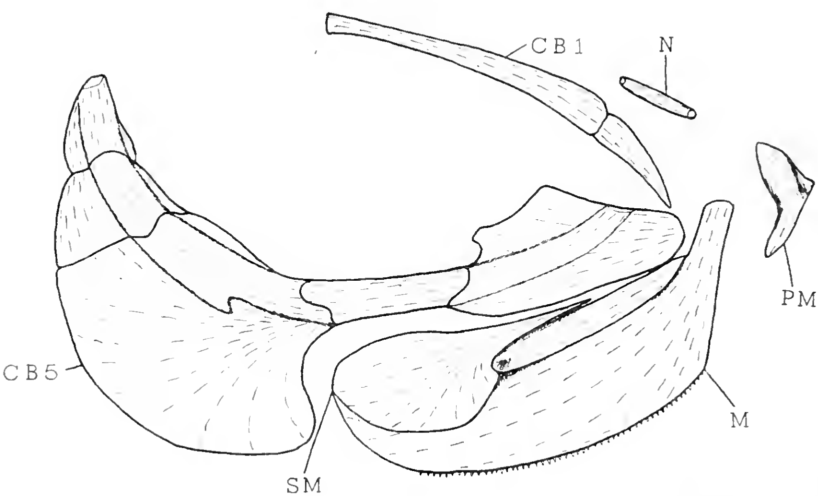

FIG. 3. Circumorbital bones and upper jaw of the herring, *Clupea pallasii*, ×5.

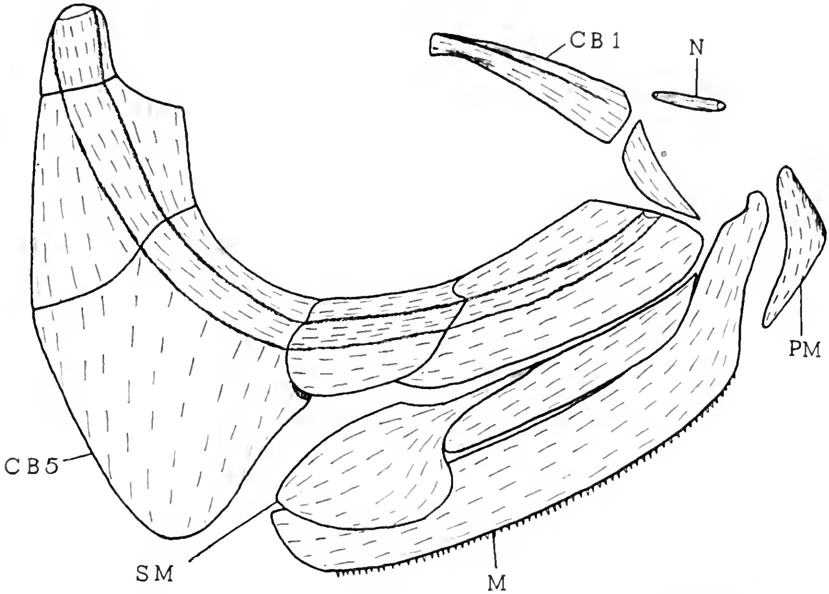

FIG. 4. Circumorbital bones and upper jaw of the shad, *Alosa sapidissima*, ×8.

the pores of the circumorbital bones of the lateral line system. Otherwise the circumorbital bones of the thread-herring are as in the herring.

The fourth bone of the series is notably longer and more slender in the herring than in the shad, and is relatively more slender than in the sardine. The fifth bone of the series is the largest in all the Clupeidae, and its shape is diagnostic and constant in three of the genera under consideration. In the sardine the bone is broader than in the other genera, the anterior edge is slightly convex, and the bottom and posterior edges are evenly rounded. In the shad the bone is narrower and deeper, coming to a point ventrally. The anterior edge is a little concave, and the posterior edge is nearly straight. In the herring and thread-herring the anterior edge of the bone is distinctly and typically concave so that it fits around the end of the upper jaw bones, and the ventral and posterior edges are evenly rounded. In the shad the sixth circumorbital bone has a broad, pointed flange in the inner edge not found in the other genera, and the seventh bone is much smaller in relation to the sixth than in the other genera.

Upper Jaw

The maxillary (Figs. 2, 3, and 4) bears a single row of tiny teeth, in all genera except the thread-herring, along the entire ventral edge of the bone behind the premaxillary, although in the sardine the teeth are so small as to be scarcely visible without magnification.

Lower Jaw

The mandible is high, especially in the thread-herring, and long. The anterior, biting, surface of the dentary (Figs. 5, 6, 7) is characteristically sloped in the different genera. The slope is steepest in the thread-herring (Fig. 5), in most specimens closer to the vertical than that

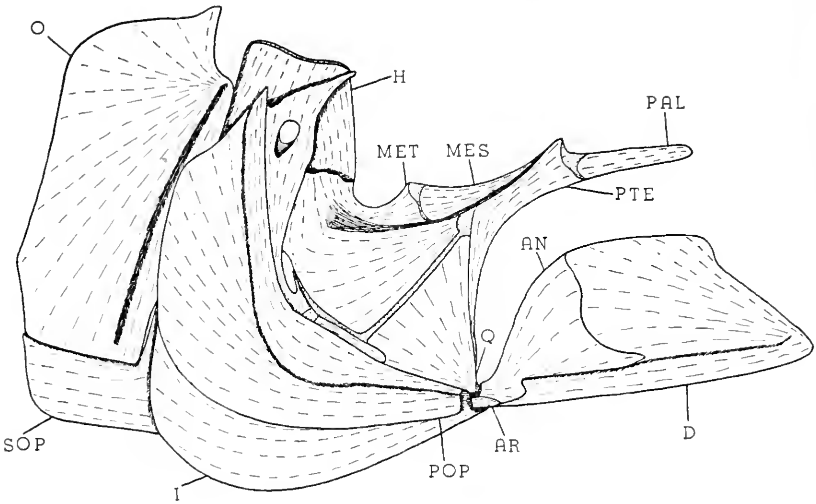

FIG. 5. Lateral view of the suspensorium of the thread-herring, *Opisthonema libertate*, ×5.

illustrated; almost as steep in the herring; lower and longer in the shad (Fig. 6); and nearest the horizontal in the sardine (Fig. 7). The sesamoid articular is applied to the articular and Meckel's cartilage at the posterior end of the latter. It is small in all genera, and largest in the herring.

Palatine Arch

In the shad (Fig. 6) the metapterygoid and the quadrate, where they meet, are both deeply notched so that the cartilage between them, which is an uniformly narrow band in the other genera, is expanded into a broad oval pad. Ridewood (1904) shows this also for the European shad.

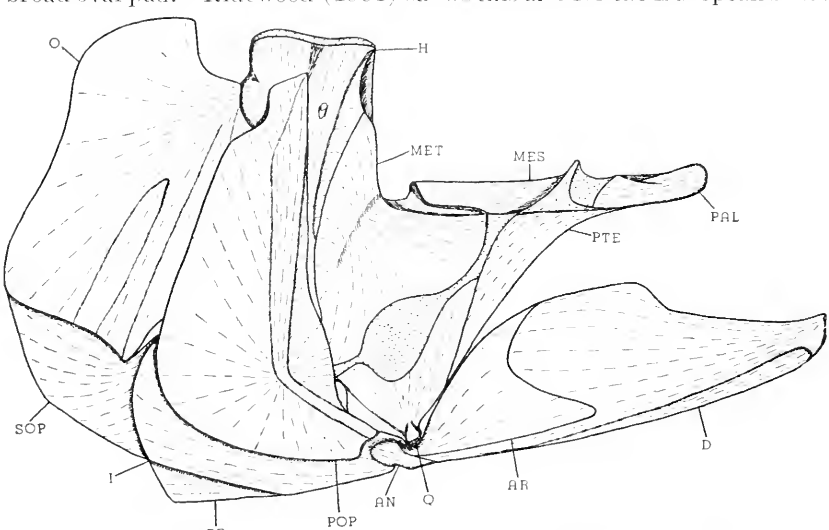

FIG. 6. Lateral view of the suspensorium of the shad, *Alosa sapidissima*, ×8.

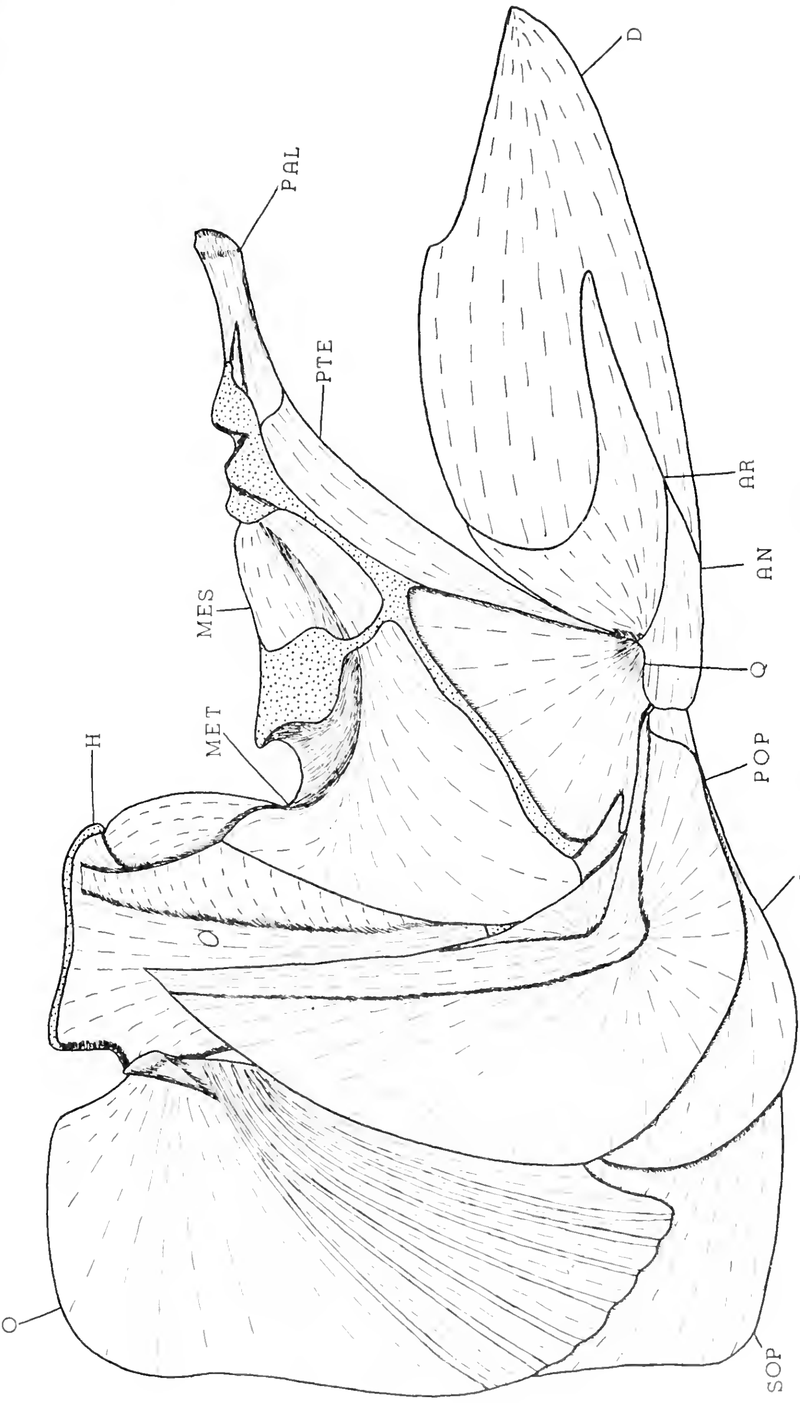

FIG. 7. Lateral view of the suspensorium of the sardine, *Sardinops caerula*, ×5.

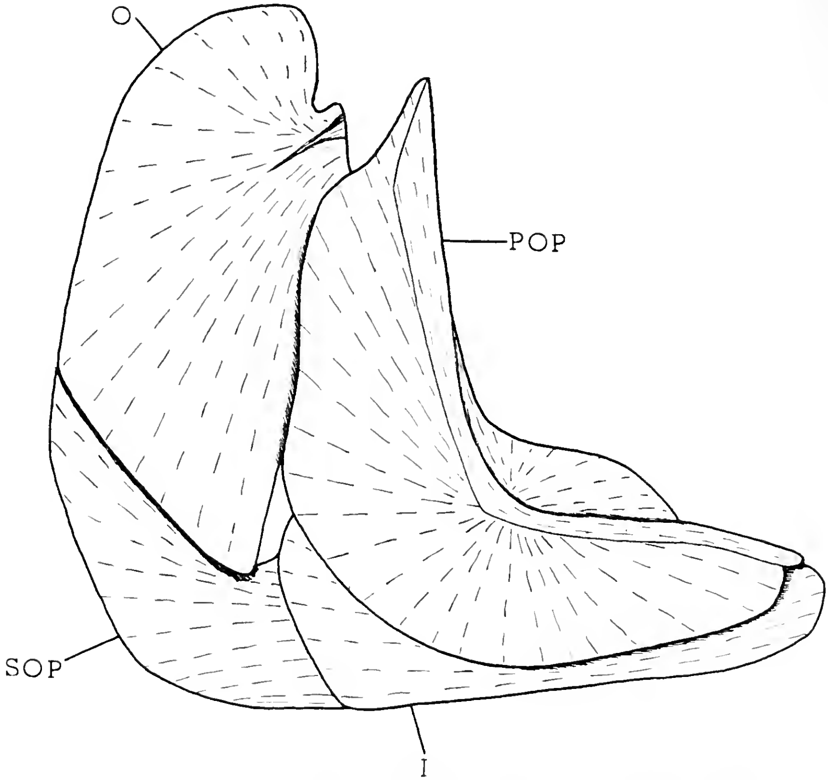

FIG. 8. Lateral view of the opercular bones of the herring, *Clupea pallasii*, ×5.

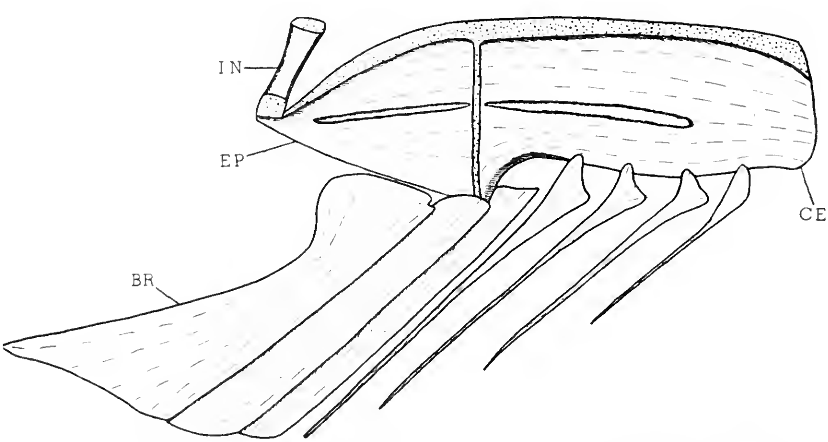

FIG. 9. Lateral view of the hyoid apparatus of the sardine, *Sardinops caerulea*, ×5.

Hyoid Arch

In all genera the head of the hyomandibular is heavy and broad, articulating over nearly the entire postorbital length of the cranium. The head of the bone is in all instances single, but there is a strong tendency for the thrust to go separately to the anterior (sphenotic) and posterior (pterotic) surfaces, with little in between. In the shad this has reached the point where the two articular surfaces are separated, but the bone, while lighter and somewhat grooved between them, is still single. The most posterior branchiostegal ray (Fig. 9) is always the largest, and is broadened distally. This is particularly true in the thread-herring (Fig. 10) where it becomes scythe-like.

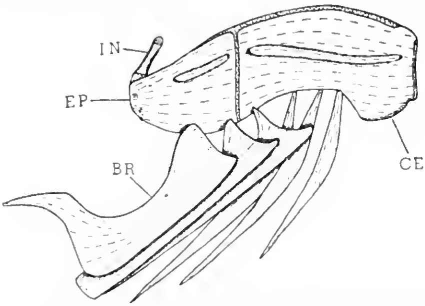

FIG. 10. Lateral view of the hypohyals of the thread-herring, *Opisthonema libertate*, ×5.

Opercular Apparatus

The opercular bones are sufficiently dissimilar to be diagnostic of all the genera under consideration. In all genera a series of sensory canals radiate outward and downward from the edge of articulation with the hyomandibular over the outer surface of the opercle (an unique feature of the Clupeoid fishes among living bony fishes). In the herring these canals leave no trace on the bone, and its surface is smooth. In the sardine the bone bears a number (depending somewhat on the age of the fish) of very definite grooves in which these canals lie. In the thread-herring there is a single groove parallel with the anterior edge of the bone which is more or less closed over into a tube. In the shad there are two or three shallow grooves, not distinctive as in the sardine, and most of the bone remains smooth.

The posterior outline of the opercular series is rather square cut in the sardine (Fig. 7) and thread-herring (Fig. 5), whereas in the herring (Fig. 8) it is noticeably more rounded. This is largely a reflection of the shape of the subopercle, which in the sardine and thread-herring has a squarish surface with the dorsal edge nearly horizontal. In the herring the ventral edge of the bone is rounded continuously with the posterior edge, and the dorsal edge slopes sharply upward, so that the bone is higher than long, whereas the reverse is true in the other two genera. In the shad (Fig. 6) the ventral edge is rounded as in the herring, but the dorsal edge is more horizontal, so that the bone is more slender and is longer than high. In the thread-herring the ventral edge of the opercle is square-cut and almost horizontal, in the sardine it is rounded off posteriorly, in the shad it is nearly horizontal but always slightly concave (usually more than in Fig. 6), and in the herring it slopes sharply upward posteriorly. The shape of the antero-dorsal corner of the bone as well as the width and height of the bone is distinctive and fairly constant.

There is a wing of thin bone in the angle of the two arms of the preopercle (Figs. 5, 6, 7, and 8). In the sardine this wing is nearly

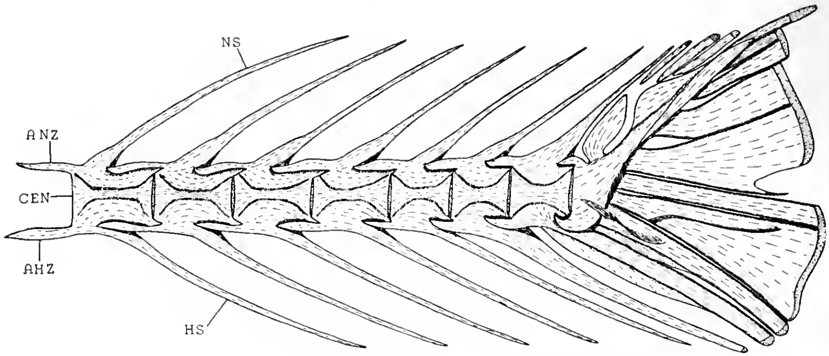

FIG. 11. Caudal skeleton of the sardine, *Sardinops caerulea*, ×8.

symmetrical in relation to the angle; in the shad the dorsal part of the wing is much larger than the ventral part; in the herring the ventral part is larger than the dorsal part; and in the thread-herring the wing is scarcely developed at all, so that the ventral end of the hyomandibular is exposed to lateral view, and the metapterygoid does not touch the preopercle.

Axial Skeleton

In the herring there is a considerable range in the number of vertebrae, and the variation has been extensively used in racial determination. Along the Pacific Coast the variation is from about 47 to 55 (Rounsefell and Dahlgren, 1935; Chapman, Katz and Erickson, 1941). There is also considerable variation in the sardine, although this variation does not occur latitudinally. The number ranges from 49 to 55, and is usually 51 or 52 (Thompson, 1926; Clark, 1936). Two specimens of thread-herring counted had 44 vertebrae each.

On the sardine vertebrae (Fig. 11) there is a striking development of the anterior zygapophyses in the caudal region. On the terminal vertebra the zygapophyses are characteristically clamped around the posterior end of the penultimate vertebra in a claw-like grasp. On the other vertebrae of the caudal peduncle the anterior neural and haemal zygapophyses cling closely to the preceding vertebra and extend to or beyond its middle. Over the back of the abdomen the anterior neural

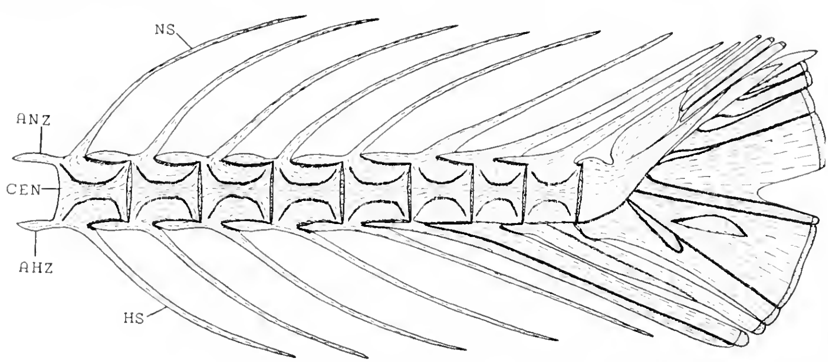

FIG. 12. Caudal skeleton of the thread-herring, *Opisthonema libertate*, ×8.

zygapophyses grow gradually shorter until they disappear on about the twentieth vertebra; the anterior haemal zygapophyses likewise grow shorter anteriorly and disappear on about the twenty-fourth vertebra. They remain parallel to the ventral edge of the centrum and do not project downward.

In the thread-herring (Fig. 12) the vertebral column, neural and haemal spines are sturdy and strongly imbricated as in the sardine. As in that genus the anterior zygapophyses are long and closely hug the preceding vertebra, but those on the terminal vertebra are noticeably smaller and less clawlike than in the sardine. The anterior neural zygapophyses grow smaller and shorter anteriorly but still overlap the posterior neural zygapophyses of the sixteenth abdominal vertebra. The anterior haemal zygapophyses are even more pronounced on the first few caudal vertebrae (not figured), where they project downward at a sharp angle to the parapophyses and reach almost to the preceding haemal spine. They terminate on the eighteenth abdominal vertebra. The haemal spine of the antepenultimate vertebra is enlarged and closely applied to that of the preceding vertebra in the thread-herring, quite unlike the condition found in the sardine, herring and shad.

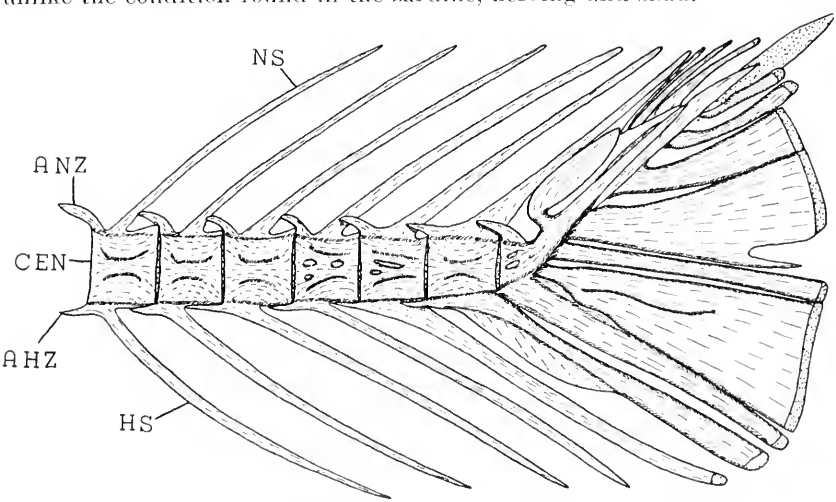

FIG. 13. Caudal skeleton of the shad, *Alosa sapidissima*, ×8.

In the shad (Fig. 13) the anterior neural zygapophyses in the region of the caudal peduncle extend upward instead of hugging the end of the preceding vertebra. They are much heavier and longer than in the herring, and almost always reach upward far enough to touch the neural spine of the preceding vertebra, which they never do except on the last three or four vertebrae in the herring. In large adults these structures are more massive then in the specimen illustrated.

The herring (Fig. 14) has all of the bones of the axial skeleton proportionately weaker and less strongly imbricated than in the other genera. The anterior zygapophyses project away from the preceding vertebra rather than closely hugging it, and even on the caudal peduncle these structures are never as much as one-third the length of the preceding vertebra. Under the end of the dorsal fin, and from there

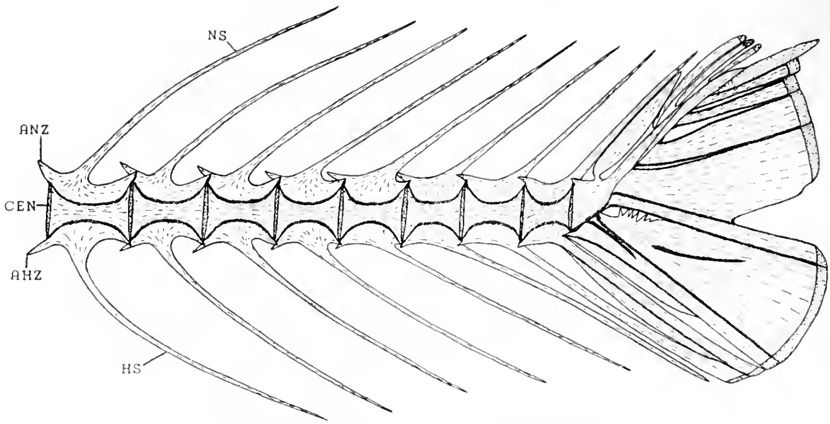

FIG. 14. Caudal skeleton of the herring, *Clupea pallasii*, ×8.

anteriorly, the anterior neural zygapophyses are no longer than the posterior neural zygapophyses, and do not overlap them. The anterior haemal zygapophyses are tiny, but they persist on all the caudal vertebrae and on a few of the posterior abdominal vertebrae.

In the anchovies there are small, slender wand-like bones which lie in the lateral edge of the myocomma. In the familiar zig-zag of the myomeres of the fish body they lie in the dorsal-most and ventral-most zigs. Dorsally they occur on all except the first few segments, one end at the dorsal midline, and the other projecting postero-ventrally. Ventrally they occur on all the segments behind the anus. These are the myorhabdoi or muscle-rods). In all four of the genera dealt with in this report the basic structure of these rods is present. In the sardine, shad and herring they appear only as a thickened ligamentous edge to the myocomma. In the thread-herring only, they are ossified and rodlike along the dorsal edge of the body, just under the scales, but ventrally over the anal fin they are ligamentous and unossified.

On all of the segments over the abdomen between the shoulder girdle and the anus in all four of the genera are the ventral scutes, which are a characteristic of the Clupeidae. These are commonly referred to as "keeled" scales and considered to be modified scales (Phillips, 1942). It is doubtful that these structures are homologous with scales. The dorsal processes lie under the skin and in those species where the ventral portion is not, or only slightly, keeled, as in the herring, the whole structure lies under the skin. They are arranged segmentally and usually their dorsal end is in contact with the epipleural over the middle of the abdomen. It is the writer's opinion that these structures are homologous with the myorhabdoi noted above and are therefore modified intersegmental bones rather than scales.

In the sardine and herring (Figs. 16, 17, and 19) the dorsal processes of the ventral scutes are long between the pectoral and pelvic fins, but directly behind the insertion of the latter the dorsal processes are much reduced in length and taper down until on the last one or two scutes in front of the anus there are no dorsal processes at all. The first scute behind the insertion of the pelvics likewise has practically no dorsal processes. In the sardine the scutes are slightly keeled but not sufficiently to cause a serration of the belly. In the herring the scutes have scarcely any keel and are much weaker and more pliable than in the sardine.

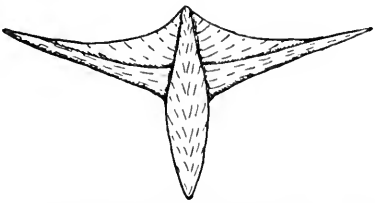

FIG. 15. Ventral view of the second ventral scute anterior to the insertion of the pelvic fins in the thread-herring, *Opisthonema libertate*, ×6.

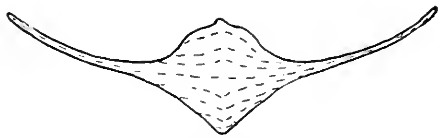

FIG. 16. Ventral view of the second ventral scute anterior to the insertion of the pelvic fins in the herring, *Clupea pallasii*, ×6.

FIG. 17. Ventral view of the second ventral scute anterior to the anus in the herring *Clupea pallasii*, ×6.

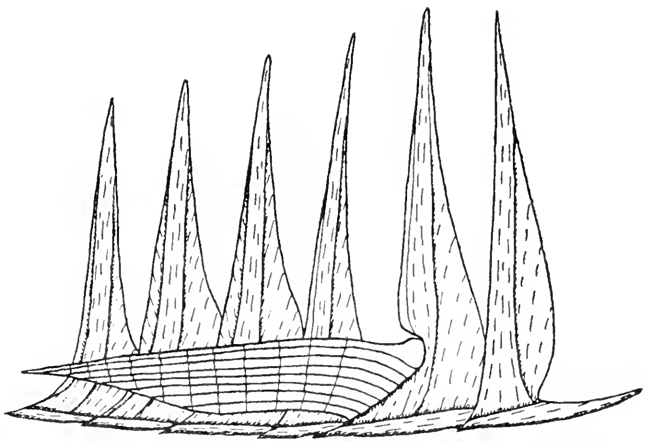

FIG. 18. Lateral view of the ventral scutes in the region of the pelvic fins in the thread herring *Opisthonema libertate*, ×6.

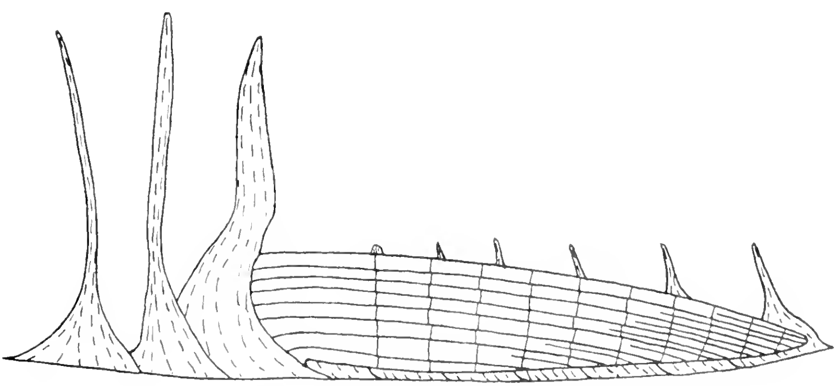

FIG. 19. Lateral view of the ventral scutes in the region of the pelvic fins in the herring *Clupea pallasii*, ×6.

In the shad and thread-herring (Figs. 15 and 18) the dorsal processes of the scutes do not decrease in height abruptly behind the pelvics, but only decrease gradually in height and the scutes directly in front of the anus still retain long dorsal processes. The scutes are very strongly keeled, especially ahead of the pelvics, and the keels project downward so that the belly is more or less serrate. In the thread-herring the scutes are especially broad, heavy and strong. They are ankylosed together ventrally into a solid line along the abdomen and they form a strong support and protection for that region.

The following synoptic key will permit the separation of these fishes from other fishes, and from each other:

Synoptic Key to the Genera of Herring-Like Fishes of California

A. Isospondylous fishes with premaxillary small and restricted to anterior end of mouth; maxillary broad, forming most of upper edge of jaw, articulating by heavy condyle in a deep facet in the mesethmoid and ethmoid cartilage; at least one supramaxillary present, usually two; all four opercular bones present and well developed; temporal foramen present between parietal and frontal; metapterygoid strongly developed and broadly attached to the hyomandibular; mesocoracoid always present; post-temporal attached to epiotic and opisthotic bones by ligaments; seven circumorbital bones; epineurals, epicentrals and epipleurals strongly developed, the first and third present on all vertebrae and especially broad and strong over the caudal peduncle; air-bladder with duct; pseudobranchiae present; gill membranes separate and free from isthmus; no photophores; no scales on head; ovaries with oviducts.

Suborder Clupeoidei

B. Two supramaxillaries on each side; fifth circumorbital bone charteristically cut away antero-ventrally to fit around end of maxillary; hyomandibular with a single articular head articulating on both sphenotic and pterotic; metapterygoid firmly attached to hyomandibular, with no opening between the bones ventrally; posterior edge of preopercle rounded and narrow so that most of interopercle, and junction between subopercle and interopercle visible in lateral view; preopercle shaped like boomerang with a distinct anterior arm; gape small or medium, not reaching behind eye; glossohyal present but without teeth; suprabasal restricted to first basibranchial and not toothed; teeth found dorsally only on fourth gill arch; a median wing from basisphenoid descending to parasphenoid; a single postcleithrum present; ventral scutes present on all abdominal segments; myorhabdoi present or absent dorsally but never present ventrally over the anal fin; posterior haemal zygapophyses not projecting downward strongly on posterior abdominal vertebrae; pelvic fins under or ahead of dorsal, never behind it; belly somewhat constricted and often narrow and serrate, never smoothly rounded; anal fin moderately long, about like dorsal; adipose layer over eye with a narrow vertical slit over pupil.

Family Clupeidae

C. Vomer without teeth; prootic deeply indented posteriorly by auditory foramen; articular facets of hyomandibular on sphenotic and pterotic joined; anterior edge of fifth circumorbital bone slightly convex and bottom and posterior edges smoothly rounded; cartilage between metapterygoid and quadrate straight and narrow; posterior branchiostegal ray broadened but not scythe-like; opercle with a series of grooves on the external face radiating downward from the point of articulation; ventro-posterior corner of subopercle square-cut and the exposed surface of the bone roughly square; wing of bone in angle of preopercle about equally developed dorsally and ventrally and covering most of ventral end of hyomandibular; ventral edge of opercle rounded off posteriorly; anterior zygapophyses long, bulky, and closely applied to the preceding vertebra on caudal peduncle, usually at least half as long as preceding vertebra; zygapophyses of last centrum characteristically enlarged and clasped around preceding vertebra; anterior haemal zygapophyses not projecting strongly downward on posterior abdominal vertebrae; ventral scutes weakly keeled; behind pelvic insertion the dorsal extensions of the ventral scutes become abruptly shorter and smaller than on those ahead of the fins; no myorhabdoi found dorsally.

SARDINE *(Sardinops caerulea)*

CC. Anterior crest of vomer enlarged and bearing ten or eleven small, hooked teeth; posterior edge of prootic almost straight and only forming anterior edge of auditory foramen; articular facets of hyomandibular on sphenotic and pterotic joined; anterior edge of fifth circumorbital bone distinctly concave, with ventral and posterior edges evenly rounded; cartilage between metapterygoid and quadrate straight and narrow; posterior branchiostegal broadened but not scythe-like; lateral surface of opercle without grooves; ventro-posterior corner of subopercle evenly rounded and the bone higher than long; wing of bone in angle of preopercle with ventral part considerably larger than dorsal part; ventral edge of opercle sloping up sharply posteriorly; anterior zygapophyses small even over caudal peduncle, pointing upward and never as much as one-third as long as preceding vertebra; zygapophyses of last vertebra small and not strongly clasped around preceding vertebra; anterior haemal zygapophyses tiny on posterior abdominal vertebrae; ventral scutes thin and pliable, with practically no keel; dorsal extensions of ventral scutes becoming abruptly shorter and smaller behind the pelvic fin insertion; no myorhabdoi found dorsally.

HERRING *(Clupea pallasii)*

CCC. Vomer without teeth; posterior edge of prootic almost straight and only forming anterior edge of auditory foramen; articular facets of hyomandibular on sphenotic and pterotic entirely separate from each other; fifth circumorbital bone narrow and deep, coming to a point ventrally, and with the anterior edge not concave; metapterygoid and quadrate both deeply notched so that cartilage between them is expanded into a large oval pad; posterior branchiostegal ray broadened but not scythe-like; lateral surface of opercle with two or three shallow grooves; ventro-posterior corner of subopercle rounded but the bone longer than high; wing of bone in angle of preopercle with dorsal part much larger than ventral part; ventral edge of opercle nearly horizontal and a little concave; anterior zygapophyses of caudal vertebrae sloping upward away from preceding vertebrae to nearly always reach the neural spine of preceding vertebra; zygapophyses of last vertebra not strongly clasped around posterior end of preceding vertebra; anterior haemal zygapophyses not projecting strongly ventrally on posterior abdominal vertebra; ventral scutes with a sharp, strong keel; dorsal extensions of ventral scutes becoming gradually shorter behind pelvic fins, with processes of considerable size remaining on last scute before the anus; no myorhabdoi dorsally.

SHAD *(Alosa sapidissima)*

CCCC. Vomer without teeth; posterior edge of prootic almost straight and only forming anterior edge of auditory foramen; articular facets of hyomandibular on sphenotic and pterotic somewhat joined together; fifth circumorbital bone with anterior edge concave and ventral and posterior edges evenly rounded; cartilage between metapterygoid and quadrate straight and narrow; posterior branchiostegal ray broadened and scythe-like; lateral surface of opercle with a single, deep, almost tubular, groove parallel to anterior end of bone; ventro-posterior corner of subopercle nearly a right angle; wing of bone in angle of preopercle nearly absent so that ventral end of hyomandibular is exposed; ventral edge of opercle square cut and almost horizontal; anterior zygapophyses in caudal region strong and long, and closely hugging the preceding vertebra; zygapophyses of terminal vertebra not strongly clasped around preceding vertebra; anterior haemal zygapophyses projecting strongly downward on posterior abdominal vertebrae; ventral scutes heavy and strongly ankylosed together in a firm ventral line, bearing strong keels which have posteriorly projecting spines which make belly serrate; dorsal processes of ventral scutes broad and strong and becoming only gradually shorter behind the pelvic fins; myorhabdoi present dorsally both before and behind the dorsal fin.

THREAD-HERRING *(Opisthonema libertate)*

Abbreviations Used in Figures

AHZ	anterior haemal zygapophyses
AN	angular
ANZ	anterior neural zygapophyses
AR	articular
BR	branchiostegal ray
CB	circumorbital bone
CE	ceratohyal
CEN	centrum
D	dentary
EP	epihyal
H	hyomandibular
HS	haemal spine
I	interopercle
IN	interhyal
M	maxillary
MES	mesopterygoid
MET	metapterygoid
N	nasal
NS	neural spine
O	opercle
PAL	palatine
PM	premaxillary
POP	preopercle
PTE	pterygoid
Q	quadrate
SM	supramaxillary
SOP	subopercle
VS	ventral scute

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BLACK-SPOTTED TROUT IN BLUE LAKE, CALIFORNIA[1]

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Introduction

During the course of a study of the black-spotted trout (*Salmo clarkii henshawi*) in Upper Blue Lake, carried on during the summers of 1940 and 1941, rather complete records of the size, composition, and other characteristics of the spawning runs of these fish were collected. Additional information was obtained concerning the after-effects of spawning upon the adults, and the status of natural reproduction in the lake. It is the purpose of this paper to present and to discuss these data. A brief description of the lake is included to furnish the reader the necessary background. A full account of the results of limnological studies carried on at Blue Lake, together with considerable additional material concerning the trout, is contained in a thesis submitted to the School of Biological Sciences of Stanford University (Calhoun, 1942).

FIG. 20. Upper Blue Lake in winter.

The black-spotted trout was the native cutthroat of the Lahontan drainage system (Snyder, 1917). It has been introduced into numerous streams and barren lakes on the headwaters of the Mokelumne River, including Upper Blue Lake. Gill and Jordan (1878) first described the species from individuals collected at Lake Tahoe, as *Salmo henshawi*. Recent work (Schultz, 1934, 1936) has demonstrated that the subgroups within the cutthroat series can not legitimately be given the rank of full species. The black-spotted trout should accordingly be designated *Salmo clarkii henshawi*.

[1] Submitted for publication, October, 1943. This paper is based on work done under the auspices of the California State Division of Fish and Game, in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Stanford University.

Upper Blue Lake afforded an unusually favorable opportunity for studying the spawning runs of this trout. It presented the novel situation of an essentially pure stock, under almost virgin conditions, except for the affects of artificial propagation. The lake had been closed to fishing since 1934. Upstream traps on the tributaries made possible the accurate enumeration and study of the fish in the annual spawning migration. Moreover, the lake had been used in the past as an egg-taking station by the California Division of Fish and Game, and some information on the size of the spawning runs was available going back as far as 1934.

Description of Upper Blue Lake and Its Tributary Streams

Upper Blue Lake will for the sake of convenience hereafter be referred to simply as Blue Lake. Lying above Lower Blue Lake, it forms one of the headwaters of the North Fork of the Mokelumne River. It is located in Alpine County, California, 20 miles south of Lake Tahoe, at an elevation of 8,130 feet. It is about a mile long and half as wide,

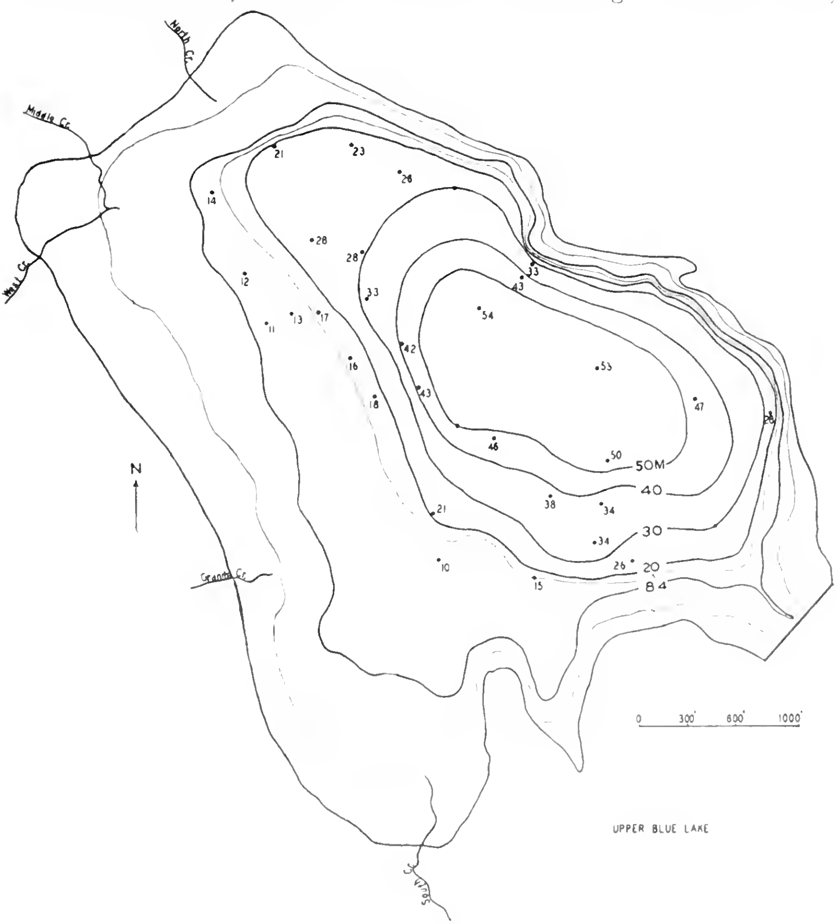

FIG. 21. Map of Upper Blue Lake, showing depths in meters

and has a surface area of 344 acres. The map of the lake (Fig. 21) shows the form of the basin by means of depth contours. Soundings are represented by dots, accompanied by the corresponding depths in meters. Contours shallower than 15 meters (49 feet) were traced from a map prepared in 1908 by the engineers of the Pacific Gas and Electric Company, before the water level was raised by a 30-foot dam across the outlet. The drainage basin of the lake comprises approximately 2.5 square miles. The climate of the region in which it lies is rigorous, and the lake is ordinarily frozen six months out of the year.

Blue Lake is highly and typically oligotrophic (oligotrophic lakes are poor in available dissolved nutritive material, and rich in dissolved oxygen; they are usually deep. *Cf.* Welch, 1935, p. 310). The water is clear. A Secchi disk is ordinarily visible to a depth of about nine meters (30 feet), and there is little variation in this respect during the summer. The development of thermal stratification during the summer of 1941 is illustrated in Figure 22, which shows a seasonal sequence of depth-temperature graphs extending over the period from June 23, when the ice melted from the lake, to September 13, when observations were discontinued. Figure 23 contains a corresponding series of graphs showing the relationship between depth and concentration of dissolved oxygen, as determined by the modified Winkler method (American Public Health Association, 1936), over the same period. Conditions in 1940 were essentially the same as those shown for 1941. In both years the thermocline became established at a depth between four and six meters (13 and 20 feet) some three weeks after the ice had melted from the lake, and was maintained throughout the summer, sinking progressively deeper, until by mid-September it lay in the neighborhood of ten meters (33 feet). The dissolved oxygen in the deeper hypolimnion was gradually depleted during the summer, but it did not at any time reach dangerously low concentrations for trout except in the late summer of 1940, and then only

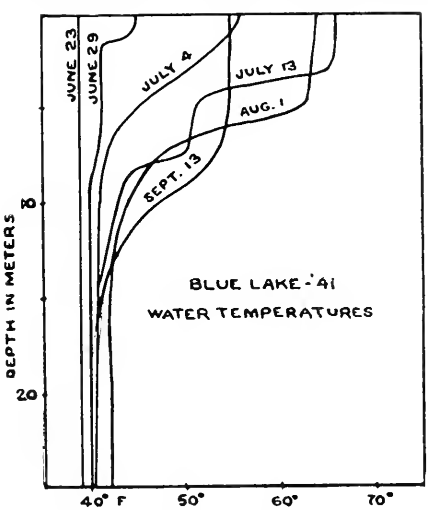

FIG. 22. Thermal stratification in Blue Lake, summer 1941.

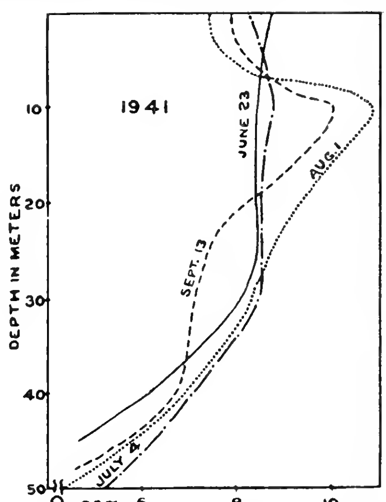

FIG. 23. Vertical distribution of dissolved oxygen in Blue Lake, summer 1941.

at depths greater than 40 meters (131 feet), where it fell to less than four parts per million. It is evident that neither lack of oxygen in the hypolimnion nor excessive temperatures in the epilimnion are of any significance as direct limiting factors of the trout population in Blue Lake.

Analysis of a large series of bottom samples collected during the summer of 1940 yielded an overall estimate for the lake of 134 pounds of organisms per acre, wet weight. This is a moderate amount for a lake of this sort. Chironomid larvae were the dominant organisms. No quantitative study of the plankton was attempted, but numerous hauls made in 1940 revealed it to be small in amount.

In early summer the trout ascend the five small tributaries of the lake to spawn. The locations of these tributaries are shown in Figure 21. West Creek is by far the most important in so far as the fish are concerned. More than half the run ascended this stream in 1940 and again in 1941. The first impassable barrier to their further passage upstream lies some 300 yards above its mouth. The stream bed, of coarse, unconsolidated sand, is only 2 to 4 feet wide. The four other creeks are even smaller than West Creek. Granite Creek drops into the lake over a scarp, and is inaccessible from its very mouth. The other three present impassable barriers two, or at the most three hundred yards above their mouths.

Description of the Spawning Runs at Blue Lake

Each year, from 1934 to 1941 inclusive, the fish in the annual spawning migration were taken in permanent traps located near the mouths of each of the streams tributary to Blue Lake. Prior to 1938 the trapping was carried on by hatcherymen for egg-collecting purposes, and the records which they kept are limited to notations in log books as to the number of fish "spawned," i.e., stripped of their eggs or milt. In 1938, the warden stationed at the lake began to keep a count of the number of fish of each sex trapped each day during the run. These observations were continued in 1939, and a series of measurements and scale samples was taken as well. In addition, the fish trapped that year were marked by removal of the adipose fin before they were returned to the lake. The collecting of eggs for purposes of artificial propagation ceased with that year. My work began with the 1940 run, and was continued in 1941. In 1940, each fish trapped was measured and marked, and its sex was determined, before it was released upstream to spawn. In 1941 all fish were again marked, and their sex determined, and a large part of the run (68 per cent) was measured.

In the four years for which there is information on the subject, the time at which the run began corresponded closely to the time of final melting of the ice. In 1938, which was a very late year, the fish began to enter the creeks on June 27, a week before the ice was gone. In 1939, an exceptionally early year, the ice melted May 11, and the run began May 17. In 1940 the first fish were trapped June 11, just one day after the ice was gone, as compared to two days before (June 20) in 1941. The graphs in Figure 24 show the numbers of fish ascending the creeks daily during the runs in the four years, 1938-1941. The numbers of females are shown by dotted lines, and the numbers of males, by solid lines. The runs of 1939, 1940, and 1941 display a common pattern. The 1938 run was quite unlike the other three, for no apparent reason.

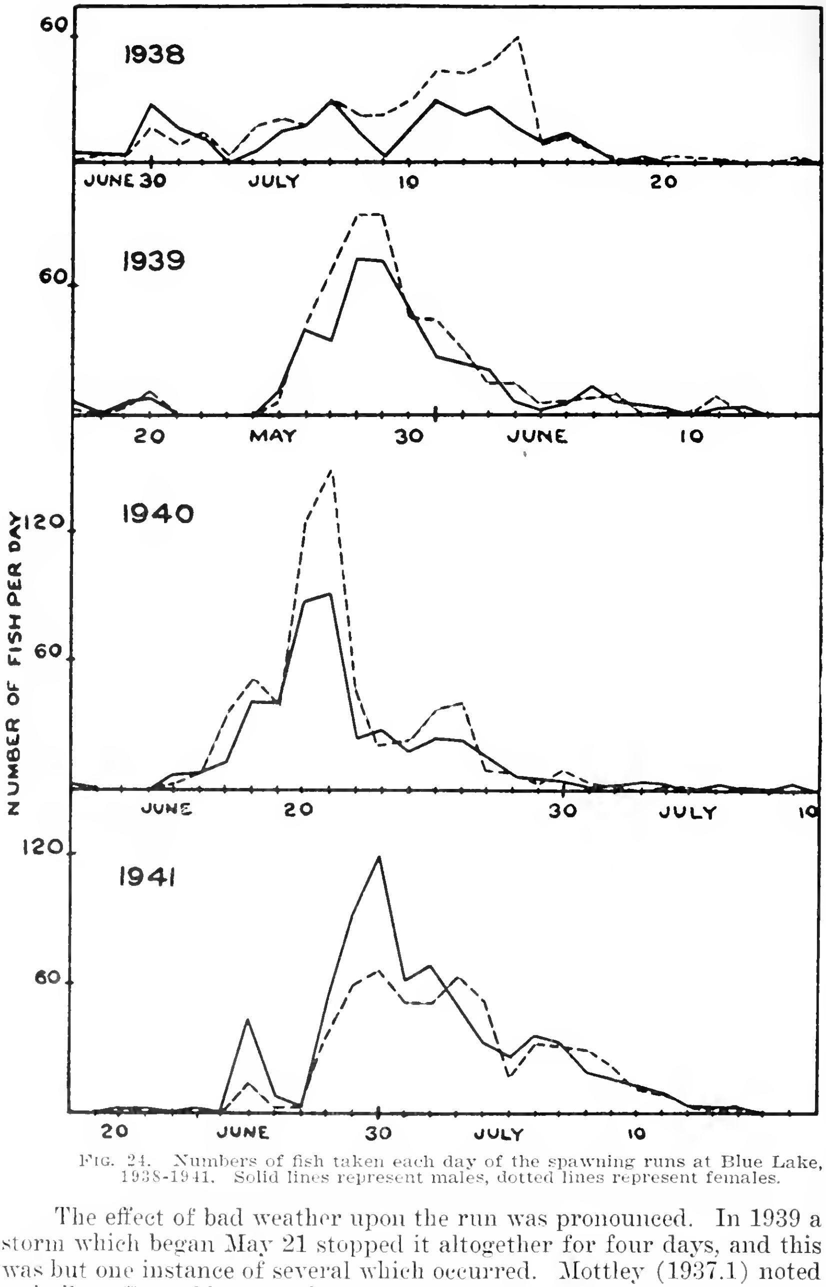

FIG. 24. Numbers of fish taken each day of the spawning runs at Blue Lake, 1938-1941. Solid lines represent males, dotted lines represent females.

The effect of bad weather upon the run was pronounced. In 1939 a storm which began May 21 stopped it altogether for four days, and this was but one instance of several which occurred. Mottley (1937.1) noted a similar effect of bad weather upon the runs of Kamloops trout at Paul Lake.

The spawning behavior of the black-spotted trout has been described. (Smith, 1941).

Number, Size and Age of Trout in the Spawning Runs

The numbers of fish ascending the creeks to spawn each year from 1934 to 1941, inclusive, in so far as known, are shown in Table 1. It has been pointed out that the only information available concerning spawning runs before 1938 is the number of trout "spawned" by the hatcherymen. This represents a fairly reliable record of the actual number of fish in the case of females, but not in the case of males, which may be "spawned" a number of times before being released. The erratic behavior of the sex ratios where they are known (Table 1) precludes any possibility of estimating accurately the number of spawning males on the basis of the number of females "spawned" in these years. This explains why only the numbers of females are given for years before 1938 in Table 1.

TABLE 1

Size of Spawning Runs at Blue Lake

Year	*Number Males*	*Number Females*	*Total*	*Ratio: Females/Males*
1934	---	815	----	---
1935	---	971	----	---
1936	---	376	----	---
1937	---	476	----	---
1938	284	422	706	1.49
1939	424	509	933	1.20
1940	455	612	1,067	1.35
1941	688	557	1,245	.81

TABLE 2

Lengths of Spawning Fish

Year	*Sex*	*Number*	*Mean length in cm.**	*Standard Deviation*
1939	male	124	38.6	2.31
	female	210	37.9	3.09
1940	male	448	37.5	2.57
	female	586	35.7	2.45
1941	male	527	36.9	2.36
	female	358	35.6	2.17

* 1 in.=2.54 cm.

Mean lengths of representative series of trout from the 1939, 1940 and 1941 spawning runs are given in Table 2. The length used was the distance from the tip of the snout to the fork of the tail, read to the next largest centimeter. The mean lengths of the spawners [2] varied from 38.6 to 36.9 cm. (15¼ in. to 14½ in.) in the case of the males, and from 37.9 to 35.6 cm. (15 in. to 14 in.) in the case of the females.

Studies of scales indicated that there was a general uniformity in the age of spawners in 1939 and 1940, with nearly all fish having spent four winters in the lake. Results from reading scales from 259 trout spawning in 1939 and from 94 spawning in 1940 are given in Table 3. These readings were founded on a study of representative series of trout of all ages (Calhoun, 1942).

[2] "Spawner", for convenience, refers to both females and males in the spawning run.

TABLE 3
Age of Spawning Fish from Scale Readings

Year	Size of sample	3 years Number	3 years Per cent of run	4 years Number	4 years Per cent of run	5 years Number	5 years Per cent of run
1939	83 males	0	0	72	86.8	11	13.2
	176 females	0	0	163	92.6	13	7.4
1940	48 males	1	2.1	44	91.8	3	6.2
	46 females	1	2.2	42	91.4	3	6.5

The photographs in Figure 25 illustrate the nature of the scales and the manner in which they were interpreted. They represent scales typical of 1-, 2- and 3-year immature trout and of a 4-year "ripe" fish.

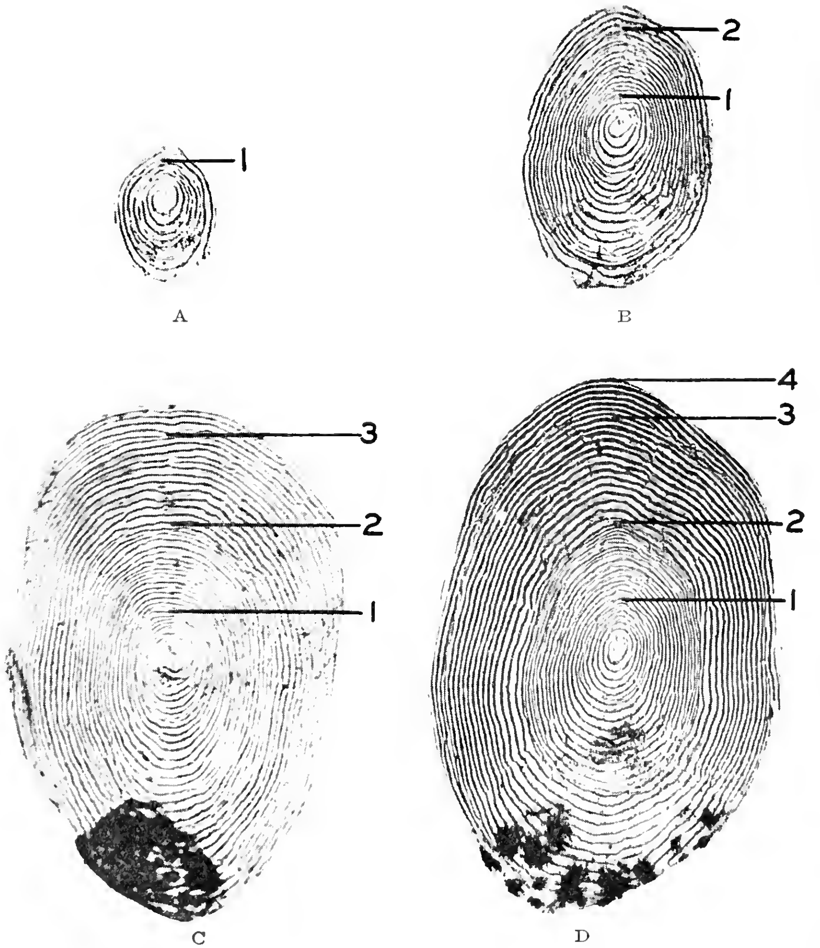

FIG. 25. Photographs of typical scales from Blue Lake trout. (×30). A, $2\frac{7}{8}$ in. long, 1 year completed and 2d growing season started; B, $7\frac{1}{2}$ in. long, 2 years completed and 3d growing season started; C, $15\frac{1}{2}$ in. long, 3 years completed and 4th growing season started; D, $14\frac{1}{4}$ in. long, ripe female at end of 4th year. Guide lines indicate annuli.

It must be pointed out that the determinations in Table 3 do not indicate true age in all instances. What they actually represent is age at first spawning. The reason for this is that these trout do not grow appreciably after they have once spawned, as will be shown, with the result that scales reveal nothing beyond the time of first spawning. However, the importance of this discrepancy is minimized by the fact that by far the greater part of the runs were composed of fish spawning for the first time, in 1940 and 1941 at least.

All 625 trout trapped in the 1939 spawning run were marked by clipping off the adipose fin, and then released. All 700 trout trapped in the 1940 run were marked by clipping off two other fins. Fish that had been trapped in either year could thus henceforth be recognized if captured or trapped again. The number of such marked fish which reappeared in subsequent runs were surprisingly small. In 1940, when a single preceding run had been marked, only 3.1 per cent of the fish running were found to be marked, as compared with 7.9 per cent in 1941, when two preceding runs had been marked. The actual figures are given in Table 4. These data leave no question that the vast majority of the

TABLE 4

Relative Numbers of Marked and Unmarked Trout in the 1940 and 1941 Spawning Runs at Blue Lake

Spawning run of	*Number of unmarked fish in run*	*Number of fish bearing 1939 mark*	*Number of fish bearing 1940 mark*	*Total run*	*Per cent of previously marked fish in run*
1940	1,034	33	--	1,067	3.1%
1941	1,147	54	44	1,245	7.9%

fish in the 1940 and 1941 runs were young ones spawning for the first time, although the situation is perhaps less extreme than they would indicate. For one thing, an occasional unmarked female was found to contain partially resorbed eggs,[3] proving that she had spawned previously. In addition, there must have been at least a few old trout which had spawned the first time before marking was initiated, although their presence in any considerable numbers need not be considered seriously in the light of the severe after-effects of spawning upon the fish, to be discussed. Another element is of more concern. It consists of fish which ripened for the first time in some previous year, but failed to ascend a creek, and, as a result, were not marked. Such fish, if they spawned again, although suggesting by their condition (to be discussed) that they were repeat-spawners, could not be definitely classified as such unless they contained old eggs. Initially it had seemed reasonable to assume that almost all ripe fish would ascend one or another of the creeks to spawn. To check this point, fishing was carried on in 1940 and 1941 during the latter half of the spawning run, and continued through the rest of the summer. It was anticipated that the percentage of ripe,[4] unmarked trout

[3] Eggs not voided appeared normal during the summer of the year in which they matured, but in subsequent years they shrank and became quite abnormal in appearance, so that they could be readily differentiated from eggs of the year.

[4] The term "ripe" is used in this discussion for any fish which matured sexually in the spring of the year in which it was caught.

in the catch (i.e., those which had matured sexually in the spring of the year in which they were captured, but had not ascended a creek, and therefore had not been marked or counted as being in the spawning run of the current year) would fall from an initially high level while the run was still in progress to practically zero after the run was over. Such fish were readily recognizable, even in late summer, by virtue of their unique coloration. This was essentially what happened in 1940. As shown in

TABLE 5

Changes in the Percentage of Ripe, Unmarked Fish Caught in the Lake in 1940

Time of capture	*Total catch*	*Number ripe * unmarked*	*Per cent ripe unmarked*
June 22-July 9	57	7	12.3
July 10-July 22	56	6	10.7
July 23-September 19	138	1	0.7

TABLE 6

Changes in the Percentage of Ripe, Unmarked Fish Caught in the Lake in 1941

Time of capture	*Total catch*	*Number ripe * unmarked*	*Per cent ripe unmarked*
June 29-July 10	50	20	40.0
July 11-July 19	49	11	22.5
July 20-August 2	62	24	39.0
August 3-September 16	98	16	16.4

* The term "ripe" is used here and in the accompanying discussion for any fish which matured sexually in the spring of the year in which it was caught.

Table 5, the percentage of such fish fell from 12.3 per cent of the catch during the latter half of the spawning run (June 22-July 9; see Figure 24 in this connection) to less than 1 per cent in the latter half of the summer. In fact, only one ripe, unmarked fish was taken during almost two months of the late summer, out of a total of 138. The catch consisted of fish over 27 cm. in length, below which size none spawn. In 1941, on the other hand, the situation was altogether different. Fish which had ripened that spring but had no mark and therefore had not been trapped in the creek mouths formed a considerable element of the catch during the entire summer, as shown in Table 6. It is quite evident that a significant portion of the fish maturing in 1941 did not migrate into the streams. The apparent failure of the fish to spawn in the lake itself, which will be discussed, renders this all the more surprising.

It should be emphasized that the exceptions which have been mentioned do not by any means invalidate the conclusion that the great majority of the fish in the 1940 and 1941 runs were spawning for the first time, but they do modify the very extreme situation represented by the data in Table 4. Further substantiation for the belief that most of the fish actually were first-time spawners lies in their appearance. Unmarked spawners were uniformly in good condition, firm-fleshed and brightly colored, while marked fish spawning for the second time were characteristically emaciated, soft-fleshed, and dark. It is particularly significant that unmarked fish in poor condition were not present in appreciable numbers. Repeat spawners never previously marked would have been expected to fall into this latter category.

The Effects of Spawning Upon the Fish

Observations of fish which were marked at the time they spawned, then released, and later recaptured, yielded unanticipated results. Such trout failed to grow after spawning. They were in markedly poorer condition than immature fish of the same length, either when caught in the lake in subsequent summers or when trapped in later spawning runs. Few such fish actually reappeared in the spawning runs, and, of those which did, the females produced relatively few eggs compared to those spawning for the first time.

As already stated, all spent spawners returned to the lake in 1939, 1940 and 1941 were marked by having fins clipped. The lengths of fish in these runs are known, from measurements of adequate samples (Table 2). Surprisingly enough, the mean lengths of the fish in the 1939 run did not differ significantly from the mean lengths of the samples of these same fish recaptured later, even after an interval of two years. The means and standard deviations of the lengths for this series of samples are given in Table 7. The first column indicates the origin and time of

TABLE 7

Lengths of Trout Marked in the 1939 Spawning Run and Recaptured Later in the Lake

When measured	*Interval in months between release and recapture*	*Sex*	*Number*	*Mean length in cm.*	*Standard deviation*
At time of marking in 1939 run	0	male	124	38.6	2.31
		female	210	37.9	3.09
1940 run	12	male	7	38.1	--
		female	26	37.3	2.77
1940 catch	14	both	24	37.8	2.92
1941 run	24	male	18	37.0	2.00
		female	8	36.1	--
1941 catch	26	both	15	37.3	2.40

The word "run" in the first column designates fish trapped in the spawning migration; the word "catch," those taken in the lake during the summer months of the year indicated, by angling or with a gill net.

capture of the samples. These data show conclusively that marked spawners taken as a group did not grow appreciably after they had spawned. Corresponding measurements of fish marked in the 1940 run and recaptured during 1941 presented an identical picture. Further corroboration is provided by measurements of a few tagged fish. A number of spent spawners was tagged in 1940, using numbered celluloid disks. These were held on each side of the back just beneath the dorsal fin, by means of a nickel pin run through the body of the fish. (See Clark and Hatton, 1942, for a fuller description of this method.) Four of these marked fish were recaptured in 1941, three in the spawning run and one in the lake. None had grown measurably in the year between marking and recapture.

All fish caught in the lake in 1940 were routinely weighed and measured. It soon became apparent from these observations that marked fish weighed consistently less than unmarked ones of the same length. In order to find out if this was generally the case, all marked fish in the 1941 spawning run were measured and weighed, except in a few instances where conditions in the field made their handling impracticable. A sample of unmarked spawners was weighed for comparison. Figure 26

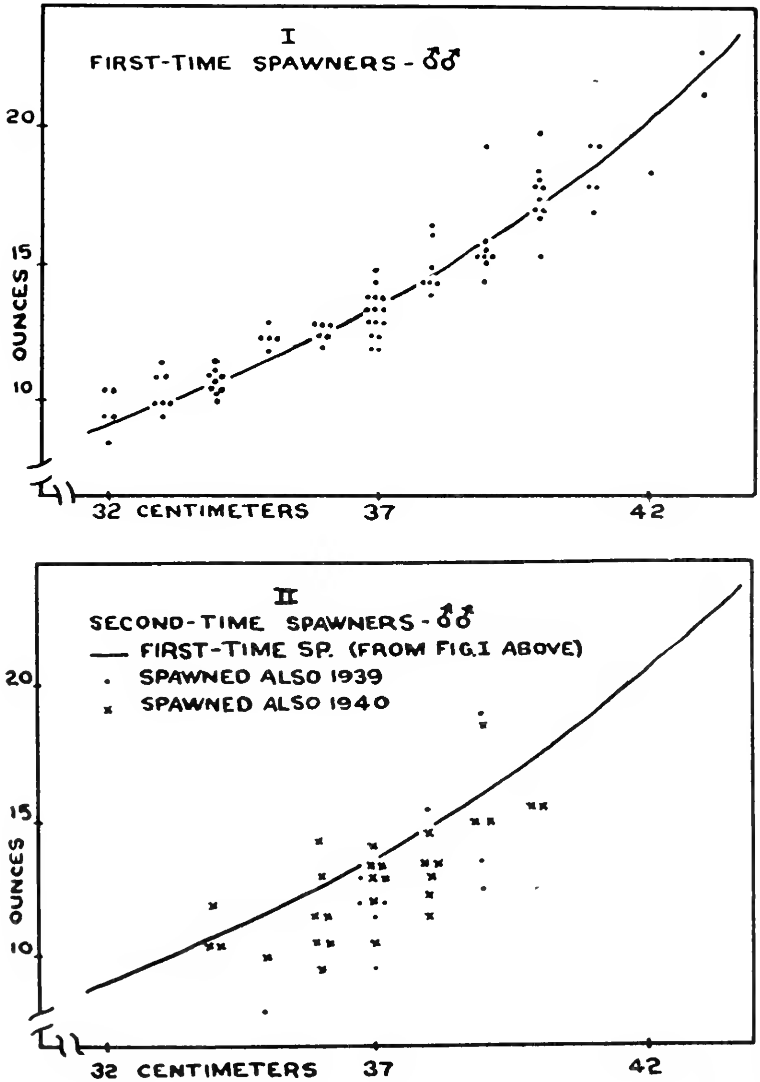

FIG. 26. Length-weight relationships in marked and unmarked (i.e., first- and second-time) male spawners in the 1941 run.

shows these data for males, and females do not differ appreciably. The single points represent the weights and lengths of individual fish. The solid line in the top graph is the trend, drawn "by eye". It has been transferred directly to the bottom graph to facilitate comparison of the marked and unmarked fish. It will be seen that the weights of the marked fish fall below this trend consistently. Moreover, the lower limit of the range in weight for fish of a given length is characteristically much lower in the case of marked than of unmarked fish. In the 1941 spawning run, second-time spawners were frequently so emaciated that they could be recognized at a glance while they were still in the dip net. The same poor condition was a consistent characteristic of unripe, marked fish caught in the lake during the summer. Such individuals frequently had atrophied gonads.

TABLE 8

Numbers of Fish Spawning a Second Time

Year marked	*Number marked*	*In run one year later*		*In run two years later*	
		Number	*% Original*	*Number*	*% Original*
1939	625	33	5.3	54	8.7
1940	700	44	6.3	--	--

It has been shown that most of the fish in the spawning runs of 1940 and 1941 were spawning for the first time. In other words, the numbers of fish which spawn a second time are not great. This is further brought out in Table 8, which follows the reappearance in the spawning runs of trout from among the original 625 marked in 1939 and the 700 marked in 1940. Of those marked in 1939, only 87, corresponding to 14 per cent, had reappeared within two years. Only 6.3 per cent of those marked in 1940 reappeared in the 1941 run.

In order to determine how females spawning for the second time compared in egg production with those spawning for the first time, egg counts were made on a number of fish in the 1941 run. Fifty-five unmarked females (first-spawners) of representative lengths were selected at random, to provide an index of normal egg production of young trout spawning for the first time. Eggs of all marked females (repeat spawners) were counted, except in a few instances where it was not practicable to do so; the number so counted was 38.

The method was as follows. The fish was opened, and all eggs were removed. A sample of 50 eggs was counted, and its volume determined by the displacement of water in a 10 c.c. graduate. The volume of the remaining eggs was found in an identical manner, using a 200 c.c. graduate. The total number of eggs could then be readily computed. Actual counts on several females checked with the number arrived at by this method within 5 per cent. When partially resorbed eggs were present in marked females, they were discounted. The number in a random sample of fifty eggs was found, and the total was corrected accordingly.

The data for number of eggs have been plotted in Figure 27. The top graph shows the numbers produced by the 55 unmarked individuals; the bottom one shows the numbers produced by the 38 which were marked. Each point represents the number of eggs in an individual fish. The solid line in the top graph is the trend, drawn "by eye", and it has been transferred directly to the bottom graph. A similar treatment of the

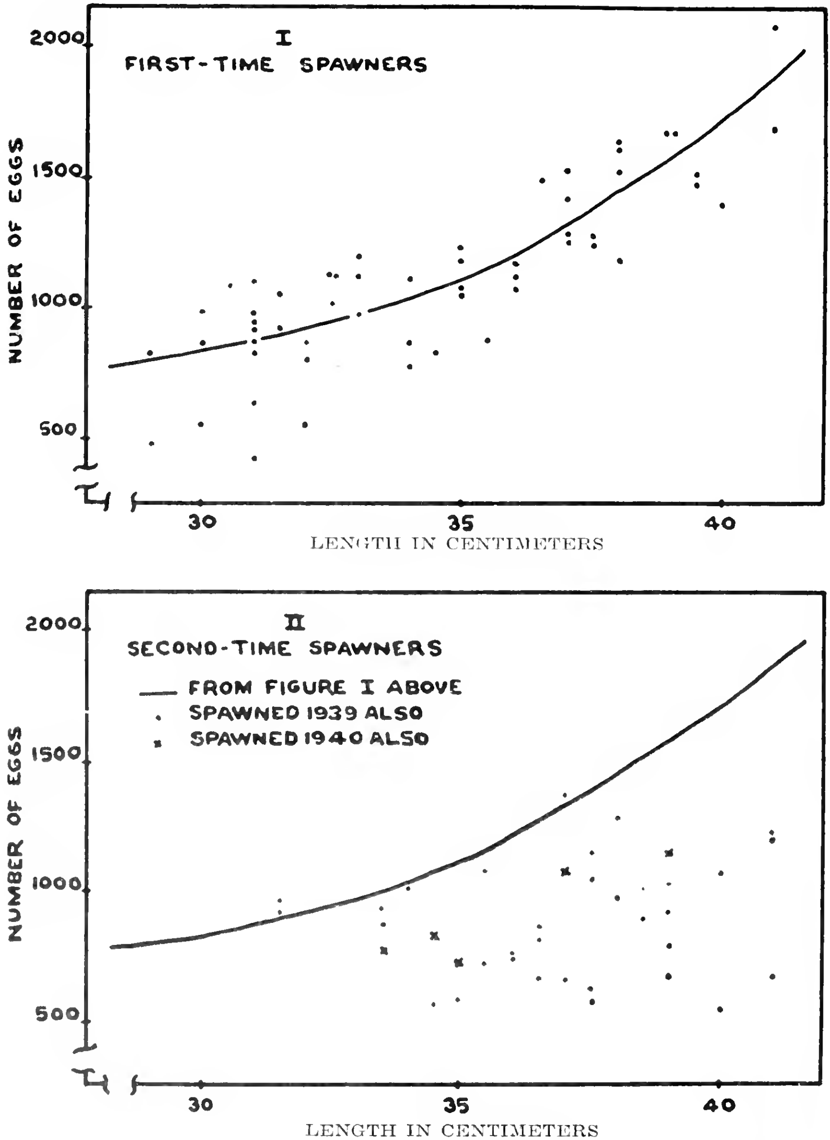

FIG. 27. Numbers of eggs produced by first- and second-time spawners in the 1941 run at Blue Lake.

figures for the volume of eggs gives an identical picture. It is evident that marked fish fall consistently below unmarked fish in the numbers of eggs produced, and this is equally true of volume.

What is the explanation for this general failure on the part of Blue Lake cutthroats to recover from spawning? A number of factors appear to contribute. To begin with, ripe fish which are about to spawn averaged lighter in weight by about 2½ ounces than immature fish of the same length. The length-weight relationship of immature fish caught in the lake was found to be

$$W = .000234\ L^{3.086}$$

where W is weight in ounces and L is length in centimeters. This equation was derived from the regression of log weight on log length (for method see Snedecor, 1938, p. 102), based on measurements of 287 trout ranging in length from 15 to 43 cm. (6 to 17 in.). When this equation is plotted alongside the weight-length curves of males and females spawning for the first time (Fig. 26 for females and a similar curve for males), it parallels them about 2½ ounces above them. From this it can be concluded that the trout have already expended their stored food reserves to a considerable extent by the time they are ready to spawn. This was further borne out by an examination of a number of fish caught early in the spring of 1941, before the run began. Large fat bodies were present in all immature fish, but they were uniformly absent in all ripe ones. The stomachs of these same ripe fish contained little food, almost without exception, in marked contrast to those of the young trout, which were typically gorged. Thus the ripened fish, having exhausted their stored food reserves in the process of gonadal development, go one step further and fail to take advantage of a period of great abundance of food in the lake. The period of active spawning in the streams, without feeding, together with the actual discharge of eggs or sperm, results in a further loss in weight. Mottley (1937.2) found such losses during spawning to be 16.7 per cent and 25.3 per cent of the original body weight for males and females, respectively, in the case of Kamloops trout in Paul Lake.

Examinations of large series of stomachs suggested late summer and fall to be times of low food availability in Blue Lake. This being the case, fish returning to the lake after spawning will have small opportunity to build up food reserves to tide them over the winter, when the lake is frozen for six months. Failure to recover subsequently may be further attributed to a lack of food suitable for *large* fish. Observations over a longer period of time would be required to determine the importance of overcrowding as a contributing factor. Certain evidence which suggests a developing overpopulation is presented in the discussion at the end of the paper. Whether or not this particular form of trout may have a genetic tendency approaching the condition in the species of Pacific salmon, which invariably die after they have spawned, is another question. Observations in other lakes, where conditions for recovery are less adverse, would help to clarify this point.

Natural and Artificial Propagation of Blue Lake Trout

Judging from available accounts, Blue Lake produced large trout in considerable numbers before any stocking program was instigated. Indications are that the population was able to maintain itself at a rather high level for many years under conditions of light fishing. The lake was closed to fishing in 1934. The first recorded stocking of cutthroat trout was made in that same year from stock reared from eggs collected at the lake that same spring. Fifty thousand or more small fingerlings have been introduced annually since 1934, as shown in Table 9. There is no record of the original introduction of the trout into the lake.

TABLE 9

Stocking Record for Upper Blue Lake, Black-spotted Trout

Date	*Planted*	*Number*	*Size in number per ounce*
1934	August 22-27	90,000	55
1935	September 10	100,000	80
1936	September 13	100,000	110
1937	September 13	75,000	70
1938	October 3	81,000	60
1939		50,000	46
1940	late August	50,000	50
1941	late August	50,000	60

The five streams flowing into Blue Lake do not begin to provide adequate spawning facilities for the trout population currently present. They are small and shallow. They are accessible to the fish only for short distances above their mouths. The bottom materials in West and Middle creeks, up which most of the fish migrate, are generally unsuitable for spawning, being coarse, unconsolidated granitic sand (*cf.* Hobbs, 1940, p. 49). South Creek and North Creek dry up in their lower stretches in late summer, with the result that the fry in them are unable to migrate into the lake. Granite Creek is inaccessible from its very mouth. All the streams become very much reduced in size in late summer.

In 1940 a careful watch of the creeks was kept for emerging fry. The first ones were seen below the trap in West Creek on August 15. A downstream trap was installed near the mouth of the stream the next day, in order that a record of the migration into the lake could be obtained. This record is given in Table 10. In a period of slightly less than a month, only 25 fry were taken. Examination of the entire length of the creek accessible to fish above the trap indicated an almost complete absence of fry. More than 500 spawners ascended West Creek in 1940, and the resulting reproduction must have been singularly low.

TABLE 10

Fry Trapped in the Downstream Migrations in West Creek in 1940 and 1941 and in Middle Creek in 1941

Period	*West Creek 1940*	*West Creek 1941*	*Middle Creek 1941*
August 17-23	16	0	0
August 24-30	2	0	0
August 31—September 6	4	7	2
September 7-12	3	2	44
September 14-16	0	0	14

None of the fry which emerged in North Creek reached the lake, because that stream dried up at its mouth in mid-summer, and the drying progressed upstream. Eventually all pools in which fry had been seen dried up completely. South Creek also dried up at its source, but some of the fry may have survived, for the drying did not progress upstream as had been the case in North Creek. Only two fry were ever seen in Middle Creek. All in all, reproduction in the streams in 1940 appears to have been most unsuccessful.

Certain features of the downstream trap installed in West Creek in 1940 made it appear unsatisfactory. It had been installed after fry were observed below the trap, so that it obviously had missed a part of the migration. It overflowed when the stream was high for a short while following several rainstorms, and the possibility that fry migrated downstream at such times could not be overlooked. To check these points, and to provide confirmation of the extremely low level of reproduction indicated for West Creek in 1940, traps were so built in 1941 that no overflow was possible, and they were installed August 13, in both West and Middle creeks. The first fry were not trapped until over two weeks had passed, giving good reason to believe that none passed downstream before the traps were in place. The entire cross-section of the trap boxes through which the streams flowed was screened with fine-meshed window screen. At no time during the period of observation did the water reach the tops of the screens, so there was no overflow. The record of the numbers of fry trapped is given in Table 12. Only 9 fry were trapped in West Creek, and only 60 in Middle Creek. The traps had to be dismantled September 16, when work at the lake was discontinued for the summer, but there seems little reason to believe that any great numbers would have appeared subsequently. None at all had been taken in West Creek during the preceding five days. None was seen above the traps in either West or Middle creeks at the time the traps were dismantled.

There can be little question that natural reproduction in the creeks was singularly unsuccessful in 1940 and in 1941.

The question whether or not trout are able to spawn successfully in the actual bodies of lakes is of great interest, from a lake management point of view. There is no little difficulty in proving that such spawning does *not* occur. The available evidence indicates that the trout probably do not spawn at all within Blue Lake. In the first place, the bottom of the lake is generally unsuitable for spawning, and it is improbable that eggs could develop there even if they were deposited and fertilized. It is a gravelly soil, containing considerable humus. Any agitation raises clouds of silt in the water. A few hundred eggs were planted at a depth of about three inches in shallow water in three places around the shore of the lake, and all were dead on recovery a month later. Controls underwent normal development. While this can by no means be considered proof that the fish themselves are unable to deposit eggs at certain places in the lake in such a manner that they will develop, at the same time it does verify the generally unfavorable nature of the lake bottom.

No trout were ever seen spawning in the lake. This again can not be considered proof that they do not do so. If subsurface springs exist along the short stretch of clean talus on the east shore of the lake, spawning might conceivably have some chance of success.

Other evidence from an entirely different source indicates that the trout not only do not spawn in the lake, but that they do not even release their eggs if they fail to spawn in a creek. It arises from an examination of the female spawners of the year caught in the lake in 1941 after the spawning run was over. Twenty such females which were unmarked, i.e., had not ascended a creek, were caught during the summer of 1941 after the run was over. Of the 20, 16 still contained their full complement of eggs, two still contained several hundred, another had about one hundred, and one did not contain any eggs. Spawning in the creek mouths below the traps might well account for the four which were more or less spawned-out. Spawning activity was seen there. The question of distinguishing between unmarked fish which had ripened in the spring of the year and voided their eggs and sexually immature females is pertinent. Actually, there is no difficulty, for the former have a characteristic appearance which is unmistakable, compounded largely of their poor condition, soft flesh, and faded and darkened spawning coloration. In sharp contrast, immature trout are fat, firm-fleshed, and brilliant silver in color.

Discussion

Certain implications of the findings which have already been discussed are worthy of further attention. It will be recalled that Blue Lake was closed to fishing in 1934, and that it was then planted heavily each succeeding year, with the idea in mind of establishing and maintaining as large an egg-producing population as the lake could support. There is good reason to believe that this program actually defeated its purpose and resulted instead in a slight overpopulation of the lake, with a reduction in the size of the spawning fish, and a mild depletion of the food supply. There was certainly no increase in the numbers of fish in the spawning runs over the period in which the lake was closed and planted heavily. As was shown in Table 1, the number of females spawning in 1934 was actually greater than in subsequent years, with the exception of 1935, and the relatively large size of that year's run probably resulted from the removal of fishing pressure during the summer of 1934 on the age group that spawned in 1935. There is indirect evidence that the fish decreased progressively in size from 1934 to 1941, at the same time that the numbers spawning failed to increase. The hatcheryman in charge of spawning operations during and before 1939 maintained that fish in earlier years were larger than they were in 1940 and 1941. This, taken with the small but significant decrease in the average lengths of the spawners which took place from 1939 to 1941, for which years adequate data are available, is indicative of a progressive decrease in the trout's size at maturity. The decrease in the range of the lengths from 1939 to 1941 was much more pronounced than the decrease in the mean (Table 2 and Figure 28), and reflects a constriction of the right-hand tail of the length-frequency distribution of the spawners, year by year, as shown in Figure 28. The year by year decrease in the numbers of fish in the higher length groups is very apparent in these graphs. It is probable that this decrease is, in turn, a reflection of a gradually developing overpopulation beginning to restrict the maximum growth attained by the fish before they spawn, and perhaps afterwards. It is of interest to note that fish of the same strain in nearby Heenan Lake, in which food is extremely abundant, are much larger at the time of spawning. The bottom graph in Figure 28 represents a series of measurements of spawning fish trapped at Heenan Lake in 1941. The very great difference in the length of trout at maturity in the two lakes must be entirely environmental in origin, for Heenan Lake is artificial and of recent origin, and it was planted with trout reared from eggs collected at Blue Lake.

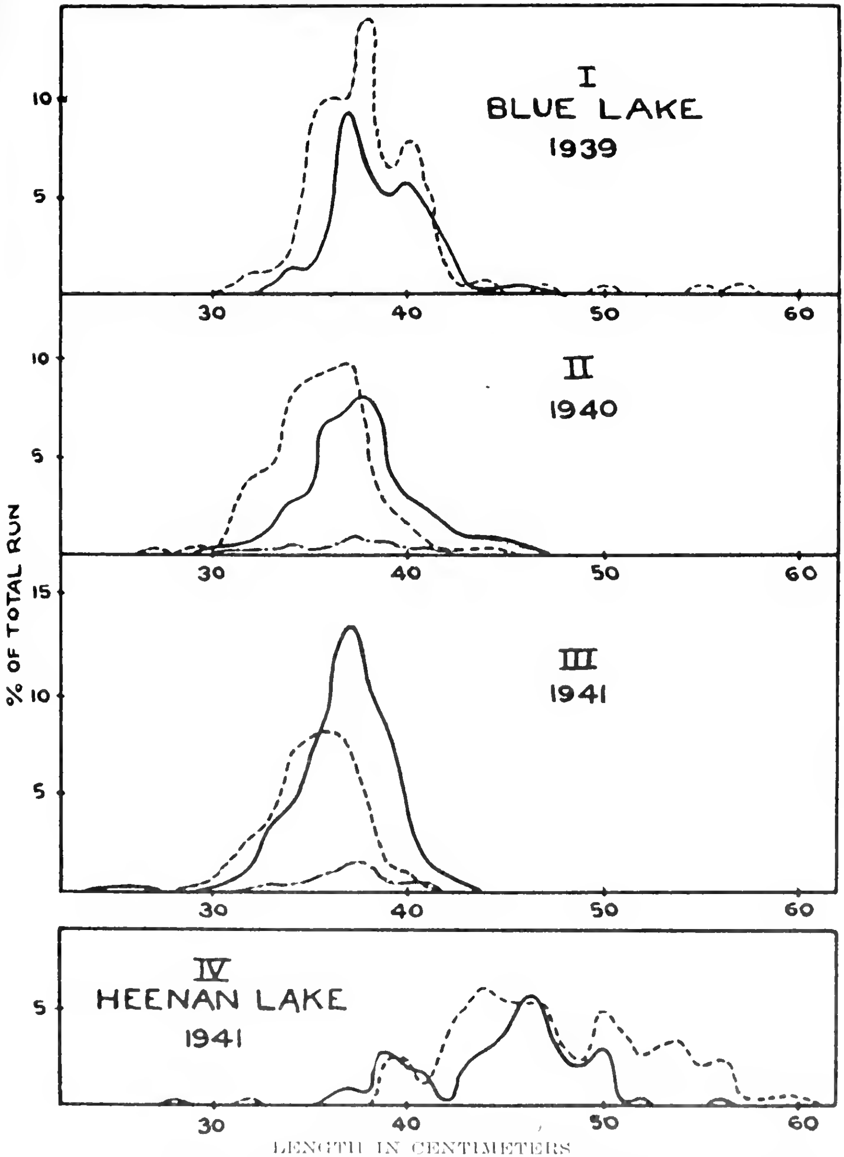

FIG. 28. Length frequency distribution of Blue Lake spawners in three years, with a series from Heenan Lake for comparison. Solid line, males; dotted line, females; broken line marked fish spawning a second time.

Available food for trout in Blue Lake has probably decreased in amount during the last few years. Several hatcherymen who visited the lake while I was there commented on the scarcity of *Gammarus* and caddice fly larvae, which they remembered to have been present around the shore in great numbers in past years. It is entirely possible, of course, that factors other than overfeeding by the trout—such as more rapid annual draw-down of the water for power use in recent years—may have reduced the numbers of food organisms present, but whatever the explanation, it is quite apparent that by 1941 a condition of incipient overpopulation was developing in the lake. The fact that immature fish caught in the lake were in excellent condition, in marked contrast to those which had spawned once, indicated that it was not extreme.

Had Blue Lake been maintained as an egg-collecting station, some radical departure from the management plan that was being followed would have been necessary. However, since the lake has been opened to fishing (1942), and will certainly be heavily fished, the problem of overstocking will take care of itself in short order.

Certain suggestions regarding the management of other mountain lakes reserved for the taking of trout eggs can be formulated on the basis of the observations made at Blue Lake. First of all, accurate data on the size of the run and the size and condition of the spawning fish are extremely valuable as an index of what is happening to the population, and can usually be obtained readily in conjunction with the regular spawning routine. Whenever there is evidence of overpopulation, as shown by a progressive decrease in the length and/or a decline in the condition of the spawning trout, it will be undesirable to return the fish to the lake after they have been stripped. Even in the absence of overcrowding it may be poor practice to return such fish to the lake, and this will be a point worth determining, by marking experiments designed to see if their return is justified on the basis of the numbers of eggs they contribute to later spawning runs balanced against the competition with young trout for food, and the possibility of serious predation upon fry. The closure of egg-taking lakes to fishing, coupled with heavy planting, lays them open to the ready development of a large population of stunted fish in a lake depleted of its food supply. Every effort should be made to prevent such a situation from arising, through control of the stocking policy, based on continual observation of the state of the population.

There will be numerous questions of management to answer now that Blue Lake has been opened to fishing. It is evident that natural propagation can not be counted upon to maintain the population at a high level under existing conditions. But just how many trout should be planted, when, and at what size to get the most trout into angler's creel at the least cost? These are difficult questions, and their answers will come only from trial and error coupled with accurate observations, in future years. It is nevertheless apparent that the introduction into the lake of from 50,000 to 100,000 small fingerlings in the fall, as has been done in the past, must be a wasteful procedure. Feeding conditions around the shore of the lake were notably poor at this season, and the fingerlings must compete with a horde of minnows of their own size (*Rhinichthys oscula*) for what little food is available. There are unfortunately no hatchery facilities available for carrying the fingerlings through the winter, and if cutthroat are to be introduced, they must be planted in the fall of the year while they are still quite small. The desirability of introducing fewer, larger fish, in the spring of the year can not be questioned, but this would require either the establishment of an all-year hatchery for the rearing of cutthroats in the Blue Lake region, or a change in the species planted. Of these two alternatives, the former is by all odds the more desirable, if for no other reason than that the waters of Alpine County constitute the last stand of the black-spotted trout, a unique and attractive fish, and every effort should be made to preserve it in this limited area.

Summary

Upper Blue Lake is an oligotrophic lake lying at an elevation of 8130 feet in the California Sierra Nevada. It has a surface area of 344 acres and a maximum depth of 50 meters. Temperature and oxygen are favorable for trout except for some oxygen depletion below 40 meters (131 feet) in summer. The lake contains black-spotted trout, which spawn in five tributary streams. The spawning run begins in June or July in most years, approximately coincident with the melting of the ice from the lake. From 1938 through 1941 the numbers of fish spawning varied from 706 to 1255. The mean lengths of the spawners varied from 38.6 to 36.9 cm. ($15\frac{1}{4}$ to $14\frac{1}{2}$ in.) in the case of the males, and from 39.7 to 35.6 cm. (15 in. to 14 in.) in the case of the females. Scale studies indicated that nearly all spawning fish had spent four winters in the lake and were at the end of their fourth year. Marking experiments showed that most of them were spawning for the first time.

In 1941 a significant proportion of the trout which matured sexually failed to ascend a creek to spawn. This was not true in 1940. There is good reason to believe that trout do not spawn in the lake itself.

A large number of spawning trout was marked and returned to the lake for several years. Such fish failed to grow subsequently, and they remained in poor condition compared to immature fish of corresponding length. Few such fish reappeared in later spawning runs. Females which did spawn again produced few eggs compared to those spawning for the first time.

The tributary streams do not provide adequate spawning facilities for the trout in the lake. Trapping of downstream migrants showed natural reproduction to be at a very low level in 1940 and 1941.

Heavy annual introductions of small fingerlings, coupled with closure to fishing, over a six-year period, did not increase the numbers of fish in the spawning runs at Blue Lake. In fact, this program probably led to a slight overpopulation and a minor depletion of the food supply of the trout. In situations paralleling those at Blue Lake, it appears undesirable to return spent spawners to the lake. In any lake which is being reserved for egg-taking purposes, such fish should be marked and observed subsequently to see whether or not their return is justified.

I wish to thank Dr. Willis H. Rich of Stanford University and Mr. Alan C. Taft and Mr. Brian Curtis of the California State Division of Fish and Game for invaluable cooperation and advice.

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FRESH OCEAN FISH AS A TROUT DIET[1]

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Starting in 1939 the offspring from the selected, fall-spawning strain of rainbow kept at the Mt. Shasta hatchery were more or less affected by a peculiar disorder. This trouble was more serious in these fall-spawning rainbow than in other strains or in other species of trout. It was also more serious at Mt. Shasta but it did occur to some extent in several other hatcheries.

For a while the writer thought the disorder was due to the intracellular stage of *Hexamita* but this possibility was definitely ruled out. At about the same time it was shown that the addition of horse meat was helpful in reducing the disease. In 1942 a mixture of 50 per cent fresh ocean fish and 50 per cent fluky beef liver was tried out in the experimental hatchery and found to be most satisfactory so in 1943 the entire crop of rainbow fingerlings at Mt. Shasta hatchery was fed this diet except for a few control lots fed 100 per cent fluky beef liver. These few lots which received no fish in their diet were seriously affected by the disorder while the remainder were normal, healthy fingerlings.

Experiments with Ocean Fish and Liver Diet

Method

Eight standard hatchery troughs were used for these tests. The fish in four of these were fed the mixture of 50 per cent sea-fish and 50 per cent liver and the other four received 100 per cent liver. Each trough contained 14,000 rainbow fingerlings on April 1, 1942, when the experimental diets were started. The quantity of fish in each lot was reduced in a uniform manner when they became too crowded. The tests were discontinued on September 1 after having run for five months.

It was impossible to use only one kind of ocean fish in the test diet but the major part was hake (*Merluccius productus*). Some small flounders were also fed. All these fish were iced in San Francisco and reached the hatchery in good condition on the following day. Shipments were not made oftener than twice a week and it was necessary to hold the fish for a few days before they were fed. During this time decomposition frequently set in. On the other hand the fish were often frozen while in storage at the hatchery and had to be thawed out before feeding. These changes in the condition of the fish may have had some bearing upon the problem but they did not seem to be at all harmful.

The whole sea-fish were first ground through the "finest" plate of the food chopper (5/64 inch) then mixed by hand with an equal volume of ground fluky beef liver. The mixture was reground before feeding. Only enough food was prepared each time to provide three meals. Two-thirds would be fed within seven hours and the remaining third fed about

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22 hours after mixing with the liver. No tests were conducted in which the fish and the meat were fed separately.

The trout receiving the fish and liver and those fed nothing but liver were given all the food they could consume three times a day.

Results

Those fingerlings which received ocean fish and liver mixed were markedly superior to those that were fed on liver alone. This superiority was most noticeable in lower mortality and in greater vigor. The general appearance of the fingerlings receiving ocean fish was so much superior that even the uniformed visitor could not help but see the difference. Those which received nothing but liver were, as a group, weak and lifeless. For the most part they could be picked up in the bare hands as they swam in the troughs and they would lie almost motionless until released. During the first part of the epidemic a large number of swollen fish could be seen, while later the swelling became less noticeable and the number of weak, emaciated individuals increased. In the troughs fed fish and liver it appeared for some time as though none of the disorder would develop. However, later a few individuals became swollen but at no time were they numerous. In fact the disease was so inconsequential in the group fed fish and liver that in the producing hatchery it would probably have been overlooked entirely. The vigor of this group of fish was everything that could be hoped for.

Conclusions

These results are of particular interest because they appear to contradict the findings of Green and Evans (1940) and Green, Carlson and Evans (1941) who found that fresh fish could not be combined with meats without producing B_1 avitaminosis in foxes. It was shown by Spitzer, Coombes, Elvehjem and Wisnicky (1941) that there is some factor in fresh fish which breaks down vitamin B_1. Wolf (1942) demonstrated that this B_1 avitaminosis occurs in trout when they are fed a mixture of raw sea fish or fresh-water fish and meats. More specifically he showed that fresh fish and meat could not be mixed together and allowed to stand for 24 hours without a loss of the B_1 content and that such a diet brought on a serious avitaminosis in trout. Wolf also showed that raw fish could be fed separately from meat, i.e., on alternate days, or that the mixture could be fed immediately after preparation, without causing the avitaminosis. He also found that when the fish was cooked it did not destroy the vitamin B_1 in the foods with which it was mixed. Our tests conducted in the experimental hatchery in 1942 verified Wolf's observation that fish and meat could safely be used if fed soon after mixing. Two-thirds of any batch of our mixture was fed within seven hours of its preparation and one-third was fed about 22 hours later. This system was entirely practical and during the 1943 season the entire crop of several million rainbow fingerlings at the Mt. Shasta hatchery were fed in this way. No evidence of B_1 deficiency could be seen and we feel safe in recommending this method of feeding.

This diet and feeding method were not only safe but produced healthier and more vigorous rainbow than those fed meat alone. This was particularly true at Mt. Shasta where the fish had suffered annually from a diet deficiency; however, in several other California hatcheries similar results were noted.

Our tests were with a diet of 50 per cent raw fish and 50 per cent meat, but the percentage of fish can probably be raised. To what extent we can not say at present.

Deficiency Disease in Trout Not Receiving Fish

In 1939 a disorder appeared in the rainbow trout fingerlings at the Mt. Shasta hatchery. These fish were offspring of the new rainbow brood stock brought a short time previously to Mt. Shasta from the Hot Creek hatchery. Through selection this strain of fish had been developed into a rapidly growing, fall-spawning stock. The first offspring of this brood stock had been reared at Mt. Shasta in 1938 but no serious trouble was noted until 1939. From this time on very heavy losses were experienced and the rainbow fingerlings as a whole were not strong. At first theories were advanced that the artificial selection of this brood stock for fall spawning had, somehow, been accompanied by weaknesses and susceptibility to diseases. It was also believed that the recently instituted practice of feeding condemned, fluky beef liver was the cause. Prior to this time most of the food at Mt. Shasta was edible beef liver which had not been frozen for a great length of time and which had not been subjected to the hot dye treatment required for marking fluky beef livers. The scarcity and high price of the edible liver had made it necessary to use the condemned product.

In 1940 the writer advanced the theory that the disorder in the rainbow fingerlings was due to the intestinal protozoan *Hexamita* (*Octomitus*) which was supposed to be able to encyst in the gut walls and bring on symptoms resembling those exhibited by these fish.

In 1941 tests were designed to see if horse meat added to the diet of liver would control the disorder. It was clearly shown that one feed of horse meat (muscle) and two feeds of fluky beef liver a day reduced the loss from the disorder as contrasted to the diet of 100 per cent beef liver. However, it was proven by a large number of intestinal examinations that the motile form of the protozoan *Hexamita* was not reduced by the inclusion of horse meat in the diet. This fact threw some doubt on the theory that the peculiar symptoms in the rainbow fingerlings were caused by the intracellular form of *Hexamita*. We did have, however, some reason for believing that horse meat contained an element lacking in the beef liver.

In 1942 it was clearly shown that both ocean fish and kelp meal contained an element which was necessary to the well-being of Mt. Shasta rainbow fingerlings from the local brood stock of fall-spawning fish. This element was lacking in the usual beef liver diet. Both the horse meat and ocean fish might have been thought to contain a better balanced protein or some vitamin not sufficiently abundant in the beef liver but when we found that kelp meal also controlled the disease it appeared more likely that the missing factor was a mineral. Definite proof of this can only be furnished by discovery of a mineral which when added to beef liver will prevent the disease. Such proof must wait until it is possible to run suitable experiments.

The first symptoms of this deficiency disease in the 1942 Mt. Shasta rainbow became evident during March, at which time they weighed about

90 per ounce. At the start of the trouble an occasional fish would be found lying on the trough bottom and in the next few days the number would increase. The different troughs varied considerably in the number of affected fish but what was more remarkable was the manner in which the number rose and fell in waves during the season. A trough which appeared to be nearly free of the trouble would in a few days time develop many swollen specimens. Then with equal rapidity these affected fish disappeared so that the trough might appear free of the disease again. Swollen fish were to be seen until sometime in August. Thereafter the only indication of the disease was in the thin, weak fish which might be very abundant. These were so weak and listless that they could be picked up in the bare hands.

It is evident that there are two phases in this disease. First is the muscular dropsy, evidenced by the distension of the entire body through the accumulation of serous fluid among the muscle fibers. Second is the stage characterized by emaciation and listlessness. That the two are related was proven by an experiment described later in this report. Those fish which do not die from dropsy in the first stage recover their normal shape through the absorption of the serous fluid in the muscle. Then these same fish slowly become enaciated until their slender bodies contrast greatly with the normally shaped heads. We can not explain this recovery from the dropsical stage of the disease. We do know, however, that the disease injures the kidneys and liver and to some extent the gut walls. The emaciated stage which follows the dropsy is probably due to the kidney and liver injuries. We have no evidence that fish recover from this second stage although possibly a few of them do.

Microscopical examination of the kidneys, liver and intestinal walls shows considerable injury. The kidneys become pale and the liver becomes more or less orange. Hyaline, degeneration bodies can be found scattered abundantly through the tissue. These degeneration bodies in the intestinal walls resemble encysted protozoans sufficiently so that the writer labored for some time under the impression that these fish were suffering from the intracellular stage of *Hexamita* described by H. S. Davis.

Throughout the disease the fish exhibited great weakness although they did not lose their equilibrium until very near death. During the stage of dropsy they tended to lie on the bottom. During the second, emaciated stage they swam up in the water in a normal position but they were so feeble that one could pick them up on a flat dip-net and they would lie there with little or no struggle. Those few which did live to be planted must have been of little value for they would be easy prey for any enemy.

On June 25, 1942, 675 rainbow fingerlings were segregated from several troughs in one of the Mt. Shasta hatchery buildings. These individuals were all seriously affected by the deficiency. Their bodies were greatly distended by the accumulation of serous fluid in the tissue. From their appearance one would think that all were doomed. During the first 24 hours after they were segregated the loss was high but it quickly dropped and by the end of a month only about 50 per cent had died. The remaining fish had lost their swollen appearance and seemed quite normal. However, their appearance did not long remain normal for they gradually became emaciated and weak and most of them died. It is doubtful if those which lived ever resumed normal growth.

Other 1942 Experiments

Experiment with Kelp Meal

When it became apparent that ocean fish was a desirable addition to the liver diet it was natural to suspect that the fish might be supplying a mineral deficient in the beef liver. Therefore on May 21 we began feeding four troughs of rainbow fingerlings on a diet of 25 per cent kelp meal and 75 per cent fluky beef liver. These tests were continued until September 1 by which time it was quite evident that the kelp had not only reduced the mortality but had increased the vigor of the fish. The benefit from the kelp was not as marked as from the fish but this might have been because the kelp was not started at the very first of the season. Kelp meal contains most of the minerals found in sea water and it is also supposed to contain some vitamin A, B_1, riboflavin and pantothenic acid. We can not be sure, therefore, whether it supplied a necessary mineral or a vitamin but the fact that this same strain of rainbow fed the same food (beef liver) in other California hatcheries did not show the deficiency at all or only to a slight degree is some evidence that the Mt. Shasta water lacks a mineral which is present in the other hatchery supplies. The Mt. Shasta hatchery water is unusually free of dissolved minerals.

Experiment with Vitamin Supplements

On June 28 we started an experiment to determine whether or not vitamins A, D, and B_1 were important in the deficiency disorder. Vitamins A and D were chosen because they were known to be present in ocean fish in considerable amounts. Vitamin B_1 was fed because other workers had shown that this vitamin was essential to trout. Two troughs were fed beef liver to which had been added the vitamins. The method was to take a quantity of liver thought sufficient for the two troughs for one day. Into this were mixed 5,000 International Units of thiamine chloride, 75,000 U. S. P. units of A and 7,500 U. S. P. units of D. The tests were run for 28 days by which time the very heavy losses in the group receiving vitamins made it necessary to end the experiments. Apparently the quantities of the three vitamins were too great, otherwise the loss would have been no higher than in the controls. It is possible that some benefit would have resulted had we not fed such large amounts of the vitamins.

Summary

1. A diet of 50 per cent fresh ocean fish and 50 per cent condemned beef liver mixed together and fed in less than 22 hours after preparation successfully controlled a diet-deficiency disorder in Mt. Shasta rainbow fingerlings. Not only was the mortality normal but the vigor was also normal. The controls fed beef liver without the addition of fish suffered serious losses and the vigor of the group was most unsatisfactory.
2. A diet of 25 per cent kelp meal and 75 per cent condemned beef liver was also successful in controlling the disease. The results were much the same as in the feeding of ocean fish and liver.

3. A diet of liver strongly supplemented with vitamins A, D and B_1 was not successful in preventing the disorder, in fact the mortality was increased. This may have been caused by too large additions of the vitamin concentrates.
4. The disorder is characterized by two phases: the first is muscular dropsy in which considerable swelling is produced by an accumulation of serous fluid in the musculature. Second, the dropsy disappears and the trout become greatly emaciated. Degeneration is noted in the kidneys and liver, thus even if the trout recover from the dropsy they are impaired, perhaps permanently, by the injury to the kidney and liver.
5. A diet of ocean fish and liver did not produce the vitamin B_1 deficiency reported by Wolf and others. This was probably because the mixture was fed as soon as possible after preparation whereas in most of the experiments conducted by Wolf the mixtures were held at least 24 hours before they were used, giving the fish an opportunity to destroy the B_1.

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EXTENSIONS OF RANGE FOR BLENNIOID FISHES IN SOUTHERN CALIFORNIA[1]

By Carl L. Hubbs and Percy S. Barnhart
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Specimens recently acquired by the Scripps Institution of Oceanography make it possible for us to extend the known range of three blennioid fishes in southern California. These extensions of range have a bearing on some of the general problems of fish distribution along the West Coast.

Two of the records represent southern extensions of known occurrence. The single specimens each of *Cebidichthys violaceus* and of *Anarrhichthys ocellatus* from near San Diego were taken at depths greater than those usually frequented by the species farther north. Such seems to be a common phenomenon. Tide-pool species of the north commonly occur below tidal limits farther south, and shallow-water species of the colder latitudes live at greater depths in the south. The controlling factor appears to be temperature. The principle represented is that of isothermal distribution.

The other record, that of *Ulvicola sanctae-rosae* from the kelp beds of the mainland, disproves the previous assumption that this species is confined to the shores of the Channel Islands. The supposed distinctiveness of the Channel Islands fauna therefore receives another bit of contrary evidence. Only a few of the fish which have been known solely from these islands, or have been recorded in southern California only from islands, still remain unknown from the mainland. A sculpin, *Montereya recalva* (Greeley), may now also be deleted from the island list. It has been attributed (Hubbs, 1926, p. 17), south of Pt. Conception, only to Los Coronados Islands, but on August 2, 1943, we took several specimens in a reef-top pool at White's Point, near San Pedro.

Two of the records, for *Cebidichthys* and for *Ulvicola*, are for specimens taken in the beds of giant kelp. The *Ulvicola* would seem to be perhaps the most common and most consistent inhabitant of the near-surface waters in the kelp beds. These discoveries emphasize the very scanty nature of knowledge of the fish life in the kelp beds, which constitute one of the main ecological communities of the southern California coast. The fish fauna of the kelp would provide a very propitious field of inquiry, with bearings on fish management as well as ecology.

Cebidichthys violaceus Ayres

This elongate blenny, the largest of the "eels" that are fished for between tidal limits in central California, is commonly said to range from northern California to "Point Conception" (a very loose term in statements of distribution). Hubbs (1927, p. 368) gave the range more precisely as Crescent City to Carpinteria, California, on the basis of collections from the tidal reefs. The record for Santa Cruz Island (Barnhart,

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1936, pp. 87-88, fig. 265) refers to 28 specimens collected by Hubbs, Croker and Fry in tide-pools on a reef at the west end of the island. The southernmost published record is that of Clark (1936), for a 62 cm. adult caught on a hand line at San Nicolas Island. We now extend the range to San Diego County. A young specimen, 68 mm. in standard length, was taken by Dr. Dennis Fox, of the Scripps Institution of Oceanography, in the holdfast of a kelp plant pulled up in the kelp beds off Pt. Loma.

South of Santa Cruz Island, the "monkeyfaced blenny eel" has never been encountered in the numerous collections made by us and others in the tide-pools and among the boulders of the intertidal zone of the rocky reefs, its common habitat in central California. It appears that, to the southward, the species inhabits deeper water, shunning the tidal zone in which the water often becomes much warmer than in the open sea.

Ulvicola sanctae-rosae Gilbert and Starks

This ribbon-shaped blenny has been "definitely known only from Santa Rosa and Santa Catalina Islands off southern California and Guadalupe Island off Lower California" (Hubbs, 1927, p. 392). It has therefore been treated as an island species. Until recently no specimens had been collected along the mainland, and the only ones we had seen were a half-grown from Isthmus Harbor, Santa Catalina Island, taken by the University of Southern California on November 27, 1913, and an adult taken at the surface with a dip-net by Hubbs, Croker and Fry, on the night of August 28, 1934, in Forney's Cove, near the west end of Santa Cruz Island.

That *Ulvicola* also occurs along the mainland shore of southern California is proved by a collection of three adults, 224 to 268 mm. long, secured by J. F. Wohnus on the deck of a kelp-cutter off Pt. Loma, May 17, 1942. According to investigators as well as workers at the kelp plants "eels" of this type are regularly and frequently drawn up onto the barges during the harvesting of the kelp. Despite the lack of previous records we suspect that *Ulvicola sanctae-rosae* is a common member of the fish fauna of the kelp beds, along the mainland as well as about the offshore islands of southern and Lower California. An examination made at the kelp plant of Philip R. Park, Inc., at San Pedro, confirms this belief. Collecting as many fish as was practicable from a boat load of about 170 tons of kelp which had been cut on August 6 about Gull Island on the south shore of Santa Cruz Island, we obtained the following species list:

Pipe fish, *Syngnathus californiensis californiensis* Storer: 1 adult (3 to 4 dozen often taken on a trip).
Kelp blenny, *Gibbonsia metzi* Hubbs: 7, young to adult.
Kelp blenny, *Heterostichus rostratus* Girard: 3, young to adult.
Kelp-eel (as it may be called), *Ulvicola sanctae-rosae* Gilbert and Starks: 33, large young (one) and adult.

Three other specimens of *Ulvicola sanctae-rosae* were secured during the harvesting of kelp in West Cove, San Clemente Island, on August 17, 1943.

Anarrhichthys ocellatus Ayres

The southernmost previous records of the "wolf-eel" are from Venice (Ulrey and Greeley, 1928, p. 3) and off Redondo (Hubbs, 1916,

p. 165), both in Los Angeles County. In the Cabrillo Beach Museum at San Pedro there is a large mounted adult that was taken off Santa Catalina Island in October of 1937. Another, displayed in the Scripps Institution, was taken on August 6, 1941 by two fishermen (Dick Hiner and Roley Ramson) at a depth of about 400 feet in the La Jolla Submarine Canyon. This record constitutes a definite southward extension of range, and suggests that this species, like certain other fishes, usually lives in deeper water to the southward.

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RECORD OF THE OILFISH *(RUVETTUS PRETIOSUS)* IN CALIFORNIA [1]

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The fish family Gempylidae (the "escolars") has been known in California only from Myers' (1932) record of a specimen of *Xenogramma carinatum* Waite, which was found cast up on the strand at Long Beach. We are now able to report that another gempylid visits the shores of California, at least occasionally.

An oilfish (*Ruvettus pretiosus* Cocco), apparently the first to be made known from the eastern Pacific, was caught off Encinitas, San Diego County, California, on August 13, 1942. Unfortunately the details of capture are unknown, but since the oilfish was brought to market with a catch of rockfish (*Sebastodes*), we may presume that it was taken on a set-line. According to reports the oilfish usually lives between depths of 50 and 400 fathoms. The specimen which we are recording measures 475 mm. in standard length. It is preserved in the museum of the Scripps Institution of Oceanography. Its photograph is reproduced as Fig. 29.

FIG. 29. Oilfish, *Ruvettus pretiosus* Cocco, caught off Encinitas, California.

Ruvettus pretiosus is best known from the two sides of the North Atlantic, but has also been recorded from various South Sea islands (Gudger, 1928), and from the East Indies, Japan, Hawaii and South Africa. The Pacific population has been referred to a distinct species by Weber (1913, pp. 401-404, pl. 8, fig. 4), Jordan and Jordan (1922, p. 34) and Jordan and Hubbs (1925, p. 221), but this conclusion is not accepted by Fowler (1928, p. 135, pl. 10, fig. A), nor by Kamohara (1938: 46-47). Whether a Pacific species (*Ruvettus tydemani* Weber) is separable from the Atlantic (or circumtropical) *R. pretiosus*, or whether more than one species or subspecies occur over the vast Pacific, can only be ascertained by a careful comparison of specimens from different regions. The chief character supposed to distinguish a Pacific species is the low number of dorsal and anal rays, but it is not clear from the descriptions whether Weber and Jordan included in their counts the small rays at the front of the fins. Depending on whether or not these rays are enumerated, one might refer the California specimen to *R. pretiosus* or to *R. tydemani*. Pending a revisionary study we pro-

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visionally recognize only one species of *Ruvettus* and refer the California specimen to *R. pretiosus.*

The flesh of the oilfish is charged with an oil having strong purgative properties (Gudger, 1925). *Xenogramma carinatum* is also reported to be an extremely oily fish. It is just possible that these species may become the object of a commercial fishery, if the oil is found to be of value for medicinal or industrial uses and if the species are found to be common in the little exploited—in fact almost unexplored—deep-water basins that lie off the coast of southern California.

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THE TENCH IN CALIFORNIA[1]

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The Tench, *Tinca tinca* (Linné), the largest European species of the family Cyprinidae, to which the Carp and our various chubs belong, is present in a limited area of California. Its presence in this State has previously been recorded by Dill and Shapovalov (1939) and Marr (1940), but the history of its introduction and a description of its distribution have not hitherto been published.

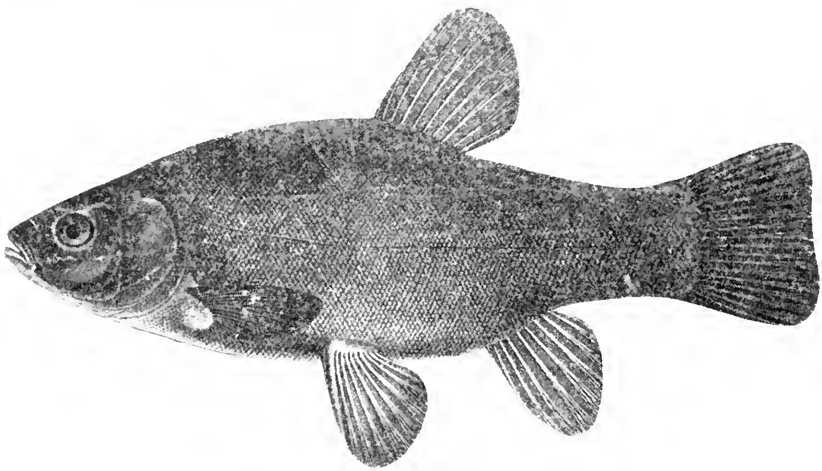

FIG. 30. Tench, male, 8½ inches long.

According to information secured by the writer from Mr. Pietro Balanesi, who with his brother Joseph first planted the Tench in California, the original specimens were brought from Italy by a Mr. Graviati in 1922 and introduced into a reservoir on the Balanesi ranch at the site of the Mackay Radio Station at Lobitas Creek, about six miles south of the town of Half Moon Bay, San Mateo County. The writer has also interviewed a number of residents of Half Moon Bay and vicinity who were present at the time, and although their recollections of the event have been somewhat dimmed by the intervening years, the various accounts agree in all essentials. Apparently Mr. Graviati made the trip to Italy with the express purpose of securing Tench for speculative purposes. The losses among the fish, which were carried on the ship in a two and one-half or five gallon can, were heavy. About one dozen to two dozen fish four to six inches in length survived the trip and were stocked in the above mentioned reservoir. Mr. Paul Nerli of Princeton, who sold the ranch to the Balanesi brothers in 1921, told the writer that the Tench had not yet been introduced when he moved out in the spring

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(probably May) of 1922, so that they were brought in sometime after that. The fish soon reproduced quite freely. On March 20, 1925, five specimens were brought from this site to the Steinhart Aquarium in San Francisco and soon after employees of the Aquarium seined "a large number" of Tench on the ranch.

Since the time of its introduction into California the species has been gradually spread by ranchers from reservoir to reservoir (locally called "lakes"), until now it is distributed throughout large parts of Santa Cruz and San Mateo counties. Some fish have probably escaped into a few of the local streams, but it is very doubtful that they survive or at least thrive in the small coastal streams of the vicinity, since the Tench is primarily a lake species.

FIG. 31. Reservoir at Lobitas Creek, San Mateo County (site of Mackay Radio Station), where the Tench was introduced into California. The almost treeless landscape is typical of the coastal strip in which the Tench is distributed. Photograph by the author, September 7, 1942.

Mr. Myron Moore, formerly of the California Division of Fish and Game, has reported the presence of Tench to the writer as follows:

May 11, 1940: in ponds of Mr. Jack Bandy at Bonny Doon, Santa Cruz County;

Nov. 9, 1941: in a reservoir just south of Half Moon Bay, San Mateo County, observed during 1940;

Nov. 12, 1941: in two other reservoirs in Santa Cruz County, one of these just north of the city of Santa Cruz and the other, known as the Big Ranch Reservoir, just north of Davenport. Mr. Moore stated that Mr. Albert Quilichi had put a thousand Tench in the latter reservoir seven or eight years previously (1933 or 1934).

On August 2, 1941, the writer learned from local residents that the Tench had been introduced into a reservoir near Princeton, about six miles north of the town of Half Moon Bay. Fresh-water sculpins (*Cottus*) present in this reservoir are reported to have eaten all of the eggs and young, however, so that the species has not reproduced successfully in this place.

Dill and Shapovalov (1939) noted the presence of the Tench "in ponds near Half Moon Bay," but stated that it was not yet an inhabitant of the natural waters of the State. Since then Marr (1940) collected it from one of the Mud Lakes, which are a series of enlarged sag ponds in San Mateo County. According to the owner of the property, the stock for this lake was "brought from a pool near Half Moon Bay about six years ago" (Marr, *loc. cit.*).

At this point attention is called to the fact that Section 561 of the California Fish and Game Code provides that it is unlawful to place or plant any live fish, whether from without or within the State, into any of the waters of California without written permission from the Fish and Game Commission. The main reason for this regulation is to guard against the introduction of undesirable fishes into waters in which they are not already present. It is considered that the Tench would be an undesirable addition for the same reasons that the Carp is undesirable, namely, because it would interfere with the production and catching of more valuable fishes.

One of the oldest, although fanciful, claims to fame of the Tench was its reputed ability to cure the diseases of other fish and even of man, from which it derived the appellation "physician fish." Now, like the Carp, it is extensively cultivated in ponds in Europe as a food fish. Although a slower grower than the Carp, it is hardier, and so is used in ponds where adverse conditions prevail. Its tenacity of life in the presence of little oxygen is remarkable. As regards growth, it has been found in Europe that under certain pond conditions Tench one year old, weighing one-quarter of an ounce at the beginning of a growing season, will gain two ounces during the growing season and six ounces during the following growing season, while one year old Carp, weighing two ounces at the beginning of the growing season, will gain 12 ounces during the season and 32 ounces during the following season.

In California, the Tench reproduces freely in most of the reservoirs in which it is now found, but data regarding time of spawning and egg production are not available. In other areas the spawning period extends over the months of May-July and average egg production is 350,000-400,000. In the California reservoirs the species commonly reaches a weight of two or three pounds; occasional specimens are reported to weigh from four to six pounds. The food of the Tench in these reservoirs is not known, but European authors report that it takes snails more readily than anything else if these are available.

The usual method of catching the fish in the reservoirs is by netting. The Tench is generally reported to be difficult to take with hook and line at any time of the year; one man reported that it takes a hook only around November. "Tyee" (preserved salmon egg clusters) or worms are the usual bait. The local Italian population prizes it highly as a food fish. It is prepared for the table in a number of ways.

Mr. Paul Nerli told the writer that where he lived in Italy there was "a ditch around every acre of ground and Tench in every ditch." The fish are caught, he said, by blocking off a section of ditch with small earthen dams and muddying the blocked-off section; the fish then come to the surface and are caught by hand. Mr. Nerli stated that the Tench thrives only on mud bottoms.

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EYE WORM *(THELAZIA CALIFORNIENSIS)* INFECTION IN DEER IN CALIFORNIA [1]

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Bureau of Game Conservation
California Division of Fish and Game

Fig. 32.
Eye worms from deer (actual size)

Hunters, game conservationists and ranchers frequently report blindness in deer. Many refer to this condition as pinkeye, a disease not uncommon in cattle and sheep. The purpose of this paper is to report the occurrence of roundworms in the eyes of deer which also may cause blindness and should be differentiated from cases of pinkeye.

The worms were first reported from dogs in California by Allerton (1929). Price (1930) gave them the specific name *Thelazia californiensis.* Price (1931) has identified these worms from the eyes of several dogs in California. Kofoid, Williams and Veale (1937) reported further cases and Douglas (1938) lists this parasite from a number of dogs in many parts of the State. Douglas (1939) has identified the same worms from a cat. Stewart (1940) observed the infection in sheep. Hosford, Stewart and Sugarman (1942) record these worms from the eye of a black bear. Kofoid and Williams (1935), Kofoid, Williams and Veale (op. cit.) and Hosford, Stewart and Sugarman (op. cit.) have reported human infections.

Oberhansley (1940) recorded an outbreak in which several deer were infected in the Sequoia National Park. The parasites from one deer, which had about 50 worms in one eye and a number in the other, were identified by Stewart as the same species seen in dogs, cats, sheep, bear and man.

We have observed these worms in the eyes of a deer taken near Cloverdale (Sonoma County) by Warden Jack Sawyer, December 27, 1942. The animal was a yearling doe Columbian blacktailed deer *(Odocoileus hemionus columbianus)* caught alive in a weakened condition. It was suffering also from a heavy infection of intestinal worms. Five small roundworms were recovered from the eyes, two in one and three in the other.

The known reports of this worm in animals and man are from many localities in California. They have not been reported in animals from any other State. The worms are small, round, and white, usually very active. They occur in the space between the eyeball and the lids, particularly in the conjunctival sac, and may migrate into the lacrimal duct, but are not known to penetrate tissue. They were easily observed at autopsy by pulling back the lids of the eye. They can be readily preserved in alcohol for identification purposes. In dogs, sheep, and man they occasionally can be seen moving serpent-like across the eyeball.

[1] Submitted for publication, October, 1943.

They set up an irritation, often causing a severe inflammation and accumulation of pus, sometimes with a running of the eyes. The blindness may be caused by a resultant opacity of the cornea or the accumulation of matter in the eye, or simply a closing of the eyes in an effort to alleviate the irritation. There may be also a general nervous reaction as well as evidence of blindness in the deer.

The size of the worms is illustrated in the accompanying photograph (Figure 32), which pictures the worms obtained from the Cloverdale deer. Some variations have been observed in the size of the parasites from several animals, ranging from 7.7 mm. to 18.8 mm. (about 0.35 to 0.85 inches). The male worms are usually slightly smaller than the females.

Nothing is known of the means of transmission of the worms from one deer to another. Parasites of the genus *Thelazia* infect a variety of birds and mammals and in no case has the life-history of the parasite been determined. A closely related eye worm of chickens is known to require a cockroach as an intermediate host, but Kofoid, Williams and Veale failed to infect cockroaches with larvae of *T. californiensis*. Stewart has suggested that transmission may be found to occur in one of two ways, using an arthropod (such as an insect, tick or mite) as an intermediate host. One: the eggs of the worms may pass by way of the nasolacrimal duct to the ground or vegetation where they could be eaten by an appropriate intermediate host which, in turn, could be eaten by the deer; the other: the larvae (young) of the worms may get into the blood and be taken up by an intermediate blood-sucking arthropod host which would then infect another deer. Neither of these methods has been investigated fully in the case of *T. californiensis*. Perhaps further information on the geographical range of this parasite in deer and other mammals may narrow the number of possible intermediate hosts and thus suggest further experiments with these worms. A direct transmission is rather unlikely and attempts to transplant the adult worms from one animal to another by Kofoid, Williams and Veale indicate that there is probably no hazard involved in the handling of infected deer.

We would like to obtain more information on this disease and to this end solicit the cooperation of the reader. Evidence of blindness in deer, or worms collected, should be addressed to the Laboratory, Bureau of Game Conservation, Division of Fish and Game, Ferry Building, San Francisco. The worms are preserved best in alcohol.

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EDITORIALS AND NOTES

TROUT FISHING RESTORED TO MODOC COUNTY RESERVOIR

The April, 1943, number of CALIFORNIA FISH AND GAME carried a note on the poisoning of Ballard Reservoir in Modoc County. A large number of chubs were killed and it was believed that without these pests the lake would again furnish the excellent trout fishing which it did in former years. Ten thousand 5-inch rainbow trout were planted in December, 1942, after the poisoning, and in the following May 5,000 4-inch rainbows were planted.

During the summer of 1943 there seems to have been little fishing and reports were received that the reservoir was devoid of fish. On September 23d the writer visited the lake and caught 17 very scrappy rainbow ranging in length from $8\frac{1}{2}$ to $11\frac{3}{4}$ inches. They were unusually plump and deep-bodied, with an average condition factor of 1.4. Their flesh was slightly pink and very good eating. The lake was apparently well supplied with food despite the large number of rapidly growing trout. Many fresh water shrimp or scuds were seen along shore in the aquatic plants, and the water had a great many copepods.

This rehabilitation effort was made at the request of Fish and Game Commissioner W. B. Williams and all indications are that it is going to be a success.—*J. H. Wales, Bureau of Fish Conservation, California Division of Fish and Game, September, 1943.*

HESPEROLEUCUS SYMMETRICUS REPORTED FROM CLEAR LAKE, LAKE COUNTY, CALIFORNIA

An examination of the fishes in the collection of the Department of Zoology, University of California, revealed two specimens of *Hesperoleucus symmetricus* from Clear Lake. This species has not been recorded from the Clear Lake area. They were collected by James G. Cooper in 1870. The label reads, "Mylopharodon-Clear Lake, Oct., 1870, J. G. C., 1506." What the number 1506 refers to is not clear, none of Cooper's field notes being available. That the label was written by Cooper is easily verified by comparison with known samples of his writing. The specimens are undoubtedly from Clear Lake, Lake County, California, as his publications show he frequented the area about 1870.

Subsequent to this discovery a survey of the fishes of the Clear Lake region was made in August, 1943. *Hesperoleucus symmetricus* was found to be abundant in the following streams: Scott Creek, Middle Creek, Clover Creek, Kelsey Creek, and Lower Lake Creek. They are abundant in the tributaries of the upper part of Cache Creek, and while not normally taken in lakes the species could easily make its way through Clear Lake to populate the streams.

The fact that sportsmen commonly use these minnows for bait and in the past have brought them from neighboring streams such as Putah Creek might cast doubt on their native occurrence in the region were it not for the two specimens collected in 1870. Although *Hesperoleucus venustus* and other forms were undoubtedly introduced into the Clear Lake drainage when Scott Creek was diverted from the Russian River system to the Clear Lake drainage by the landside which created Blue Lakes, a preliminary examination of the material from Scott Creek indicates that the population is not related to *Hesperoleucus venustus* found in the Russian River, but rather to *H. symmetricus* of the Sacramento drainage. An introduction of this size would probably be genetically swamped by the population present at the time of transfer, unless they possessed some strong selective advantage. This same fate would be meted out to any individuals introduced by fishermen.

A very common native fish not reported from the Clear Lake area is *Mylopharodon conocephalus*, which was not taken on the survey. Three possibilities remain for this fish: the proper ecological conditions may not be present; it is present in very small numbers; or introduced fishes have locally exterminated the species. If *M. conocephalus* is not present in Clear Lake or its tributaries it is probably due to lack of ecological conditions suitable to the species. *Mylopharodon* is usually found in larger streams from low to medium elevation. In summer the streams that might meet this condition in the Clear Lake region go dry in the lower reaches. This may explain its absence.—*Garth Murphy, Department of Zoology, University of California, September, 1943.*

TWENTY-FIVE YEARS AGO IN CALIFORNIA FISH AND GAME

A description of the shrimp fisheries of San Francisco Bay by N. B. Scofield was the leading article in the January, 1919, issue of CALIFORNIA FISH AND GAME. At that time the question of removing the restrictions on the Chinese shrimp or bag net was a recurring topic in the State Legislature, and in anticipation of forthcoming legislative debate, Mr. Scofield felt it important to point out the destructive features of this type of gear.

These fine-meshed bag nets were introduced by the Chinese in 1871. Fished across the tide in series, they took great numbers of young fish as well as of shrimp. "The total annual catch of the Chinese junks at the time they were stopped from fishing in 1911 was considerably in excess of 10,000,000 pounds of fresh shrimp and fish combined. Of this amount no more than 800,000 pounds of the shrimps were used fresh. The rest was all dried and marketed as dried shrimp meat and fertilizer"—the bulk of which went into the Oriental export trade. In another part of the paper Scofield estimated that the young fish varied from 10 to 75 per cent of the entire catch, depending on the season, and emphasized the fact that in the Upper Bay especially they had been largely of such valuable species as striped bass, salmon, shad, herring and smelt. He felt that serious depletion of these species had resulted, as well as depletion of the shrimp population itself.

From 1911 to 1915 the use of the Chinese net was completely forbidden, but shrimps were so scarce that the old Italian method of seining for them could not profitably be carried on. The ban on the Chinese nets was then lifted in southern San Francisco Bay only; here the valuable young fish are much fewer in number, and the damage consequently reduced. Since 1919 the law has forbidden the drying of shrimps, except that unmarketable shrimps unavoidably taken in fishing for the fresh market may be dried to the extent of not more than 50 per cent of a load of shrimps brought in by any boat.

Under these regulations the Chinese have continued to operate their junks, driven by motor now instead of by sail, in the southern part of the bay. Trawling, a method much less destructive to young fish, has been permitted in the northern part, and has made a significant contribution to the shrimp fishery. In 1929 the total catch was 3,000,000 pounds, in 1939, 1.2 million pounds. There were 19 Chinese shrimp "camps" in the South Bay in 1919, and 12 in 1930. Just before Pearl Harbor, there were 11 "camps" on Hunter's Point; of these only one now remains, the rest having given up when the Navy took over the land on which they operated. So far in 1943 the total monthly catch from the South Bay has varied from 1,000 to 26,000 pounds, with the latter a high peak; and shrimps are being imported from New Orleans to supply the local demand.

A thought-provoking article by Carl L. Hubbs dealt with the natural fitness of the native stickleback as a mosquito-destroyer. Others have pointed out this same fact. While it is now recognized that the stickleback is effective in controlling mosquitoes in waters in which it occurs naturally, no organized efforts have been made in this State to extend its range artificially. On the other hand, the introduced top-minnow, *Gambusia affinis*, the "mosquito-fish," has been widely distributed for the purpose of mosquito control. The advantage of the stickleback in its greater ability to withstand cold winters is not of primary importance in California. Its spiny defense against predators is perhaps offset by *Gambusia's* tendency to frequent extremely shallow water where larger fish can not reach it. In *Gambusia's* favor stands the rapidity with which it multiplies, due both to its early sexual maturity and the frequency of its breeding periods; and perhaps above all its recognition and its outstanding success as a mosquito-controlling agent in other parts of the world.—*Brian Curtis, Editor, California Fish and Game.*

REPORTS

FISH CASES

July, August, September, 1943

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalones: undersize, overlimit, no license, out of shell, below high tide, taken commercially without a license	114	$3,012 50	
Angling: set lines, closed stream, no license, more than one rod, back-dating angling license, using license of another, between sunset and sunrise, from fishway, 150 ft. of dam, fail to show license, from fish ladder	74	1,280 00	
Bass: undersize, no license, buying striped bass, taking other than hook and line, after sunset, two poles, overlimit, set lines	53	1,325 00	
Clams: no license, overlimit, closed season, undersize	10	220 00	
Commercial: no license, selling without a license	5	55 00	
Gill net in possession in district 19a, closed waters, net in boat, no boat numbers, no commercial license	8	1,225 00	
Lobsters: closed season, oversize	2	50 00	
Pollution	5	675 00	
River Otter: closed season	1	10 00	
Salmon: fishing with snag hooks, undersize	3	75 00	
Trout: overlimit, other than angling, closed lake	36	1,025 00	
Use non-native minnows as bait	1	25 00	
Use and possess otter-board trawl	4	225 00	
Totals	316	$9,202 50	

GAME CASES

July, August, September, 1943

Offense	Number arrests	Fines imposed	Jail sentences (days)
Bear: closed season	2	$75 00	
Deer: hunt in refuge, female deer, spike buck, hunt at night, spotted fawn, spotlighting, firearms in refuge, closed season, closed area, forked horn deer district 1¾	77	5,455 00	25
Deer meat: closed season, illegal	32	1,925 00	
Deer tags: fail to tag, fail to complete deer tag, alter and deface, use tags of another, transport deer without having tag countersigned	14	445 00	10
Doves: overlimit, use license of another, closed season, no license, using unplugged gun	31	1,625 00	
Ducks: closed season, unplugged guns	13	675 00	
Game birds: closed season	2	250 00	
Hunting: no license	16	230 00	
License: failure to show on demand	1	10 00	
Pheasants: closed season, no license, hen	32	1,585 00	
Pigeons: closed season	1	50 00	
Quail: closed season	4	200 00	
Rabbits: closed season	3	75 00	
Seized evidence destroyed	1	10 00	
Selling domesticated birds without a game breeder's license	2	25 00	
Shooting from auto and from public road	13	340 00	
Taking fully protected game birds	3	150 00	
Totals	247	$13,125 00	35

SEIZURES OF FISH AND GAME
July, August, September, 1943

Fish:

Abalones	61
Abalones, red	313
Abalones, green	23
Abalones, black	49
Bass, black	69
Bass, striped	8
Bluegill	16
Clams, cockle	101
Clams, pismo	8
Lobsters	16
Salmon	16
Sunperch	18
Swordfish, Marlin, lbs.	3,000
Trout	474
Trout, Rainbow	440
Trout, Eastern Brook	62
Trout, lbs.	22

Game:

Bear meat, lbs.	60
Deer	32
Deer meat, lbs.	351½
Doves	209
Ducks	47
Pheasants	16
Pheasants, cock	16
Pheasants, hen	26
Pigeons	1
Quail, valley	2
Quail, gambel	2
Rabbits, brush	1
Rabbits, cottontail	4

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(Continued from inside front cover)

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CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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TABLE OF CONTENTS

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Killed in Line of Duty

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EFFECT OF HUNTING ON A VALLEY QUAIL POPULATION [1]

By Ben Glading
Bureau of Game Conservation
California Division of Fish and Game
and
Roy W. Saarni
U. S. Forest Service

One of the most perplexing problems confronting public and private managers of resident game is to determine how large a proportion of the population may be safely harvested annually by hunters. Such studies have been made by various workers on eastern species of small game and on deer, but similar knowledge of the harvestable surplus in valley quail is unknown.

During the investigation of life history and management on valley quail (*Lorphortyx californica*) at the San Joaquin Experimental Range [2] in Madera County, California, an opportunity was presented to begin a study of shootable surpluses.

The following experiment was devised to determine what percentage of a fall population could be safely killed without damaging the seed stock.

One area of approximately 720 acres was chosen as a hunting ground and another similar plot of about the same size was used as a nonhunting, population check area. These two areas, experimental and control, were chosen to be as similar as conditions would permit. Both were covered with about the same type and amount of brushy cover and were essentially south slope in exposure. Varying rates of cattle grazing at the Range made it desirable to include pastures subjected to the same rates and season of grazing in each. Thus, in each there were included one 160-acre pasture grazed at the rate of one head per 10 acres, one 240-acre pasture grazed at one head per 15 acres, and one 320-acre pasture grazed at one head per 20 acres. All were grazed in late winter and spring only.

To get the same rates and season of grazing in the check or nonhunting area, it was necessary to split the latter into two blocks, one of 160 acres and the other of 560 acres. This manner of splitting up the check area and the nearness of experimental and check areas admittedly was

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[1] Submitted for publication, January, 1944.

[2] A branch of the California Forest and Range Experiment Station maintained by the Forest Service, U. S. Department of Agriculture, at Berkeley, California, in cooperation with the University of California.

The quail study was under the guidance of a committee composed of Tracy I. Storer, chairman, and J. T. Emlen, Jr., of the University of California College of Agriculture; E. E. Horn and H. S. Fitch of the U. S. Fish and Wildlife Service; Gordon H. True, Jr., of the California Division of Fish and Game; E. I. Kotok, M. W. Talbot, H. H. Biswell, J. Bentley, and J. W. Nelson of the California Forest and Range Experiment Station, U. S. Forest Service; and F. P. Cronemiller and Ivan Sack of Region 5, U. S. Forest Service. Messrs. Storer, Horn and Cronemiller formed a special technical advisory committee. Funds for the project were supplied by Region 5, U. S. Forest Service. The authors were engaged by the Committee as resident investigators at the Range (Glading, 1936-40; Saarni, 1941-42). Additional help in various projects was obtained through the use of U. S. Forest Service Junior Assistants to Technicians and Civilian Conservation Corps enrollees for manual labor. Studies began in December, 1936, and were suspended in 1942.

undesirable, but necessary because of the lack of other available areas comparable in cover, amount of water, slope and degree of grazing.

To provide a further control, the spring censuses of the hunting area were compared with spring censuses of the entire Range (3,000 acres, 1936-38; 4,000 acres, 1939-42).

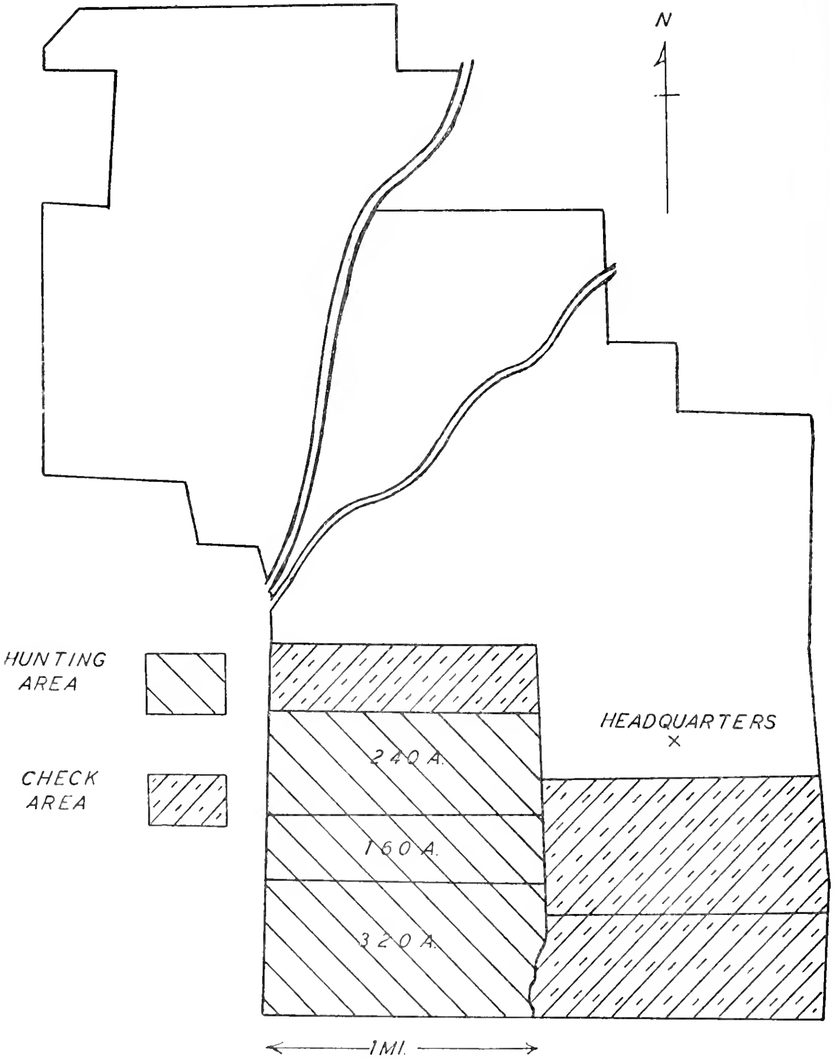

FIG. 33. San Joaquin Experimental Range, showing entire extent and also the hunting and check areas.

When first designed, it was hoped to conduct the experiment under several different degrees of hunting, increasing gradually until the maximum permissible hunting pressure was determined. Premature suspension of the project due to war time conditions precluded this, and hence only the initial stages of the experiment are presented here.

Annual quail censuses had been taken of the entire Range starting in March of 1936 (Glading, 1941). These annual counts were used as the basis for pre-experimental period censuses of the hunting and control areas, and for the post-season counts after the hunting experiment was started in 1938.

Prior to each hunting season, a horseback census was made of each area and the number of quail was recorded. Plans were made for removing a bag of 25 per cent of the birds counted in the pre-season census. It was estimated that each hunter would take an average of seven quail; enough hunters, therefore, were sought to effect the desired removal. After each hunting season, another census was made of the areas. This entire procedure was carried out in each of four consecutive years starting in November, 1938.

Hunters for the experiment were chosen by the Madera County Sportsmen's Club with Mr. E. E. Nelson acting as coordinator between the Quail Committee and the club. The following memorandum was sent to Mr. Nelson prior to each hunting season.

1. Approximately ---- hunters will be chosen by you to help us out in getting figures on known hunting pressures on known quail populations.
2. These men will hunt one day apiece on designated areas of the San Joaquin Experimental Range.
3. The hunting days will be spaced so that no more than three men may hunt during any one week, and the first, third, and last week of the season must have at least two hunters per week.
4. These hunters will be allowed to take the State bag limit (10 birds) during their one day each of hunting.
5. The hunters must check in at the headquarters before hunting to receive further instructions as to exact area to be hunted, etc.
6. Hunters will check in after the hunt in order to check the bag and to have crops removed from the birds for stomach examination.
7. The exact number of hunters to be chosen by you to hunt during the season will be given to you on or before November 12.
8. You will have entire say as to the choice of hunters for the experiment. It is hoped, however, that lots be drawn, or some other chance method be used in selecting the men in order that the groups will represent as nearly as possible a true cross-section of the hunting population.

The hunters were to represent as nearly as possible a reasonable cross-section of those who ordinarily would hunt quail in the Sierra foothills. About equal numbers were chosen from among local ranchers and residents of the town of Madera or other nearby communities. How close an approximation of representative hunting ability was obtained is a matter of conjecture. A total of 38 individual hunters took part during the four years, comprising in all, 58 hunter visits.

Hunters were given a sheet of instructions and also a map of the hunting area, on which was shown the location and numbers of quail by coveys as determined in the pre-season census. In general, the hunters were not accompanied by any of the Range staff while hunting, but each was asked to check out his bag and to submit to an oral questionnaire at the end of his shoot. All of the hunters complied with the regulations, so that the figures for total birds in the bag are considered accurate. The sheet of instructions given to each cooperating hunter reads as follows:

Suggestions to Hunting Experiment Cooperators

The purpose of this experiment is to secure data on the effect of a known hunting effort on a known population of quail. There are more than ---- valley quail on the hunting area and it is planned to take off approximately 25 per cent (about ---- birds) in this experiment. Future censuses will be made to determine the long time effect of such an annual cropping rate. Through your cooperation, figures will also be obtained on age and sex ratios, cripple-kill ratio, predator counts, and other data. In order that mutual benefit will be secured from the results of this hunt, it will be appreciated if you will observe the following suggestions:

1. Check in at the headquarters of the San Joaquin Experimental Range for instructions and a map of the hunting area.
2. Confine your hunting entirely within the boundary of the hunting area.
3. Do not shoot hawks, owls, jays, or any birds or mammals except valley quail.
4. Keep a check on the number of birds crippled but not secured.
5. Keep a count of the number of Cooper's hawks (blue darters) seen.
6. Keep a count of the number of shells used. (These figures may be used later in obtaining rough estimates of quail population of other areas of similar cover conditions. This data is not intended as a check on your ability as a hunter!)
7. Check out at the headquarters building where a member of the staff will check your birds as to age, sex, and weight, and remove the crops for a food habits study. You will, of course, retain the birds.
8. California Fish and Game laws as to bag limit, etc. are to be complied with in the conduct of this hunt.

We thank you very much for your cooperation in conducting this hunt and sincerely hope that you will have a successful day.

(Signed) Cooperative Quail Management Committee

After the day's shoot, each hunter was questioned on the following: Time started to hunt, time stopped hunting (man hours), type of gun used, bore of gun, size of shot, number of birds in the bag, number of birds crippled but unretrieved, whether or not a dog was used, number of Cooper's hawks seen, and number of shells used. In addition, each was asked for his opinion on the number of quail present.

Hunters were spread out during the season (November 15-December 31) in about the same manner as occurs under normal quail hunting—the intensity of hunting greatest near the opening of the season and dwindling toward the end. As each season progressed an attempt was made to regulate the remaining number of hunters so that as near 25 per cent of the pre-season quail population was killed as was practicable.

In addition to the information derived from the above oral questioning, every quail bagged was examined for age and sex, weighed, sampled for blood parasites, and the crop removed for a food habits study. These data made up parts of other reports on the San Joaquin Experimental Range quail studies (Glading, Biswell, and Smith, 1940; Storer, Horn, Glading and Saarni Ms.).

Results

The percentage of the pre-hunting season population taken off during each of the four years was as follows: "In the bag," 1938, 26.5%; 1939, 25.3%; 1940, 18.6%; 1941, 24.1%. Unavoidable complications during the 1940 hunting season accounted for the smaller kill in that year.

Table 1 summarizes for each year the pre-season quail censuses, the number of quail bagged, the reported number of unrecovered cripples, and the post-season census. For the check area, only pre-season and post-season counts are given.

TABLE 1

Summary of Census Data and of Bag and Cripple Losses in Experimental Hunts, San Joaquin Experimental Range, 1938-1942

Hunting Area	*1938-39*	*1939-40*	*1940-41*	*1941-42*
Pre-season (November) census	513	245	278	349
Total bag	136	62	52	84
Unrecovered cripples	57	26	14	25
Total bagged and crippled	193	88	66	109
Post-season (March) census	214	141	167	184
Check Area				
Pre-season (November) census	349	288	256	325
Post-season (March) census	257	185	216	202

The information gathered from questioning the hunters of possible importance in evaluating quail populations by hunter success is shown in Table 2. Table 3 compares the number of cripples reported by hunters using dogs versus those without dogs. The types of shooting equipment used by individual hunters are summarized in Table 4.

TABLE 2

Miscellaneous Data on Hunter Success in the Experimental Hunts

	1938	*1939*	*1940*	*1941*	*Totals*	*Averages*
Number of hunters	21	10	11	16	58	--
Pre-season quail population	513	245	278	349	1385	--
Total birds bagged	136	62	52	84	334	--
Birds per hunter	6.5	6.2	4.4	5.2	---	5.76
Birds per man-hour	1.4	1.4	.9	1.0	---	1.18
Cripples per bag of 10	4.1	4.2	2.7	3.0	---	3.65
Shells used per bird in the bag	3.7	3.3	3.7	3.4	---	3.53

TABLE 3

Comparative Crippling Losses Experienced by Hunters Accompanied by Dogs Versus Hunters Unaccompanied by Dogs

	1938	*1939*	*1940*	*1941*	*Total*	*Average*
Number of hunters using dogs	8	0	4	7	19	---
Cripples per bag of 10 with dogs	1.5	--	3.2	0.3	--	1.47
Number of hunters without dogs	13	10	7	9	39	---
Cripples per bag of 10 without dogs	6.4	4.2	2.4	4.4	--	4.71

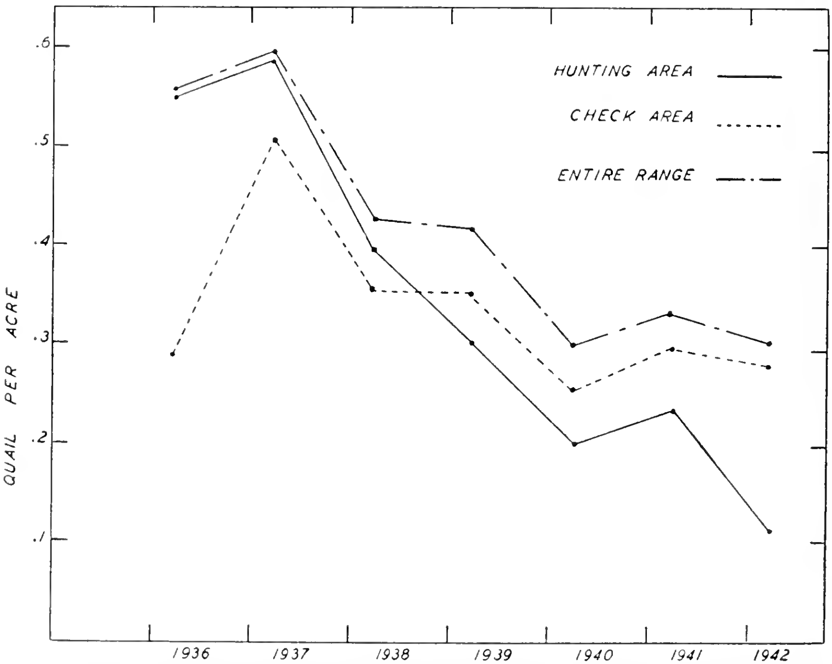

FIG. 34. Valley quail population densities as determined by horseback census in March of each year for the hunting and check areas (hunting began November, 1938). The population densities for the entire range included as an additional control.

Figure 34 shows the population trends as revealed by the spring or post-season counts only. In addition to data for the hunting and control areas, counts for the entire Experimental Range are given as an additional check.

Figure 35 displays the population trends, in birds per acre, on the hunting and check areas for three spring counts prior to the start of the experiment in November, 1938. Pre-season and post-season counts are depicted in this graph after November, 1938.

Discussion

A study of Figure 34 (summary of March censuses on hunted and unhunted areas) will at first glance give the impression that hunting has resulted in a considerable reduction of quail on the hunted area. It must be realized, however, that these counts were all taken in March, after the hunting season, and that in addition to natural losses, the hunted area has had up to 40 per cent loss each year by birds brought to bag and those crippled. Figure 35, which has both pre-season and post-season counts represented, gives a truer representation of what actually has happened. Each year the March census showed the hunted area population to have dropped below that on the check area, yet, by the next autumn, the two populations were nearly equal; in fact, during the last two years, the hunted area showed a few more birds than the unhunted.

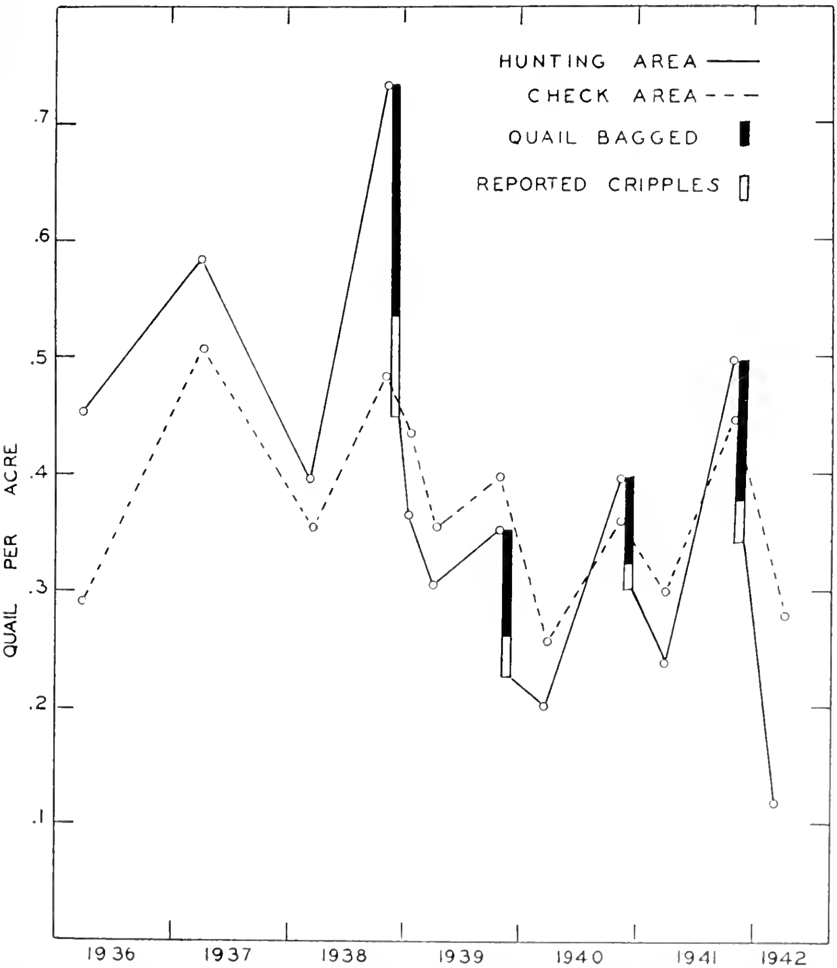

FIG. 35. Population densities of valley quail on the hunting and check areas, based on both pre-season and post-season censuses after the beginning of the hunting experiment (November, 1938). The bars show, per acre, the number of birds bagged and the crippling losses. Suspension of the studies in 1942 unfortunately precluded any opportunity to ascertain whether the great decrease in that year would be overcome subsequently.

Figure 34 shows that the population density in March, for the years following hunting, were lower on the hunting area than on either the check area or the entire Range; yet the same general trend in population is exhibited by all three curves. Thus, from the peak in March, 1937, all three curves show a marked decline through the first two years of the hunt (1938-39, 1939-40), then a slight rise (1940-41), followed by another drop (1941-42). This suggests that other factors, admittedly unknown to us, are far more important than a moderately heavy hunting season kill.

The best objection to the above conclusions is that movements of birds from the unhunted area to the hunted area were chiefly responsible for the "come-back" exhibited annually on the hunting area. Fortunately, a partial refutation of this objection is available from the extensive banding program (since 1936) in the areas east of and adjacent to the hunting area. For two years prior to and during most of the course of the hunting experiment, many (764) quail were banded in an area about 100 to 1,500 yards east of the northern half of the hunting area. Only three of these banded birds were subsequently shot in the annual hunts. Two of them were taken not more than 100 yards from the east boundary, and only one well inside of the hunting area. This indicates that wholesale movement did not occur from the east.

The adjacent country to the west and south of the hunting area was privately owned and open to shooting. While the exact degree of hunting on that land was unknown, it was felt to be comparable to the hunting effort on our experimental area. Hence, overflow was not likely to come from those directions.

Census errors could be a factor in misinterpretation, but every possible precaution was taken and the counts are thought to be reasonably accurate (Glading, 1941).

Probably the greatest source of error was in the comparatively small size of the experimental area; greater acreages would minimize the effect of coveys wandering across boundaries during censuses.

At the start of the experiment it was believed that some use later could be made of such figures as birds per hunter, birds per man hour, or shells per bird in the bag for determining an unknown population of quail. Examination of the results, as shown in Table 2, indicate that such figures probably are not correlated to any degree with the number of quail available. At least if any correlation is present, it certainly is not in direct ratio. The above-mentioned ratios, therefore, do not seem to be indices of quail density on this area.

Table 3 indicates that hunters using dogs recovered more crippled quail than those without dogs. The former group lost an average of 1.47 quail per bag of 10, versus 4.71 unrecovered per bag of 10 by hunters without dogs. A personal element, however, is likely to creep in here since dog owners, in their pride, may have biased the results to some degree by a little bragging. The senior author, being a staunch dog addict, recognizes this failing in the clan.

Table 4 is of only local significance, indicating that the preferred quail hunting equipment was a 12-gauge, double barreled gun using No. 7½ shot. Too many individual combinations of gun caliber, model, and shot size were used to obtain any correlation as to which combination was the most effective.

TABLE 4

Summary of Types of Shooting Equipment Used by Individual Hunters, San Joaquin Experimental Range

Type of Gun	*Number of Hunters*
Double barrel	17
Pump	12
Automatic	9
Gauge of Gun	
12 gauge	24
16 gauge	8
20 gauge	5
.410 gauge	1
Size of Shot Used	
No. 6	1
No. 7½	22
No. 8	7
No. 9	8

No value was placed on answers to the question, "How many Cooper's hawks were seen?" since this seemed to depend on the hunter's ability to recognize Cooper's hawks; few could.

Comments by hunters on the number of quail present likewise were meaningless. In general, if a hunter had good success he reported, "There are plenty of quail"; but if his take was small, "The population is down." Then, too, the hunters were more or less aware of the comparative numbers of quail counted in the census, which probably tended to bias the answers to this question.

Summary

1. The observed valley quail population on the San Joaquin Experimental Range was apparently able to withstand an annual bag kill of 25 per cent of the fall population plus the incident cripple loss.
2. Reasonable hunting is less likely to affect a valley quail population through a series of years than are other factors.
3. Movement of quail probably did not play a major part in replenishing their numbers on the hunting area. This was indicated by the results from an extensive banding program carried on to the east of the hunting area.
4. Hunting and check areas several times larger than those used in this study are desirable to minimize boundary effects (local movements, etc.).
5. No apparent correlation was found between the pre-season number of quail and the birds taken per hunter, birds per man hour of hunting, or shells used per bird bagged.
6. There is indication that hunters using dogs lost fewer quail as cripples than those without dogs.
7. The favorite shooting equipment was a 12-gauge, double barreled gun using No. 7½ shot.

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THE FOOD OF THE BLACK-SPOTTED TROUT *(Salmo clarkii henshawi)* IN TWO SIERRA NEVADA LAKES

By A. J. CALHOUN [1]
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Upper Blue Lake and Heenan Lake lie in Alpine County, California, at elevations of 8,130 and 7,100 feet, respectively. Both lakes contain populations of black-spotted trout (*Salmo clarkii henshawi* Gill & Jordan), the native cutthroat of the east slope of the Sierra Nevada. This is the only species of fish in Heenan Lake. In Blue Lake there are also rainbow trout and rainbow-cutthroat hybrids, but together they constitute less than one per cent of the total trout population. A single species of minnow (*Rhinichthys oscula*) is present in Blue Lake.

Blue Lake is roughly a mile long, and half as wide, with a surface area of 344 acres. Heenan Lake has a surface area of 140 acres. They are about as dissimilar as two lakes could be, in spite of the fact that they are less than 15 miles apart, and are near enough the same size to be biologically comparable.

Blue Lake, almost on the crest of the Sierra, drains to the west. It lies in a deep, natural granite basin in a sparsely forested region with an annual snowfall in the neighborhood of 10 feet. A 28-foot dam raises the original level; maximum depth is 177 feet when full (see Fig. 39 in this magazine for a depth contour map). It is rich in dissolved oxygen. A sharp thermal stratification develops two or three weeks after the ice melts, which it usually does in June, and is maintained during the summer. The maximum surface temperature attained in 1940 and 1941 was 68° F. The water is clear. A Secchi disk is ordinarily visible to a depth of about 30 feet. The bottom fauna was found to average 134 pounds per acre, wet weight, during the summer of 1940, on the basis of 45 Ekman dredge samples. The littoral fauna is very poor.

Heenan Lake lies on the other side of the divide from Blue Lake, on the drier eastern slope of the Sierra, in a sage brush region which has a lighter snowfall. It is entirely artificial, being formed by a 35-foot dam built across a gently sloping swampy meadow formerly grazed by cattle. Maximum depth was only 24 feet in 1940 and 1941. Observations made during 1941 indicated a maximum surface temperature of about 70° F. for that year. The shallowness of the lake prevented the development of thermal stratification. Frequent strong winds kept the water well mixed during the summer of 1941. The organic content of the water was so great that there was a pronounced odor of decaying plankton around the shore in late summer. At that time, the visibility depth of a Secchi disk was less than three feet in the middle of the lake, and fell to practically zero around the shore. The dissolved oxygen was depleted at the

[1] Submitted for publication, December, 1943. The work on which this paper is based was done under the auspices of the California State Division of Fish and Game, in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Stanford University.

bottom of the lake early in the summer, but the turnover resulting from wind action was adequate to prevent stagnation from reaching a stage dangerous for the trout population. The bottom fauna in the littoral zone was fantastically rich. Stretches of muddy bottom were literally covered with swarms of aquatic insects, scud (*Gammarus*) and snails. Along the face of the dam, rocks the size of a grapefruit carried 15 to 25 scud, together with snails, caddice pupae, notonectids and planaria upon their lower surfaces. The corresponding littoral fauna of Blue Lake was so poor that it was ordinarily difficult to find organisms of any sort around the shore except at the mouths of the tributary creeks.

The difference in amount of food available for trout in the two lakes is reflected in the much better condition of Heenan Lake trout as compared to those in Blue Lake. In the length range from 30 cm. to 40 cm. (2.54 cm. = 1 in.), they averaged from 3 to 8 ounces heavier than Blue Lake trout of the same length. At the same time, Blue Lake trout were by no means thin, and are probably nearer the norm for the species than those in Heenan Lake.

Trout stomachs were collected at Blue Lake during the summers of 1939, 1940 and 1941; and at Heenan Lake in 1941. The results of the analyses of these stomachs are presented in the form of pie diagrams in the accompanying figures.

In carrying out the analyses, the contents of an individual stomach were placed in a watch glass. The various foods were then sorted out, and a visual estimate was made of the percentage by volume of each sort of food in each stomach. In arriving at the condensed results in the pie diagrams, the following method was used. Each stomach was weighted according to the amount of food it contained. Three degrees of fullness were recognized, defined as follows: (1) very full—walls of stomach distended with food, (2) moderately full—stomach cavity filled or nearly so, but walls not distended, and (3) nearly empty—stomach cavity not nearly filled. The percentage of a given food in an individual stomach was multiplied by an appropriate factor (1, 2 or 3, depending on whether they fell into category 3, 2 or 1, respectively, as defined above). The resulting products were then added for all fish in a series, taking each food separately. The summation for an individual kind of food, taken as a percentage of the corresponding summation for all foods, yielded the final figures which were used in making the diagrams. This method gives, essentially, the average per cent by volume of a given food in all stomachs of a series. The weighting of the stomachs according to their degree of fullness provides that fish which have been feeding most actively will contribute more strongly to the final figure than those which have nearly empty stomachs. It also discounts the importance of nearly empty stomachs containing a few atypical organisms.

Figure 36 contains the condensations of the results of analyses of stomachs from Blue Lake trout taken during the summers of 1939, 1940 and 1941. These fish were all between 27 cm. and 43 cm. long. The diagrams in this plate are divided roughly into four seasonal groups, based upon conditions at the lake, to facilitate the comparison of the series for the different years. Each vertical row contains series which are comparable insofar as season of capture was concerned. To give an idea of the relative advancement of the season in the different years, the final melting of the ice from the lake took place May 11, June 10 and June 22 in 1939, 1940 and 1941 respectively.

Taking the summer as a whole, the most important foods of the Blue Lake trout were larval and pupal chironomids, commonly called "blood worms"—the immature aquatic stages of small two-winged flies or midges. Microcrustaceans (daphnia and copepods), terrestrial insects, and immature stages of various aquatic insects other than chironomids, followed in that relative order of importance. Chironomid pupae were far and away the most important single food, for they constituted a major part of the diet of the fish during the early summer, when feeding was heaviest, and they were present in all samples in important amounts. There was a change in the relative proportions of the different foods as the season progressed. Immature chironomids became decreasingly important at the same time that other foods, notably microcrustaceans, increased in importance. This shift in the kinds of food eaten was accompanied by a decrease in the quantity of food found in indivdual

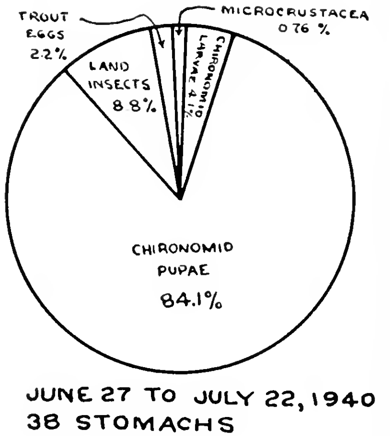
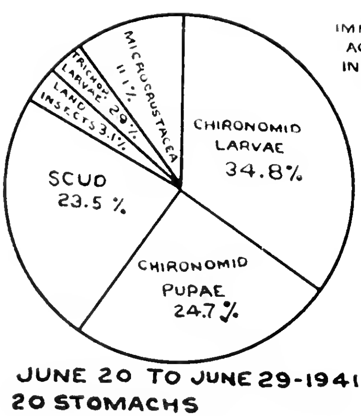
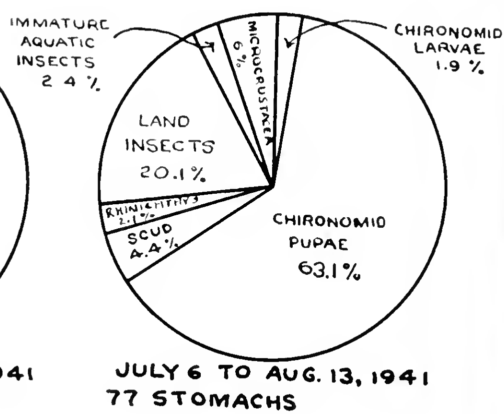


FIG. 36a. Stomach contents of Blue Lake trout 27 to 43 cm. long during three summers, 1939-1941.





stomachs, in general. Those taken in June and July were commonly filled almost to bursting with chironomid pupae alone. The estimated numbers of pupae in three such stomachs, from fish 32, 33 and 34 cm. long, containing 20, 21 and 28 c.c. of food, were 9,615, 9,849 and 13,132, respectively. After late July nothing even approaching such a condition was found except in rare instances where individual fish had eaten great numbers of terrestrial insects. In August and September, stomachs typically contained from 1 to 5 c.c. of food.

The only evidence of cannibalism appeared in the late summer of 1940 following the introduction of 50,000 fry into the lake.

The almost complete absence from the stomachs of the small minnow (*Rhinichthys oscula*) which is abundant in the shallows around the lake came as a considerable surprise. Only three stomachs of a total of 267 examined contained minnows, and each of these had only one. The most probable explanation for the failure of the trout to utilize these minnows for food lies in the observed fact that the minnows confine their activities during the summer to the very shallow water around the shore of the lake, where they are beyond reach of large trout. On several

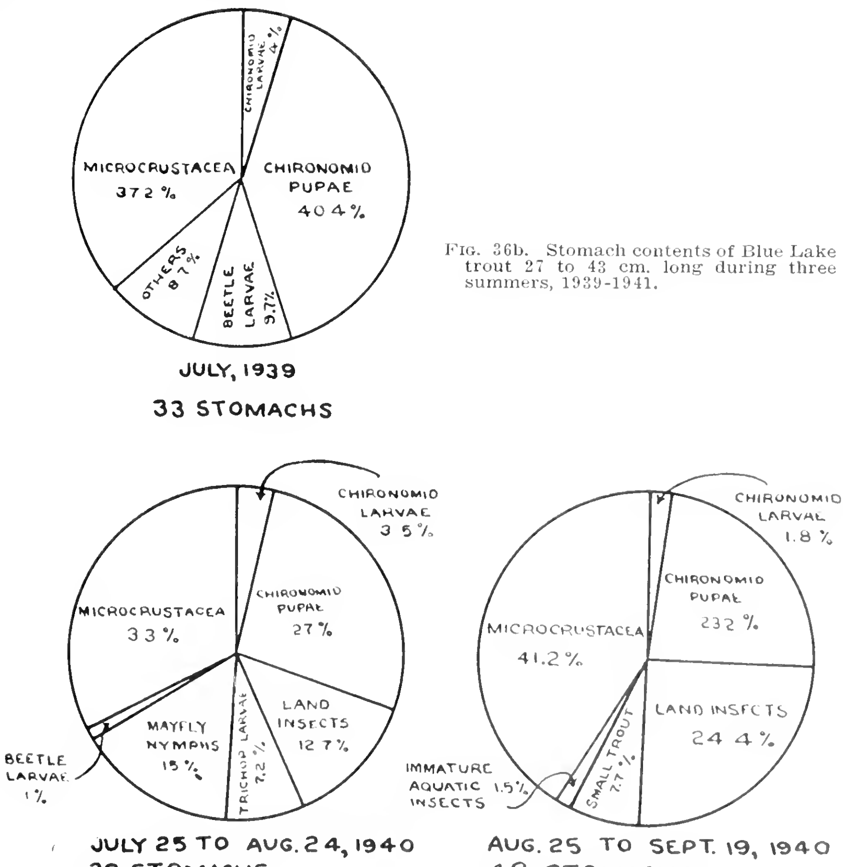


FIG. 36b. Stomach contents of Blue Lake trout 27 to 43 cm. long during three summers, 1939-1941.

occasions trout were observed in obviously unsuccessful pursuit of small schools of them.

It will clearly be inadvisable to introduce *R. oscula* into lakes under conditions comparable to those at Blue Lake with the idea in mind of improving feeding conditions for the trout. They are not consumed in significant quantities, and in addition they may compete seriously with

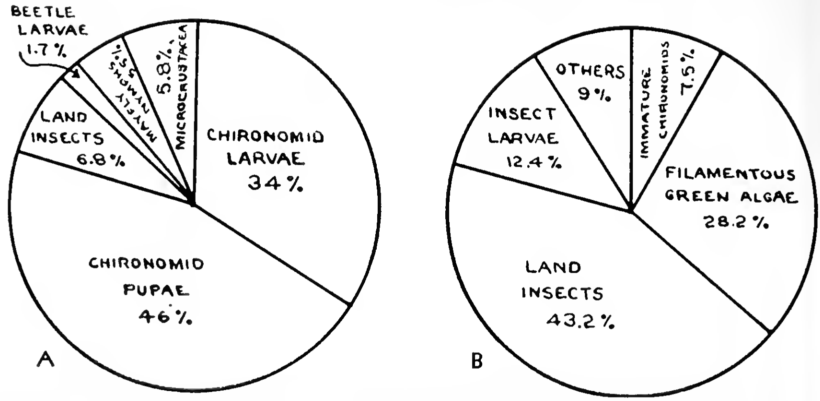


FIG. 37. A: Stomach contents of 18 Blue Lake trout fingerlings (3 to 5 cm.) taken September, 1940. B: Stomach contents of 17 Blue Lake minnows, *Rhinichthys oscula*, taken July, 1941.

young trout for food. In this connection, a considerable overlap was found to occur between the food of minnows and of trout fingerlings in Blue Lake. A series of young trout, 3 to 5 cm. long, was seined from around the shore of the lake in September of 1940, shortly after they had been introduced from the hatchery. The results of the analysis of the food in their stomachs is given in Figure 37-A. The series of minnows which was taken at the same time for comparison of feeding habits was not well enough preserved for study, but another series, taken in mid-summer of 1941, was studied, and the results will be found in Figure 37-B. While neither the young trout nor the minnows provide sufficiently extensive series for a reliable index of their foods during the summer, they nevertheless do show, without question, that the minnows eat the sort of thing upon which the small trout were feeding, and probably compete severely with them. The paucity of organisms in the littoral zone of Blue Lake has been pointed out.

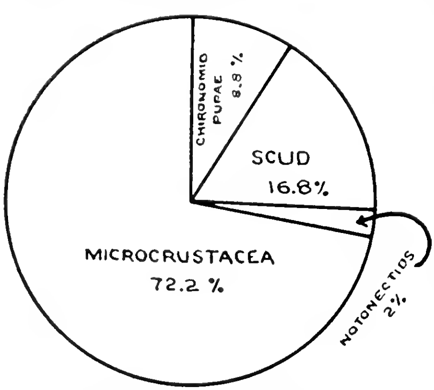


FIG. 38. Stomach contents of 61 Heenan Lake trout (30 to 50 cm. long) June 15 to September 17, 1941.

Stomachs from 61 trout, 30 to 50 cm. long, were collected at Heenan Lake in 1941, between mid-June and mid-September. They were consistently alike over that period, and have all been lumped together into a single series. The results from their analysis is given in Figure 38.

Plankton crustacea (daphnia and copepods) were the major constituent of the diet of these fish, in marked contrast to the situation found at Blue Lake, where the bottom fauna was the primary food source, with immature chironomids the major food. This is particularly interesting in the light of the limnological differences between the two lakes which have been pointed out. The complete absence of terrestrial insects from the Heenan Lake stomachs is surprising, particularly inasmuch as trout were seen to feed on the surface of the lake on several occasions, and at times they could be taken on flies, so that such forms must be of some minor importance in the diet of the fish. It was not unusual to find individual stomachs from Heenan Lake trout containing large numbers of scud. Such stomachs were almost never encountered at Blue Lake. Chironomid larvae and pupae were of minor importance during the summer, but may have been of more significance earlier in 1941, before sampling began. They were plentiful in bottom samples from Heenan Lake taken in mid-June.

Summary

The black-spotted trout in Upper Blue Lake, a deep granite basin at 8,130 feet elevation, subsisted largely on chironomid larvae and pupae. They failed to utilize the rather abundant population of the minnow, *Rhinichthys oscula*, which competes with young trout for food.

The trout of Heenan Lake, a former grazing meadow at 7,100 feet transformed by a dam into a 25-foot deep reservoir, subsisted largely on plankton crustacea (daphnia and copepods). The extremely abundant bottom fauna of the littoral zone provided only 17 per cent of their food (scuds of the *Gammarus* type); immature chironomids, plentiful in bottom samples, less than nine per cent.

Heenan Lake trout were in much better condition than those of Blue Lake, reflecting the relative richness of the two lakes.

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THE BOTTOM FAUNA OF BLUE LAKE, CALIFORNIA

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Upper Blue Lake is in Alpine County, California, at an elevation of 8,130 feet in the Sierra Nevada. It is a natural granite basin across the outlet of which a 28-foot dam was built in 1881. In Figure 39 the original shore-line is represented approximately by the 8.4 meter contour. It has a surface area of 344 acres, and a maximum depth of 54 meters (177 feet). It is a typical oligotrophic lake (cf. Welch 1935, p. 310): deep, clear, rich in dissolved oxygen, poor in dissolved nutrient materials. Limnological observations during two summers have been summarized in a previous paper (Calhoun, 1944.1).

A quantitative evaluation was made in 1940 of the standing crop of bottom fauna of Blue Lake—as Upper Blue Lake will hereafter be called in this paper for convenience—in connection with a study of its black-spotted trout (*Salmo clarkii henshawi*). The bottom organisms were found to constitute the trout's primary source of food (Calhoun, 1944.2). Bottom samples were collected with a standard 6-inch Ekman dredge. A series of 24 bottom samples was taken between July 13 (five weeks after the ice went out) and August 8, and a series of 21 samples during the second week of September. Dredging was done for the most part along the traverse line A-B (Fig. 39). A few samples in each series were collected in other parts of the lake, designated by appropriate letters in Figures 39, 40 and 41.

During the bottom sampling the water surface was approximately at the 4-meter contour (Fig. 39), which constitutes the "zero" reference point for all depths mentioned hereafter. From this shoreline to a depth of about 4 meters, in other words down to the original shoreline prior to construction of the dam, the bottom was a gravelly sand too highly consolidated to permit sampling with an Ekman dredge. For that reason this zone was excluded from the quantitative study. Frequent observations indicated that few organisms were present around the shore except at the creek mouths. At depths between 4 meters and 8 meters (13.1 feet and 26.2 feet), there was a transition from gravel to silt. Beyond 8 meters the bottom was a fine silt, with varying amounts of wood particles, except along the precipitous northeastern shore of the lake, where a lava talus slope extended down to a depth of 20 meters (65.6 feet) in some places.

A bed of *Nitella* or some closely related alga extended the length of the southwestern shore. It was sharply confined to a narrow zone between depths of 6 and 9 meters (19.7 and 29.5 feet).

Dredge samples were screened through a 30 mesh copper screen. The portion of the sample retained by this screen was transferred to a white-enamel pan, from which the organisms were picked out, sorted,

[1] Submitted for publication, December 1943. The work on which this paper is based was done under the auspices of the California State Division of Fish and Game, in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Stanford University.

counted, and preserved in 70 per cent alcohol. Later, the volumes of the various components of each sample were determined by the displacement of water in a burette, after excess alcohol had been removed by placing the organisms momentarily upon a blotter. In transposing to units of weight, it was assumed that the specific gravity was one. This has been found to be approximately correct for organisms of the kinds involved (Davis, 1938, p. 12; Cooper, 1940, p. 65). Tables 1 and 2 contain the results of the analyses of the two series of bottom samples. The forms have been separated into four arbitrary categories, and for each sample the number and volume of each category has been given, as well as the total volume and number for the sample.

There were few kinds of organisms present on the lake bottom, particularly in deep water. At depths greater than 15 meters (49.2 feet), the only forms found were immature chironomids (*Chironomus* sp. near *cristatus* and *Procladius* sp.),[2] and tubifex worms. At depths of

[2] Identified by O. A. Johannsen, Cornell University. Chironomids are small two-winged flies which deposit their eggs in water, where the whole larval life is passed. The larvae are sometimes called "blood-worms."

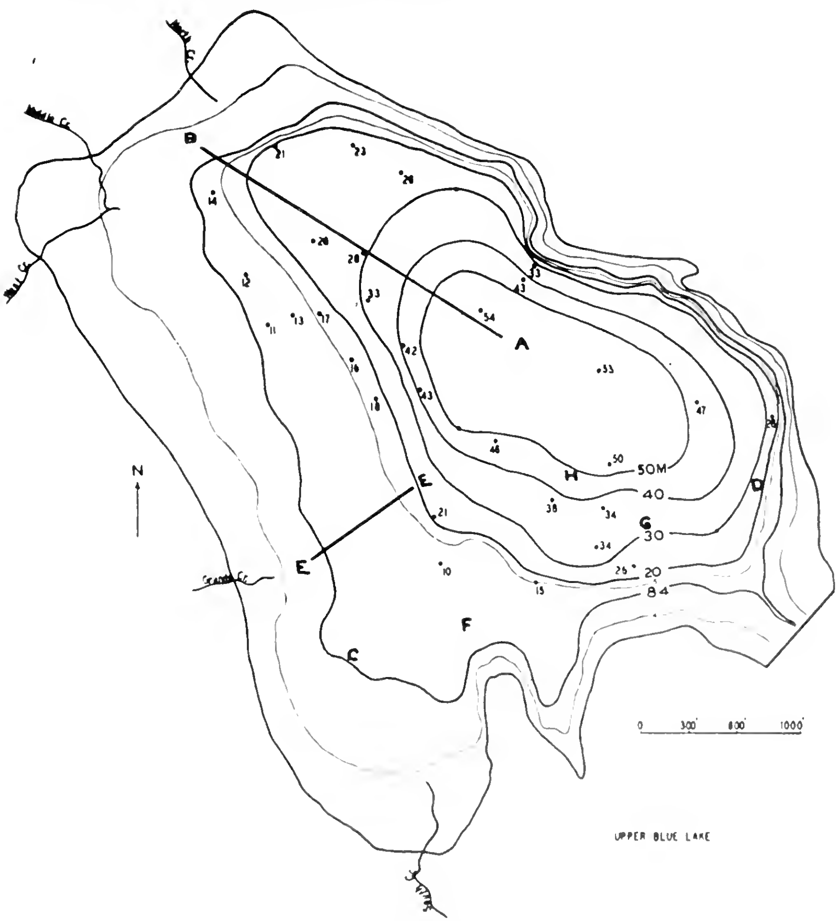

FIG. 39. Map of Upper Blue Lake. Depths are shown in meters (1 meter = 3.28 feet).

TABLE 1

Bottom Samples, Blue Lake, July 13 to August 8, 1940

Volumes (in cc.) and numbers of organisms per ¼ square-foot dredge

Location*	Depth	*Chironomus* sp. near *cristatus*		Other chironomids		Tubifex worms		Other forms**		Total	
		Vol.	Number	Vol.	Number	Vol.	Number	Vol.	Number	Vol.	Number
A-B	42 m.	.07	7	.03	4	.18	25	—	—	.28	36
A-B	7	.12	12	.04	17	.01	47	—	—	.17	76
A-B	6.5	.02	4	.03	15	.03	18	.01	3	.09	40
A-B	0.25	—	—	.03	38	—	—	—	—	.03	38
A-B	16	.30	26	.11	45	.01	29	—	—	.42	100
A-B	11	.45	48	.04	16	.10	17	—	—	.59	81
A-B	13	.18	17	.02	15	.10	26	—	—	.30	58
A-B	20	.18	19	.01	4	.07	21	—	—	.26	44
A-B	27	.08	5	.005	2	.10	9	—	—	.19	16
A-B	39	.08	7	—	—	.15	31	—	—	.23	38
A-B	50	—	—	—	—	.005	1	—	—	.005	1
A-B	9.5	.51	54	.04	22	.04	9	.01	1	.60	86
A-B	13	.39	34	.01	4	.07	9	—	—	.47	47
A-B	6	—	—	.06	61	.07	11	.09	9	.22	81
A-B	10	.52	46	.07	19	.10	11	—	—	.69	76
A-B	8.5	.20	23	Not det	ermined	Not det	ermined	Not det	ermined	Not det	ermined
A-B	27	.42	35	.01	3	.05	8	—	—	.48	46
E-E	7	.21	19	.03	39	.05	28	.02	5	.31	91
E-E	6	.10	14	.11	101	.02	15	.06	5	.29	135
E-E	13	.23	18	.11	80	.01	3	—	—	.35	101
E-E	14	.16	33	.01	4	.02	14	.01	4	.20	55
F	14.5	.13	23	.13	93	.01	10	—	—	.27	126
G	32	.10	6	.01	3	.02	13	.01	1	.14	23
H	48	—	—	.02	5	.19	33	—	—	.21	39

* For locations see map in Figure 39, on which corresponding letters mark locations of stations. Where two letters are given, the sample will have been taken along the line connecting them, at the indicated depth.
** *Gammarus*, turbellarians and hydrachnids.

TABLE 2

Bottom Samples, Blue Lake, September 8 to 16, 1940

Volumes (in cc.) and numbers of organisms per ¼ square-foot dredge

Location	Depth	*Chironomus* sp. near *cristatus*		Other chironomids		Tubifex worms		Other forms		Total	
		Vol.	Number	Vol.	Number	Vol.	Number	Vol.	Number	Vol.	Number
A-B	8.5 m.	52	60	.06	27	.05	10	.02	4	.65	101
A-B	5.5	.14	58	.07	18	.02	22	.11	11	.34	109
A-B	12.5	.22	34	.04	21	.03	9	—	—	.29	64
A-B	16	.35	34	.04	17	.03	13	—	—	.42	64
A-B	26	.20	15	—	1	.08	12	—	—	.28	28
A-B	28	.17	19	.01	1	.09	24	—	—	.27	44
A-B	9.5	.59	54	.07	55	.07	13	.01	9	.74	131
A-B	14	.32	34	.04	19	.10	36	—	1	.46	90
A-B	20	.32	25	.01	4	.10	23	—	—	.43	52
A-B	34	.02	3	—	—	.07	6	—	—	.09	9
A-B	39	.08	10	.01	2	.25	41	—	—	.34	53
A-B	44	—	1	.02	4	.23	34	—	—	.25	39
A-B	49		—	—	—	.18	22	—	—	.18	22
A-B	51			—	—	.05	6	—	—	.05	6
A-B	7	.34	34	.10	32	.02	16	—	—	.46	82
A-B	10.5	49	41	.09	39	.13	18	—	—	.71	98
A-B	32	05	7	.02	3	.13	24	—	—	.20	34
E-E	12	.36	24	.10	69	.03	12	.05	22	.54	127
E-E	6	.11	28	.07	16	.01	6	.08	4	.27	54
C	7	—	1	.03	15	.02	16	.80	*45	.85	77
D	17	.39	31	.04	19	—	—	.02	9	.45	59

* *Gammarus*.

less than 15 meters, there were these as well as other chironomids (*Tanytarsus* sp., *Chironomus* spp. and *Psectrocladius* sp.)[2] and also a few *Gammarus,* hydrachnids and turbellarians. The predominant organism in the lake was the large red larva of *Chironomus* sp. near *cristatus.* A sharply developed zone of concentration of organisms between 7 meters (23 feet) and 15 meters (49.2 feet) resulted largely from an abundance of this form, particularly in terms of volume. The other, smaller chironomids were almost equally important from the standpoint of numbers present in this region. These relationships are shown in Figures 40 and 41, in which numbers and volumes of organisms, respectively, are plotted against depths of samples. This has been done in each figure for the different categories of organisms individually as well as for all forms collectively. The trends shown were drawn in "by eye," and are, of course, only approximate. These two sets of graphs are based on the data in Table 2, for the second series of samples. When the values for the earlier series in Table 1 are graphed in the same way, the results are almost identical, and they are not included for that reason. The great similarity between the two series is interpreted to indicate both a high degree of stability of the bottom fauna during summer and early autumn and a satisfactory degree of accuracy of the method used.

The situation shown in these two sets of graphs resembles closely the one found by Eggleton (1931) in Douglas Lake and Third Sister Lake in Michigan. He found a similar zone of concentration, and showed that the reduction in the amounts of organisms with increase in depth beyond this zone was a result of unfavorable conditions in the deeper hypolimnion during the period of summer stagnation. This is probably equally true for Blue Lake. The marked decrease in numbers and volumes of organisms on the shallow side of the zone of concentration in Blue Lake appears to be correlated with the change in the nature of the bottom, which has been discussed. Depth alone can not be the important factor, because the organism largely responsible for the zone of concentration, *Chironomus* sp. near *cristatus,* occured abundantly on the muddy bottom of nearby Heenan Lake at depths between 2 and 4 meters (6.6 and 13.1 feet).

The considerable differences in the amounts of organisms present in different depth-zones in the lake made it impossible to arrive at any reasonable estimate of the amount of bottom fauna in the lake as a whole from any simple numerical average of all samples. The following procedure was carried out in order to obtain the estimates in Table 3. The lake was divided into four depth-zones, as shown in the first column of this table. The areas of these zones were determined on the basis of the depth contours in Figure 39. The average number of organisms in a given zone was derived from the bottom curve in Figure 40, as follows. The curve was transposed to a sheet of graph paper on which one unit was equal to one meter on the abscissa and five organisms on the ordinate. The mean ordinates under the four segments of the curve corresponding to the four depth-zones were estimated by counting the number of entire squares falling between a given segment and the abscissa, adding to this an estimate of the number of entire squares equivalent to the area represented by incomplete squares along the curve, and dividing the sum (the area under the curve) by the number of vertical columns of squares (the number of meters in the zone).

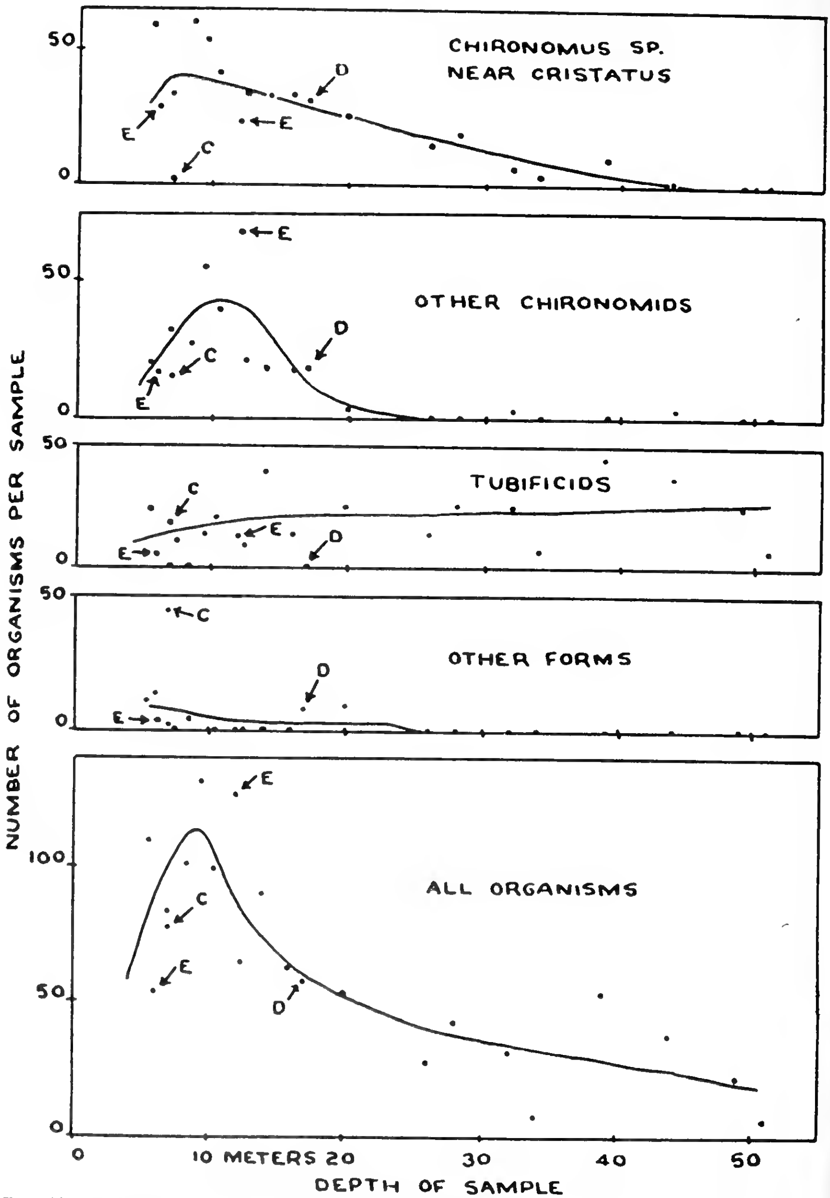

FIG. 40. Relationships between numbers of organism and depth of sample for the 21 samples in Table 2.

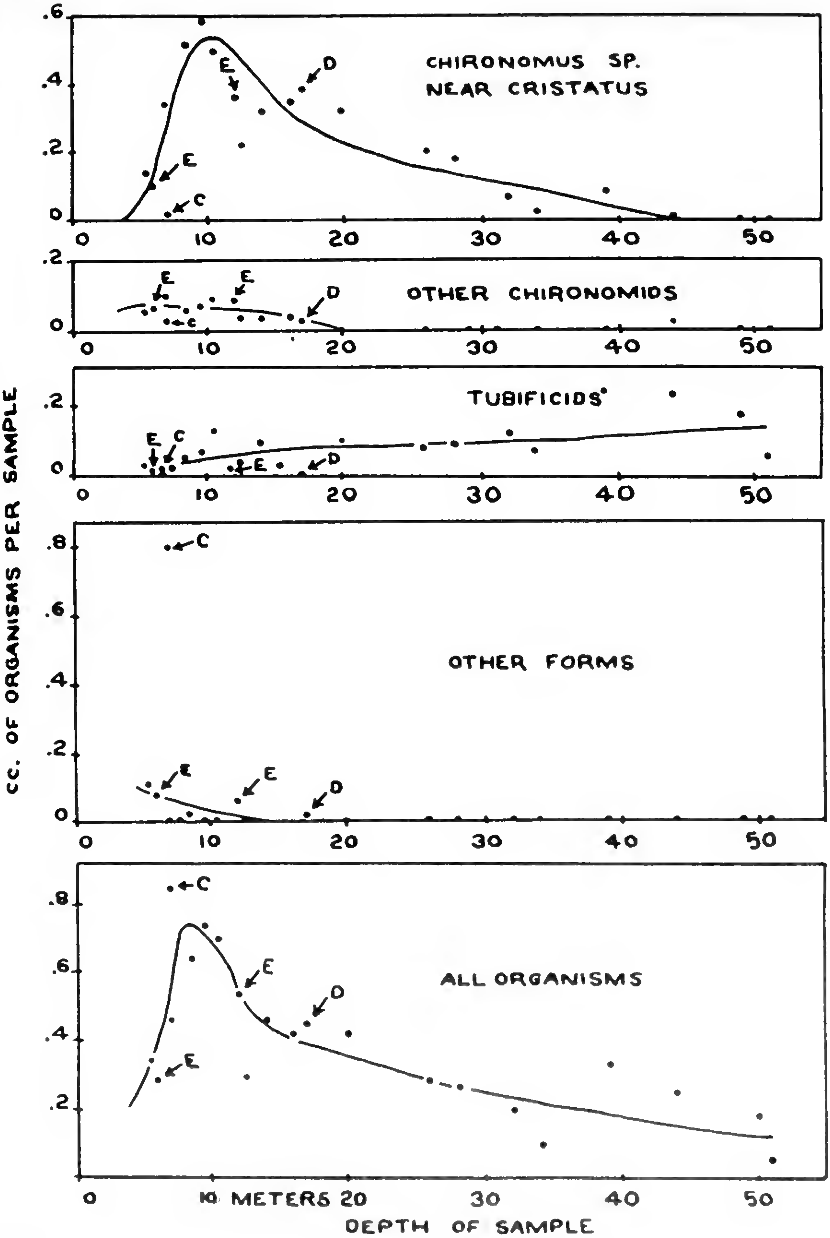

FIG. 41. Relationships between volumes of organism and depth of sample for the 21 samples in Table 2.

These mean ordinates are the values which have been used for the mean numbers of organisms in the four zones in Table 3.

TABLE 3

Standing Crop of Organisms in Blue Lake

Depth zone	Area of zone	Mean number organisms per sample	Number per square meter	Millions per acre	Millions in zone	Mean cc organisms per sample	Pound per acre wet weight	Pounds in zone
4–15 m.	128 A.	88	3,793	15.35	1,964	.481	224	28,672
15–30	52	49	2,112	8.54	444	.240	112	5,824
30–40	36	32	1,379	5.58	202	.048	22	792
40+	50	25	1,078	4.36	218	.020	9.3	465
4+	266		*2,627		2,828		**134.4	35,753

* Summation of column 6 divided by combined area of all zones, in square meters.
** Summation of column 9 divided by combined area of all zones, in acres.

The same procedure was followed in arriving at the estimates of the volumes of organisms in Table 3. In this case the bottom curve in Figure 41 was used.

The estimates for the lake as a whole were derived by adding the totals for the four zones and dividing the sum by the total area of the four zones, in the appropriate units. The average wet weight of organisms for the lake as a whole, beyond a depth of 4 meters, was 134 pounds per acre. According to Rawson (1930), this is roughly equivalent to 27 pounds per acre dry weight. The estimated number of organisms per square meter of lake bottom was 2,627.

The number of western lakes for which quantitative estimates of the bottom fauna have been derived is limited. A comparison with such results as are available indicates that Blue Lake supports a good fauna per unit of area for a deep, oligotrophic lake of its size.

The bottom fauna of Paul Lake, British Columbia (Rawson, 1934) offers a fairly close parallel to that of Blue Lake. The figure of 32.5 pounds per acre dry weight as an overall estimate can not be considered to differ significantly from the corresponding figure of 27 pounds for Blue Lake. On the other hand, the estimate of 1,363 organisms per acre was only about half the figure for Blue Lake, which was 2,627. Moreover, the types of animals comprising the fauna in Paul Lake were somewhat different. *Hyallela*, *Gammarus* and various molluscs formed a significant element. In Blue Lake, *Gammarus* was of minor importance, and no *Hyallela* or molluscs were found. Two rare species of mollusc are reported to occur in Blue Lake,[3] but I was unable to find them.

Lake Arrowhead, California (Needham, 1937) offers an interesting comparison with Blue Lake. It has essentially the same limited sort of fauna, with chironomids predominating. The area of the lake is 750 acres, the elevation is 5,102 feet, and the maximum depth is 150 feet. Needham's samples indicate the low figure of 9.1 pounds of organisms per acre, wet weight, which is only about $\frac{1}{15}$ the amount found in Blue Lake. Needham does not include tubifex worms in his figures, but that could account for only a very small portion of such a difference. As he

[3] Personal communication from G. D. Hanna, California Academy of Sciences.

points out, the fact that the samples were taken in late November, when a bottom fauna of this sort would be at a minimum as a result of the emergence of the chironomids, might be at least partially responsible for the small numbers of bottom organisms found.

The only lake at all near Blue Lake for which an estimate of the bottom fauna is available is Angora Lake, north about 25 miles, at an elevation of 7,800 feet. Needham and Sumner (1942) estimated that it averaged only 49 pounds per acre, wet weight, and 1,667 individuals per square meter. The lake has an area of about 5 acres, and a maximum depth of 50 feet. The same types of organisms were present as at Blue Lake, except that *Hyallela* replaced *Gammarus*. Considering its small size and its shallowness, both factors which would be expected to increase the bottom fauna, Angora Lake appears to be considerably less productive than Blue Lake.

Curtis (1934) gives data for one of the Cottonwood Lakes (Lake 4), in California, at an elevation of 11,000 feet. The greatest depth of this lake is 43 feet, and its area is 33 acres. Curtis estimates an average of 155 pounds per acre, wet weight, of the *Chironomus tentans* type of larva alone. When allowance is made for the smaller size of this lake, and the shallowness of its basin, compared to Blue Lake, the two appear to be on about the same level of bottom fauna production.

Summary

The bottom fauna of Blue Lake at depths greater than 4 meters was limited to chironomid larvae and pupae, *Gammarus*, hydrachnids, turbellarians, and tubifex worms. Over 50 per cent by volume consisted of immature *Chironomus* sp. near *cristatus*. The greatest concentration of organisms centered at a depth of about 10 meters. There was a sharp decline in amount above 8 meters and below 12 meters. The average wet weight of organisms for the lake as a whole, beyond a depth of 4 meters, was 134 pounds per acre. There were an estimated 2,627 organisms per square meter of lake bottom. Blue Lake supports a good bottom fauna for a lake of its size, type and location.

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SELECTIVE BREEDING OF RAINBOW TROUT AT HOT CREEK HATCHERY[1]

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California Division of Fish and Game

As is well known, Rainbow trout in California ordinarily spawn during the spring of the year. Sometimes at high elevations spawning may occur as late as June or early July. Undoubtedly the spring spawning habit of the Rainbow in California is that best adapted to natural conditions. However, artificial propagation in hatcheries and rearing ponds is difficult where eggs are obtained during the late spring months. Where cold hatchery waters are used the resulting fish may be only one and one-half or two inches in length by early August and fish of catchable size can only be produced by holding the fish in ponds through the following winter.

Fig. 42. Hot Creek Hatchery in winter.

At Hot Creek in Mono County four springs provide water ranging from 55° to 63° F., each spring being constant in temperature throughout the year. With the development of our trout hatchery there, it became apparent that great advantage could be obtained if eggs from fall spawning Rainbow were available. Fish hatched in the fall would, in waters of these temperatures, continue rapid growth throughout the winter, and be four to six inches long by the middle of the following summer when planting could be done most advantageously.

It was known that such fall-spawning Rainbow strains had been developed at Springville, Utah, by the U. S. Bureau of Fisheries, now the Fish and Wildlife Service, and through their assistance eggs from this stock were obtained for the Hot Creek Hatchery. The resulting fish

[1] Submitted for publication, January, 1944.

were two years old in the fall of 1935. At that time about 20 per cent of the prospective brood stock females had eggs, but the eggs could not be successfully taken from the fish because they were slow in coming free in the ovaries. These brood fish were being held in a pond of 60° water. Wild trout in the springs were tested and it was found that good eggs could be taken in the springs of lower temperatures. Accordingly, the brood fish were moved into a pond of 56° water in January, 1936, and in the autumn, at the age of three years, were spawned successfully. No selective work was done in connection with spawning at this time. The fingerlings were raised in ponds on natural foods throughout the ensuing winter. In the spring of 1937 they were graded and the best of them held for future brood stock selection.

Definite plans were made for selective breeding in 1938. It was resolved to select rapidly growing fish which produced a large number of eggs at two years of age, with these ideas in mind: to obtain a high percentage of females spawning at two years; to increase the egg production per female; and, by selecting the largest two year olds, to develop a strain that would make rapid growth. The shape, size and color of the select fish was also taken into consideration.

This work was carried on by breeding two year old selected fish every second year to develop brood stock for the next generation. To keep the spawning season within the same months each year, fish for the future stock were chosen from those spawning on or near October 25th.

In the fall of 1938 the first generation of Rainbow brood fish from eggs taken at Hot Creek Hatchery was two years old, and 53 per cent of the females spawned. On October 25, 1938, 48 of the best females were chosen and bred with males that had made the most rapid growth. The eggs were hatched as a lot and the fingerlings kept together until the spring of 1939 when 5,000 of them were graded from this group and put into the brood pond for future stock. In the fall of 1940, at the age of two years, 95 per cent of the resulting females spawned, and on October 25th the second selection was made. Twenty-five females were chosen for the same qualities as in 1938, and the same procedure was followed with eggs and fingerlings.

The resulting two year olds were ready for their first spawning in the fall of 1942. On October 23d, 60 females were picked for size and for number of eggs produced; but a new method was used in handling the eggs. It had become apparent that losses in the eyed eggs at Hot Creek were higher than normal, running from 15 to 35 per cent in the different lots and resulting in large part at least from poorly developed embryos. Various causes were suspected, including types of food given the parent fish, and long periods spent in warm water between spawnings. Experiments were run to check these sources of trouble and some corrections were found possible. Among other things it was discovered that a few fish produced eggs which were practically an entire loss; some, a normal loss; and some, nearly perfect eggs. It was concluded that the group handling of the selected eggs was a mistake and that better results could be obtained by segregating the eggs from each female.

Accordingly, the eggs from each fish in 1942 were counted and kept in separate compartments in egg trays in the hatchery. The losses of each lot were recorded until hatching time arrived. Just before the eggs hatched they were carefully picked to remove as many of the poorly developed ones as possible. The eggs from four females were then selected, paying more attention to the quality than to the quantity. These eggs hatched 97.1 per cent. The egg losses from some of the rejected lots were as high as 80 and 90 per cent.

The results of the foregoing are set forth in condensed form in Table 1.

TABLE 1

Results of Selective Breeding of Two Year Old Fish

Year	*Per cent of 2 year females spawned*	*Average number of eggs per female spawned in October*	*Number of females selected for brood stock development*	*Average number of eggs per selected female*
1938	53	723	48	958
1940	95	1332	25	1782
1942	98	1693	60	2106*

* Average production for four lots chosen for quality from the egg lots of the 60 selected females.

Table 1 sheds light on two of the objectives of the selective breeding plan. Fish spawning for the first time at two years of age have been increased from 53 per cent to 98 per cent in three generations. Egg production has been raised from 723 per two year old female to 1,693 per two year old female, in the ratio of 2.34 to 1. (Egg production of the selected females in the last column is less significant, since they are merely the heaviest producers of each year—except in 1942 when quality was considered more important than quantity, and when on the latter basis alone the figure would have been 2,637 per female.) This increase in egg production is evident also in the older fish. In 1941, 13 three year olds averaged 2,112 eggs per fish, and in 1943 nine three year olds averaged 3,072 eggs per fish. These counts were from females individually selected for eggs of good quality as well as quantity.

That selection of rapidly growing fish for brood stock has increased the growth rate is shown in Table 2.

TABLE 2

Average Weights of Selected Yearlings on October 1 *

Year	*Average Weight of Fish*
1939	5 ounces
1941	6 ounces
1943	8 ounces

* Eggs taken in October of the preceding year.

The hatchery and rearing ponds were rebuilt in 1941. Before that date operations were carried on under very crowded conditions and the advantages given by the changes made in 1941 make it difficult to present comparative figures of growth from year to year, but the fish raised for planting show results similar to those given in the above chart.

It is possible that a few more generations of selective breeding of Rainbow brood fish will bring greater increases in the egg production and that through individual selection of the parent fish, the quality of the eggs can be greatly improved. There is little doubt that greater progress can be made to increase the growth rate of fingerlings through selective breeding of brood fish.

EDITORIALS AND NOTES

SKULL OF A CALIFORNIA GRIZZLY

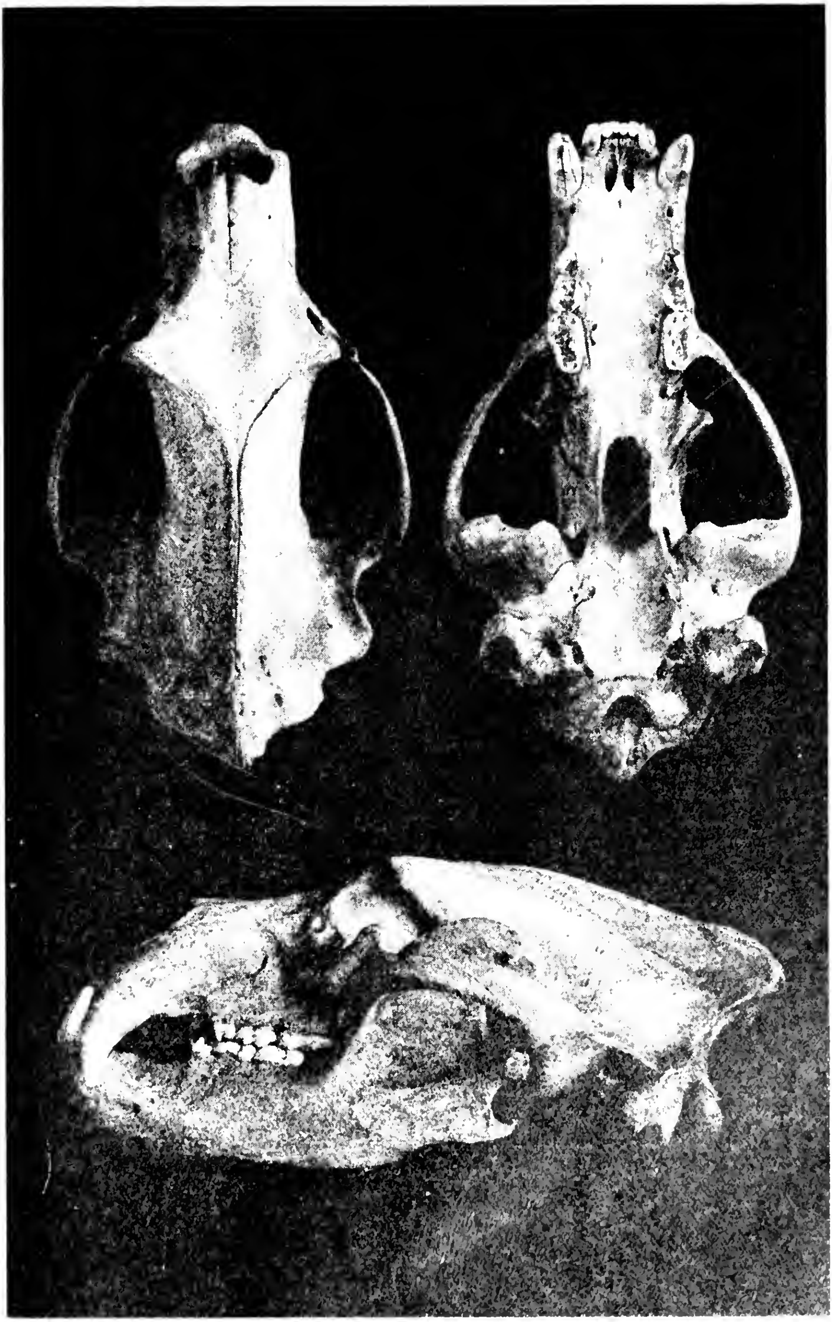
A paper by Dr. E. Raymond Hall, "The Grizzly Bear of California," published in this magazine in July, 1939, calls attention to the great rarity in museum collections of specimens of this now extinct form and emphasizes the scientific importance of securing additional remains. Even such material as the Museum of Vertebrate Zoology possesses is largely of a fragmentary nature; Grinnell, Dixon and Linsdale (Fur-Bearing Mammals of California, Vol. 1, p. 68, Univ. Calif. Press, 1937) list only two complete skulls. For this reason, it seems worth while to add details of another complete skull (Fig. 43) at present in the collection of the Museum of Comparative Zoology at Harvard. The Peabody Museum at Salem, Mass., formerly owned this specimen, but disposed of it when it decided to limit its natural history exhibits.

Written on the skull in faded but still legible ink is the following: "Ursus horribilis Ord. Grizzly Bear. California pres. by W. O. Potter May 15, 1862." A tag with it indicates that it was one of the skulls studied by C. Hart Merriam in 1915 when working on the grizzly bears although it does not have his identification. Dr. Thomas Barbour of the Museum of Comparative Zoology states that Dr. E. S. Morse, formerly Director of the Peabody Museum, told him that tradition had it that the bear was killed in the hills not far from San Francisco. Unfortunately, the date on the skull appears to refer to the time when the skull was presented to the museum and not to when the animal was killed.

Measurements in millimeters are as follows: Total length, 410; basilar length, 345; palatilar length, 179.2; greatest length of nasals (not exact as the naso-frontal suture is ossified), 101; zygomatic width, 221; mastoid width, 172.5; width of braincase, 108; interorbital width, 79; width across postorbital processes, 129.8; length of upper cheek teeth (from anterior border of canine to posterior border of M^2), 144; width across upper cheek teeth, 91.4; crown length of M^1 and M^2, 59.7; crown length of M_2, 36.2; length of lower cheek teeth, 159.—*Barbara Lawrence, Museum of Comparative Zoology, Harvard College, Cambridge, Massachusetts, October, 1943.*

A "SPECIMEN" OF GRIZZLY BEAR FROM ALAMEDA COUNTY, CALIFORNIA

Specimens of grizzly bears from California are so few in museums that any are of interest even if incomplete. On July 10, 1943, I found a third right lower molar of a grizzly bear in Corral Hollow, one and one-half miles east of Tesla, Alameda County, California. The tooth was lying on the surface of the sand and gravel of the wash and probably had been carried from upstream by flood waters. Other fragments from the same individual are doubtless scattered along the watercourse but the chance of finding any of them seems small. A search in the



vicinity for other parts was fruitless. The tooth is in excellent condition except for small surface cracks. It is therefore reasonable to suppose that the tooth had been buried until recently as teeth usually fall to pieces in a short time when exposed to sunlight and heat. The crown surface is almost unworn, indicating that it was from a young individual. The crown is 23 mm. long and 16 mm. wide. This indicates that the tooth came from one of the larger kinds of grizzlies and is support for the supposition that it came from one resident in the vicinity, since it is known that grizzlies in California were larger than those from most other areas. There is, however, much individual variation in the size and shape of the third lower molar in all kinds of grizzlies. The identification of the tooth as that of a grizzly is certain, but it is not possible at present to determine the specific or racial identity of the tooth. According to present knowledge of distribution, and the present nomenclature, and assuming that the specimen actually is from a bear which lived in the vicinity, the tooth represents a specimen of *Ursus californicus, Ursus colusus*, or *Ursus tularensis*.

This tooth is the only "specimen" known to me of a grizzly bear from Alameda County, but it does not furnish a new record of locality. Rather, it substantiates some published records that grizzlies were once present in Corral Hollow. In T. H. Hittell's "Adventures of John Capen Adams: Mountaineer and Grizzly Bear Hunter of California" (Charles Scribners Sons, 1926) there is an account (pp. 301-305) of the killing in 1855 of a female and two cubs in "Devil's Den," in which place in Corral Hollow was a bed of coal and a sulfur spring. This locality may be the present coal mine of Tesla, but I have not attempted to learn if there are other coal beds and sulphur springs in the vicinity. The tooth was found a mile and a half downstream from Tesla. It can hardly be assumed, of course, that it is from one of the bears killed by Grizzly Adams.

The last record for Corral Hollow is 1861. This is cited in Grinnell, Dixon, and Linsdale's "Fur-bearing Mammals of California" (University of California Press, 1937) on page 81, and refers to an old companion of Grizzly Adams who was "badly used by a bear last spring."

It is possible that some members of the families of pioneer settlers have knowledge of later occurrences of grizzlies in the vicinity and may even possess specimens. Dr. E. Raymond Hall, in an article concerning grizzly bears in California (California Fish and Game, vol. 25, 1939, pp. 237-244) has pointed out the scarcity of specimens of California grizzlies and the desirability of preserving any existing specimens in a safe place and making them available for study. It is also desirable that any definite and trustworthy information concerning grizzlies and their habits be placed on record.—*Seth B. Benson, Museum of Vertebrate Zoology, University of California, October, 1943.*

DIAMOND-BACK TERRAPIN INTRODUCED INTO CALIFORNIA

Diamond-back terrapin, highly rated as a table delicacy in the eastern United States, were planted in California on May 13, and May 30, 1943. The first lot consisted of 485 yearlings and the second of 77 adults, of which 52 were females and 25 males. Both lots were obtained through the cooperation of the U. S. Fish and Wildlife Service, the

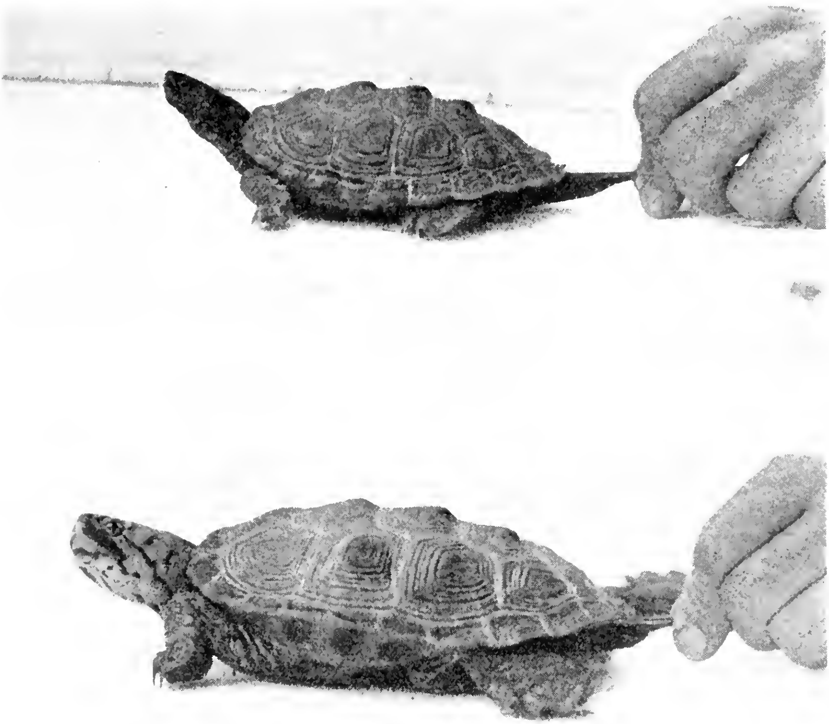


FIG. 11. Diamond-back terrapins. Male above, female below.

yearlings having been raised at their station at Beaufort, North Carolina and the adults purchased from commercial dealers in the same area. The introduction of terrapin was initially suggested by the Consolidated Sportsmens Clubs of the Peninsula through their secretary, Mr. G. W. Philpott of San Mateo, and the club by supplying funds facilitated purchase of the adults.

The locality chosen for the planting was an unnamed island lying just off shore from Radio Station KPO in the southern part of San Francisco Bay between the mouths of Belmont and Steinbergen Sloughs. The island is about 1700 yards long and 350 yards wide. At high tide all but the westernmost portion is submerged. Lowlying marsh lands of this type are the habitat of the animals on the Atlantic coast and similar types of food such as mussels and small crabs are abundant. The island is thickly covered with marsh vegetation, so much in fact, that the animals have a great abundance of cover and will be extremely difficult to find.

On October 9, 1943, a trip was made to the island by two observers. Careful search was made over the west end of the island and along the offshore side but no signs of terrapin could be found. A previous introduction of terrapin was attempted in 1896, when 129 of the animals were brought to California and planted in an unrecorded locality on San Francisco Bay. The present planting will be more carefully followed to determine the success of the introduction.—*A. C. Taft, Chief, Bureau of Fish Conservation, California Division of Fish and Game, January, 1944.*

IN MEMORIAM

RICHARD DE LARGE

The career of Richard DeLarge, Lieutenant, United States Army Air Force, came to a tragic end on February 24, 1944, at Douglas Air Base, Arizona, when the plane in which he was instructing an aviation cadet in night flying crashed because of motor failure coming into a landing.

Born in Omaha, Nebraska, on May 14, 1918, DeLarge grew up in Los Angeles, where he attended the John Marshall High School and the Glendale Junior College. After working for the Citizens National Bank of Los Angeles and the Southern California Gas Company, he joined the staff of the California State Division of Fish and Game in 1940 and was stationed at Mt. Whitney Fish Hatchery with the rank of Assistant Warden. He enlisted in the Army Air Corps in May of 1942, but was not called to duty until January of 1943. He received his training in California and at Douglas, Arizona, where he was commissioned November 3, 1943. He immediately became an instructor at that field, and up to the time of the fatal accident had made full-fledged pilots out of 41 flying cadets.

He is mourned by his parents, Lula and Jules DeLarge, and by his many friends in the Division.—*A. C. Taft, Chief, Bureau of Fish Conservation, California Division of Fish and Game.*

REPORTS

FISH CASES

October, November, December, 1943

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalones: Undersize, no license, overlimit	6	$145 00	
Angling: No license, closed stream, at weir, spear in closed area, use gaff and snag hooks, night fishing, illegally taken fish, possession of spear within 300 ft. of stream, at dam, failure to show fish on demand	52	985 00	140
Bass, black: No license, undersize	2	35 00	
Bass, striped: At night, undersize, two rods, no license, overlimit, before sunrise, in salmon net	17	310 00	
Clams: Undersize, in refuge	19	460 00	15
Commercial: Fail to pack minimum cases to the ton, no license	2	110 00	
Lobsters: Undersize, in traps	2	125 00	
Salmon: Overlimit, at night, illegally taken, at fish screen, no license, spearing, closed area, closed stream, other than angling	42	1,350 00	30
Pollution	1	300 00	
Totals	143	$3,820 00	185

GAME CASES

October, November, December, 1943

Offense	Number arrests	Fines imposed	Jail sentences (days)
Bear: Closed season	1	$25 00	
Deer: Closed season, doe, failure to complete deer tags, no deer tags, use tags of of another, kill deer no permit, forked horn deer in District 1¾, refuge, no license, spike buck, spotlighting, fawn	99	6,770 00	20
Deer meat: Closed season, illegal, fail to have stamped	15	1,355 00	
Doves: Overlimit, closed season	4	60 00	30
Ducks: Closed season, failure to show game on demand, no license, early and late shooting, shooting from power boat, unplugged gun	114	4,762 50	55
Geese: Overlimit, unplugged gun	16	375 00	
Hunting: No license, false statement to secure license, transfer license, firearms on refuge, at night, unplugged gun, closed area	97	2,895 00	
Nongame birds	4	100 00	
Pheasants: Closed season, shooting from vehicle, no tags, use tags of another, no license, unplugged gun, use license of another	193	6,690 00	
Quail: Closed season, trapping	10	260 00	
Rabbit, Cottontail: closed season	1	25 00	
Sage hens	3	125 00	
Swans	2	50 00	
Trespassing	1	10 00	
Tree squirrel	1	100 00	
Shooting from public road and car	11	175 00	
Disturbing and removing traps of licensed trapper	1	50 00	
Trapping for profit, no license	3	30 00	
Totals	576	$23,857 50	105

SEIZURES OF FISH AND GAME

October, November, December, 1943

Fish:	
Bass, black	2
Bass, striped, pounds	1,500
Clams	392
Clams, Pismo	66
Lobsters	7
Lobster traps	45
Salmon	6
Salmon, pounds	520
Salmon, king	25
Salmon, silver, pounds	45
Trout, rainbow	3
Trout, steelhead, pounds	1½
Game:	
Deer	36
Deer meat, pounds	433
Doves	162
Ducks	540
Ducks, mallard	3
Ducks, pintail	92
Ducks, sprig	16
Geese	51
Pheasants	10
Pheasants, hen	48
Pheasants, male	199
Quail	7
Rabbits, cottontail	1
Sage hens	2
Squirrel	1
Swan	1
Wood duck	2

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(Continued from inside front cover)

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CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 30 SAN FRANCISCO, JULY, 1944 No. 3

TABLE OF CONTENTS

CALIFORNIA FISH AND GAME is a publication devoted to the conservation of wildlife. It is published quarterly by the California Division of Fish and Game. All material for publication should be sent to Brian Curtis, Editor, Division of Fish and Game, Ferry Building, San Francisco 11, California.

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In The Service of Their Country

Now serving with the armed forces of the United States are the following 156 employees of the California Division of Fish and Game, listed in order of entry into the service:

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Garrie Heryford
Robert O'Brien
Kenneth Doty
Don Chipman
Howard Twining

Killed in Line of Duty

Byron Sylvester
Arthur Boeke
Richard DeLarge

THE FISHERY OF THE LOWER COLORADO RIVER[1]

By WILLIAM A. DILL

Bureau of Fish Conservation

California Division of Fish and Game

TABLE OF CONTENTS

[1] Submitted for publication, April, 1944.
Photographs, except where individual credit is given, are by Chester Woodhull and the author. Map and graphs drawn by Samuel Kaletkov.

The cooperation of the Arizona Game and Fish Commission, especially that of Messrs. K. C. Kartchner, former State Game Warden, H. L. Reid, Director of Fisheries, and Mervin Smith, Yuma County Deputy, is appreciated.

Mr. Geno A. Amundson, Refuge Manager of the United States Fish and Wildlife Service's Imperial N. W. Refuge, and members of his staff, especially Mr. Thomas E. Rochester, have been most helpful. Mr. Walter P. Schaefer, Superintendent of the Havasu Lake N. W. Refuge, has furnished data on Lake Havasu.

Much detailed information on the dams and diversions and the physical aspects of the river has been contributed by members of the United States Bureau of Reclamation. Sincere thanks are extended to Messrs. Ernest A. Moritz, Regional Director, and R. G. MacDonald of the Boulder Canyon Project at Boulder City, Nevada; S. A. McWilliams and Boyd E. Coffey at Parker Dam; Leo J. Foster and John K. Rohrer of the All-American Canal and Gila Project at Yuma, Arizona; C. B. Elliott, W. A. Boettcher, and Daniel Martinez of the Yuma Project at Yuma.

The United States Geological Survey has, through Mr. John H. Gardiner, District Engineer at Tucson, Arizona, taken water temperatures for us, and contributed other physical data. Thanks are also due to other members of the Survey: Messrs. W. L. Heckler of Tucson; Fred S. Anderson of Boulder City; R. L. Blake and Sherman O. Decker of Phoenix, Arizona; Martin D. Dykers, Yuma; C. S. Howard, Albuquerque.

Mr. C. P. Mahoney, Manager, Palo Verde Irrigation District, and other members of his staff, and Mr. Arch Griffin, Director of the North Gila Irrigation District, have furnished information. Special thanks are due Mr. Mahoney for securing water temperature records near Blythe.

Data on the Headgate Rock Dam was furnished by Mr. R. H. Rupkey, Senior Engineer, Colorado River Indian Reservation Project.

Visits to the lower portion of the Colorado River Aqueduct were made possible by Mr. Julian Hinds, General Manager and Chief Engineer of the Metropolitan Water District of Southern California, and by Mr. R. F. Stringfellow, Chief Special Agent, of the District.

Mr. James H. Gordon, Meteorologist of the United States Weather Bureau at Yuma, furnished data on the climate of the lower basin. Mr. L. V. Wilcox, Agronomist of the United States Bureau of Plant Industry's Rubidoux Laboratory at Riverside, California, has furnished chemical analyses of Colorado River water.

Two of the bullheads collected were identified by Dr. Carl L. Hubbs of the University of Michigan, and Dr. Robert L. Miller has contributed notes on some of the fishes. Some information on fishes supplied by several other individuals will be used in a later paper, and my debt to them will be acknowledged there. Mr. L. M. Klauber of San Diego has furnished notes.

A sincere debt of appreciation is due to members of the Yuma Valley Rod and Gun Club, Blythe Chapter of the Izaak Walton League, and Needles Boat Club, and to the many fishermen and other residents encountered during the field-work. It would be difficult to thank all of them individually, and the names of many are unknown.

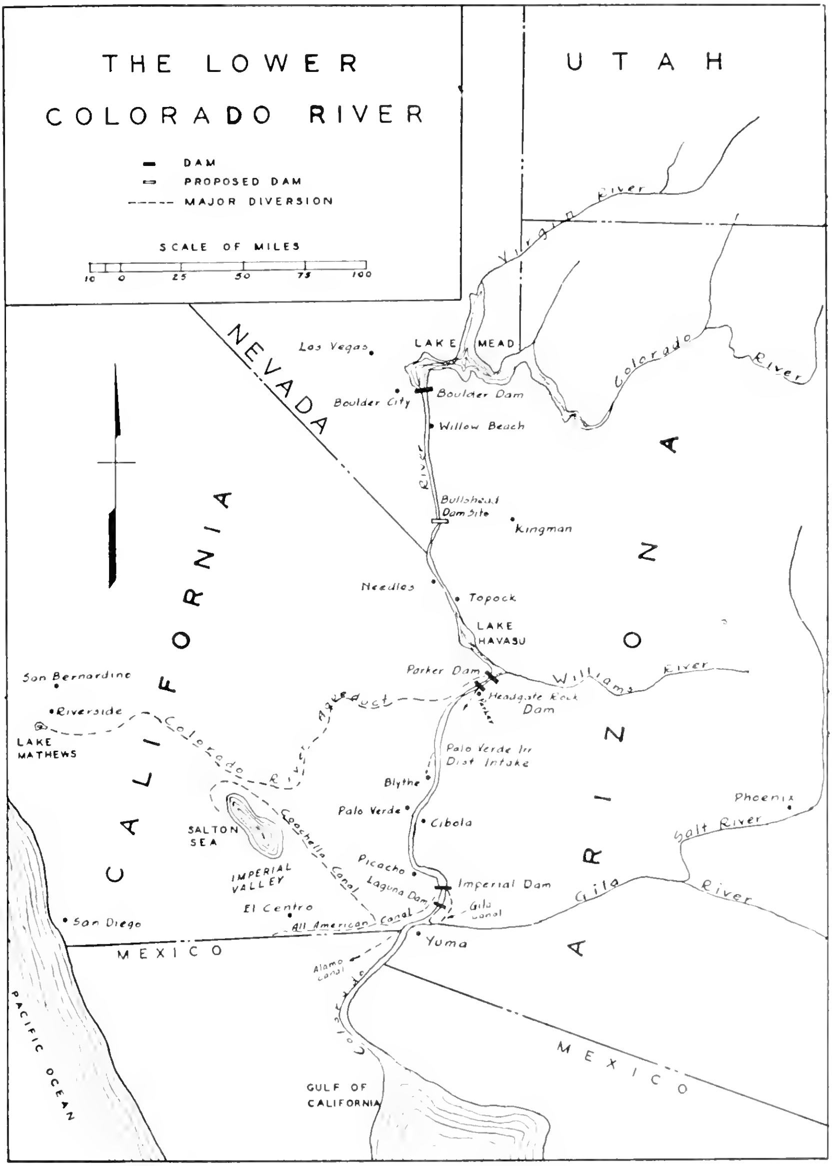

FIG. 46. The lower Colorado River and adjacent territory. (A composite sketch from several maps.)

THE COLORADO RIVER BASIN

General Description

Any account of the lower river must be preceded by a description of the Colorado as a whole.[2] Its basin covers 1/13 of the area of the United States and part of northwestern Mexico. This is naturally divisible into two parts: (1) an upper basin, an area of high plateaus bounded by towering mountain ranges; (2) a lower basin or desert country of low plains broken by short mountain groups.

Major John Wesley Powell has described the formation of the river in his book "First through the Grand Canyon": "The upper two-thirds

FIG. 47. The Colorado River between Blythe and Parker. Feb. 1942.

of the basin rises from four to eight thousand feet above the level of the sea. This high region * * * is set with ranges of snow-clad mountains, attaining an altitude above the sea varying from eight to fourteen thousand feet. All winter long, on its mountain-crested rim, snow falls, filling the gorges, half burying the forests, and covering the crags and peaks with a mantle woven by the winds from the waves of the sea—a mantle of snow. When the summer-sun comes, this snow melts, and tumbles down the mountain-sides in millions of cascades. Ten million cascade brooks unite to form ten thousand torrent creeks; ten thousand torrent creeks unite to form a hundred rivers beset with cataracts; a

[2] In this report, the term "lower river" usually refers only to that section between the Nevada-California boundary and the Mexican boundary.

hundred roaring rivers unite to form the Colorado, which rolls, a mad, turbid stream, into the Gulf of California.''

With the source of nearly all its water in the high mountains, but with its course through the arid plains and table lands, it has cut a deep and narrow gorge for more than a thousand miles. Year after year the river cuts deeper and deeper, and carries thousands of acre-feet of silt downstream. Today, Boulder Dam marks the end of this canyon region, and is the key to the lower Colorado. Since its completion in 1935, the river below no longer rolls mad and turbid, but has been changed into a clearer and more constant stream whose flow can be largely controlled by man.

Beyond Boulder lies the lower basin, a land of excessive heat and aridity. Here the river flows at low gradient through a succession of valleys bordered by low hills or mountains alternating with narrow rocky passages. On either side it is bounded by far-reaching deserts, and only two tributaries of importance enter the stream.

A few miles below Yuma the force of the river is spent, and near the Mexican boundary is the apex of its great delta. Here the land slopes away to the south, southwest and west. The stream now has a most devious course as it flows to the Gulf forming distributaries and lagunas. Carrying the water derived from seven states and Mexico, the Colorado terminates its course of 1,700 miles.

One more feature of the river must be mentioned—its geographical relationship to the Imperial Valley or Salton Sink. This basin, which is occupied in part by the Salton Sea, is separated from the Gulf of California by the delta-plain of the river. It is below sea level, the deepest part about 275 feet below. Blake (1854) considered that it represents the extreme head of the Gulf of California which has been cut off by the delta barrier, and this belief seems to persist in most recent literature, although studies by Free (1914) and Buwalda and Stanton (1930) advance a most convincing alternate theory. These indicate that the basin was not inundated by the Gulf, but that it was sinking progressively as the delta was growing. Thus, the river excluded the Gulf from the newly forming depression by building and maintaining a huge alluvial cone across the southern part of the basin. Waters from the Colorado, shifting on its delta well above the level of the sink, have flowed into this basin both before and since the advent of our historical records. The present Salton Sea is the result of an accidental diversion of the river during the 1905-1907 period, which formed a lake 445 square miles in area. Since then its area has decreased to 287 square miles with its water surface about 244 feet below sea level. Despite a high evaporative rate, its present level remains fairly constant because of the continuous inflow of waste irrigation waters through the New and Alamo rivers at its southeastern end. These streams were old distributaries from the delta of the Colorado, but are now to be considered as drainage ditches or wasteways. A number of intermittent streams also enter the Sea from southwest to northeast.

The floodplain of the lower river has been cultivated for many years—first by the Indians, later by the Jesuits, and finally by the Americans of today. The soil is fertile and the growing season is long. By diversion of water agriculture has been extended far beyond the bordering alluvial flats—to mesa lands and the great Imperial Valley.

But the unpredictability of the Colorado, its alternate periods of drought and flood, has sorely troubled agriculturists. And, always, there has remained the remembrance of the deluge of 1905-07 when, for 18 months, almost the full flow of the river poured into the Imperial Valley.

To eliminate this menace, and for many other reasons, there is now a series of new dams on the river, and more are projected. Flood and silt control, water for irrigation and for domestic and industrial use, and generation of hydroelectric power are the major purposes of these dams. But they have also had other effects of which the new fishery of the river is an outstanding example.

Detailed Description of the Lower River [3]

Most popular descriptions of the river have been confined to those of the Grand Canyon or to the rushing waters traversed by explorers and adventurers who "ran" the Colorado. To those who have thought of the river only in terms of the flaming canyon walls as painted by Dellenbaugh or Moran, the more subdued coloring along the lower

FIG. 48. "Placid waters near Yuma." The Colorado River in the vicinity of Picacho. Jan. 1942.

stream will prove disappointing. And a first glance at seemingly placid waters near Blythe or Yuma will surprise those whose concept of its flow has been based on tales of boats hurled and smashed in the rapids of the upper gorges.

The section to be described here does lack many of the attributes which have given fame to the Colorado. Grinnell (1914) said that it flowed "* * * in relatively sober fashion." But while it lacks the

[3] Other descriptions of this same section based on biological surveys will be found in Grinnell (1914) and Tappe (1942).

rapids which have brought disaster to many, its currents and whirlpools have a danger not realized by the unwary. Nor does it lack in historical or romantic interest. It was the lower river which was first discovered by the Spanish when Hernando de Alarcón entered the Sea of Cortés in 1540 and sailed up the Colorado to become the first European to see Alta California. The old settlement of Cibola serves to preserve the memory of Coronado's search for the "Seven Cities." Oñate, who gave the river its present name, Father Garcés, Captain de Anza, Jedediah Smith—these and many others are linked closely with its history.

In the river section with which we are concerned, it is first necessary, for orientation, to describe briefly both its natural and man-made features. Perhaps the simplest way to accomplish this task is to start at the lower end of the surveyed area and proceed upstream. Many of the distances which are given are approximate ones.

California-Mexican Boundary to Laguna Dam (21 miles)

From Andrade (Pilot Knob) near the apex of the delta northeast to Laguna Dam the river is somewhat muddy, and confined to a fairly narrow channel fringed by trees. The immediate country is flat and the former floodplain provides fertile irrigable areas in both Arizona and California. Striking evidence of meandering remains in the form of Haughtelin Lake, an oxbow on the California side near Bard.

One irrigation diversion, the old Alamo or Imperial Canal, takes out on the California side at Rockwood Gate, $1\frac{1}{2}$ miles above the international boundary. This canal was the only source of irrigation water for the Imperial Valley from 1901 to 1940. It was completely supplanted for this purpose by the All-American Canal in 1942, and at present it carries water only to Mexico. Water from the All-American Canal can be diverted through the Pilot Knob Wasteway into the Alamo Canal or be returned to the river through Rockwood Gate.

FIG. 49. Rockwood Gate, diversion point for the Alamo Canal. Upstream view. Jan. 1942.

FIG. 50. Yuma Project Canal. Jan. 1942.

One of the few bridges across the river is found at Yuma. Here, too, is an inverted siphon carrying water from the All-American Canal under the river to the Arizona lands of the Yuma Project. Waste water from the Project's main canal and from irrigated fields enters the river through a ditch (Yuma Main Canal Wasteway) three-quarters of a mile below the bridge on the California side.

Yuma is the largest town on the lower river (population 5,325 in 1940). From here and the nearby agricultural settlements come a fairly large number of people to fish the waters from the Mexican border to Imperial Dam. The heaviest concentrations of anglers are found: at the dams themselves; near the head of the Alamo Canal ("Mullet Bay"); at Haughtelin Lake; and along the canals, wasteways, and drain ditches of the Yuma Project lands.

Only one natural stream, the Gila River, is tributary to this portion of the stream, 5 miles above Yuma. In its lower reaches it is normally dry, save where some water from the Colorado backs up into its mouth, and in small potholes along its course. However, it is subject to severe floods even if of but short duration. Some of these floods have been reported as even greater than the highest peak floods of the Colorado. (Kleinsorge, 1941, p. 11.)

Laguna Dam to Imperial Dam (5 miles)

About 12 miles northeast of Yuma, Laguna Dam (completed in 1909) extends across the river. At one time it provided all the irrigation water for the United States Bureau of Reclamation's Yuma Project in both states through a heading on the California side. Its western heading now supplies only about 10 miles of canal in California and its eastern heading diverts water for the small North Gila Irrigation District in Arizona. It is probable that sometime in the near future no water will be diverted here. However, the dam will be maintained as a control for tailwater at Imperial Dam, and the sluice gates will be left open to pass the silty discharge from above.

Laguna is a low diversion weir of the Indian type which raises the water level about 10 feet at low stage and can accommodate the entire flow of the river over its crest at flood stage. It is passable to fish because of its low height and some breaks in it. Only a shallow silting basin is created above it. It does not form a true lake or reservoir, but the river has been widened and one finds shallow sloughs, ponds and potholes behind it. Mittry Lake is one such area. The river immediately below the dam is a popular fishing spot.

FIG. 51. A pool in the intermittent Gila River near Dome, Arizona. May 1942.

Imperial Dam to Headgate Rock Dam (135 miles)

Of more importance to the fishery is the Reclamation Service's new (1938) Imperial Dam, the diversion point for the All-American and Gila canals. The All-American Canal has a maximum capacity of 15,155 c.f.s. It carries irrigation water to the Imperial Valley, and its Coachella branch will supply the Coachella Valley. It now supplies most of the Yuma Project lands through a turnout, has a wasteway into the Alamo Canal, and will eventually deliver water to a lateral leading to San Diego. The Gila Canal, with an ultimate diversion of 6,000 c.f.s., furnishes irrigation water to lands in Arizona. Ordinarily, the discharge from the dam is through a sluiceway provided with radial gates, but a spillway is provided for floods.

Imperial Dam raises the normal water surface 23 feet, and has a profound influence upon the river above. Here, as at Laguna, it is preferable to speak of the "reservoir" as a silting basin rather than a lake (as in the sense of Lake Mead). Large areas are very shallow. The spread of the river through swift shifting and interconnecting channels keeps the water turbid and unsuited for the establishment of aquatic life. However, the backing up of the waters has created wide shallow "lakes" such as Ferguson (California) and Martinez (Arizona) on either side of the channel. In these areas where the water is clearer and quieter one can find good fishing.

A few miles above Picacho the influence of Imperial Dam becomes less noticeable and a short bottleneck separates the reservoir area from the low lands of Cibola and Palo Verde. Although rocky sections are found throughout this stretch, alluvial bottom lands on one side or the other flank the greater portion. And wherever the river is unconfined by resistant walls one may find side-lakes or sloughs, often with their connection obscured from view by the thick vegetation.

A short distance above Cibola is the mouth of the Palo Verde Slough, a semi-natural channel fed with waste irrigation water and navigable by small boat.

Another highway bridge crosses the river at Blythe. About 14 miles above here is a large diversion taking water into the Palo Verde Irrigation District (California) without the aid of a dam. Between here and the town of Parker the extensive low-lying lands of the Colorado River Indian Reservation border the Arizona side. The river meanders and separates into channels, but there are not the number or variety of adjacent channels and lakes found further downstream.

The small towns of Earp, California, and Parker, Arizona, are connected by a third highway bridge, and about a mile above the town is the newest dam on the river.

Headgate Rock Dam to Parker Dam (15 miles)

This dam (1941) was constructed by the United States Indian Service and supplies irrigation water to the Colorado River Indian Reservation. With an ultimate diversion capacity of 2,100 c.f.s., only 200 to 300 c.f.s. are expected to be used for several years. The dam is merely a series of radial gates and only enough of these are lowered to bring water into the canal. Only at low flows is the river backed up to any extent and even then no lake is formed. The dam has but little effect on the fishery except in its creation of some favorable spots to fish.

From here to Parker Dam the stream is rather constricted but has a few alluvial flats. The clear water is an astonishing sight to those who have known only the muddy Colorado.

Parker Dam to Topock (Lake Havasu and Mohave Canyon) (42 miles)

This dam raises the water level 72 feet to form Lake Havasu. Discharge here is through spillway gates of the Stoney type, some of which are always open, and from a powerhouse.

Built by the United States Reclamation Service in 1938 with funds from the Metropolitan Water District of Southern California, it is operated by the Federal Government at the District's expense. Its primary function is to provide water for the District's Colorado River Aqueduct. Other functions are reregulation of the flow from Boulder, flood control (of the Williams River) and the generation of power. The headworks for the aqueduct (Intake Pumping Plant) is about two miles above the dam. From here water is carried through a series of pump-lifts, reservoirs, and conduits across the deserts and mountains to supply Los Angeles and other cities of southern California.

One tributary of intermittent flow, the Williams River, enters from the Arizona side just above the dam. Like the Gila it usually has no effect upon the Colorado, but flash floods of great intensity occasionally occur.

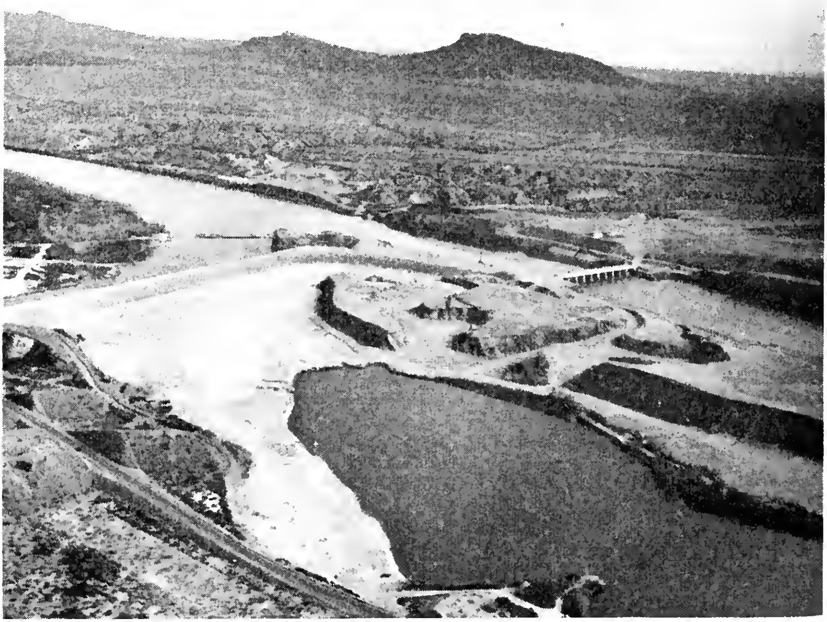

FIG. 52. Headgate Rock Diversion Dam, upstream view. Photograph through courtesy of U. S. Indian Service.

Havasu is a long and narrow reservoir but has an irregular shoreline with many bays and coves. Due to the current persisting throughout its course it is better termed a run-of-the-river lake than a lake in the sense of Lake Mead. However, its expansions where it swells out into old valleys give it large, quiet water areas. The relative weights of its fluvial and lacustrine characteristics await further study.

At full capacity (elevation 450.54 feet) it has an area of 25,000 acres and stores 717,000 acre-feet of water. With the spillway gates closed, the depth of the lake at the dam is 75 feet; 25 feet with the gates open.

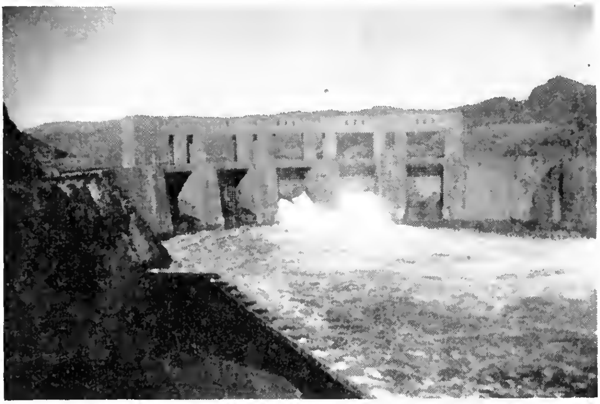

FIG. 53. Upstream view of Parker Dam. Foundation for power house on left. Photograph by D. A. Clanton, Jan. 25, 1939.

For efficient pumping into the Colorado River Aqueduct the water surface should be maintained between 440.54 and 450.54 feet. Therefore, under a contract between the Metropolitan Water District and the United States, the Federal Government possesses only the limited right to regulate the top 10 feet of storage except with the permission of the District or in case of an emergency. While even this limited fluctuation might be harmful to fish at times, it can in no way be compared to the excessive fluctuation found in so many western reservoirs.[4] However, for various reasons the elevation of Lake Havasu has dropped below 440.54 feet several times since 1938, the lowest elevation being 412.09 feet on June 25, 1942. Not until October 11, 1942 did it again reach 440.54 feet and it has been above that stage since. In 1943 the regulation of the water surface was very favorable for fish. The reservoir rose from 441 feet in early January to 450 feet by the first of April. It maintained a level between 450 and 449 feet for over four months and then gradually descended to an elevation of 445 at the end of December. A favorable regulation is also expected in 1944 with the water level being raised by easy stages to 449 by May 1st and possibly to elevation 450 for June and July. Following July it will probably be lowered at about the same rate as in 1943. The continuance of such regulation should ensure successful reproduction of bass and sunfishes in this reservoir, insofar as it is governed by changes in water level.

Much of the immediate shoreline and bottom is composed of small rubble, gravel, and sand. There are patches of cattails, and a relatively narrow fringe of tamarisk and arrowweed grows in some places just at the highwater line. Otherwise, the surrounding land vegetation is scanty and typical of the desert. Near the old river channel there still persist the submerged trees which once bordered it. Drowned trees and shrubs are also found in the shallow waters of some coves. *Najas* was the only submergent plant seen in 1942 and is said to be increasing rapidly.

Above the dam the lake is typically from one-half to a mile in width until it reaches the old Chemehuevi Valley 20 miles upstream. Here is its greatest expansion of about three miles; and here, at Needles Boat Landing, is the largest "resort" area

[4] For example, Lake Mead has a "* * * postulated annual water level fluctuation of 65 feet * * *" according to Moffett (1943). The new Millerton Lake on the San Joaquin River in California is expected to have an annual fluctuation of over 100 feet even in the most favorable years.

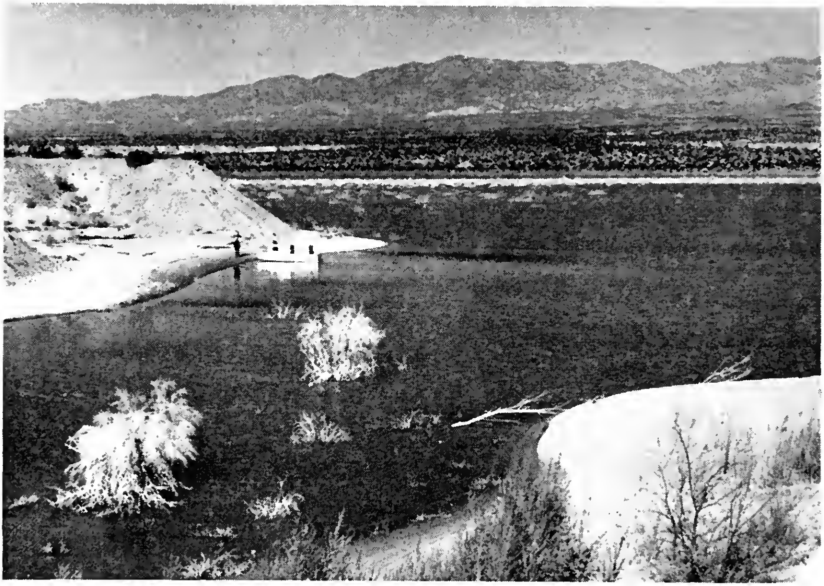

FIG. 54. A bay in Lake Havasu below Needles Boat Landing. Feb. 1942.

on the lake, with a store, a few cabins and facilities for renting and docking boats. About 30 miles above Parker Dam the lake narrows, and the rocky Mohave Canyon some 10 miles long separates it from the Topock region. There may be small bays here, but the water is swift and decidedly different from that of the lower lake.

Topock to Boulder Dam (112 miles)[5]

Above the narrows of Mohave Canyon there is an extensive series of marshes and a large silting basin where the water level has risen. Throughout the river bottom are many sloughs and potholes and generous stands of trees and "tules."

There is a highway bridge at Topock, the fourth on the river. Fifteen miles above Topock is the town of Needles, the last real town for hundreds of miles. Cutting by the river muddies the stream and this persists until one nears Boulder Dam. For about 25 miles below the dam the water is clear and cold. (See Moffett, 1942, for a description of this section.)

PHYSICAL AND CHEMICAL CONDITIONS INFLUENCING THE FISHERY

The lower river runs through a desert land. This is mostly plain or low country with a mean annual precipitation of only about three inches, and a high evaporative rate; consequently, there are almost no natural tributaries. The Gila, with its source in high forested country, and the Bill Williams rivers may contribute important quantities of water at times, but the other streams draining towards the trunk of the Colorado are "lost rivers" usually disappearing before reaching it. Its normal flow is derived almost entirely from snow run-off in the upper basin.

Under normal discharge, the width of the lower river has varied from a few hundred feet to about half a mile. At flood stage it has inun-

[5] The section studied in 1942 terminated at the California-Nevada boundary about 12 miles above Needles. However, this is a political boundary and there is no basic change in the river at this point.

dated its valleys and this has required extensive leveeing to protect agricultural lands. The depth of its channel has also varied greatly depending upon the rate of flow and the deposits of silt. At the Yuma gaging station, for example, such average depths as 1.9 feet (at a flow of 2,020 c.f.s.) and 31.1 feet (at 89,600 c.f.s.) have been recorded by the United States Geological Survey.

Its normal gradient from Topock to Yuma is about 1.5 feet to the mile. It is higher above and lower below this section. At Yuma such widely separated mean velocities as 6.40 and 0.07 feet per second have been measured. These do not represent extremes.

Where the river cuts through rocky spurs one finds narrow-sided canyons, hard banks, and a steepened gradient. Here its course is subject to little change. But in its alluvial basins, of recent unconsolidated silt, old channels have been abandoned for new. Sloughs, lagoons, oxbow lakes have appeared and disappeared. On the bottom land there has been a progressive downstream movement of the meanders so that wide areas have been worked over by the river, with continuous destruction of the banks and marginal vegetation, and equally continuous deposition of sediment and growth of new plants. All rivers change, but some only slowly. On the Colorado one is impressed by the ephemeral character of many of its natural features—the effects of normal lateral cutting, of drought and plant succession, and of flood-stage erosion.

Flow

The flow in the Colorado usually reaches its peak in June, diminishes greatly in August, and is very low from September to February. However, it varies greatly from year to year and even from day to day. Before the erection of Boulder Dam, the usual discharge at this point ranged from 3,000 to 150,000 c.f.s. (Anon., 1941, p. 45.) But there have been even greater extremes here and further down the river. It has been estimated, for example, that in 1884 there was a flood of about 384,000 c.f.s. at Needles. (Weymouth, 1930.) At Yuma, a maximum flow of 250,000 c.f.s. (Jan. 22, 1916) and a minimum daily flow of only 18 c.f.s. (Aug. 25-27, 1934) have been recorded.[6]

Contributing to the unpredictability of its run-off have been the sudden "flash" floods (usually in the late summer and winter) when walls of water have come coursing down the Bill Williams, the Gila, or the numerous washes. The Colorado has been a rampaging torrent; it has been a sluggish creek. And, until recently, man has had but little control over its whims.[7]

The completion of Boulder Dam in 1935 has enabled the storing of great quantities of flood water; the entire average flow of the river can be held back for two years. With release during the dry season, it is now possible to maintain a more or less constant flow in the stream below the dam. A number of factors (natural ones, and the changing demands for power and water) make it impossible to predict the future flow in the lower river with accuracy. Both Weymouth (1930) and Stevens (1938) suggested that the mean annual discharge might be around

[6] Diversion of water above Yuma and inflow from the Gila affects the river here, of course.

[7] For a fascinating (albeit a bit fanciful) account of man's struggle against the river see Woodbury (1941).

FIG. 55. The mouth of a small wash showing destruction by flash floods. On the Colorado River about 35 miles above Blythe. May 1942.

20,000 c.f.s.; the latter believed that the average annual spring-flood discharge might be of the order of 75,000 c.f.s. In Anon. (1941, p. 46) it is stated: "With the river regulated by Boulder Dam the steady flow ranges from 12,000 to 20,000 cubic feet per second. The maximum flow to be expected is about 45,000 cubic feet per second, to control the usual seasonal floods. This may reach 75,000 cubic feet per second once in about 100 years." (It should be noted that, as far as practical, an even rate of flow is desirable for flood control, power production, and the diversion of water for irrigation and into the Colorado River Aqueduct.)

A second control is possible at Parker Dam through the alternate impoundment and release of water. However, Lake Havasu's potential regulatory power is minimized by the 10-foot limit to the variation in its water level already mentioned as necessary for efficient pumping into the Aqueduct. The other dams below here can not be considered regulatory as they do not enclose large storage reservoirs.

While its flow has been stabilized to a great extent, the Colorado is still not tamed, and plans exist for further regulation. The projected Davis Dam at Bullshead about 67 miles below Boulder, which would back the water up close to the foot of the latter dam, is designed to minimize the effects of large releases from Lake Mead for power in excess of irrigation requirements. Flood control dams are contemplated for the Williams River, at the Alamo site, and at the Sentinel site on the Gila, which already has some flood protection.

Regulation of its flow can mean that there will no longer be the alternate periods of flood and dessication which are so harmful to aquatic life. And, provided that the rise and fall of the river is gradual, a certain amount of continued fluctuation should actually be beneficial through the accompanying fertilization from the land.

Silt

"Too thick to drink; too thin to plow" is the old saw which once described the Colorado. It still does describe it above Lake Mead where the silt load continues undiminished and where it is a source of wonder that any fish could endure such heavily charged water. The aridity of the climate, soft deposits, lack of vegetation, and violent floods are among the reasons for the great erosive action which has made the Colorado the greatest silt-carrying stream in the world.[8]

FIG. 56. The heavy silt load of the Colorado River above Lake Mead. Grand Canyon. April 1942.

Although some of the first products of erosion may be large in size, by the time the load has reached the lower river its fragments have been so pulverized that they approach the fineness of Portland cement. Thousands of samples of silt have been taken from the lower river and but little of this could be classified as coarse sand. In typical analyses, fully 50 per cent has passed a standard sieve of 200 meshes to the inch. (Fortier and Blaney, 1928, p. 3.)

This silt has been classified into two major types: the fine suspended silt, and the heavier bed silt which is carried along near the bottom of the stream. These types are interchangeable to some extent under different hydraulic conditions. Even at quite low velocities (any exceeding two-thirds of a foot per second) the finer silt continues in suspension. Hence even low-grade irrigation canals have been extremely turbid. Where the velocity is retarded the bed silt is deposited temporarily, only to be picked up again during floods and so move progressively downstream.

[8] The Tigris is its only strong competitor for this title. (Senate Hearings before the Committee on Irrigation and Reclamation, 69th Congress, 1st Session, Colorado River Basin, Part 1, 1925, p. 27.)

The quantity of silt transported allows one to present some startling statistics. Prior to the erection of the new dams it was estimated by Fortier and Blaney (1928) that the total silt load at Yuma (exclusive of Gila silt) was about 138,000 acre-feet annually. About 80 per cent of this was suspended silt; 20 per cent bed silt. This is enough material to cover about 215 square miles of land to a depth of one foot, and the suspended silt alone passing Yuma each day weighed almost half a million tons.

There are several different ways in which this silt may have been deleterious to aquatic organisms. (1) The bed silt is moved along the bottom in a rolling movement or in waves or steps like sand dunes. The "boils" seen in the river are the result of sudden displacements of such masses. The progression of such "dunes" would quickly smother any food organisms which had had a chance to become established. Studies at Yuma in 1916 further showed that for every foot of rise in the river there was a scouring out of approximately $2\frac{1}{2}$ feet in the river bed. (Calif. Colo. R. Comm., 1931, p. 273.) Since the stream has been subject to many rises, some of great proportions, it is clear that there has been no stability of the bottom. The character of the bottom deposits in itself has offered but little chance for the firm establishment of organisms serving as fish foods. (2) The comparatively inert chemical character of the silt, coming as it does from areas where there is but little soil, has not been conducive to the growth of organisms. The major constituent of this silt is silica. (See: Collingwood, 1892; Moffett, 1943; Fortier and Blaney, 1928.) (3) Light is essential for the production of green aquatic plants of which the microscopic ones form the initial link in a river's food chain. It has been impossible for light to penetrate the turbid waters. (4) The mechanical effect of silt on fish, other

FIG. 57. Upper end of Lake Havasu. Silt deposition and erosion. Feb. 1942.

aquatic organisms and their eggs has not been studied in this river, but it must have been somewhat deleterious. (5) Finally, even if there had been any large number of game fishes present, it is well known that continually muddy water does not promote good fishing.

The only way in which silt might seem to have been useful to the fish here was in lessening their vulnerability to predators. Grinnell (1914, p. 117) remarked, "* * * the opacity of the moving water of the main stream is so complete as effectually to prevent fishing here by piscivorous birds in the usual manner."

It should be mentioned that, "Although it requires very little velocity to transport the silts of the Colorado the material in suspension usually settles rapidly when the water is brought to rest * * * This is undoubtedly greatly influenced by the chemical composition of the water which produces flocculation." (Fortier and Blaney, 1928, p. 52. See also Breazeale, 1926.) Despite the turbidity of the main channels there have always existed lateral channels, depressions, overflow lakes, and small bays where the silt had a chance to settle out. Undoubtedly the bulk of the fish populations were found here before the dams were built. The introduced game fishes were not abundant however, and according to the best report the native fauna was rather limited. Ellis (1937) has attributed the limited fish fauna of parts of the Yellowstone and Missouri to muddy water.

It has been estimated that Boulder Dam would hold back 137,000 acre-feet of silt annually from the lower river. Since its erection and that of the other dams below it, there has been a material diminishment of opacity in all of the lower river. In 1940, the annual silt content at Yuma was only 2,071 acre-feet according to U. S. B. R. Yuma Project (1941). All of the silt is removed at Boulder, and for about 25 miles below the water is unclouded. The lower portion of Lake Havasu is clear, and the river for some distance below Parker Dam has been freed of silt.[9]

While the silt load has decreased tremendously, it should be noted that one can not hope for the immediate creation of the "silvery Colorado" of song. The clear water which issues from Boulder soon becomes muddy again as the stream meanders and cuts across alluvial flats. The erection of Davis Dam would extend the section of clear water further downstream, but silting in Lake Havasu and aggradation in the Needles area encourages cutting unless the stream should become entrenched. In one section of the river it is even to be expected that the water will become muddier than it is now. At present much of the load picked up below Parker Dam is being deposited in the extensive silting basin behind Imperial Dam.[10] But as this basin fills (and it is filling rapidly) the heavier silt will again move downstream. At that time it is planned to desilt the water entering the All-American Canal, and this silt will be flushed out into the river below the dam. Even with a good control of the Gila and Bill Williams, there is no insurance against cloudbursts and the subsequent products of erosion which can be washed into the river. However, the silt content has been and will be so lowered that conditions will be quite suitable for fish throughout most of the river.

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[9] When there is a flood on the Bill Williams, the discharge from Parker is cloudy, however.

[10] The total drainage area above this dam is about 187,000 square miles. Of this total, Boulder controls about 167,000 and Parker about 10,000 square miles.

Effects of Changes in Silt and Flow

It is impossible to consider the changes in flow and silt-load in the Colorado River separately, and these bring about other changes in the physical character of the stream. In general, the new dams with their reduction of flooding and silting affect gradient, velocity, character of the bottom material, and marginal vegetation. With the disappearance of floods the flow can be carried on a reduced gradient and in a reduced cross-sectional area. The bed becomes flattened and marginal areas become overgrown with vegetation. As the reservoirs fill in, the stream above becomes aggraded. Below dams retrogression sets in. A further change is the gradual increase of coarse material on the river bottom.

FIG. 58. The formation of a "lake" in miniature. As the bar grows it willl become invested with vegetation and cut off the bay from the main channel. Upper part of Lake Havasu. Feb. 1942.

At present the section immediately below Boulder Dam is undergoing retrogression and its bed material has become coarse by removal of the fines. (See Stevens, 1938, Fig. 4.) "From Boulder Dam to Willow Beach the Colorado River is now paved with coarse material, the smallest sizes of which run about two or three inches." (Letter of R. G. MacDonald, to the author, March 2, 1944.) Downstream from Davis the tendency will be for the stream bed to become coarser also.

Aggradation can be expected above Parker Dam. Between Parker and Imperial Dam there is an area of potential retrogression. Imperial Dam itself will quickly silt up. From Imperial Dam to Laguna Dam the section may be built up by desilting operations and channel flushing may possibly be resorted to. The fate of the river below Laguna seems to be uncertain, but ultimately the delta may extend further upstream.

A word of explanation as to the "lakes" along the Colorado is pertinent here. Where the river widens out, either naturally as in a valley or artificially above a dam, quieter water areas exist to the side of the main channel. As the stream drops its load it spreads out and sand (silt) bars are formed which partially cut off the expanded areas near the borders of the main channel. Growth of these bars, especially when accompanied by the establishment of vegetation on them, may eventually result in a sizable lake or slough which may become quite distinct from the main river. If the lake is shallow and silt continues to be deposited in it, it may be turned into a marsh by the growth of bulrushes and cattails. However, if the expansions are rather deep and the bars extend so completely as to almost cut them off, sizable areas bearing some lacustrine characteristics are created, with quiet waters much clearer than the channel. Often, as at Martinez Lake, they are filled with drowned vegetation. All such lakes along the river are rather impermanent and may be destroyed by increases in flow, shifts in the river's course, or silt deposition. At Imperial Reservoir at least one large lake has already disappeared, and how long any lake will exist is unknown.

Stevens (1938) has discussed the effects of the dams on the lower river, and his conclusion may be repeated here, "* * * it is well to point out that it will take many years to establish the new regimen, possibly a matter of 30 to 50 years, that no one can predict with accuracy what will happen." One must realize that the Colorado is still in a state of flux, but generally speaking the changes appear beneficial to the fishery as a whole. Wherever there is clearer water, more uniform flow, coarser and more permanent sediments, slackened velocity and marginal vegetation the establishment of aquatic life is more certain.

Air Temperature

Exceptionally high air temperatures prevail in the basin of the lower Colorado. Yuma, for example, has a mean annual temperature of about 72° F., and a maximum temperature of 120° F. has been recorded here. "Afternoon temperatures reach 100°, on an average, from June 8th to September 13th and 105° from June 26th to August 16th" according to Gordon (1942). The high air temperatures permit an all year round agricultural season in the fertile valleys along the river. Thus there is need for irrigation 365 days of the year. This has a direct effect on the fishery of the region as the main canals flow throughout the year and thus afford a rather permanent habitat for fish. The direct effect of air temperature on the duration of the fishing season can be easily perceived. (See p. 189.)

Naturally the trend of air temperatures is directly reflected in the trend of water temperatures. (See Fig. 59.) The river becomes very warm during the summer months, and never drops to a very low temperature.

Water Temperature

The only long term records of water temperature for the lower river known to the author are presented in this report. Any of the graphs (Figs. 59, 60, 61) can be used to point out the general range and trend of water temperatures in the lower Colorado.[11] Their comparison shows that all points in the study section have a similar and fairly regular pattern. That is, we can usually expect a low point (of about 50° F.) in January, after which there is a rise to a peak between 80° and 90° which holds during most of the June-September period, followed by a renewed decline. The available records show that temperatures vary from a maximum of 90° to a minimum of 40° F., but the normal range appears to be about 10° less extensive than this.

Favorable temperatures for most of the fishes found in the river are indicated. They are certainly satisfactory for the introduced game fishes such as sunfishes, bass, and catfishes. They are not suitable for trout or other cold water species. There have been times, of course, when the summer flow in the Colorado has been very low, and even the main current must have reached temperatures far exceeding the ones recorded here. Some residents have reported many dead fish during such periods. Now that a good constant flow is assured we should not expect a repetition of these conditions.

The influence of temperature upon many of the river's fishes is insufficiently understood to warrant much discussion here, but its effect on largemouth bass, the major game fish, can be treated with some assurance. It has been reported that at water temperatures below 50° F., largemouth bass usually cease to take food. (Markus, 1933.) Their rate of metabolism is low and they can not be caught easily even at temperatures somewhat above this point. Even so, there would be only a short period when the bass of the Colorado would not be active. Cold water in the river does not appear to have as decided an effect on channel catfish and these can usually be taken even when the bass are unresponsive. It may be noted here that the scientific collecting for fishes in 1942, with baited hoop-nets and gill-nets, was poorest during the early months of cold water.

It seems to have been quite generally assumed that the spawning season of most fishes is regulated largely by water temperatures. Some recent work (Hoover and Hubbard, 1937; Swingle and Smith, 1943) has shown that both the onset and duration of the spawning season may be influenced by other factors, such as light, physical condition of the fish, or abundance of food. Nevertheless, it is still true that spawning seasons generally show a correlation with temperature, and that the spawning of some fishes can be brought about almost at will by merely raising the water temperature. (See, for example, Creaser, 1934.) Judging from the observations which have been made in other localities, we might expect the bass in the Colorado to spawn when the water attains a temperature of about 65° F. (See: Jones, 1941; Wiebe, 1935.) Such a temperature is usually reached here about March or April, and

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[11] Fig. 59. Water temperatures taken by the United States Geological Survey at its gaging station at Yuma, Arizona. Readings made 15 times a month on the average, usually at about 8 a.m. (M.S.T.). Air temperatures from the United States Weather Bureau, Yuma, Arizona.

Fig. 60. Based on graphs furnished by the United States Bureau of Reclamation, Yuma Project, Yuma, Arizona.

Fig. 61. Temperatures of the river at Yuma from Fig. 59. Temperatures of the river near Blythe taken by the Palo Verde Irrigation District about 14 miles above Blythe. Readings made daily at 4 p.m. (P.S.T.) from February 14, 1932, to September 30, 1943, except during the following periods: July 1-17, 1942 (no records); October 1, 1942-January 22, 1943 (no records). Temperatures of the river at Parker taken by the United States Geological Survey at its gaging station at Parker, Arizona, 4.1 miles downstream from Parker Dam. Readings made 4 to 5 times a month on the average. Two-thirds of the readings made in the morning; one-third made in the afternoon.

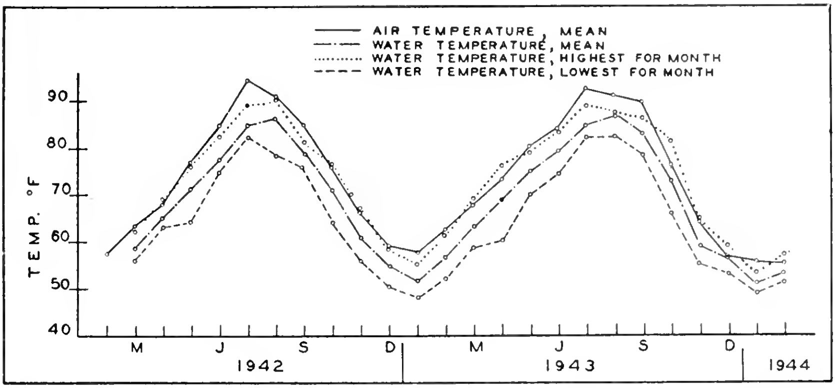

FIG. 59. Mean monthly, and maximum and minimum recorded water temperatures of the Colorado River, and mean monthly air temperatures, at Yuma, Arizona.*

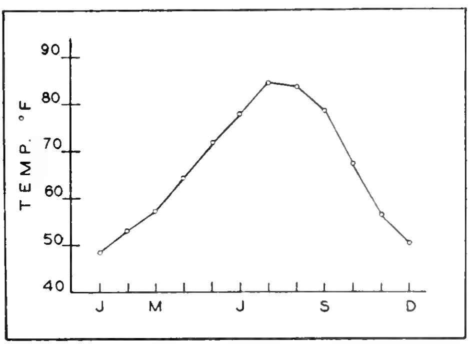

FIG. 60. Approximate average of mean monthly water temperatures of the Colorado River at Yuma, Arizona, for the years 1917-1924.*

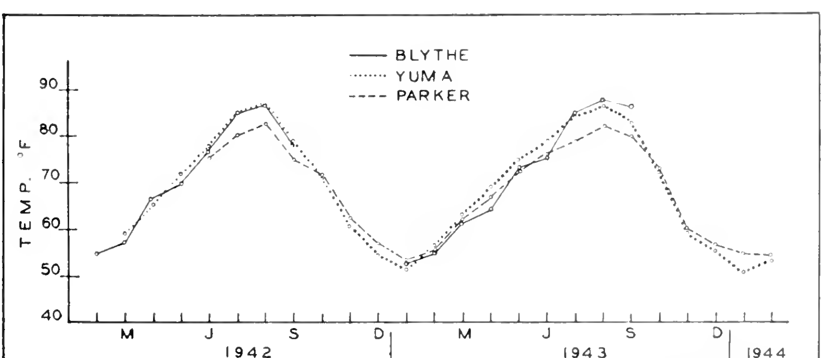

FIG. 61. A comparison of mean monthly water temperatures of the Colorado River at Yuma, near Blythe, and at Parker.*

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* See footnote, p. 130, for sources of data.

in 1942 it is known that spawning was in progress then. Not enough information is at hand to determine the exact spawning periods of the different species of the Colorado. Those of some (bluegills, for example) may be fairly extended. However, with the exception of the mullet, known to spawn in the autumn, it seems probable that most of the fishes spawn here during the period when the water temperature is rising. That is, they are spring spawners, rather than fall spawners.

The growing season for fish is also largely dependent upon temperature. During the warm periods more food is produced and the metabolism of fish is increased. In Norris Reservoir, Tennessee, Jones (1941) determined the growing season of the largemouth bass to be about four months in duration, corresponding closely to that period during which the water is 75° F. or above. If his findings are applicable here we might expect a growing season of about the same duration—roughly from mid-May to mid-September.

It should be noted that while the graphs for the river show the general trend of water temperature, they do not necessarily present a complete picture of the conditions prevailing in all parts of the Colorado district. These temperatures were taken in the main river channels. Much higher temperatures undoubtedly occur in the bays and coves, in shallow expanses of the lakes, in quietly flowing sloughs, and in cut-off waters. Since it is in such areas that the game fishes are most abundant we might expect a somewhat longer growing season and an earlier spawning season than has been indicated above.

So far we have dealt only with surface water temperatures. However, there is usually but little difference in the temperature of surface and subsurface waters in streams. This is especially true in a river such as the Colorado where the flow is fairly rapid and which lacks, in the ordinary sense of the word, deep pools. Temperatures at depths were taken only in Lake Havasu. On February 15, 1942, temperatures were taken in the expansion of the lake opposite Needles Boat Landing. Here there was a difference of only 3° F. between the surface water (55° F.) and the bottom at 27 feet (52° F.). On May 20, 1942, another series was taken at the lower end of the reservoir a few hundred feet above the dam. A difference of 10° obtained between the surface (80° F.) and the bottom at 40 feet (70° F.). The lake was being lowered on this occasion. Any discussion of the thermal characteristics of Lake Havasu awaits the collection of temperature records at different depths, stations, and seasons, and under varying conditions of draw-off. It seems doubtful, however, that there would ordinarily be any degree of thermal stratification which could markedly affect the fishery.

The thought has been expressed by a few people that the section of the Colorado River immediately below Parker Dam has been so altered by the dam that it is now suitable for trout. It is true that below Boulder Dam a portion of the stream has been changed to trout water through removal of the silt and reduction of the water temperature. Aside from the similarity in clarity of the river for some miles below Parker Dam, there can be no comparison of the two areas. Water at Lake Mead is usually released at depths of from 120 to 320 feet below the surface, depending on the water level and on the discharge gates used. The water from such depths is cold, ranging between 54 and 61° F. during 1940 and 1941. (Moffett, 1942.) At Parker Dam, the normal discharge occurs through spillway gates whose lower level is only 50 feet below the extreme high-water mark of the reservoir. Fig. 61 shows that the water temperature here continues to follow the same fluctuating cycle found further downstream. It is but little cooler during the spring and summer than it is at Blythe and Yuma.

FIG. 62. Colorado River downstream view from Parker Dam. The water here is clear but warm. May 1942.

In contrast to this Moffett (1942) describes the water 10 miles below Boulder Dam (Willow Beach, Arizona) as having a remarkably even and cool temperature. "These temperatures did not fluctuate over one or two degrees Fahrenheit winter or summer during the years 1939 and 1940." Moffett's graph (his Fig. 23) shows the temperature during this period to average about 55° F. During the five-year period of October 1936 to October 1941 the highest temperature recorded at Willow Beach was 77° F. This was an unusual occurrence due to the discharge of water over the Arizona spillway of Boulder Dam. During August-November, 1941 this discharge raised the average temperature at Willow Beach to 61-69.5° F. In speaking of this, Moffett (1942) remarked, "Should such a spillway discharge reach the river during midsummer, resulting high temperatures might be disastrous to trout. It is very unlikely that any further spillway discharge will be made."

It can be easily seen that temperatures considered extreme just below Boulder Dam are the usual thing below Parker. Here, the minimum recorded temperatures 4.1 miles below the dam were above 70° F. for five months in 1942, and for over four months in 1943. Temperatures of 85° F. in 1942 and 84° F. in 1943 have been recorded here, and these do not necessarily represent extremes.

Moffett (1942) considered that only about 25 or 30 miles of the river below Boulder Dam were important as trout waters. Trout have been caught much further downstream, and undoubtedly will continue to be caught there occasionally. However, these are stray migrants mostly during the cold season. No permanent establishment of trout could be expected in the lower river.

Water Chemistry

Many agencies have made analyses of Colorado River waters, and a detailed study of these analyses might have considerable value in determining the effect of chemical conditions upon its aquatic fauna. While no such study is attempted here, the statement can be made that in general the chemistry of the river water affords conditions for abundant food supply and good growth of fish.

The supply of dissolved oxygen found in surface samples from the river and its connected lakes in 1942 (range, 7.6-11.4 p.p.m.) is more than sufficient for the adequate maintenance of fish life. Although there is comparatively little plant life, there is ample chance for oxygenation through agitation. It was impossible to obtain oxygen samples from the deepest part of Lake Havasu when the reservoir was full. The dissolved oxygen content taken in this reservoir opposite Needles Boat Landing on February 15, 1942, varied from 10.0 p.p.m. (surface) to 9.6 p.p.m. at the bottom (27 feet). Samples taken just above Parker Dam on May 20, 1942, showed 8.2 p.p.m. at the surface and at a depth of 10 feet; 7.6 p.p.m at a depth of 20 feet; 6.8 p.p.m. at the bottom (40 feet). It would be of interest to make further analyses especially in summer when the lake is high. However, the character of Lake Havasu is such that a rather complete mixing of the water is indicated, and the usual absence of decomposing organic matter would appear to preclude much depletion of oxygen.

There has, however, been an occasion in recent years when an unusually high oxygen demand has been created at the lower end of this reservoir and in the river below accompanied by a severe loss of fish. On Sep-

FIG. 63. Downstream view of Parker Dam showing the mass of drift washed in by a flood on the Williams River. Photograph by State Division of Fish and Game, Sept. 1939.

tember 4 to 7, 1939, a flash flood occurred in the Bill Williams River carrying a large amount of organic debris into Lake Havasu. Dead fish (carp, catfish, sunfish and largemouth bass) were found for 10 miles down the Colorado River below Parker Dam. Analysis of the water revealed an exceptionally high oxygen demand due to its high organic content. (From reports of Mr. C. L. Towers of the California Division of Fish and Game's Pollution Detail, dated Oct. 16 and 20, 1939.)

The river water is characteristically alkaline. Readings of pH 7.6 to 8.2 are shown in Table 1; and readings from pH 8.1 to 8.4 were taken at various points along the lower river during the 1942 field work. Methyl orange alkalinities from 152 to 176 p.p.m. $CaCO_3$ were recorded by the 1942 survey from surface waters of the river; but the levels ran very much higher in early 1942 in certain important fishing waters, such as Palo Verde Slough, which carries irrigation drainage into the river, and Haughtelin Lake, which is entirely cut off from the river—304 p.p.m. for the former and 316 for the latter.

TABLE 1

Chemical analyses of water samples of the Colorado River at the Yuma Gaging Station before and after control by Boulder Dam, February 1935

A. Before control by Boulder Dam

	1934 January 2	1934 April 2	1934 July 2	1935 January 7
Laboratory numbers	8,171	8,447	8,883	9,426
Number of samples	1	1	1	1
Discharge cfs.	2,660	2,950	1,400	2,450
Conductance ($Kx10^5$@25°C)	188	169	114	213
Dissolved solids, p.p.m.	1,340	1,145	826	1,565
pH	7.6	8.2	7.7	7.9
Boron, B, p.p.m.	0.16	0.21	0.12	0.24
Calcium, Ca, p.p.m.	137	109	79	147
Magnesium, Mg, p.p.m.	56	43	28	61
Sodium, Na, p.p.m.	211	218	121	242
Carbonate, CO_3 p.p.m.	0	12	0	0
Bicarbonate, HCO_3 p.p.m.	271	201	160	237
Sulfate, SO_4, p.p.m.	535	455	283	587
Chloride, Cl, p.p.m.	184	192	121	240
Nitrate, NO_3, p.p.m.	9	7	7	9
Silica, SiO_2, p.p.m.	7	11		

B. After control by Boulder Dam

	1943 January 1-10	1943 April 1-10	1943 July 1-10	1943 October 1-10
Laboratory numbers	17,007	639	1,159	1,353
Number of samples	10	9	9	8
Mean discharge cfs.	11,214			
Conductance ($Kx10^5$@25°C)	100	105	108	107
Dissolved solids, p.p.m.	705	706	699	691
pH	7.8	8.2	7.9	7.7
Boron, B, p.p.m.	0.18	0.07	0.11	0.09
Calcium, Ca, p.p.m.	93	98	93	94
Magnesium, Mg, p.p.m.	25	26	27	27
Sodium, Na, p.p.m.	88	101	99	92
Potassium, K, p.p.m.				5
Carbonate, CO_3, p.p.m.	0			
Bicarbonate HCO_3, p.p.m.	160	168	149	158
Sulfate, SO_4, p.p.m.	289	312	319	306
Chloride, Cl, p.p.m.	67	75	73	72
Nitrate, NO_3, p.p.m.	2	2	1	2
Silica, SiO_2, p.p.m.		12	14	14

All analyses in Table 1-A, and Laboratory No. 17007 in Table 1-B, made by the United States Bureau of Plant Industry, Rubidoux Laboratory, Riverside, California, from samples collected by the United States Bureau of Reclamation at Yuma Gaging Station.

Analyses in Table 1-B, Laboratory Nos. 639, 1159, 1353, made by the United States Geological Survey, Albuquerque, New Mexico, from samples collected by it in Yuma Main Canal.

Table 1, presented through the courtesy of Mr. L. V. Wilcox, shows analyses of river water near Yuma before and after control of the river by Boulder Dam. Although the samples were collected over limited periods, they at least offer an indication of the changes in chemical conditions wrought by impoundment in Lake Mead and the fairly regular release of water into the lower stream. In commenting upon these analyses, Mr. Wilcox (letter of March 10, 1944) says: [in Table 1-A] "you will note the wide variation in total solids and in several of the constituents * * *. This was characteristic of the river prior to the time it was controlled. The flood water of May and June was of relatively low salinity, while the low flow at other seasons of the year was often of very high salinity * * *. The significant feature of * * * [the analyses in Table 1-B made after control by Boulder] * * * is the remarkable uniformity, as to total salinity and composition."

In general, it seems that the effect of the dam has been beneficial to fish life, especially in stabilizing the composition, reducing alkalinity, and reducing total dissolved solids. The high concentration of total dissolved solids remains nonetheless one of the outstanding features of this river, as of most streams in the southwestern United States, which are characteristically higher in this respect than in any other part of the country. While the concentration here of around 700 is evidently not too high for the fishes now present, it should be noted that concentrations of around 1,000 at the State trout hatchery at Fillmore, California, are suspected as the reason for the inability to keep trout eggs alive there through the early stages.

A considerable amount of the available fishing water close to centers of population is represented by the drain ditches (channels carrying subsurface, irrigation wastewater, and spill-water from canals). The character of drainage water, as compared with incoming canal or river water, is dependent upon a number of factors such as the chemical composition and permeability of the soil, amount of irrigation water applied, etc. It may vary considerably in different localities and at different seasons. The examination of several analyses secured from the Palo Verde Irrigation District showed the concentration of dissolved solids to be markedly higher in the drainage water than in the river water at the intake. On May 31, 1940, for example, the total dissolved solids at the intake were 860 p.p.m., and 1,573 p.p.m. at the Outfall Drain. Some drainage ditches provide very good fishing; others seem to be deficient in supporting desirable game fishes. Only careful study can determine the reasons for such differences. There is at least a possibility that differences in chemical composition may be of importance in determining whether or not a certain ditch will produce an abundant crop of game fish or one in which coarse species predominate.

BIOLOGICAL FACTORS

Vegetation

Land Plants

In the arid land through which the Colorado flows the vegetation is relatively sparse except near the river. Where the stream is bordered by rocky cliffs or by bench lands there are but few plants which might be expected to have an influence on aquatic life. Cacti, creosotebush

FIG. 64. Desert vegetation and the willow-cottonwood association. Colorado River between Blythe and Parker. Feb. 1912.

(*Larrea*), bur-sage (*Franseria*)—the list is long—may be common. But these are upland plants. Nor are the plants of the washes such as catsclaw (*Acacia*), or of the mesquite (*Prosopis*) and saltbush (*Atriplex*) thickets above the riparian zone usually of importance to the river.

There are, however, several plants which through their proximity to the river are of much greater importance. Foremost among these are: willows (*Salix*), cottonwood (*Populus fremontii*), seepwillow (*Baccharis glutinosa*), *Tamarix* (often called salt-cedar, locally), and arrowweed (*Pluchea sericea*). These plants, in various combinations, often form dense stands or jungles along the areas inundated by high water. Those which become covered, even in part, offer shelter for fishes. They provide some food directly as in the form of seeds and leaves; other food, indirectly, either through fertilization of the water or as a source of insect food.

The capriciousness of the Colorado has and still does cause it to change its course frequently. When this occurs these plants are destroyed with a subsequent enrichment of the water. It is true that this enrichment may be a very temporary one in the main channel. However, it should be of considerable value in the quieter water where such debris may lodge long enough to decay. Where the water level has been raised artificially one finds large areas where not only the plants of the willow-cottonwood association have been inundated, but where the water has covered many less strictly riparian species. Mesquite and saltbushes may persist for some time as submerged zones of shelter.

Grinnell (1914) has devoted a study to the plant associations on the lower river with reference to their influence on birds and mammals. Although their effect on aquatic animals is far less, it must receive consideration.

Aquatic Plants

Bulrushes (*Scirpus*) and cattails (*Typha*) form good stands in many places along the river as in the marshes at Topock. Similarly, they may be common in sloughs or seepage areas at some distance from the stream. The cattail is an active competitor of the bulrush and is one of the first plants to establish itself on sandbars. It may be expected to dominate many of the silting basins, although it in turn may be replaced by willows.

But few submergents were seen during the season when the river was visited. Ditch grass (*Ruppia*), the holly-leaved naiad (*Najas marina*), and *Potamogeton* were the commonest forms observed. Except in a few areas, submergents did not appear to be abundant enough to be of much importance to fish.

Only a species of blue-green alga seemed to be common in the river. In quiet bays and sloughs this was often abundant and formed a coating on the bottom and along the shores. Green algae were also found, and on the aprons of dams it is a common sight to see carp grazing on the "moss."

The clearing of the water has promoted the growth of aquatic plans and a continued stabilization of the river and its substratum will bring about an increase in both emergent and submergent vegetation. In the area around Blythe there is a striking correlation between the decrease in siltation and the increase in plant growth. There, the irrigation district has made plans to add silt to the canal water to keep down the growth of weeds. On the other hand the shifting of channels and silt movement as in areas above Imperial Dam offers continued resistance to the establishment of many plants. Work by the Fish and Wildlife Service on its two river refuges should hasten plant growth through seeding and the building of dikes or revetments.

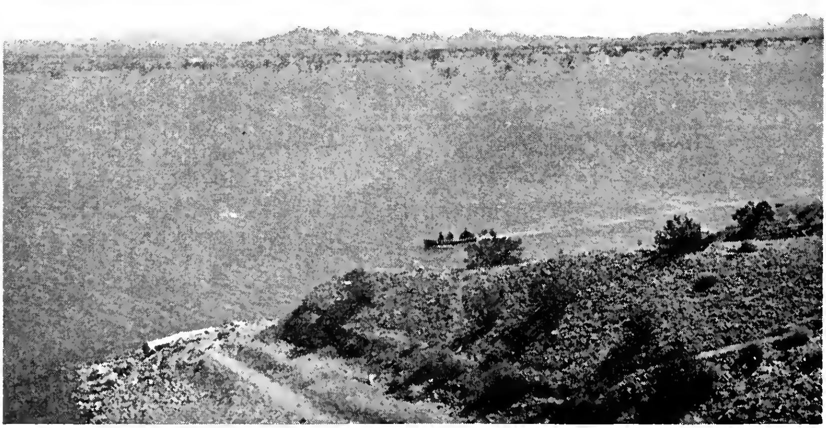

FIG. 65. Drowned trees in Lake Havasu. May 1942.

FIG. 66. Cattail beds in Haughtelin Lake. Jan. 1942.

The aquatic plants of the Colorado have a variety of direct and indirect relationships to its fishes. Some, such as *Najas,* are eaten by certain fish. They afford habitat to insects, snails, and other foods. They offer areas of refuge to young fish and provide spawning places. It is expected that the roots of the bulrushes and cattails, for example, would be attractive sites for the nests of sunfishes and bass. They hold silt and organic material at their bases, and decrease bank erosion. Some of the submergents and algae should be important oxygenators in quiet waters. Their decay contributes fertilizing elements to the water and thus promotes the increase of micro-organisms. The larger aquatic plants may also absorb, and thus remove temporarily, basic salts otherwise available for phytoplankton. However, the abundance of these salts in the Colorado appears to preclude any danger of material diminution. The encroachment of heavy vegetation can, of course, cut down a water area otherwise suitable for fish or fishing. In general, however, the increase of plants should be of decided benefit to the stream's economy.

Food

As a consequence of the several natural factors mentioned before, food production is undoubtedly poor along the main channel of the river. On the other hand, there are large areas such as the lateral sloughs or lakes, bays, and cut-off bends where conditions are quite satisfactory for the establishment of aquatic food organisms. Most of these areas have a silt bottom but here it is more compacted and provides a more satisfactory water-bottom-interface. Organic debris has a chance to lodge here, thus increasing its richness. Often there is an establishment of algae and rooted plants conducive to food production.

Only a few quantitative bottom samples were taken in 1942. All were taken with an Ekman dredge and represent the organisms taken from one-quarter square foot of bottom after screening through a No. 30 soil sieve. In Lake Havasu nine samples were taken in February near Needles Boat Landing at depths ranging from 1.5 to 27 feet. The average number of organisms taken per sample from here was as follows: 0.11 mayfly nymphs; 0.33 caddisfly larvae; 11.0 chironomid larvae. Two samples taken at Palo Verde Slough near Palo Verde at 8 and 12 feet on February 9th had an average of: 2 oligochaetes; 0.5 snails; 21.5 chironomid larvae. Three from Haughtelin Lake taken on January 30th, at depths ranging from 3 to 5.5 feet, averaged: 7 oligochaetes; 1.66 snails; 1.33 mayfly nymphs; 2.33 caddis larvae; 11.0 chironomids. The number of organisms taken per unit area was not large. However the samples, few as they are, at least indicate the presence of more bottom food than was found by Moffett (1943) at Lake Mead. In twelve one-quarter square foot samples he found no organisms large enough to be retained in a 30-mesh per inch screen, with the exception of a single midge larva.

The population of fishes is large in the three sampled areas, and it is considered that it is far better to depend upon their abundance and good condition as an indicator of food production than to rely heavily on a few bottom samples. For a general picture of the food relationships of the fishes of the lower Colorado see Table 2.

Plant Foods

Microscopic algae are utilized directly by some fishes, especially by mullet. They are, of course, the primary food of the invertebrate animals which, directly or indirectly, form the basic food of most of the river's fishes. The larger filamentous forms were also found in some fish stomachs. Fragments of higher plants (*Najas*, cattail, and leaves of terrestrial plants) and their seeds are also eaten by some fishes. A greater importance of the larger algae and aquatic spermatophytes in food production probably lies in their affordance of a habitat for crustacea, rotifers, and insects.

Animal Foods (Invertebrate)

Among the invertebrate animals which are usually classed as important fish foods, only a few types were not found during the survey. Stoneflies (Plecoptera) and hellgramites and alderflies (Neuroptera) seemed to be unrepresented among the aquatic insects.[12] No "shrimp" (amphipods) were seen. No clams or mussels were taken. Grinnell (1914) stated that "As far as known * * * [i.e., to him] * * * in the Needles-to-Yuma section of the river valley there are no aquatic molluscs * * *." However, in 1942, snails were fairly common along the shores of Lake Havasu and were also found in the river itself near Blythe, in Palo Verde Slough, and in Haughtelin Lake.

Small crustacea (cladocerans, ostracods, and copepods) were found in many fish stomachs. These forms were most abundant in cut-off waters but were also numerous in waters connected directly with the river. Surface plankton hauls taken at Haughtelin Lake on January 31, 1942,

[12] Moffett (1942) reported stonefly nymphs as occurring rarely in the river below Boulder Dam.

TABLE 2

The food relations of some common Colorado River fishes as determined from stomach analyses. X, predominant food item; x, food of lesser importance; p, present

Species of fish	Number of stomachs examined	Food items																			
					Crustaceans					Aquatic insects								Fishes			
		Ooze or detritus	Algae, filamentous	Higher plants	Cladocera	Ostracoda	Copepoda	Isopoda	Crayfish	Ephemerida (Mayflies)	Odonata (Damsel-, dragonflies)	Notonectidae (Backswimmers)	Coleoptera (Beetles)	Trichoptera (Caddisflies)	Chironomidae (Midges)	Hydracarina (Water mites)	Terrestrial insects, spiders	Channel catfish	Mosquitofish	Sunfishes	Fish, unidentified
Humpback sucker	*4	X	X																		
Carp	*55		X	X																	
Channel catfish	43	X	x	X				x		x	X	X		X	X		x			x	x
Yellow bullhead	1			p					p		p										p
Mosquitofish	10				X		X								X		X				
Mullet	10	X																			
White crappie	8				X	x	x			x	x	x			X					x	
Black crappie	2					p				p		p			p						
Bluegill	73		X	X	X	x				X		X		x	X	x	X				
Green sunfish	62		X	x	x						X	X	x	x	X		x		X	x	
Largemouth bass	26								x			X	x		x		x	x	X	X	

* Examination of gut only

contained about 80 per cent copepods and 20 per cent cladocerans. Great swarms of *Daphnia* and copepods were found in Palo Verde Slough on several occasions. Quiet waters such as the mouth of the intermittent Gila River may also support such forms in abundance. As yet, crayfish (*Cambarus*) seem to be established only near Yuma.

Damselfly, dragonfly, mayfly, caddis, and chironomid larvae appear to be abundant and staple food items of the fishes here as in most waters. Among the other common aquatic insects found in stomachs and seen in the waters were beetles and backswimmers (Notonectidae).

Forage Fishes

A good supply of forage fish appears to be a requisite for the needs of adult bass. The larger crappies and perhaps the larger channel catfish are also piscivorous. In the Colorado River are found at least three fishes which are acknowledged food for bass: bluegill sunfish; green sunfish; mosquitofish. All of these species are abundant. Possibly the young of several other of the abundant fishes such as the carp and mullet are utilized also.

It has been felt by some that the present scarcity of native minnows may prove harmful to the bass and catfish. However, the supply of the introduced sunfishes and mosquitofish is so great that it is believed that no concern need be felt on this score. In many modern stocking programs it is customary to stock only sunfish (especially the bluegill) along with largemouth bass, and the combination has proved very satisfactory. Bluegills and mosquitofish can utilize the smaller invertebrate foods in a very satisfactory manner. The latter are thus made available in the form of fish-flesh to the predaceous game fishes. Since there is no lack of well-conditioned bass or catfish in the river, it should be apparent that their source of food must be a good one. None of the game fishes in the lower Colorado are in any way dependent upon specific food organisms which are not now represented in the river.

Predation

Predation of animals other than fishes is believed to be comparatively unimportant here. However, representatives of four classes of vertebrates may be listed as potential predators.

The introduced Bullfrog (*Rana catesbeiana*) is fairly numerous in some localities, and is sometimes listed as a fish predator. Most studies indicate, however, that fishes form but a small portion of the diet of this species.

The Desert Garter Snake (*Thamnophis marcianus*) is native to the lower Colorado and has been spreading along irrigation canals into the Imperial Valley according to Klauber (1931, 1939). It is well known that several species of garter snakes prey on fish. However, their degree of predacity is so varied that it would be unwise to list *T. marcianus* other than as a suspect. Klauber (1939, p. 53) says that this species preys "* * * largely if not entirely, on frogs and toads * * *." In a letter of Dec. 10, 1943, to the writer, he suggests that it should not be a serious threat to fish.

At least two species of turtles are found here: the Sonoran Mud Turtle (*Kinosternon sonoriense*) and Emory's Soft-shelled Turtle (*Trionyx emoryi*). Little is known of the natural diet of this mud turtle, but it is probably of small consideration as an enemy of fishes in the Colorado. Meehean (1942) considered *Trionyx ferox* to be an important fish predator, and all the members of this genus have been reported to eat fish. However, in studies of *Trionyx s. spinifera* made in Michigan by Lagler (1940) this member of the genus, "* * * long thought to prey extensively on fish, was found to feed mostly on crayfishes and burrowing mayfly larvae and other insects." He points out that the actual significance of turtles either as predators or as food competitors must be determined separately for each body of water. (This can be equally well applied to any of the Colorado suspected predators or competitors.) Residents claim that soft-shelled turtles are fairly common in the lower river, but their influence on the fishery must be slight.

A variety of piscivorous birds are found here: grebes, terns, cormorants, pelicans, mergansers, herons, kingfishers, etc. Grinnell (1914) lists the species and their abundance in 1910 (later lists have appeared in "The Condor") and says, "* * * herons were notably plentiful because of the supply of catfish and carp made abundant at intervals by the drying-up of overflow ponds.'' Stranded fish appeared ''* * * to be the chief source of food of all the species of herons occurring in the region. The stomach of one blue heron [*Ardea herodias treganzai*] contained a semi-liquid mass of fish, identifiable * * * as carp; another contained a large catfish.''

White Pelicans (*Pelecanus erythrorhynchos*) have been reported as quite numerous at times along the river, and there is a fairly large breeding population in the Salton Sea. Dawson (1923) mentioned fishes believed by him to be *Catostomus latipinnis* and *Xyrauchen texanus* as the most common among those which contributed to the food of the Farallon Cormorant (*Phalacrocorax auritus albociliatus*) in the Salton Sea in 1913. Both of these birds were attracted to the Sea when it was first formed. MacDougald (1914) stated that carp afforded a food supply of some importance to them. At a later date, Coleman (1929) described ''* * * a great area [near the New and Alamo rivers] in which the water was only a few inches deep and in which great numbers of pelicans and other fish-eating birds were feasting on the minnows and young fish coming down these rivers * * *.'' Some of the residents of the Imperial Valley evidence a decided antipathy towards these birds, and claim that they devour enormous quantities of valuable fish. In the Salton Sea area it is doubtful that any species except mullet could be preyed upon heavily today.

Only one mammal is known to be piscivorous here, the Pallid Coon (*Procyon lotor pallidus*). Grinnell (1914) considered it to be abundant along the river and believed that its chief food was fish. These would, of course, be taken mainly from ponds which were drying up.

It is true that no careful study has been made of the piscivorous habits of any of these animals on the Colorado River. But it seems doubtful that any such study need be made at present, nor is any control of them recommended. It seems probable that a large percentage of the fishes eaten are those which have been stranded only to die and rot unless utilized by other animals, or are species of little value to the fishery.

Both bullfrogs and soft-shelled turtles are now utilized to some extent as food by man, and this indirect control is certainly sufficient. Man will undoubtedly continue to kill snakes—whether they are harmful or beneficial to him. Coons are entirely unprotected by California law and may be taken from November 1st to March 1st in Arizona. The birds mentioned receive varying degrees of protection in the two states. In California, cormorants and the White Pelican are classed as ''predatory birds'' and receive no protection; the others listed here are given complete protection as ''nongame birds'' or as ''game birds'' (mergansers). In Arizona, kingfishers can be taken at any time; the merganser is classed as a ''migratory game bird.'' The others are given complete protection, except that all of them ''* * * may be taken when caught in the act of destroying domestic live stock, poultry, game, other protected birds * * * or fish.'' (Arizona Game and Fish Laws, 1939, Sec. 35.)

It might appear then that a considerable amount of local control could be (and probably is) exercised over these birds by hunters. The game refuges on the Salton Sea and on the Colorado afford some compensatory protection.

Parasitism

No study of the parasites of the fishes was carried out. Nematodes (round-worms) were noted in the viscera of largemouth bass and those of several other species. However, such parasitism is common among warm-water species in California. No unusual complement of worms or other parasites was observed which would be expected to be harmful.

THE FISHES

The fish fauna of the Colorado River is still not well known, and offers one of the most fertile fields for investigation in North America. With full recognition that their list needs revision, it is of interest to note the fishes recorded by Gilbert and Scofield (1898) from the lower Colorado and Gila Basin. Based on collections made in 1890 and records of fishes credited to this area up to 1898, they list: 1 introduced fresh-water species (the carp); 19 native fresh-water species; 2 marine fishes from the mouth of the Colorado River. The fresh-water fishes were represented by only four families (Catostomidae, Cyprinidae, Cyprinodontidae, and Poeciliidae). Two families (Gobiidae and Paralichthyidae) represented the marine fishes, and these are not an integral part of the river's fauna.

To their list we can now add records of at least 14 species and five other families in the lower Colorado: Elopidae (1 native species); Salmonidae (1 native species; 1 exotic); Ameiuridae (4 exotic species); Poeciliidae (1 exotic species); Mugilidae (1 native species); Centrarchidae (5 exotic species).

With but few exceptions, the fishes of paramount importance today both in abundance and interest to the angler have been introduced from other waters.[13] On the other hand, the native fishes are apparently scarce today in the lower river. It is possible that the native fauna has not diminished to as great an extent as the collections of 1942 indicate. Further collecting at different seasons, and especially by seine, might reveal the presence of more individuals and species. Still, of the native fresh-water fishes recorded by Gilbert and Scofield (1898) which could be expected in the Yuma-to-Needles section only one was seen during almost three months of collecting in 1942, and this upon only one occasion. Moffett (1942 and 1943) has also made recent collections in the river just below Boulder Dam and in Lake Mead. He records only three native species from these areas, and has but few remarks on their abundance.

Furthermore, there was an absolute agreement among the many residents interviewed (fishermen, irrigation company workers, dam tenders, rivermen, etc.) that the indigenous fishes were quite rare now.[14] Many accounts of the disappearance of these fishes have been heard, and there is a very fair agreement that the decline became most evident during the 1930s. The following statements of California game wardens are

[13] A detailed discussion of the origin of exotic species in the Colorado River is not included here, as this subject will be treated in a forthcoming history of the introduced fishes of California (Dill, ms.).

[14] While it is true that nongame fishes often escape the attention of anglers, there are many points along the river (as at dams and intakes) where fish are easily viewed. For example, during sluicing operations at Laguna Dam, fish are stranded temporarily in potholes on the downstream side.

typical of these: "In all my time in Imperial County [1932-1935] I never saw a humpback sucker in the Colorado River, but all the natives told me * * * they were very numerous before 1930. * * * I have seen a few of the so-called Colorado River salmon * * * some as large as 12 lbs., but they were scarce in 1932." (Letter of Mr. J. W. Harbuck to the author, February 14, 1943.) Mr. W. C. Blewett has patrolled the river since 1939. In a letter of April 9, 1944, he says: "In my five years observation of the fish life of the Colorado River I have observed about 3 bony-tails and about the same number of humpback suckers. I have seen no Colorado River 'salmon'." From 1941 until the close of 1942, Mr. Leo Rossier was stationed in Imperial County and made extended checks of the river. He writes: "I never saw a bony-tail, 'salmon,' or humpback sucker while I patrolled the river. One only hears rumors of such fish being present." (Letter of April 9, 1944.) It may be noted that the men quoted also disclaim any knowledge of the other native minnows or suckers of the Colorado. There are some who claim to have noted the decline around 1925; others say that it was most evident shortly after Boulder Dam was completed (1935).

The memory of observers is often faulty, and an increase in abundance is often noted more quickly than a decrease. The following facts seem assured, however. (1) The native fishes of the river were once abundant. Those noted most frequently by residents were: the humpback sucker, bony-tail, Colorado River squawfish. (2) Their decline was noticeable shortly before or after 1930. (3) As this decline became evident, it was also noted that there was a great increase in the numbers of the exotic species, especially the channel catfish and largemouth bass. The increase in channel catfish was apparent even before 1930 but both it and the other exotic fishes increased tremendously after Boulder Dam was built. (4) At about the same time there were several periods of great drought in the river and there were some heavy floods. At such times "thousands of dead fish" (native) were observed.

The loss of fish at Parker Dam in 1939, due to flood and the subsequent oxygen demand created by the decomposition of organic debris, has already been related. Several occurrences which appear to be similar to this one have been described to me by "old timers." Extreme low water would raise the river temperature and strand fish. Such processes have, of course, been going on for many years in the unstable Colorado, and it seems probable that the native fish populations have undergone alternate periods of rise and fall. But each period of destruction was followed by a period during which the population could rehabilitate itself. Before the dams were built the native fishes were at the mercy of an adverse physical environment, but the deleterious effect of predaceous exotic fishes must have been slight. That is, the population of the latter fishes was small before the creation of Boulder Dam, and floods and droughts must have worked just as severe a hardship—and probably more—on them. Because of the unfavorable water conditions around the early thirties it seems possible that the population of native fishes sank to one of its low points, and that the coincidental advent of clear water following Boulder Dam brought about a heavy production of bass and other alien fishes which preyed upon the already reduced natives. Competition as well as direct predation may have played a large part in this supposed destruction.

It may be argued that physical changes in the river (whether beneficial or adverse) would affect both the native and alien species alike, and that, therefore, the population of the natives should have increased again. This argument is probably a valid one. The native fishes probably had a high biotic potential which allowed them to survive the great environmental resistance of the "pre-Boulder" Colorado River. And—had it not been for the presence of competing exotics—with lowered environmental resistance the realization of this potential might have resulted in an increase in their numbers even exceeding the high points of previous populations. But it is equally true that the biotic potential of the introduced fishes had been suppressed, and with the erection of Boulder Dam it had its first chance for full expression—an expression culminating in their ascendancy. We are assuming here that the "new" river presents a more favorable habitat for both native and exotic fauna. While this is probably true, one must not overlook the possibility that changes in the stream may not have been entirely advantageous to the silt-adapted resident forms. Doan (1941), for example, suggests that higher turbidities in western Lake Erie actually increase the survival of young saugers (*Stizostedion canadense*). His work is cited, not because similar conditions are believed to obtain in the Colorado, but merely to point out that a factor which is generally considered to be unfavorable may actually be beneficial.

The foregoing discussion is purely theoretical, of course. Whether it was the complete set of peculiar circumstances related above, or whether it was some other factor or combination of factors can not be determined.[15] But we have apparently witnessed a rather complete biological revolution in which a native fauna has been largely replaced by a new one within only a few short years.

No attempt is made in this report to present an up-to-date checklist of the fishes of the lower river.[16] Only those fishes are discussed which are known to be of importance to the present fishery, or which may be expected to come to the angler's attention. In general, literature on Colorado River fishes prior to Gilbert and Scofield (1898) has not been consulted.

In the following account each species is treated under some or all of these headings.

Local Names. Those names known to be applied by residents of the Yuma-to-Needles section. (The lists could undoubtedly be extended.)

Recognition Characters. There is as yet no single key or descriptive list which will enable one to identify all of the fishes of the lower river. Nor will the brief treatment of recognition characters given here fulfill this purpose. It has been thought advisable, however, to list enough characters for each fish or group of fishes so that the most common ones

[15] Tarzwell (1939) has described changes in the Clinch River caused by the construction of Norris Dam which released water of about 48° F. into a stream whose normal summer temperature was 80° or over. "Most of the bottom organisms and fish formerly present in this section moved out or were destroyed." While the change to a low temperature below Boulder Dam might have caused some change in the fauna similar to that in the Clinch River, this effect would be confined to but a short section of the lower Colorado.

A most ingenious explanation of the decline of the native fishes has been proposed by several rivermen. They believe that during one of the droughts in the pre-Boulder period, most of the fishes swam far up the river seeking cooler water. Here, so they say, one can still find them—trapped by the dam.

[16] The references cited by Hubbs and Miller (1941) offer a good start for the compilation of such a list.

can be recognized. It should be understood that they they do not completely describe each fish and that this list does not include all of the native species which have been recorded. In some cases a fairly large number of negative characters (such as "absence of spines") has been given in order to avoid the use of technical terms.

Distribution; Abundance; Habitat. With but a few exceptions no attempt has been made to indicate the distribution or abundance of any fish outside the limits of the surveyed section. Similarly, "habitat" refers to the type of environment frequented by each species in the study area. In indicating collections, the use of the term "survey" refers to collections made by Mr. Chester Woodhull and the author in 1942.

Size; Growth; Condition. All records of lengths and weights are given in inches and pounds. (While it is often convenient for the scientific worker to use the metric system for such measurements, the use of the English system is more intelligible to fishermen.) Unless otherwise noted, lengths denote measurements from tip of snout to fork of caudal fin.

Reproduction. Under this heading such subjects as spawning season, size at maturity, etc. are discussed.

Food. Although a considerable number of stomachs was examined, the absence of large samples of several species of fish taken from the same locality or type of habitat at the same time makes it impossible to indicate clearly the food preferences of individual species. In most cases only a resume of the stomach analyses is presented. A general picture of food relationships has already been given (Table 2).

Place in the Fishery. An attempt is made to summarize briefly the role of each species in the lower Colorado: its value either as a sport, food, bait, coarse, or forage fish; its interrelationships with the other fishes; its place in the stream's economy.

This rather elaborate system of subheadings by no means implies that we have even a fairly complete knowledge of any of the fishes of the river. On the other hand it should enable one to see clearly just how many large blanks remain to be filled by further study.

Elopidae. Ten-pounders

Ten-pounder, *Elops affinis* Regan

Local Names. It seems likely that the "gars," "pikes," and "anchovies" reported by local fishermen are *Elops*. A few people insist on calling them "tarpon."[17]

Recognition Characters. The slender, graceful body, bright silver color, long forked tail, and large eyes make it easily recognizable. No other fish in the river has the following combination of characters: absence of spines in the fins; dorsal and anal fins depressible into a high sheath of scales; toothed mouth; bony plate between the branches of the lower jaw.

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[17] Many names have been applied to *Elops* (awa, awaawa, big-eyed herring, big-sized herring, bonefish, bonyfish, chiro, horse mackerel, jackmariddle, John Mariggle, large-mouth herring, lisa francesca, matajuelo real). The term ten-pounder (inappropriate as it may be for this fish) seems to be most generally accepted in literature.

Distribution; Abundance. Comparatively little is known about this close relative of the tarpon, first reported from the Colorado River in 1941 by Glidden (1941). There is no reason to suspect that this was its first appearance here unless the advent of clear water was responsible. Dill and Woodhull (1942) have published the only other notes regarding its presence in the drainage (Salton Sea), and most of the following remarks and quotations are extracted from their report.

The fish have, of course, ascended from the Gulf of California where they are commonly found. Those in the Salton Sea have migrated from the river through canals. In past years residents have reported fish which may have been ten-pounders near Yuma and as far upstream as Picacho. However, Imperial Dam appears to be the physical limit of their upstream occurrence now. Apparently they are not numerous in the river, and are unknown to most fishermen.

Unquestionable records of its occurrence in this drainage are as follows: Laguna Dam, July 15, 1941, a specimen about 9.8 inches (total length) taken by L. C. Goldman (No. 36482, Stanford University collection); Laguna Dam, August 1941 (Glidden, 1941); near the head of the Alamo Canal below Pilot Knob Wasteway, one specimen 8.5 inches long taken in a gill-net on January 19, 1942 by the survey; Salton Sea at Bombay Beach, Mullet Island and mouth of Alamo River, May 1942 (Dill and Woodhull, 1942); Salton Sea at Fish Springs, one specimen weighing 1.9 pounds netted by a commercial fisherman in April 1943 (letter of Mr. W. C. Blewett to the author dated April 7, 1943).

Size. The size range of those taken in the southern end of the Salton Sea (the largest specimens yet known from this drainage) in May 1942 was 17.1-19.7 inches (1.75-2.75 pounds). Walford (1937) says that it attains a length of about 3 feet.

Reproduction. All of the males and females examined from the Salton Sea (14 fish) on May 24, 1942, were in spawning condition. The smallest male was 17.1 inches in length; the smallest female 18.7 inches. The young are ribbon-shaped and undergo a metamorphosis to attain the adult form.

It is not yet known whether the ten-pounder can reproduce successfully in the Salton Sea or in the river, or whether its establishment is dependent upon continued ingress from the ocean.

Food. "Five fish taken at Bombay Beach on May 14th [1942] contained from 1 to 9 desert minnows [*Cyprinodon macularius*] apiece. Three from Mullet Island taken on May 24th contained from 2 to 34 desert minnows apiece * * * One hydrophilid beetle was also found in a stomach."

Place in the Fishery. As yet the ten-pounder can not be considered of importance because of its scarcity. It is to be hoped that it will establish itself in the Salton Sea—long almost barren water to the angler. It can be taken on bait and spoons, and it seems possible that several types of artificial lures might prove successful for its capture. The fish is an active fighter, and several people who have eaten those taken from the Sea say that its meat is similar to that of large trout. Its predacity may, of course, prove detrimental to some of the other fishes.

Since August 4, 1943, California has accorded the ten-pounder rank as a game fish. A license is required for its capture and it can not be taken by spearing. (Calif. Fish and Game Code, 1943-1945, Secs. 421 and 490.5.) These are the only California laws relating specifically to this species and it is not mentioned in the Arizona laws. However, one reason for the minimum size of 5-inch stretched mesh specified for gill-nets used for commercial mullet and carp fishing in the Salton Sea, Alamo and New rivers is to permit the escapement of ten-pounders. (This is a regulation set by the State Fish and Game Commission, and is not a game law.)

Salmonidae. Trouts

The trouts are the only fishes known from the lower river which have an adipose dorsal fin (a small fleshy tab without supporting rays behind the rayed dorsal fin on the back), and also possess scales. (The catfishes, Ameiuridae, possess the adipose dorsal fin but lack scales.)

Colorado River cutthroat trout, *Salmo clarkii pleuriticus* Cope

Recognition Characters. In general, the cutthroat trouts have the following characters which help to distinguish them from the rainbows: red dash in a cleft under each side of the lower jaw; presence of hyoid teeth (those behind the patch of teeth on tip of tongue); maxillary extends beyond eye in adults; smaller scales. The Colorado River cutthroat trout is said to possess, characteristically, a red lateral band. (Such a band is also typical of rainbow trouts.) Jordan and Evermann (1896) say that it has a nearly immaculate head, red or orange lower fins, and from 185 to 190 scales along the lateral line.

Distribution; Abundance. This subspecies is native to the upper waters of the Colorado River. Records of its occurrence in the lower river's drainage are rather old and some may be dubious. Evermann (1916) visited the Salton Sea in May 1916, and saw one there about 16 inches long. He reported that, "It is said to be fairly common." Coleman (1929) spent considerable time studying the Salton Sea in 1927, 1928, and 1929. His only observation on this trout is to say, "The Colorado River trout is occasionally seen near the east end of the sea." The last published record of its occurrence in the lower drainage seems to be that of Bryant (1930), who states that a specimen was taken from an irrigation ditch connected with the river in Imperial County on January 21, 1930. Snyder (1940) lists the Salton Sea and New River as California localities for this trout; but says, "It has been variously reported as abundant or scarce, but no authentic information relating to it is at hand."

One could not expect any continued success for this or any other trout in the lower river, and records of its presence there are undoubtedly only chance occurrences.

Rainbow trout, *Salmo gairdnerii* Richardson

Recognition Characters. Characters which serve to distinguish it from the cutthroats include: lack of red dashes under lower jaw; absence of hyoid teeth; maxillary seldom extending beyond eye; larger scales (about 130 to 160 along lateral line). A reddish band along the side is characteristic.

Distribution; Abundance. The rainbow trout is not native to the Colorado. However, the upper waters of this drainage have been stocked with rainbows for many years. Recently, fairly large numbers have been planted in the river just below Boulder Dam. For a discussion of this fishery refer to Moffett (1942).

There have been several reports of rainbows taken much further downstream, i.e., in the area discussed in this article. A few are said to be taken regularly in winter about 12 miles above Needles and they are found occasionally at Topock according to Mr. James Brown of Needles. (Oral communication of February 17, 1942.) Mr. J. A. Danner of Needles Boat Landing told me (February 15, 1942) that a 16-inch rainbow was taken in Lake Havasu in the late fall of 1941. Two 18-inch rainbow were reported caught in this reservoir in the winter of 1942 according to Mr. Meadows of the United States Fish and Wildlife Service at Needles. (Oral communication of May 5, 1942.) The lowermost record known to the author was furnished by Mr. W. C. Blewett in a letter of February 17, 1943. While fishing for catfish in lower Palo Verde Slough on January 29, 1943, Mr. J. C. Bowen took a 16-inch rainbow "carrying two large layers of eggs." The head of this trout was sent to the author for verification of the identification.

Obviously, the lower river is unsuitable for the establishment of a permanent population of trout. We may, however, expect continued records of occasional downstream migrants especially during the colder seasons.

Catostomidae. Suckers

The only fishes known from the lower river which do not possess toothed jaws are the suckers and minnows (Cyprinidae). The mouth of the suckers is located on the underside of the head; the lips are thick, very protractile, and are covered with small fleshy projections.

Humpback sucker, *Xyrauchen texanus* (Abbott)

Local Names. Humpback sucker; razorback sucker; camelback; buffalo (?).

Recognition Characters. The large sharp-edged hump rising immediately behind the low flattened head readily identifies this fish.[18]

Distribution; Abundance. This unique native species is found only in the Colorado River drainage. In 1890, "It was found extremely abundant at Yuma and at all points below as far as the Horseshoe Bend, and in Hardee's Colorado," according to Gilbert and Scofield (1898). Grinnell (1914) took it near Mellen (Topock), Arizona, in 1910 but says nothing of its abundance. In 1916, Evermann (1916) says that it was rather common in the Salton Sea. Coleman (1929) states that it "is reported as rather common" there. In recent years, Moffett (1942 and 1943) has observed it a short distance below Boulder Dam and in Lake Mead but does not discuss its abundance at either place.

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[18] Jordan and Evermann (1896, p. 184) give the coloration as "plain olivaceous." Ellis (1914, p. 31) says that the general color is "* * * bluish gray to olivaceous * * * dorsal color fading gradually to silvery white below." The following color notes taken from the fresh specimens described in this report may, therefore, be of interest: dorsal surface of the body and head, and sides of head, grey; sides of body brownish with a distinct copperish cast; ventral surfaces of head and body yellow; fins grey or olive.

Certainly it was most plentiful at one time throughout the lower river and in the agricultural ditches according to residents. It is now very scarce. This was the only native fresh-water species seen in the river by the author in 1942, and it was noted at only one point. On the evening of May 19th, a small school of humpbacks was seen in a bay just below the Headgate Rock Dam near Parker. Attempts to surround it with a seine were unsuccessful, but an overnight gill-net set caught 13 specimens. Three of these escaped, and six others were released after measurements had been taken. The following information is based almost solely on the examination of these fish.

Size. Ten of these fish averaged 16.4 inches in length (range, 13.4-20.8 inches) and 2.26 pounds (range, 1.1-3.37 pounds) in weight. Jordan and Evermann (1896) state that this species reaches a weight of 8 to 10 pounds.

Reproduction. The gonads of the 4 fish examined showed them to be mature fish. Several of the males which were released had flowing milt.

Food. The digestive tracts of 4 fish were examined. In each case the entire gut was packed with silt which was rich in microscopic organisms (especially diatoms) and filamentous algae. The gut is long, being 62.5 inches in length in a specimen 16.9 inches long. It seems probable that the ingestion of large quantities of bottom silt enables them to derive sufficient nutriment from its organic constituents. In this regard, the feeding habits of the humpback sucker are similar to those of the mullet.

Place in the Fishery. This sucker is not a game fish, and the author has no information as to its use as a food fish by the residents of the lower river. Ellis (1914) reports that it "* * * is taken in numbers by the Mohave Indians from the Colorado River near Fort Mohave," and that (in Colorado) it is marketed along with the flannel-mouthed sucker (*Catostomus latipinnis*).

If silt or detritus is its primary source of food this species would not appear to be in direct competition with any other fish except the mullet. It seems probable that it is able to utilize much potential food which would otherwise go to waste. Furthermore, if young suckers are eaten by game fish, this species would thus serve as a valuable link in a food chain and actually increase the productivity of the river.

Cyprinidae. Minnows

These and the suckers (Catostomidae) are the only fishes found here which lack teeth in their jaws. The mouth of the minnows has a "normal" or terminal position (i.e., it is not located distinctly on the underside of the head), and the lips are not thick or covered with small fleshy projections. Some members of the minnow family reach a large size.

Carp, *Cyprinus carpio* Linnaeus

Local Names. Carp.

Recognition Characters. It is readily distinguished from all other fishes known from the river by: its long dorsal fin with a toothed spine;

short anal fin also with spine; two barbels (fleshy "whiskers") on each side of the upper jaw.

Most of the carp seen were of the "scale" variety; only two "mirror carp" being found among several hundred specimens.

Distribution; Abundance; Habitat. The earliest record of the carp in the lower river is that of Gilbert and Scofield (1898), who reported it as "* * * a stranger in the Colorado River" in 1890. These Asiatic fish had been widely distributed throughout the United States prior to that time, and those in the river may have come from several stocks in several states.

It is now everywhere abundant in the stream and its distributaries. Carp roll in the clear waters of Lake Havasu and endure with equanimity the silty, brown flood of the Alamo River. They are even found

FIG. 67. Fishing for carp (and anything else that will bite). A drain ditch near Palo Verde. May 1942.

in the Salton Sea although their greatest concentration there is near the entrance of tributaries where the water is freshest. The adaptability of this species to adverse conditions is well known, and it is not surprising that they are so well established here.

Size. While the largest carp taken by the survey was 15 inches long, much larger ones are found. Messrs. W. C. Blewett and Leo Rossier report seeing them about 24 inches in length or about 8 pounds.

Reproduction. Almost all of the fish taken in the May 1942, collections were in spawning condition. Residents reported that they started spawning in Haughtelin Lake in early April of 1942.

The smallest sexually mature males seen were 7.7 inches long; the smallest mature females, 7.6 inches. The largest immature carp seen were: 6.7 inches (males); 8.3 inches (females). (Based on the examination of 55 fish, 5.2 to 12.1 inches long.) Maturity at such a small size is unknown in carp from other sections of California.

Food. The stomachs of these 55 specimens taken in May from several parts of the river were examined. All were empty. The intestinal contents appeared to be composed primarily of algae and the remains of higher plants. Numerous studies of carp from other waters have made it clear that it is omnivorous.

Place in the Fishery. Unlike most people in California, the local residents as a whole do not evidence a very strong antipathy towards the carp. Generally speaking, it is neither praised nor condemned. Many of the poorer citizens fish purposely for this fish as food, using cane poles and various types of baits. Carp are also used either as live bait or as cut bait.

Fish believed to be carp appeared in the Salton Sea in great numbers and then died off between 1906 and 1915 according to Thompson (1920). Thompson and Bryant (1920) said: "* * * some eight years ago a promotor started a company with the idea of using these carp, and other fresh water fish, for oil and fertilizer. Having built the proper buildings, installed machinery and launched boats in the sea, the company was unable to operate because it was unable to find sufficient fish." [19] With the revival of mullet fishing in the Salton Sea in 1942, a few carp are now being taken commercially here. Special permits for their commercial capture in other waters of the Colorado have also been issued by Arizona and California recently. In the fall of 1942, Arizona and California cooperated in obtaining a supply of brood carp so that the Japanese interned at the Poston War Relocation Camp (near Parker, Arizona) could raise them as food.

At present there is no evidence to show that the carp is detrimental to the sport fishery of the Colorado. It is undoubedly a competitor of the game fishes, but it may also be of some value to them as forage. There are comparatively few bass waters in the United States (good or bad) where carp are not present. In the turbid and warmer waters of the drainage it serves to augment an otherwise scanty fish fauna. On the other hand, there is no good reason to afford this species any protection as its fecundity will undoubtedly preserve it against the heaviest fishing.

Bony-tail, *Gila elegans* Baird and Girard

Local Names. Bony-tail; round-tail; Gila trout; Verde trout.

Recognition Characters. Elongate and slender caudal peduncle narrowing just in front of the caudal fin which is widely forked and has enlarged basal expansions.

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[19] Thompson and Bryant (op. cit.) did not accept, unreservedly, the "* * * identification of others than scientists * * *" that these fish were carp. However, MacDougald (1914, p. 118) indicates that carp were at least fairly numerous in the Sea *circa* 1907, and Evermann (1916) said that it was "* * * undoubtedly the most abundant species" there in 1916.

Distribution; Abundance. Gilbert and Scofield (1898) say that it was most abundant in the larger river channels in 1890. Evermann (1916) reports that it was "Said to be not uncommon * * *" in the Salton Sea in 1916, although he saw no specimens. Moffett (1942) reported it from the Colorado River immediately below Boulder Dam in 1941, but did not discuss its abundance there. At Lake Mead, Moffett (1943) says that "Rather large schools of bony tails are seen repeatedly."

Residents report that it was once one of the commonest fish in the Needles-to-Yuma section, but agreed that it was seen only occasionally now.

Place in the Fishery. The present role of this fish in the lower Colorado is unknown to the author. Apparently it can play but a minor one because of its scarcity. It is said to have been easily caught on hook and line; some "old timers" claim it was the easiest fish in the river to catch. In speaking of the allied *Gila robusta* Baird & Girard, Jordan and Evermann (1896) say that "* * * the flesh [is] full of small bones and nearly worthless as food." Ellis (1914), who considers *Gila elegans* to be a synonym of *Gila robusta,* also says that its bony body makes its value as food slight but that large specimens are occasionally eaten and are said to have a good flavor.

Colorado River squawfish, *Ptychocheilus lucius* Girard

Local Names. Colorado "salmon"; white "salmon"; "salmon."

Recognition Characters. Head long and pike-like; large terminal mouth; caudal peduncle not narrowing abruptly in front of caudal fin (as in the bony-tail).

Distribution; Abundance. At one time it was a common fish, but is now, in the section between Yuma and Needles, a decided rarity. No specimens were seen by the survey in 1942. Gilbert and Scofield (1898) said that it was abundant in the Gila and lower Colorado in 1890. Grinnell (1914) reported it as plentiful immediately below Laguna Dam in 1910. In recent years Moffett (1942) has recorded it from below Boulder Dam, but has made no comment on its abundance. Residents report that it is taken only occasionally now.

Place in the Fishery. More fame has been accorded this fish than any other native species in the Colorado River drainage. It is known as the world's largest minnow, and has been reported to attain a length of at least 5 feet and a weight of almost 100 pounds. (Ellis, 1914, p. 55.) Little is known as to its habits or life history. Other members of this genus (*P. oregonensis, P. grandis*) are considered as predators of salmonoids. Very possibly the Colorado River squawfish is also predaceous on other fishes of the river, but its scarcity makes it of little importance in this regard now.

The name "salmon" is used almost exclusively for it by residents. Some of them firmly believe that it is a true salmon and have even suggested that fish-ways should be constructed to allow it to pass over the dams. Some residents have claimed that there was an upstream migration in the spring which was especially noticeable at Laguna Dam.

Here, the Indians used to capture them with pitchforks and other gear. It was the most highly prized of the native fishes, and is reported to be quite edible.

As with other members of this genus, the Colorado River squawfish can be taken on bait or with artificial lures.

Ameiuridae. Catfishes and Bullheads

These are the only scaleless fish in the river which possess an adipose dorsal fin. They have barbels on the chin. The dorsal and pectoral fins each possess a stout spine.

Southern channel catfish, *Ictalurus lacustris punctatus* (Rafinesque)

Local Names. Channel catfish (or cat); spotted cat; blue cat; catfish.

Recognition Characters. The deeply forked tail will readily distinguish the channel catfish from any of the others known from the river. A slender head, and the presence of spots are other diagnostic characters.

It should be noted that fishermen report several kinds of forked-tailed catfishes from the river and have a variety of names for them. It was especially common to find residents speaking of "blue cats" and "channel cats" as entirely different species. The author has been unable to find any specific distinction between these two fish, and refers all of the forked-tailed catfishes seen on the lower Colorado to *Ictalurus lacustris punctatus.* The "blue cats" which were examined were all large specimens, possessed few if any spots, and had broader heads than the typical channel catfish. Otherwise, they appeared to agree in all particulars (such as fin ray counts) with the latter, and it is believed that they are merely old individuals of this species. Wickliff and Trautman (1935) say that channel cats may lose their spots after reaching a few pounds in weight and that these are called "Blue Cats" by the average fisherman in Ohio. See also the discussion in Smith and Swingle (1943, pp. 176-177).

Distribution; Abundance; Habitat. This is an introduced fish which has become common in the river only within the last few years. There are even more theories as to its origin in the Colorado than for that of the largemouth bass.

It is now abundant throughout the lower river and tolerates a wide range of environmental differences. Not only is it found in the clear, cold water below Boulder Dam (Moffett, 1942) and in Lake Havasu, but it is common in the turbid canals of the Imperial Valley. It is even taken occasionally in the Salton Sea. The larger individuals are taken most commonly in or near rather swift water. The areas below dams (as at Laguna) or along the channel edges offer good fishing spots, and the experienced fisherman pays careful attention to his selection of a place to fish. However, even dead water may provide large catches of small channel catfish.

This species far outnumbers the bullheads (*Ameiurus*) of the river even in the muddy areas where the literature might lead one to believe that it would be uncommon. Most accounts speak of its preference for clear, swift waters; while the transplanted stock may still retain this preference, it has not kept it from inhabiting some of the muddiest sections of the Colorado drainage. It has been taken from the Grand Canyon where the silt load is still extremely great, and from the Alamo and New rivers which run chocolate-brown.[20] The collections made in 1942 would lead one to believe that it has shown a greater degree of success in all types of Colorado River water than has any of the other game fishes.

Size. In the Colorado it reaches a large size which is comparable in every way to that usually attained in its native waters. Forbes and Richardson (1920) say that in Illinois "It is seldom taken of more than five pounds weight, although specimens are occasionally seen weighing from fifteen to twenty pounds." Similar statements are given by other authors.

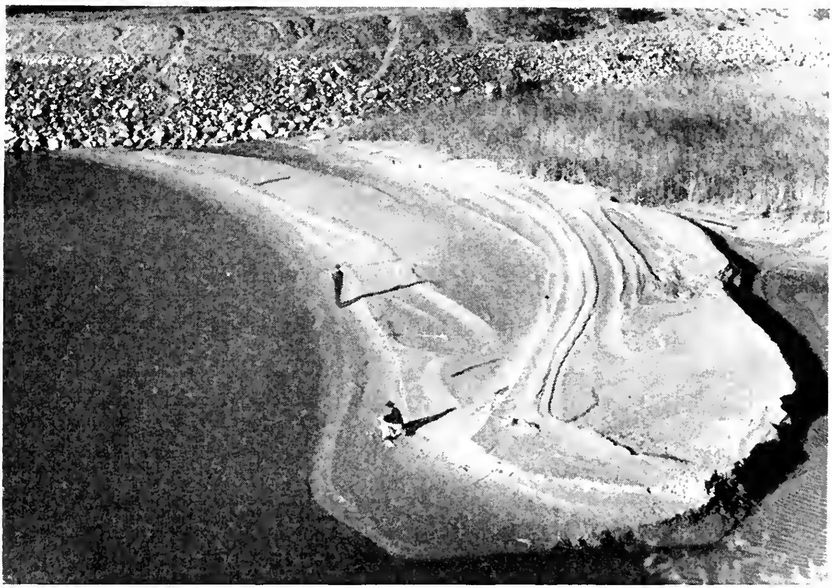

FIG. 68. Catfish fishermen at the head of the Alamo Canal. Jan. 1942.

There is a photograph at Needles Boat Landing of a catfish caught in Lake Havasu in 1941 and reported to weigh 22 lbs. 9 oz. Since 1940 the Yuma Valley Rod and Gun Club has held a "prize fish contest" during the February-April period of each year. The weights of the largest channel catfish entered in these contests are as follows: 1940, 19 lbs. 12 oz.; 1941, 14 lbs. 8 oz.; 1942, 20 lbs. 8 oz.; 1943, 16 lbs. 12 oz. (All fish are weighed on accurate scales.) Of course, as for all fish, there are reports of some phenomenal catfish in the Colorado which—had they been caught—would have far exceeded these weights. While the reports of local game wardens, the accurate records of the Yuma Club and other

[20] Several specimens taken from the Grand Canyon in 1937 have been examined by the author in the collection of the United States National Park Service at Grand Canyon Village.

photographs which have been seen make it certain that quite a number of channel catfish weighing 10 to 15 pounds or over have been taken in late years, the fish which are usually caught are much smaller. During the 1942 survey many large catches composed entirely of fish from about 6 to 11 inches in length were seen.

Reproduction. The smallest fish seen which could definitely be said to be sexually mature (adults) were two females 7.3 inches in length taken at Laguna Dam on April 14, 1932, by E. H. Glidden. In 1942 eight mature females were seen which would have spawned in that year. These ranged in size from 8.3 to 26 inches in length. Fourteen other females ranging from 7.3 to 15.0 inches in length were examined which may have been spent fish. The largest female seen which it was believed was a sexually immature (young) fish was 10.4 inches long.

The segregation of the fish examined into three classes (young or immature, ripening or ripe adults, spent adults) was not based on very firm criteria. Those classed as ripening adults were easy to distinguish. Gross examination of their ovaries showed them to be turgid and to contain large translucent eggs. Fish whose ovaries lacked these eggs could have been either immature or fish which had spawned. No exact line could be drawn between these two classes in the material available. Flaccidity of the ovaries and the size of some of the fish examined made it likely that some of those lacking the large eggs might have spawned.

Since the collections were not large enough to settle this question satisfactorily, one can not offer an opinion as to the upper size limit at which this species usually becomes sexually mature in the Colorado. It can only be said that some females spawn at the small size of 7.3 inches; and that a size of at least 10.4 inches may possibly be reached before maturity is attained.

The only fish seen which appeared to be almost ripe (i.e., having large eggs almost free from the ovarian walls) were two females, 12.0 and 16.6 inches in length, taken on April 26, 1942, at Laguna Dam. A fish in which well-developed eggs were apparent was taken as early as January 19, 1942, at Yuma. The ripening eggs from this fish (26 inches long and 9 pounds in weight) had an average diameter of 2.5 m.m. (about one-tenth inch), but were still undetached. Another fish (8.9 inches) with attached eggs of the same size was taken at Parker just four months later (May 19, 1942).[21] Mature but unspawned females were also seen at Lake Havasu on May 21, 1942. The earliest date at which fish presumed to be spent were seen was April 26th.

From such meager data it can only be assumed that the spawning season in the Colorado occurs during the spring and summer. This agrees with observations made in other regions. (See Adams and Hankinson, 1928.)

The number of mature (translucent) eggs produced was calculated for two specimens.[22] A fish 8.5 inches long taken on February 7, 1942, contained approximately 1,600 eggs; another, 26 inches long, taken on January 19, 1942, contained approximately 34,500 eggs.

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[21] All egg sizes based on the measurement of 200 eggs from each fish after preservation in 5% formalin for several months. Shira (1917) gives the size of channel catfish eggs as 3.53 m.m. when extruded.

[22] Samples of known percentage (by weight) were taken from three parts of the ovary and the eggs counted.

Food. The stomachs of 72 channel catfish (3.1 to 26 inches in length) were examined but only 43 of these contained food. The results of a quantitative study of stomachs from 38 small catfish taken from a drained irrigation canal in the Imperial Valley is shown in Table 3. Examination of 5 other stomachs containing food from fish 6.5 to 16.6 inches in length taken from other parts of the Colorado River district in early 1942 showed that substantial quantities of aquatic plants (mainly *Najas*) and backswimmers were also consumed. One fish, 7.4 inches long, contained a small bluegill. The largest fish (16.6 inches long) containing food had its stomach packed with fragments of bulrush.

From these studies and the work of other investigators it may be concluded that the channel catfish is rather omnivorous. The literature indicates that almost any available food organisms except possibly planktonic forms—large or small, alive or dead, plant or animal—are utilized. (See: the bibliography in Adams and Hankinson, 1928; McCormick, 1940; Rice, 1941.) Although it is known to be predaceous on other fishes, its piscivorous habits do not appear to be as highly developed as those of the other major game fish of the river, the large-mouth bass. Fish were found in but two stomachs from the Colorado: fragments of a small unidentified species, and a bluegill 1.2 inches long. Since most of the catfish examined were of small size it might be argued that these had not yet attained piscivorous habits. However, McCormick (1940) found even fairly large channel catfish (about 13.4 to 20 inches) from Reelfoot Lake to be eating but little fish. Trichoptera and chironomids comprised most of their animal foods. The rather high content of plant foods found in stomachs is of interest, and both small and large fish are apparently quite efficient in making use of dead organic matter. About 15 per cent of the food of young fish 0.8 to 4.13 inches was found to be "ooze and debris" by Shira (1917). Table 3 shows that this is also an important constituent of the food of small channel catfish in the Imperial Valley.

TABLE 3

The food of 38 small channel catfish taken from West Main Ditch, Imperial Valley, California, when drained on February 7, 1942. Average length 6.1 inches (range, 3.1—10.6 inches). Total volume of stomach contents 9.034 c.c. (Forty stomachs were examined; two were empty.)

Class of food organism	*Per cent of stomachs containing organism*	*Per cent of total volume*
Filamentous green algae	2.63	4.3
Higher plants (mainly terrestrial)	21.05	10.4
Isopoda	2.63	1.1
Mayfly nymphs (Ephemerida)	2.63	0.3
Odonata*	39.47	11.3
Caddisfly larvae (Trichoptera)	47.36	5.3
Midge larvae (Chironomidae)	89.47	16.0
Terrestrial insects and spiders	36.84	4.1
Fish (unidentified)	2.63	16.3
Ooze (organic detritus, sand)	31.57	20.9
Bird's foot	2.63	10.0

* All damselfly nymphs except 0.08 c.c. dragonfly nymph in 1 fish.

Place in the Fishery. The channel catfish fulfills three of the criteria usually applied to game fish, being a good fighter, having a tasty flavor, and having at least some susceptibility to the attraction of artificial lures. It is true that most of them are caught on bait, but flies, spinners and plugs can also be used with some success.

At some places (as at Lake Havasu or Martinez Lake) the catch of bass may exceed that of catfish, but in the area as a whole, including the artificial waterways, it is believed that the catch of channel catfish exceeds in both numbers and pounds that of any other fish. There are several reasons for this: abundance of fish in different types of water and in easily accessible ones; ease of capture on simple equipment; preference as an article of diet.

As has already been mentioned, this fish has an important role as a scavenger and as a utilizer of foods not taken readily by some of the other game fishes. It is possible that its predation has, in part, been responsible for the depletion of native fishes.

Yellow bullhead, *Ameiurus natalis* (Le Sueur)[23]

Local Names. Mudcat, yellowbelly, "native" bullhead.

Recognition Characters. Rounded tail; whitish chin barbels; 24-27 anal rays; yellow coloration.

Distribution; Abundance; Habitat. Its origin in the river is unknown, but the presence of this or some other species of *Ameiurus* is believed to antedate that of the channel catfish. Many of the residents have considered *Ameiurus* to be native.

The reports of fishermen (if their identification is correct) indicate that this species is the commonest bullhead in the lower river. However, only six specimens were seen during the 1942 survey. Three of these came from Haughtelin Lake; one was seen at Lake Havasu; one in an irrigation ditch near Blythe; one at the Imperial State Game Refuge on the Alamo River. There appear to be no authentic records for its presence in California outside of the Colorado River drainage.

Mr. W. C. Blewett (letter of April 9, 1944) informs me that it thrives best in backwaters and sloughs as in the Palo Verde region. Several residents of Blythe and Needles state that it is fairly common in such areas. It in no way approaches the abundance of the channel catfish, however.

Size. Those seen ranged from 7.0 to 11.4 inches in length. Forbes and Richardson (1920) give the length of this species as 12 to 18 inches, but say that it is not often found over 12 inches in length.

Reproduction. All of the specimens examined were taken between January 30th and February 25, 1942. They were all mature females which had not yet spawned. A spawning season in the spring or early summer is indicated. Authors cited by Adams and Hankinson (1928) give May and June as the spawning season in the east and middle west.

Food. Three stomachs were examined; one contained food. This fish (10.6 inches) taken in a gill-net from Haughtelin Lake on January 30th

[23] One of the specimens collected, a female 10.6 inches in length taken in a gill-net at Haughtelin Lake, January 30, 1942, has been identified as the northern yellow bullhead, *Ameiurus natalis natalis* (Le Sueur) by Dr. Carl L. Hubbs.

contained: *Najas;* fragments of cattail (?); dragonfly nymphs; crayfish; unidentified fish, probably carrion.

The work of many authors shows that the food of *Ameiurus* is most diversified. (See, for example, Cable, 1928; references in Adams and Hankinson, 1928.) Algae, higher plants, both minute and large crustacea, insects, molluscs, and fish have all been reported as food items in the stomachs of *Ameiurus natalis, A. nebulosus,* and *A. melas.* Like the channel catfish, the bullheads appear to utilize most of the available living foods and to be efficient scavengers.

Place in the Fishery. It competes for food with the other game fishes, but also acts as a useful scavenger. None of the bullheads are popular with Colorado River fishermen who often throw them away. Bullheads are considered to be very edible fish in other parts of the country. It is probable that the abundance of the gamier and more attractive channel catfish accounts for the prejudice against the lowly "mudcats."

Black bullhead, *Ameiurus melas* (Rafinesque)

Recognition Characters. Square-cut tail; grey or blackish chin barbels; 17-21 anal rays; blackish coloration; pectoral spines without strong barbs on posterior edge; fins with jet-black membranes.

Distribution; Abundance. Only two specimens were seen in 1942. On May 18th one 10.2 inches in length was taken in a gill-net from Haslam Slough, near Palo Verde, California. Another 8.9 inches long, was taken in a gill-net from the river at Headgate Rock Dam on May 20th.[24] Both were mature females. Other definite records of its occurrence in California have not yet been published.

Since fishermen on the Colorado usually seem to recognize but one kind of "bullhead" or "mudcat" it is possible that this species is confused with the others.

Remarks. Ordinarily this species does not reach as large a size as the other bullheads known from the river. Forbes and Richardson (1920) say that it is not often over 12 inches in length. The literature indicates that its feeding and breeding habits are similar to those of the yellow bullhead.

Brown bullhead or Square-tailed catfish, *Ameiurus nebulosus* (Le Sueur)

Recognition Characters. Square-cut tail; grey or blackish chin barbels; 19-24 anal rays; brownish coloration; pectoral spines with strong barbs on posterior edge.

Distribution; Abundance. This species was not seen by the author who knows of only one record of its occurrence in the lower river. Grinnell (1914) states that it was taken in a backwater slough of the river on the Arizona side above Mellen (Topock) in 1910. Fishermen may possibly confuse it with other bullheads from the river so its abundance is unknown.

[24] Dr. Carl L. Hubbs has identified this specimen as the northern black bullhead, *A. melas melas* (Rafinesque). In a letter of Feb. 23, 1943, he has informed me that he has collections of the southern black bullhead, *A. melas catulus* (Girard), from the Colorado River system in Arizona.

Remarks. This species is said to reach a length of 18 inches by Forbes and Richardson (1920), but most of those caught are considerably smaller. Its spawning season, food, and habits are similar to those of the yellow bullhead. This is a common and widely distributed fish in other parts of California, and is popular with fishermen in most places.

Cyprinodontidae. Killifishes

Desert killifish, *Cyprinodon macularius* Baird and Girard

Local Name. Desert minnow.

Recognition Characters. The killifishes and top minnows (Poeciliidae) can be distinguished from the other fishes of the lower river by the following combination of characters: scales on both head and body; teeth on jaws; no spines in fins; single dorsal fin.

Cyprinodon is a chubby little fish, usually only about 2 inches long. In the Colorado River district it is sometimes confused with the mosquitofish (*Gambusia affinis affinis*), but they may be easily distinguished by the relative positions of the dorsal and anal fins. In the desert killifish the insertion of the anal is behind that of the dorsal; in the mosquitofish it is well in advance of the dorsal insertion.

Distribution; Abundance; Habitat. This fish is, of course, not likely to come to the attention of the angler. But despite its small size and minor role in the economy of the fishing waters it deserves mention here.

Miller (1943.1) gives its range as: "The basin of the lower Colorado and Gila rivers and the Salton Sea, from southern Arizona to southeastern California and eastern Lower California, and the Sonoyta river of northern Sonora, Mexico." It is found in isolated springs and creeks of the desert, and is abundant in the Salton Sea. It is not known, however, whether or not it occurs in the main waters of the Colorado or its sloughs, "lakes" and distributaries in the Yuma-to-Needles section. Dr. Robert R. Miller knows of no records for this *Cyprinodon* in the river above Yuma, but believes that it once occurred there. (Letter to the author, October 28, 1943.) [25] More intensive collecting especially in the sloughs and ditches of this section might reveal its presence.

Its abundance in the Salton Sea has already been mentioned, and since it has been taken in irrigation ditches in the Imperial Valley it may be commoner in the larger waters draining this valley than has been supposed.

The desert killifish has a remarkable adaptability to extremes of water temperature and salinity. Miller and Miller (1942) say that it will survive winter temperatures very close to freezing and summer temperatures over 100° F. It will live and breed in both fresh water and in the saline waters of the Salton Sea.

Reproduction. Miller and Miller (1942) say that this fish breeds from about April to September (in garden pools), and that there is some evidence that it breeds the year round in some of its native warm springs.

[25] It has been taken from the Gila River (2 miles below Dome, Arizona) close to its confluence with the Colorado; other collections have been made along the Colorado in Mexico. (Miller, 1943.1.) An unpublished survey in the files of the Bureau of Fish Conservation reports "desert minnows" near Blythe, California. It is believed, however, that these fish were really *Gambusia*.

About 50 to 200 eggs are produced at one time and spawning may occur several times during the breeding period. Fish which they have reared in garden pools have attained sexual maturity within a few months after hatching.

Food. From the few food studies made of other western members of this genus, we would expect *C. macularius* to be somewhat omnivorous, subsisting on algae, crustaceans, small insects, etc. (See: Kennedy, 1916; Wales, 1930.)

Place in the Fishery. This species could have but a minor effect upon the fishery as there seem to be but limited areas in which it could come into contact with the other fishes. Any competition would be a most one-sided affair with *Cyprinodon* getting the "short end." It is not known that any direct use of this species has been made by man either as bait, for food, or as a forage fish.[26] Were it abundant in the main Colorado or had it a higher reproductive potential it would appear to be an excellent forage fish.

Relatively small populations exist in some of the desert springs. Hence it is to be hoped that collections of this interesting fish may be confined to those made by students having legitimate (rather than casual) interest in it.

Poeciliidae. Top Minnows

Western mosquitofish, *Gambusia affinis affinis* (Baird and Girard)

Local Names. Mosquitofish; mosquito minnow.

Recognition Characters. May be distinguished from the desert killifish (*Cyprinodon macularius*)—the only fish with which it seems to be confused—by the relative positions of the dorsal and anal fins. In the mosquitofish the insertion of the anal is well in front of the dorsal insertion. The male has a spike-like anal fin, and is much smaller than the female.

Distribution: Abundance; Habitat. This fish was introduced into California in 1922 for mosquito control and was widely distributed throughout the State. Possibly its advent in the lower Colorado is a result of this distribution. Coleman (1929) reported finding it in the Salton Sea and Fish Springs sometime between 1927 and 1929. The possibility of downstream migration from plants in other states must not be overlooked, however, as it is also known from Lake Mead.

It is abundant almost everywhere along the lower river, in the Salton Sea, and in the streams flowing into it. Ordinarily one does not find it in the main river channels, but it is common in sloughs, backwaters, and in the "lakes." There is hardly a ditch in the irrigated sections where it is not to be found in large numbers.

Undoubtedly many are stranded in fields, borne there by irrigation water. However, its fecundity makes this a matter of but small concern. Its adaptability to warm and brackish waters, and its ability to live in very shallow pools account in part for its success in this drainage.

Size. About 1 to 2 inches in length.

[26] *Cyprinodon salinus* Miller from Death Valley was once captured and eaten by the Panamint Indians. (Miller, 1943.2).

Reproduction. The species is ovo-viviparous and produces several broods annually.

Food. Only a few stomachs from mosquitofish of the Colorado were examined. These fish were subsisting on small crustaceans (plankters) and on aquatic and terrestrial insects of small size. Many detailed studies of the food of this species have been made, and it is well known that entomostraca and dipterous larvae are among the most important foods utilized. See, for example, Hess and Tarzwell (1942).

Place in the Fishery. Some largemouth bass and green sunfish stomachs from the Colorado have contained mosquitofish. It seems probable that they serve as a good forage fish here. Certainly many are available. They may compete to some extent with the young of game fish species, and appear to be having a deleterious effect upon the native *Cyprinodon* in the Salton Sea area.

They are used to some extent as live bait. In some places, measures have been taken to prevent their depletion by bait dealers and users. (See, Kuhne, 1939.) It can not be seen that they need any protection in the Colorado River district.

Mugilidae. Mullets

Common mullet, *Mugil cephalus* Linnaeus

Local Names. Mullet. According to Thompson and Bryant (1920) it was once called "cow-carp" in the Imperial Valley, but the name is not in common use now.

Recognition Characters. First dorsal fin of 4 slender spines, well separated from the second dorsal of soft rays. Teeth present but minute. Sides silvery with distinct dark longitudinal stripes.

Distribution; Abundance; Habitat. With the exception of the ten-pounder, this is the only fish of the river which has both a fresh water and oceanic habitat.[27] It is common in the Gulf of California and has ascended the river at least as far as the Imperial Dam. There is apparently no reason why the mullet should not have ranged upstream farther than the Imperial Dam before its construction, and it seems probable that it did. The author has heard reports of it being seen occasionally near Picacho and at Palo Verde. However, he could not find any residents of Palo Verde, Blythe or Needles who were familiar with its occurrence there. Since it is so abundant in the lower river it is surprising that Gilbert and Scofield (1898) do not mention finding this species during the survey of 1890. Some old residents report that it was always of sporadic occurrence in the river near Yuma, and did not become firmly established there until the extensive system of canals and drains was built.

During the flood of 1905-1907, mullet were carried into the newly-formed Salton Sea and have become well established there. At present they occupy the Sea almost to the exclusion of other fishes, replacing the once more abundant carp.

[27] Gilbert and Scofield (1898) list two species of marine fishes taken at the mouth of the Colorado. However, these fishes are not known to ascend the river to any distance. One is a goby, described by them as a new species, *Gillichthys detrusus*. Starks and Morris (1907) have found this fish to be indistinguishable, except in color, from *Gillichthys mirabilis* Cooper. The other is a flatfish, *Paralichthys aestuarius* Gilbert and Scofield.

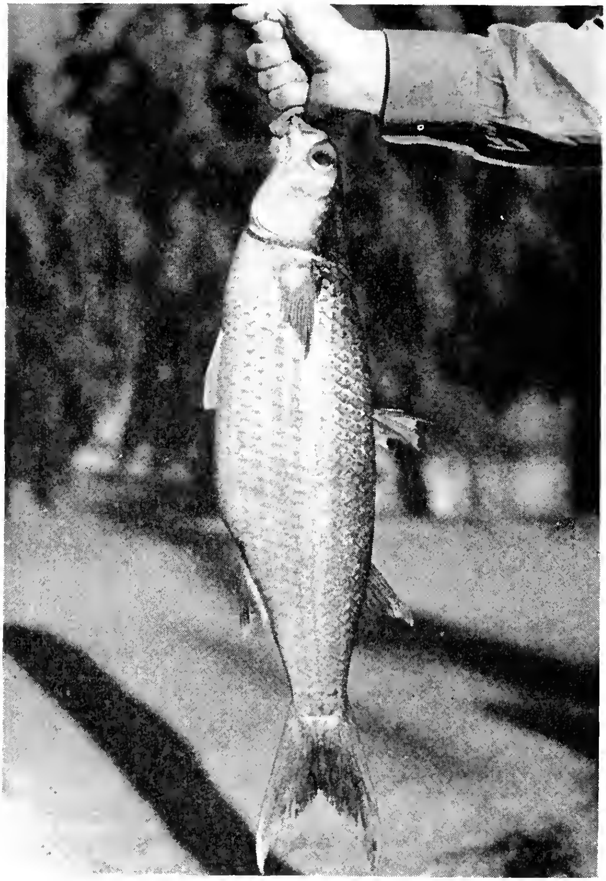

FIG. 69. A six and one-quarter pound mullet.

Schools of small mullet can frequently be seen in the river where their habit of schooling and leaping makes them easily recognizable. They are often to be seen at Laguna Dam ascending the weir in a thin sheet of water. The muddiest waters of the Alamo and New rivers seem to be to their liking as are their small partially cut-off lakes where the water is brackish and the temperature high. Mullet are numerous in the quiet canals and drain ditches of the Yuma Project, in the Imperial Valley, and thrive in the highly saline waters of the Salton Sea. In all of these waters they are one of the most abundant fishes.

Size. Several hundred mullet were taken in gill-nets in the river (between the International Boundary and Imperial Dam) and near the heads of canals diverting from it in January, February and May, 1942. The range in size of these fish was 7.8 to 15.6 inches.[28] Most of these mullet appeared to belong to a size group of about 12 inches in length. The

[28] The nets used here had a minimum mesh of 1½ inches and a maximum mesh of 4 inches (stretched measure).

smallest mullet seen here were about 4 inches in length. (These were seined.) Mr. Leo Rossier has reported seeing mullet of about 6 pounds at Laguna Dam, but large ones do not seem to be common in the river. One mullet, 21.5 inches long which weighed 6.25 pounds, was taken in Haughtelin Lake, which is cut off from the river. Its origin there is unknown.

The mullet of the Salton Sea attain a much larger size. Those caught by commercial fishermen using gill-nets of 5-inch stretched mesh in early 1943 averaged almost 5.2 pounds in weight. (Based on the fishermen's own catch records of 36,106 fish taken during the January-May period.) Only a few measurements of Salton Sea mullet have been made by the Division of Fish and Game. In October 1942, a catch of 80 fish taken with commercial gear was measured by the author. These fish averaged 20.8 inches in length (range, 18.5-24.5 inches) and 5.6 pounds in weight (range, 3.75-9.75 pounds). Due to the selectivity of the gear used, the maximum size of mullet in the Sea has not been determined. Several commercial fishermen report that a 12-pound fish is about the largest taken. Thompson and Bryant (1920) reported that the average mullet from the Sea was between 2 and 2.5 feet in length. Evidently this referred to fish taken in 1919.

Reproduction. Little is known of the life history of the mullet in the Colorado River. In other parts of the world mullet are reported to be fall spawners in salt water. Those found in the Colorado were probably spawned in or near the Gulf of California and then migrated upstream. The apparent lack of large mullet in the river near Yuma during the early months of 1942 might indicate that the population at this season was composed only or largely of juveniles.

We have a slightly better knowledge of the mullet in the Salton Sea, but here again much of it can only be conjecture. Here the fish are landlocked. They can migrate up drainage ditches or up the Alamo and New rivers for only short distances before their ascension is blocked. Therefore, their available spawning area is limited. It seems probable that they spawn in the Salton Sea itself where oceanic conditions are simulated by its salinity. It also seems probable that the bulk of the spawning occurs in the shallow waters near the mouths of the Alamo and New rivers. Certainly there was a congregation of ripe or almost ripe fish in such areas in the fall of 1942.

Three females (21 to 25 inches) taken from the Salton Sea on September 27, 1942, were almost ripe. All of 93 sexually mature mullet taken from the Sea on October 29, 1942, were ripe or almost ripe. Several of the males had flowing milt and a few of the females extruded loose eggs when subjected to gentle pressure. Mr. Leo Rossier made periodic examinations of the commercial catches throughout November 1942, and reported that all the fish he saw were ripe. Since no further examinations have been possible, the duration of the spawning season is unknown.

Sexual maturity of the mullet in the Sea is known to occur at at least 16.5 inches in males and at 20.5 inches in females. (Based on an examination of 61 males and 46 females over 16.5 inches in length, taken from the Sea on October 28th and 29th by commercial fishermen and in an experimental gill-net.) Possibly mullet do become mature here at a smaller size, but the nets took no smaller ones. Seine hauls and gill-net sets in waters of the Alamo River a few miles above the Salton Sea on October 29, 1942, took only 23 mullet, ranging from 10.0 to 19 inches in length. All of these were sexually immature. Only two were over 16.5 inches in length; these were males 18 and 19 inches long which had been stranded for some time in a cut-off pool above the Northend Dam, and were in an emaciated condition.

The commercial gear (5-inch stretched mesh) used in the Sea affords but little opportunity for taking mullet less than 18 inches in length. None of the experimental netting in the Sea (in February, May, and October, 1942) produced mullet less than 9.4 inches in length. We have no direct knowledge, therefore, of the early life history of the mullet there.

Food. Mr. Chester Woodhull (ms., 1942) examined the stomach contents of 33 mullet (8.8 to 18.7 inches in length) taken from the Salton Sea and lower Alamo River on February 24, 1942. Those from the Sea (23) were empty. The predominant food organisms found in the Alamo River samples were: diatoms; unicellular green algae (mainly desmids); blue-green algae; protozoa. A few rotifers and cladocerans were also found. Since the stomachs contained large quantities of sand and silt in addition to the food organisms it might be concluded that the fish do not select any particular food items. A gross examination of the stomach contents makes it clear why fishermen say, "They live on mud."

Mullet are frequently seen taking bits of material floating down on the surface of the canals. Much of this material is composed of masses of blue-green algae. The fish will lie in schools ranging from side to side to pick off bits of the scum as it floats towards them.

Thompson and Bryant (1920) reported that they fed on a "grass" in the Salton Sea, and Coleman (1929) has a photograph (his Fig. 74) captioned "Magdalena grass, food of the famous Salton Sea mullet."[29] Such statements are incompatible with the observations made by other authors on the feeding habits of mullet.

Place in the Fishery. Its subsistence on the smallest plants and animals (especially those of the bottom) does not place the mullet in direct competition for food with most of the other fishes of the river. In turn, the smaller ones are probably utilized as food by other fishes. Since they are also able to exist in the otherwise rather unproductive waters of the Alamo and New rivers and in the Salton Sea, they appear to be a valuable part of the fauna.

It can not be said that the potential value of mullet either for food or sport is entirely realized, however. They are a well-known food fish although their flavor is not savored by all Californians who have tried them. It is a rather common belief that they cannot be caught with hook and line, and comparatively few people angle for them along the Colorado. However, adherence to rather specialized methods (with either bait or fly) can result in their capture, and when taken on a flyrod, even small mullet make a strong spirited fight. More common methods of "sport fishing" include: clubbing, spearing or netting.

No commercial fishery for mullet exists in the river. It was carried on from 1915 until 1921 in the Salton Sea, and then abandoned volun-

[29] This "grass", whose identity is unknown, is reported by residents to have disappeared in about 1931.

tarily owing to the scarcity of fish and the difficulty of taking them. (See: Thompson and Bryant, 1920; Janssen, 1937.) In 1931 it was prohibited by law. By 1942 the supply of mullet had again increased in the Sea and in May of that year the commercial fishery was reestablished on an experimental basis under permits issued by the California Division of Fish and Game. The success of the fishery and the regulations concerning it will not be discussed here as they do not directly concern the fishery of the Colorado River itself.

Centrarchidae. Sunfishes and Black Basses

Members of this family are the only fishes found in the lower river which have thoracic ventral fins (inserted close to the pectorals). They possess a single dorsal fin with spinous and soft-rayed portions closely joined (except in the largemouth bass).

Black crappie, *Pomoxis nigro-maculatus* (Le Sueur)

White crappie, *Pomoxis annularis* Rafinesque

Local Names. Crappie; croppie; calico bass.

Recognition Characters. The crappies may be distinguished from the other centrarchids of the river by the following characters: anal fin base about equal in length to dorsal fin base; anal fin with 5 to 7 spines; dorsal fin usually with 6 to 8 spines.

The table below shows the distinctive differences between the two species of crappies.

Character	*Black crappie*	*White crappie*
Number of dorsal spines	Typically 7 or 8 (rarely 6, 9, or 10)	Typically 6 (rarely 5 or 7)
Length of dorsal fin base	About equal to distance from forward end of dorsal fin to eye	Much less than distance from forward end of dorsal fin to eye
Dark markings	Typically mottled	Typically form rings on sides

Distribution; Abundance. Neither of the crappies is native to the Colorado, and both appear to be comparative newcomers to the lower river. Few of the residents (except near Yuma) are at all familiar with them, and report their occurrence only within the last few years. The earliest record of the occurrence of *Pomoxis* in this area which has come to the attention of the author is that furnished by Mr. J. W. Harbuck who saw "crappies" in Haughtelin Lake in 1934. (Letter to the author, dated Feb. 14, 1943.) A few crappies were caught in Lake Havasu in the spring of 1940 and 1941, and one taken in the river below Palo Verde in 1941, according to reports by California wardens. The identity of the species is not known in any of these cases.

From the reports of residents it appears that *Pomoxis* is more abundant in the vicinity of Yuma than farther upstream. At Needles several fishermen told me of "the" one crappie caught in 1941. The collections made by the survey were too small to afford comments on this point. In 1942 black crappie were collected: in the Colorado River below Imperial Dam (1); Haughtelin Lake (3); Haslam Slough near Palo Verde (1); Lake Havasu (1). White crappie were collected as follows: head of the Alamo Canal (2); mouth of the Gila River (4); Haughtelin Lake (5); Headgate Rock Dam (1). In California, as far as is known, the white crappie is confined to the Colorado River drainage.

Remarks. The apparent scarcity of these fishes and the paucity of study material do not permit more than passing mention of their life histories or their roles in the river.

The largest black crappies taken were 8.1 inches in length; the largest white crappie 12.0 inches.

All black crappies seen (range, 5.7-8.1 inches) were adults. Two caught in late January had well-developed gonads. Those taken in May (4) were ripe.

Nine white crappies 5.9 inches or over in length which were seen were adults. Three ranging from 4.9 to 5.4 inches in length were considered immature. The one adult fish taken in May was a ripe female. The others were collected in January (7) and in April (1), and had somewhat swollen gonads.

The stomachs of 8 out of 9 white crappie (5.1-10.0 inches in length) which were examined contained food. The frequency of occurrence of food items found was as follows: chironomid larvae (8 times); small crustacea, primarily cladocera (5 times); backswimmers (4 times); mayfly nymphs (twice); damselfly nymphs (twice); bluegills (once). Two black crappie (5.6 and 5.7 inches long) contained ostracods, mayfly nymphs, backswimmers, and chironomid larvae. From these scanty data —or better, from our knowledge of crappies in other waters—we can assume that they may offer decided food competition to the other centrarchids of the Colorado by utilizing both the smaller and larger animal foods. It is well known that crappies may be decidedly piscivorous. For example, studies of both species in Foots Pond, Indiana, by Lagler and Ricker (1942) showed that over 70 per cent of the food by bulk was composed of fish.

Both crappies are recognized game fish or pan fish in the United States, and will, if they increase in numbers, secure this place in the Colorado River. Many anglers report that fishing for crappies is an uncertain sport. At times they seem to bite voraciously; at other times it is most difficult to take them even from waters where they are abundant. Only at Haughtelin Lake, where large schools were sometimes seen, did we find people fishing for crappies as a primary purpose. Small artificial lures or bait may be used for their capture. In other parts of California a live minnow seems to be the most killing offering.

Thompson and Bennett (1938) and Bennett (1943) have produced evidence to show that crappies may be serious competitors of largemouth bass. And in the publications of several other fisheries workers one notes a growing feeling that the presence of crappies is inimicable to the best interests of a bass fishery. Their occurrence in the Colorado may not be desirable. It may be, of course, that the competition of crappies could not attain the severity in the more open "lakes" of the Colorado that it can in closed waters.

Bluegill, *Lepomis macrochirus* Rafinesque

Local Names. Bluegill, bluegill "perch," "perch," sun perch, sunfish.

Recognition Characters. The bluegill and green sunfish can be told from the crappies by the following characters: anal fin less than half as long as dorsal; 3 anal spines; 10 dorsal spines. Their short bodies (depth about one-half standard length) and the presence of a black "ear flap" on the gill cover easily distinguishes them from the black basses (*Huro* and *Micropterus*).

These two sunfishes are frequently confused in the Colorado River as in many other parts of California. The following table will serve to distinguish them. It may be noted that these two species frequently hybridize, and hybrids were seen at several points along the river.

Character	*Bluegill*	*Green sunfish*
Portion of opercular flap bearing black spot	Thin and flexible	Stiff and bony
Upper jaw	Not extending nearly to middle of eye	Extending nearly to (or even beyond) middle of eye
Pectoral fins	Long and pointed (at least 3 times in standard length)	Short and rounded (4 times in standard length)

Distribution; Abundance; Habitat. The bluegill is abundant in the quiet waters all along the lower river, and in irrigation canals where the water is checked. It is especially common in areas where the cover is thick as in the brushy portions of the lakes above Imperial Dam, near boat landings, etc. It seems to be the most abundant of the centrarchids, despite the report that it is quite a newcomer to the river.

FIG. 70. Haughtelin Lake, an oxbow where bluegills are abundant. Jan. 1942.

Size. Only a few bluegills were seen in angler's catches so it is impossible to state the average size or size range of those usually caught. However, fish from 5 to 7 inches long were well represented in hoop-net collections at most points, and angling (with No. 12 or 10 fly or with a 3-0 spinner) produced fish of this size at these same localities. The largest fish seen were 7.7 inches long.

Reproduction. Although 242 bluegills were examined during May 1942, the number of small fish collected was not sufficient to determine the size at which they "typically" come to first maturity. During May 1942, sixty-five bluegills were examined from habitats representative of the river and its connected lakes. Sixty of these fish (ranging from 4.4 to 7.7 inches in length) were sexually mature. Five (ranging from 3.3 to 4.8 inches) were classed as immature. Since all but four of the adult fish exceeded the latter size range, the sample must be considered inadequate for the derivation of exact conclusions.

Seventy fish (1.4 to 2.9 inches long) collected from the lower Gila River on May 11th were still immature. Only four other bluegills were taken here. One of these, a male 2.5 inches long, had flowing milt; the others were adults 4.8 to 5.7 inches in length.

The largest number of small mature bluegills were taken from Haughtelin Lake. All fish (103) examined from here were sexually mature. They ranged from 2.1 to 7.7 inches in length. Sixteen of these (all males) were less than 2.7 inches long; the smallest mature females (4) were 3.0 inches.

It is certain then that in some localities (Haughtelin Lake) bluegills mature at a very small size, at least 2.1 inches in males and at least 3.0 inches in females.

The month of May (in 1942) appeared to mark the height of the spawning season. The examination of 60 adult bluegills taken from various points on the river itself from May 8th to the 21st showed that: 15 (12 males; 3 females) had swollen gonads; 36 (24 males; 12 females) were ripe; 9 (8 males; 1 female) were spent. Of 72 mature fish from Haughtelin Lake taken on May 6th and 7th, 3 (all males) had swollen gonads; 50 (43 males; 7 females) were ripe; 19 (10 males; 9 females) were spent. Four mature fish taken from the lower Gila River on May 11th had greatly swollen or ripe gonads.[30]

It is generally considered that bluegills have an extended spawning season and, in certain localities, are said to spawn throughout the summer.

Food. Stomachs containing food were examined from 22 adult bluegills (range, 4.1-6.3 inches in length) taken from several points along the river in early 1942. Stomachs from different localities varied markedly in their contents, and it was not considered that a lumping of the samples would give a true expression of the food preferences of this species. However, certain items, whether measured by frequency of occurrence, percentage of total volume, or any other method, were clearly outstanding. These were chironomids, backswimmers, small crustacea (mainly cladocerans), and higher plants. Other important foods represented

[30] Thirty-one other mature fish from Haughtelin Lake were examined in May but the exact condition of the gonad was not recorded. It should be noted that there may have been some confusion between fish not yet presumed to have spawned ("swollen") and those presumed to have spawned once ("spent"). All fish classified as "ripe" produced either milt or eggs upon gentle pressure.

to a slighter extent were: filamentous green algae; mayflies; terrestrial insects. Nepidae, caddisflies, and hydraearina were also found.

Table 4 shows the foods eaten by 51 small bluegills from the Gila River in comparison with those eaten by 38 green sunfish of about the same size from the same locality. One might conclude from this that with the same foods available bluegills have a greater dependence on the smaller animal foods than have green sunfish.

TABLE 4

A comparison of the feeding habits of 51 bluegill and 38 green sunfish of the same size, taken from the same habitat at the same time. Gila River near Dome, Arizona, May 11, 1942. Average size of bluegill, 1.8 inches (range, 1.4—2.6 inches). Average size of green sunfish, 1.7 inches (range 1.1—2.3 inches). Sixty-two bluegill stomachs examined; 11 were empty. Sixty-three green sunfish stomachs examined; 25 were empty.

Class of food organism	*Per cent of stomachs containing organism*	
	Bluegill	*Green sunfish*
Filamentous green algae	9.8	31.6
Cladocera	76.5	2.6
Ostracoda	3.9	--
Backswimmers (Notonectidae)	7.8	28.9
Beetles, aquatic (Coleoptera)	--	7.9
Midge larvae (Chironomidae)	50.9	36.8
Terrestrial insects	--	7.9
Mosquitofish (*Gambusia*)	--	2.6

Place in the Fishery. The bluegill is a valuable multi-purpose fish, and can be considered either as a small game fish or pan fish, as a forage fish for bass, or even as a bait fish. The sunfishes are specifically sought by comparatively few people along the river. They are largely neglected by the ardent bass fisherman, and are too small-mouthed to be caught on the large chunks of bait used by the catfisherman. They can be easily taken on small baited hooks or on small artificial lures such as flies or spinners, and could thus provide a good deal of unrealized sport in this area. They are sometimes caught for use as live bait by bass fishermen.

The bluegill is considered by many to be one of the best forage fishes for largemouth bass. Bennett (1943), for example, states that there is but little food competition between them, and the two species are frequently stocked together with good results. In Lake Mead, Moffett (1943) found the largemouth bass to be subsisting largely on bluegills, and it seems probable that they form a large part of the diet of adult bass throughout the lower river.

Contrariwise, an overpopulation of bluegills (or other sunfish) can be deleterious to a bass fishery especially through their predation on the eggs and young. Their fecundity is well known, and—especially when not subjected to heavy fishing—they may increase in such numbers that the fishery as a whole is harmed. It is not known whether any such condition exists in the lower river, but it is very possible that it could arise. It is quite probable that such a condition now obtains in Haughtelin Lake where there is a large population of bluegills and but few bass. Unfortunately, most anglers plug for the bass while allowing the sunfishes to remain unexploited.

Green sunfish, *Lepomis cyanellus* Rafinesque

Local Names. Sunfish; sun perch; "perch"; "bluegill"; "warmouth" (occasionally).

Recognition Characters. See bluegill, p. 169.

Distribution; Abundance; Habitat. Its advent in the river is unknown. According to some residents (who have identified it with certainty) the green sunfish has been present much longer than has the bluegill, and some speak of it as the "native perch."

As with several other fishes of the river, the collections in 1942 were not large enough in all areas to determine definitely the abundance of this species. Green sunfish were collected at most points along the lower river below Lake Havasu, and may be expected in any of its distributaries. A rough estimate (based on all types of collecting done in 1942) is that bluegills outnumbered green sunfish about 10 to 1. It is possible, however, that in the canals and turbid streams of the Imperial Valley the green sunfish have a numerical superiority. It is a common complaint in the Valley that the "bluegills here never grow up"; it is suspected that the residents are referring to green sunfish. The few collections made in the ditches here and in a small cut-off lake on the Alamo River produced only green sunfish, and most of these were of small size.

Shortly after Lake Havasu was created, green sunfish were reported by several members of the Division of Fish and Game to be extremely abundant. No sunfish were collected from here by the 1942 survey. Several residents of Needles and Blythe informed me (in 1942) that the "sun perch" or "sunfish" (which they distinguished from the bluegill) had become depleted—although there were swarms of them in 1940. Mr. W. C. Blewett (letter of April 9, 1944) tells me that this information is quite correct. He says that green sunfish were abundant in Havasu in 1939 and 1940 but declined sharply in 1941 and that by 1944 they were nearly all gone. Meanwhile, he states, the bluegill appears to have taken its place, being present in large numbers now.

Size. Only a few green sunfish were taken by angling (the smallest 5.9 inches long) and none were seen in angler's catches. Consequently, no remarks can be made regarding the size usually taken by fishermen. The largest specimen taken (in a hoop-net) was 7.1 inches long.

Reproduction. One hundred green sunfish (range, 1.1 to 7.1 inches in length) were examined in May to determine the size at first maturity. All of these fish under 2.4 inches in length (64) were sexually immature. All fish (36) either male or female 2.4 inches in length or over were adults. Hubbs and Cooper (1935) found that green sunfish in Michigan over 3 inches in total length were mostly mature; those less than 3 inches were almost always immature.

The duration of the spawning season in the Colorado has not been determined. No fish examined in January exhibited perceptible signs of ripeness. All adult fish taken during May (6th-24th) were ripe. It is probable that the spawning season of this species is rather prolonged here.

FIG. 71. Cover for largemouth bass and sunfish in Martinez Lake, Arizona. Feb. 1942.

Food. As with the bluegill, the foods eaten by the green sunfish varied decidedly depending upon the locality from which they were collected. The stomachs of eight fish containing food (2.2-4.6 inches in length) collected from a ditch in the Imperial Valley on February 7, 1942, were examined. Whether measured by frequency of occurrence or by percentage of total volume, the most important foods were: dragonfly and damselfly nymphs, chironomids and caddisfly larvae. Higher plants and aquatic beetles were also represented. But in the stomachs of 16 green sunfish (range, 2.4-7.0 inches in length) seined from the lower Gila River on May 11, 1942, backswimmers and fish (*Gambusia* and sunfish) occurred most frequently and in the greatest volume. Aquatic beetles and terrestrial insects were represented only a few times and in little bulk.

From these data and those shown in Table 4, there is an indication that green sunfish, even of small size, have a tendency to select the larger animal foods, such as fish or dragonfly larvae, rather than the smaller ones.

Place in the Fishery. To a certain extent the place of this species in the fishery of the Colorado is quite similar to that of the bluegill. That is, it has values as a pan fish, forage fish, and bait fish. Green sunfish of large size are excellent fighters and seem to take a lure with more of a rush than does the bluegill. On the other hand, several workers consider the green sunfish to be more detrimental than useful. (See Hubbs and Cooper, 1935, p. 693; Bennett, 1943, p. 362.) In many areas it rarely reaches catchable size, and it may overpopulate waters. It has a very large mouth for its size and may act as a direct competitor for food with larger game fishes as well as preying on both their eggs and young.

Largemouth bass, *Huro salmoides* (Lacépède)

Local Names. Largemouth bass; bass; black bass.

Recognition Characters. This seems to be one of the few fish in the river which is rarely mistaken for other species by fishermen. It is easily distinguished from the other centrarchids here (*Lepomis* and *Pomoxis*) by its more elongate body (depth about one-third in standard length) and deeply divided dorsal fin. However, a fair number of anglers seen in 1942 believed it to be the smallmouth bass (*Micropterus dolomieu*), a fish which is apparently not present in the lower Colorado. In the largemouth bass the upper jaw usually extends past the hind margin of the eye, being shorter in the smallmouth. The spinous and soft portions of its dorsal fin are almost separated, while they are well connected in the latter species.

Distribution; Abundance; Habitat. The presence of this introduced form has caused a great deal of speculation by fishermen. The species has been planted several times in waters of the Colorado, and the existing stock undoubtedly has a multiple origin. Although present for many years, according to "old-timers," it did not become plentiful until the water cleared.

It is now abundant throughout the lower river and its distributaries wherever the water is fairly clear and quiet. It is also present in muddy canals and drain ditches, but not as common here. Exceedingly turbid waters such as the Alamo and New rivers, their small "cut-off lakes," and the canals and drains of the Imperial Valley appear to support but few bass. Especially good bass fishing prevails in Lake Havasu and in the "lakes" above Imperial Dam.

Size; Growth; Condition. Our periods of field work did not coincide with the periods of greatest fishing intensity in 1942, and the reduced number of anglers in wartime afforded but little opportunity to examine the catches of many fishermen. It is necessary, therefore, to seek out other records in order to gain a concept of the size of bass taken in this area. During April and May, 1940, concessionaires at Lake Havasu turned in records of 264 bass to the Division of Fish and Game. These had an average weight of almost 2 pounds. According to Mr. J. A. Danner, proprietor of Needles Boat Landing, the largest bass he had seen at Lake Havasu up to February 1942, weighed 9 lbs. 4 oz., dressed. In 1943, a bass from this lake won 5th prize in the Northern Division of "Field and Stream's" national "Big Fish Contest." This bass weighed 9.5 lbs. (Anon., 1944.) The records of the first prize winners of the Yuma Rod and Gun Club's contest held each year from February through April are as follows: 1940, 6 lbs. 2 oz.; 1941, 8 lbs. 1 oz.; 1942, 8 lbs. 2 oz.; 1943, 6 lbs. 14 oz. All of these fish were caught at Imperial Dam or in the lakes above the dam. These are, of course, the more exceptional fish, but it is apparent that bass of very satisfactory size are taken. Two and three pound fish are commonly caught.

None of the bass seen in 1942 were in poor condition. Photographs of many bass taken at Lake Havasu in 1940 and 1941 and at Martinez Lake in 1942 showed them to be in excellent condition. Fishermen had no complaint and all seemed well satisfied with the fishing. The scales of only 93 bass were available for examination. Of these, 83 were taken from areas considered representative of the river and its lakes, and the results of studies of their scales are shown in Table 5. These fish were taken by a variety of methods (hoop-nets, gill-nets, and angling). Most of the larger ones are from anglers' catches. The majority of the fish were taken in May of 1942; the others during January and February of that year. The latter fish had not completed the full year shown in the table, but most of their growth had probably been attained.

Larger samples are needed to present a truer picture of growth, and it would be especially valuable to procure larger samples from the lakes above Imperial Dam and from Lake Havasu. Had the sample included fish only from these localities the growth rate would have appeared far higher.[31] The results obtained, however, are indicative of a good growth rate compared with the largemouth bass from other waters shown in Table 6. It should be noted that the bass from the lower Colorado were measured to the fork of the tail, while those from the other waters were measured to the extreme tip of the tail fin.

TABLE 5

The average size of 83 largemouth bass taken from the lower Colorado River during January, February, and May, 1942

Age in Years	*Year-Class*	*No. of Fish*	*Length in Inches to Fork in Tail*	*Weight in Pounds*
0	1942	1	1.4	---
1	1941	34	6.6	0.17
2	1940	13	9.6	0.52
3	1939	23	13.0	1.1
4	1938	8	14.8	---
5	1937	4	16.2	---

TABLE 6

Average size of largemouth bass from other localities

	Total Length in Inches		
Age in Years	*Lake Mead (Moffett, 1943)*	*State of Wisconsin (Bennett, 1937)*	*Norris Reservoir (Eschmeyer and Jones, 1941)**
1	10.3	3.3	8.2
2	12.6	7.4	12.7
3	13.4	10.5	14.7
4	14.6	12.5	15.7
5	15.2	14.0	---

* Based on data in their Table 3. The lengths given above are the averages of collections made in the reservoir (excluding sinkholes) during the 1938-1940 period.

Reproduction. In 1942 all of the bass 11.6 inches long or over which were examined were sexually mature, and all of these fish were three years of age or over. Only four fish of smaller size, all two years old, were found which exhibited sexual development. Two of these, males, 9.9 and 10.8 inches long, had swollen testes but might not have spawned in that year. One was a partly spent female 11.3 inches long; one a male 8.1 inches long with flowing milt.

[31] Ten 2-year-old bass collected in May, 1942 from potholes in the Gila River with abundant food showed a markedly higher growth rate. These 10 fish had an average length of 11.9 inches and an average weight of 1 pound. Only one contained food at the time of capture.

The available data indicate, therefore, that most of the bass spawn for the first time when three years old. (Three-year-old fish averaged 13 inches in length.) It is as yet unknown whether the attainment of sexual maturity in this species in the Colorado is correlated more closely with age than with size.

The bass of the lower river spawn throughout the March-June period according to the report of local game wardens and fishermen.[32] In 1942, none of the bass observed in January and February were ripe although some exhibited swollen gonads. The author had no opportunity to examine specimens during March or April. However, Mr. Leo Rossier reported seeing many bass taken near Laguna Dam and from the lakes above Imperial Dam containing ripe eggs in April. During May (6th-21st) the author examined 32 adults to find: 1 almost ready to spawn; 6 ripe; 25 spent. Recently hatched bass were seen at Haughtelin Lake on April 16th. These were about 1 inch in length. On May 7th many schools of fish less than 1 inch long and a number of individuals about 2 inches long were also observed here. Bass about 1 inch long were noted in the lakes above Imperial Dam on May 10th. Schools of bass of about the same size were plentiful near the head of the Alamo Canal on May 13th.

From the evidence available it is surmised that in 1942 the peak of spawning occurred in April. The duration of the season and its peak undoubtedly vary in different years and in different sections of the river. It has already been noted that for the years of record the mean water temperature of the lower river reaches 65° F. in March or April and that it seems to be rather generally assumed that bass do not usually spawn before this temperature is attained.

Food. Although 94 largemouth bass stomachs were examined, only 26 of them contained food. The food items found in the stomachs of 14 yearling bass (34 examined) were as follows: backswimmers (7 times); beetles (5 times); mosquitofish (5 times); sunfish, crayfish, chironomid larvae, and hymenoptera (once each). The intestinal tract of most of these bass contained large numbers of backswimmers. Fifty stomachs from fish two years of age or over were examined; only 11 contained food. The larger items represented were: bluegills (4 times); crayfish (twice); channel catfish (once); young passerine bird (once). A few beetles and spiders were also found.

A high percentage of empty stomachs seems to be characteristic of largemouth bass, especially large ones, and is probably to be correlated with irregular feeding habits. Nine out of 10 well-conditioned bass 11.3 to 12.9 inches long seined from a hole on the lower Gila River had empty stomachs. Since this hole swarmed with tiny sunfishes and mosquitofish it is apparent that there was no lack of suitable food available for them.

Place in the Fishery. This is the major game fish of the river and it is eagerly sought by both resident and visiting anglers.

Young bass face competition by several fishes here, especially by the other centrarchids. A certain amount of competition is entirely natural, and there is as yet no evidence (except in Haughtelin Lake) that it is harmful to the bass fishery. A few fishermen have commented that during the past two seasons comparatively few small bass have been seen or

[32] Moffett (1943) indicates that April-June is the spawning season of largemouth bass and bluegills in Lake Mead.

FIG. 72. A catch of largemouth bass from Martinez Lake, April 5, 1942. Photograph through courtesy of Joseph Lindsay.

caught in the lakes above Imperial Dam, and that their catches have been restricted mainly to bass three pounds or over in weight. These observations, if true, can not be explained easily. Such a condition could be due to any number or a combination of several factors: overpopulation of other centrarchids; poor spawning seasons as because of water fluctuations, etc.

Adult bass have but few enemies on the river other than man. They prey on the other fishes and are believed to be largely responsible for the depletion of the native species.

Other Fishes Which May be Present

It is very likely that several other species of exotic fishes may be present in the lower river.

Goldfish, *Carassius auratus* (Linn.), have been imported from fish dealers and kept in live-boxes at Lake Havasu for use as bait. Fishermen have told me that fish have escaped from these boxes, and, of course, the possibility of escape from baited hooks is good. In the fall of 1942 a farmer informed me that he had "dumped several buckets of goldfish" into the Alamo River so that "the bass would have more feed." Goldfish are well established in many waters of California, and it will be surprising if they are not or do not become residents of the Colorado. If so, they may be expected to compete with other fishes in somewhat the same manner as do carp. Their comparative value as food competitors and as forage fish can not be prognosticated.

"Buffalofish" or "buffalo-carp" have been reported by residents as being caught at several places along the lower river (near Needles, below Parker, in the Imperial Valley). Some have described them as looking something like a carp "without the whiskers." While it is possible that some of the reports allude to carp or to the humpback sucker, it is also possible that some species of true buffalofish may be present. O'Malley (1919) lists buffalofish (*Ictiobus* sp.) as planted in Roosevelt Lake, Arizona, in 1918. This reservoir is on the Salt River and some of the fish may have descended to the Colorado.

"Drum," "redhorse," "yellow perch," "gars" and "pike" are also reported by fishermen. The identity of such fish is unknown, although it is suspected that they may be confused with some of the fishes already described here. Other exotic species are known from the upper Gila basin, but are not mentioned here since this is not a part of the area discussed in this report. Shad (*Alosa sapidissima*) and yellow perch (*Perca flavescens*) were planted in the lower Colorado years ago, and striped bass (*Roccus saxatilis*) have been planted in the Salton Sea. We have no authentic reports of their survival.

OTHER ANIMALS IN THE FISHERY

Several other animals besides fishes may be mentioned because of their actual or potential place in a sport fishery here.

Crayfish

Crayfish (*Cambarus*) have been introduced but their abundance and distribution is not well known. According to several residents of Yuma, some were brought in from Los Angeles and planted in a drain ditch near Winterhaven, Imperial County, "about ten years ago." A few from this stock are also reported to have been transplanted to Picacho in 1941. They were said to be common near Winterhaven in 1942 and to extend up the river at least as far as Laguna Dam. Several were seen in Haughtelin Lake where they were also taken from bass stomachs. It would not be surprising to find them at many other points along the lower river; man is an inveterate acclimatizer.

Crayfish will eat a variety of live foods and are also scavengers. The author does not recall any studies which would indicate that they would be serious competitors or predators of the Colorado River fishes. Studies by Norton (1942), for example, showed that the crayfish of Reelfoot Lake and Bayou du Chien in Tennessee subsisted mainly on vegetation (unicellular and multicellular algae and spermatophytes). Apparently they can make good use of the primary foods which are not much used by large fishes. On the other hand, they are a well-known source of food for fishes, especially for the black basses. Baker (1942) has found them to be the chief food of bullfrogs in East Texas. On the debit side, it may be said that some species will burrow and weaken levees and cause damage to crops. Possibly this might make them obnoxious in the irrigated areas.[33]

Since crayfish are enjoyed as food by man and used as bait, an abundant supply would provide a minor fishery on the river. Neither Arizona nor California has any game laws relating to their capture. None are recommended until it is evident that they deserve or need protection.

[33] There is some evidence that crayfish may be destructive to trout, and the importation of live crayfishes into California is specifically prohibited by law. (California Fish and Game Code, 1943-1945, Appendix, p. 233.)

Bullfrogs

Another introduced form is the Bullfrog (*Rana catesbeiana*), native to North America east of the Rocky Mountains, but long an acclimatized resident of California. Sportsmen report that it was planted a few years ago near Topock where it is now common. Some are found at Blythe, and they occur on both sides of the river near Yuma. There have probably been several introductions of this species. Mr. Deane Haughtelin of Winterhaven, in a letter of April 14, 1944, informs me that he saw them about five miles above Picacho in about 1923, and that they were common near Winterhaven a few years later. Mr. Charles H. Sturges of Yuma, in a letter of February 8, 1944, reports that some from central California were planted in drainage ditches of the Yuma Project around 1941. Their increase in abundance is of much interest to local sportsmen, but it is believed that they are hunted extensively only in the Topock region. It can be expected that all of the marshy areas will support them. Although they are sometimes cited as predators of fish and young water fowl, the author can see no reason for not furthering their increase on the river. They are of value for food and sport, and also for sale to biological institutions, although this market is of limited extent.

At present the Arizona and California laws coincide as to the general regulations for their capture.[34] It is believed by some members of both State commissions that: the present season is too long; the bag limit too high; the use of guns should be prohibited as more frogs are lost than retrieved by this method of capture. With but little knowledge of the local situation, the author can make but two recommendations. (1) It is desirable that the regulations of the two States be uniform for the Colorado River area. (2) Stricter rules should be formulated if there is any danger of depletion through over-hunting. Frogs can be taken in several ways other than by shooting, especially with the aid of spotlights at night: by spearing or gigging, scapping (the use of a net on a long pole), "angling" with line and baited hook, by special "frog forceps," etc. Shooting at water is notoriously dangerous and might be banned on these grounds alone.

Man is not the only enemy of Bullfrogs on the Colorado. Fish, birds and coons may also prey on them.

Turtles

Two species of turtles were observed in 1942: the Sonoran Mud Turtle (*Kinosternon sonoriense*), and Emory's Soft-shelled Turtle (*Trionyx emoryi*).

The first, a native of the river, excites little attention from man except when it steals bait from the hooks of a fisherman. No use seems to be made of it.

Many stories of soft-shelled turtles in the Colorado were heard during the 1942 survey, and one was collected at Headgate Rock Dam on May 19th. Consequently, it came as somewhat of a surprise to the author to learn that the species found there had not been reported in scientific literature until recent years. According to Stejneger and

[34] Season, March 1st-November 30th; bag limit, 24 daily or 18 weekly; minimum size limit, 4 inches (body length); use of firearms allowed except between sunset and sunrise. (California Fish and Game Code, 1943-1945, Secs. 1350-1351.)

Barbour (1933) its natural range is the "Rivers of Texas, north into southern Oklahoma and Arkansas"; and it is often spoken of as the soft-shelled turtle of the Rio Grande (its type locality). Schmidt (1924) ascertained that it was plentiful near Phoenix, Arizona, in 1924, and thought it probable that it had been introduced there. Since that time it has been collected or observed at several other points in the Colorado River drainage. It is now known in the Colorado River from near its mouth to Pierce's Ferry in Arizona. Linsdale and Gressitt (1937), who may be consulted for a summary of the above records, were unable to determine "Whether this species is native in the Colorado River or was transplanted there in recent years * * *."

Unfortunately, while doing field-work the author was unacquainted with this evidently surprising occurrence in the Colorado, and made no attempt to question "old timers" as to the year in which they had first observed this species. However, the establishment of *Trionyx* was well known to many residents from Yuma to Needles who apparently considered it to be native.[35] The only indication that it might be a new addition came from the remarks of a few people who said that it "seems to be increasing."

To the clarification of this mystery the author can add but a few notes. Mr. Deane Haughtelin of Winterhaven came to the river in 1910. In a letter of April 14, 1944, he says that he did not see or hear of soft-shelled turtles in the Colorado until "* * * shortly after World War I." Mr. F. A. Thompson of Fresno, California, has recently informed me (oral communication of November 14, 1943) that he caught soft-shelled turtles in irrigation ditches (Gila drainage) near Sheldon, Greenlee County, Arizona, in 1919. Mr. Thompson is a careful observer and his description of the turtles fits that of *Trionyx*. Sheldon is much closer to the area in which *T. emoryi* is native than are the other Colorado drainage localities from which it has been reported. The farthest western record for this species in the Rio Grande drainage seems to be that of Little and Keller (1937) in Mesilla Valley, Dona Ana County, New Mexico. If *Trionyx* is not native to the Colorado drainage, it is at least possible that it was introduced on the upper Gila (or its tributaries), and has spread downwards to the Colorado River from where it has progressed both upstream and downstream. More intensive collecting on the Gila and on the Colorado above Pierce's Ferry, along with questioning of the residents, should go far towards solving the problem.

From the few notes taken on this turtle it may be mentioned that residents have described it as being quite common at Laguna Dam, and near Palo Verde. Specimens are found in Lake Havasu and some in this area are described as reaching a weight of 25 pounds. It was reported that they were quite edible and that they were both trapped and shot for food.

The role of turtles in the Colorado either as competitors, predators or scavengers is unknown, but the present population is probably too small to be of much significance to the fishery in these regards. On the other hand, it may be that the soft-shelled turtle could be a valuable addition to the food or sport fishery. If so, it should be given a measure of

[35] It should be mentioned that soft-shelled turtles are so distinctive in appearance that there is little danger of confusing them with other turtles. It may also be noted that most of the "old timers" also believed *Ameiurus* to be indigenous—an indication that it, too, has been resident in the river for many years.

protection and not begrudged some inroads on the fish fauna. None of our aquatic turtles receive any protection under either the Arizona or California laws. If it is desired to maintain and increase the number of soft-shelled turtles here, some regulations concerning their capture could be made. A size limit might be established or the gear so regulated that very small ones would not be caught. Since trapping would probably be the most effective method of taking them, no traps which would also capture fish should be permitted. See Lagler (1943) for suggestions.

THE DIRECT EFFECT OF DAMS AND DIVERSIONS ON THE FISHERY

The great effects of the dams in improving conditions for aquatic life have been discussed. In addition to these changes the dams and diversions have had some very direct effects on the fishery.

The Dams

1 ***Creation of fishing water.*** By backing up and spreading the water over alluvial basins or other depressions the amount of fishing water has been increased. Only at Lake Havasu has a true reservoir been formed, but great areas lying above Imperial Dam have been made most productive. Even the small dam at Headgate Rock has formed some bays which are popular fishing spots. At the dams themselves (as below Laguna and Imperial) there are areas favorable for fishing.

2 ***Barriers to migration.*** Parker Dam and perhaps Imperial are barriers to upward migration. As far as is known the blocking or deterring of migration has no detrimental effect on the fishery. In this respect

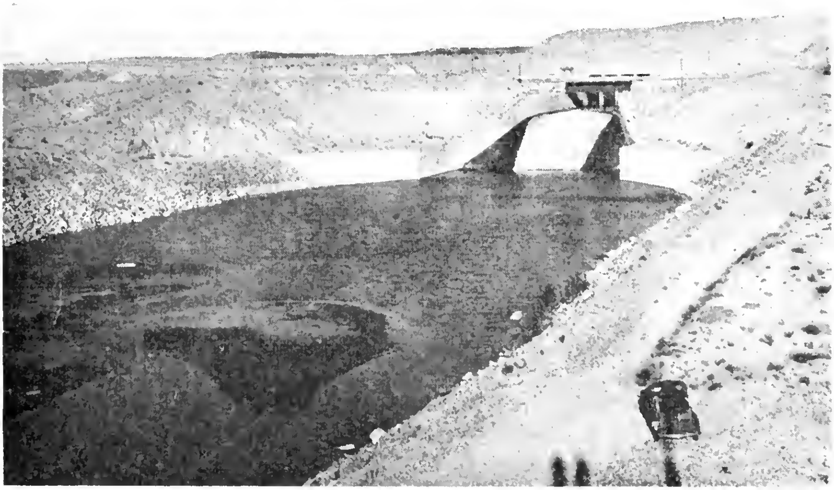

FIG. 73. Pilot Knob Wasteway on the All-American Canal. Mullet Bay (foreground) is a popular fishing spot. Jan. 1942.

FIG. 74. Fishing water created: a wide spot in a drain ditch in the Palo Verde Irrigation District. Feb. 1942.

the Colorado dams must be viewed in a favorable light as compared with those dams on western streams which block the run of anadromous fishes or dry up the stream bed for many miles below.

Diversions

1 ***Creation of fishing water.*** Thousands of miles of artificial waterways have been created in a desert land by the irrigation projects. In the Imperial Valley alone there are about 2,000 miles of canals and laterals. Smaller systems are to be found in the Yuma Project lands, those of the North Gila and Gila areas, Palo Verde Irrigation District, and Colorado River Indian Reservation. The All-American Canal and its Coachella branch total 210 miles in length, and its largest section is exceeded in size by only two other canals in the United States—both ship canals. The Colorado River Aqueduct stretches for 242 miles and flows through three reservoirs before terminating in Lake Mathews near Riverside.

While the above figures have value in indicating the size and extent of the Colorado River canal systems, they can by no means be taken as indicative of the amount of fishing water created. For numerous reasons only a small portion of the total extent of the main canals constitutes either actual or potential fishing area.

The velocity of water in some of these canals is too high to afford resting places for fish. The velocity in the All-American Canal at maximum capacity is from 3 to 3.75 feet per second, and in open sections of the Colorado River Aqueduct is about 4.5 feet per second. Rather than remaining in such a current fish will drop back to be concentrated near checks and drops and wherever quieter water can be found. At present, fishing is more or less confined to such points.

It is true that where "holes" are scoured or plants impede the progress of water the velocity will slacken. But sections of many canals are lined with concrete and designed to be non-scouring and non-silting. Aquatic plants should not develop where velocities are high, and the encroachment of riparian plants is sturdily resisted by cutting and burning. After all, these canals were not designed for fish—disappointing as this may be to the sportsmen. Drainage ditches, however, are quite like natural waterways, often being closely lined with vegetation and containing aquatic plants.

Of the Colorado River Aqueduct only 63 miles is open canal, the rest being covered conduit, tunnel, or siphon. Although the canal portion is unsuitable, the reservoirs do constitute a great potential fishing area; but all are closed to public fishing.

Even with the above and some other exceptions there remains a maze of canals and drainage ditches which afford either fair or good fishing. The total amount of such water can not be calculated without survey, but as an example of its extent one might estimate that the Yuma Project alone contains about 100 miles of waterway which seems suitable for fish and fishing. Public fishing is freely permitted in all the irrigation canals, although in 1942 a fee was charged for fishing on the Colorado River Indian Reservation.

While one can expect most of the common fishes of the river in most of the canals and drains, there are variations. In the Palo Verde Irrigation District bass and sunfishes were abundant in the angling and hoop-net collections in 1942, whereas in the upper portion of the Yuma Main Canal mullet and carp predominated. Comparatively few game fishes were taken here by the survey, but residents report catches of large bass and channel catfish elsewhere in the Yuma Project. The most deficient

FIG. 75. The All-American Canal. Feb. 1942.

FIG. 76. A typical Colorado River irrigation canal. North Gila Irrigation District, Arizona. Feb. 1942.

waters in game fishes appear to be those of the Imperial Valley and the muddy Alamo and New rivers.

2 ***Loss of fish in irrigation canals.*** Unlike irrigation in most parts of the world, it is carried on every day of the year in this land of long growing periods and arid climate. Even short interruptions of the water supply can be disastrous to crops. Therefore the main canals contain water at all times except during the short periods of repair, cleaning, or emergency; and often only small sections are closed down then and the water shunted through other canals, thus minimizing the danger to fish. That there is some loss at such times can not be denied: an inspection of one such area in February 1942, revealed a considerable number of stranded fish (mainly small channel catfish, sunfish and mullet). However, it must be remembered that we are not dealing here with migratory fishes such as salmon and trout, whose loss constitutes a serious problem in many diversions in the West.

That there may be a loss of fish when water is turned out into smaller laterals or into the fields is a possibility. We heard a few reports of this nature, but saw no loss and none of the sportsmen interviewed appeared to think that this was at all a serious problem. They were corroborated by the local game wardens.

There are no screens on any of the diversions, and none are recommended.

3 ***Removal of fish at Lake Havasu.*** From Lake Havasu the Metropolitan Water District lifts water through a 291-foot pump lift into Gene Wash Reservoir. This lake acts as a forebay for the next set of pumps and the water continues to Copper Basin Reservoir. Similar lifts

(5 in number) all equipped with the same type of centrifugal pumps, and a series of tunnels, open canals, covered conduits, siphons, surge chambers, and reservoirs finally convey this water to Lake Mathews near Riverside. This is the termination of the main aqueduct and forms the distribution point for discharge lines leading to the various cities of the district.

Pumping at the intake started on January 7, 1939, and the first water reached Lake Mathews on November 2, 1939. Soon after the aqueduct was placed in operation it was noted that fish were being drawn up from Lake Havasu. Mr. D. A. Clanton, Assistant Supervisor of Fish Hatcheries, has furnished an account of subsequent events. On February 19, 1940, he was called to Gene Wash Reservoir to conduct fish rescue operations, following a drainage of this basin. Thousands of fish had been turned into its outlet—a rocky channel about 1.2 miles long leading from the base of the dam into Lake Havasu. At his request this channel was flushed in order to drive the stranded fish down into the lake. Mr. Clanton's estimate of the number of fish saved is as follows: 1,000,000 green sunfish (2 to 6 inches long); 30,000 largemouth bass (4 to 12 inches); 30,000 channel catfish (4 to 12 inches). This was but a small portion of the fish which had been present in the reservoir.

Copper Basin (the next reservoir above Gene Reservoir) had also been drained at about this time, but members of the Division were not present. Resident employees of the Metropolitan Water District informed Mr. Clanton that many fish were also flushed out of here, but none were stranded. The outlet of this reservoir leads back into the Colorado River below Parker Dam.

A loss of fish was also reported at Hayfield Reservoir (another link in the aqueduct system which has now been abandoned) when it went dry in 1939.

Fish from the Colorado have been pumped and carried by the aqueduct as far as Lake Mathews. At present it is not believed that they can proceed farther as the outlet here is screened.

It is difficult to say just how serious the loss of fish from Lake Havasu itself should be considered. Apparently, fish pass through the pumps with comparatively little damage. It seems probable that most of the fish found in the reservoirs were not pumped from Lake Havasu but are the result of their reproduction. Apparently there has been a decline in the number of green sunfish in the lake and some residents attribute it to the steady depletion of the intake pumps. It may be noted, however, that bluegills are reported to have increased. It is difficult to see how one set of pumps near the end of a lake 40 miles long could even begin to depopulate it. However, there is always a danger of fish loss in the aqueduct system itself whenever a reservoir is drained for repairs. Furthermore, since public fishing is not allowed in the system, the continued removal of fish from public waters should not be condoned.

One of three solutions appears possible: (1) Screen the Intake pumps at Havasu. (2) Allow fish to enter Gene Wash Reservoir, but screen the Gene Pumps. Fish trapped here could then be flushed back periodically into Lake Havasu. (3) Let fish continue as far as Copper Basin Reservoir but screen its outlet to the aqueduct; by periodic draining, flush fish back into the river. Primarily, the problem appears to be one of engineering. The first solution is, of course, the most direct one and if mechanically feasible is the best. The other methods are suggested only if the installation of screens at the Intake is impossible. The outlet of Gene Reservoir could be cleaned out so it would provide a relatively smooth chute for the return of fish. The absence of debris in this reservoir should go far towards solving the screen-cleaning problem. There is no advantage in letting fish go as far as Copper Basin except that its outlet to the Colorado is reported to have a bottom where fish will not be stranded. It has a disadvantage in that the fish could not be returned to Lake Havasu itself.

4 ***Possible loss at other pumps and powerhouses.*** There are a number of powerhouses (as at Parker Dam, Siphon Drop, and on the All-American Canal) and others are projected. The intakes are unscreened except for trashracks. Possibly fish are killed going through the turbines. Again the possibility of such occurrence is minimized by the non-migratory nature of the principal game fishes.

Similarly there are other pump lifts for irrigation and domestic water along the river. More will be constructed in the future to irrigate lands which can not be reached by gravity water. A few fish are occasionally taken through the pumps which supply Yuma with its domestic water, but these are flushed back into the river from a settling basin. Fish loss at other pumps has not been reported to the author.

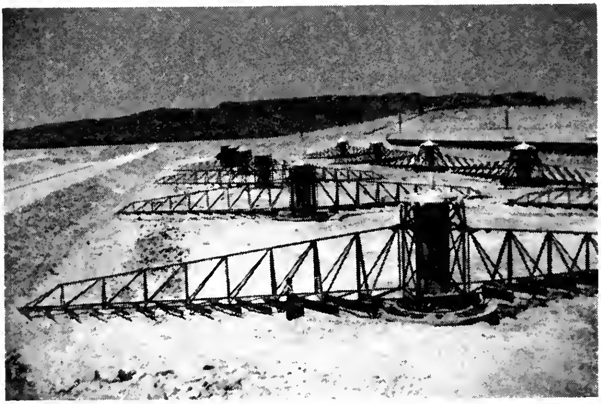

FIG. 77. Rotary scrapers in the desilting basins at Imperial Dam. Photograph by D. A. Clanton, May 1939.

5 ***Desilting at Imperial Dam.*** The All-American Canal is provided with a giant desilting works consisting of a complex series of settling basins from which rotating scrapers feed silt into collecting trenches and pipes leading back into the river below the dam. Whether or not any harm will result to fish here is as yet unknown.

Silt is also removed at the heading of the Gila Canal by simple settling in a basin which will be flushed out periodically. This can have no effect on fish.

With the exception of the points not yet clarified, the direct effect of the dams and diversions on the lower Colorado has been most beneficial to the fishery. They have increased the amount of fishing water along the river itself and extended it far from its borders.

FISHING INTENSITY

Personal knowledge of the fishing intensity on the Colorado is limited to the trips made in early 1942. Observations made then can not be said to be typical of the conditions which have prevailed or will prevail there. The United States had just entered actively into the war. Restricted travel kept away many potential fishermen from distant points. Certain areas on the river were closed to civilians. Climatic conditions during a portion of the time were unfavorable for fishing, and at Lake Havasu the water was being lowered and muddied just when the best fishing might have been expected. In order to gauge the intensity here the author has depended heavily on the observations of residents, including the State game wardens and Federal refuge managers. The following factors have a direct bearing on the amount of fishing done.

Population of Potential Fishermen

As has already been indicated the resident population along the river itself is not large. Yuma, Needles, and Blythe, the three largest towns, have a combined population of only 11,304, and the next largest town, Parker, has only 456 inhabitants. (Census of 1940.) True, the nearby communities and agricultural districts swell this population, but even then it must be considered light. Over week-ends and holidays there is an influx from more distant points such as the towns of the Imperial Valley and the coastal cities. This may be expected to increase in the future, especially if airplane transportation becomes common. Still, compared with other areas in California the total potential fishing population is not large.

Accessibility

Climatic conditions render most areas accessible throughout the year. There is some fishing, especially for catfish, at almost every point which can be reached on the river, and some very good success can be obtained close to the towns. It is a rare day, for example, when one does not see fishermen just across from Yuma or at Laguna Dam. However, some of the most popular bass fishing spots are at some distance from the towns. For example, Martinez Lake is 36 miles from Yuma (part over poor road); Needles Boat Landing is 38 miles from Needles and 92 miles from Blythe. Considered in terms of western travel such distances are not great. But as has already been noted, the resident population is not large, and the distances to large centers of population is considerable. Los Angeles is 274 miles from Yuma and 286 miles from Needles.

Furthermore, there are acres and acres of good fishing water—it is impossible to give even the roughest estimate—which can be considered almost inaccessible to the fishermen. There are no roads leading close to many of these; in other cases the roads which do lead there are almost unworthy of the name. The current of the main stream is strong and it requires a powerful motor for a boat to progress against it. Many fine "lakes" can be reached only by water and they are often so hidden that it takes an experienced man to find them. Only an airplane view can give one any conception of the extent of available water areas.

FIG. 78. Needles Boat Landing, Lake Havasu. The largest resort on the lower river. Feb. 1942.

Resorts

In 1942 there were only a few places scattered along the river which might be termed "resorts." A few boats were for rent at Haughtelin Lake (not on the river itself), but this small lake is frequented primarily by local people. At Martinez Lake there was a small temporary concession and landing spot. There were a few concessions on Lake Havasu, some closed by the war. The largest of these and the largest on the river, Needles Boat Landing, had 24 boats for rent and 34 private boats were moored there. According to the proprietor about 10 outside boats came in each week. Only at Lake Havasu were any housekeeping cabins available.

Doubtless after the war further concessions will be established. Mr. Walter P. Schaefer, Superintendent of the Havasu Refuge, informed me in 1942 that he expected three recreational areas to be established on the lake. He estimated that "over an average week-end" there would then be about 500 people at Needles Boat Landing and from 250 to 300 at each of the other two resort areas.

Practicable Fishing Season

In some parts of California heavy snows make certain areas inaccessible except for a few months of the year. In such places, the "practicable fishing season" is much shorter than the legal fishing season. Other areas may be accessible throughout the year, but unfavorable water temperatures, turbidity, and other factors limit the success of fishing during portions of the open season, and would still limit it even if the legal season were to be extended. In determining the amount of fishing intensity (and when formulating restrictive legislation) it is necessary to evaluate carefully the effect of this practicable season on the fishery.

The entire Colorado River area is accessible at any time of year. In general, the winters are mild enough so that fishing at this time will be pleasant. From the standpoint of the fisherman's comfort alone, it is only during mid-summer that he has but little desire to try his luck. Furthermore, it is possible to catch most, if not all, of its fishes at any time of year. At present the legal fishing season extends throughout the year in this area. However, there is a natural check on this activity which can be best ascribed to the factors of air and water temperature.

While reports of local fishermen differ somewhat, there is a fair agreement that the period from March to June provides the best bass fishing. A secondary period ensues during the fall (roughly mid-September to November). Thus, the summer and winter periods are considered to be the poorest and one does not find a heavy concentration of fishermen at these times. Reference to the graphs of water temperature for the river (Figs 59, 60, 61) shows that the usual spring fishing begins as the water nears 60° F., and declines as it approaches 80° F. In the autumn the "season" starts again as the temperature falls from its high summer maxima. Such a phenomenon is well known in other fisheries in California for both warm-water and cold-water fishes. The activity of the fishes is undoubtedly inhibited by cold, and both very cold water or very warm water bring a disinclination for them to strike. Thus many people fish only when conditions are most propitious.

It should also be noted that the spring fishing season coincides quite closely with the spawning season of most of the river's fishes. This, again, is a well known phenomenon. Centrarchids are particularly vulnerable to capture at such times. The author has had a fair amount of experience with fishermen in other parts of California who have urged that the bass season be opened earlier since "you can't catch the fish after the season opens." Such fishermen have invariably claimed, however, that the bass are "all spawned out" prior to the open period which was desired. While making no comment on the latter point, it was with much surprise that the writer discovered many Colorado River fishermen to be perfectly frank in saying that, of course, the best fishing was during the spawning season. One forthright individual even claimed, "You can't catch 'em unless they *are* spawning." (See p. 197, for a further discussion of this point.)

While it is undoubtedly true that a close correlation can be found between water temperature, spawning season and the usual fishing season, it is also true that the angler's own comfort plays some part in determining the latter period. With all due allowances for the favorable elements in the climate of the Colorado basin, it is no fun to fish there during mid-summer. It is claimed by some local men that fishing is not really bad during the summer (especially in early morning or evening) if you can stand the heat. The seasonal agricultural activity may also affect the fishing intensity of the residents. For example, in the Yuma area the lettuce harvesting is said to be a period when most people are too busy to fish.

Quantity of Fish Caught

No accurate figures on the number of fish or pounds of fish removed from the river at any point could be obtained. A few estimates have been given by residents, but these are founded on little actual information and were at great variance. The few catch records secured by the Division of Fish and Game in 1940 from boatmen at Lake Havasu were most incomplete. Recognition of any estimates or records here would serve no purpose. Fishing is generally considered to be excellent, however, and the catch per unit of effort, especially during the "good" season, must be large.

While it is difficult to gauge the degree of fishing pressure in a comparatively new fishery (and on such short acquaintanceship with it) the author does not believe that any of the factors previously mentioned indicate that it is high. It is true that a few of the residents have not agreed with this conclusion. However, in an area where practically no sport fishing has been in progress until recently the addition of even a few fishermen might appear to be extremely high. To one who is familiar with the large number of anglers in other portions of California the pressure on the Colorado appears to be light.

LOCAL FISHING METHODS

Indian

No attempt has been made to seek out papers which tell of the use of the native fishes of the lower Colorado by the aborigines. It may be worthwhile, however, to include a few notes taken from Kroeber (1925, pp. 735, 815). In speaking of the Mohave Indians he says: "Fish were taken with seines, or driven up shallow sloughs into scoops, *kwithata* * * *, as large as a canoe, that were quickly lifted up. The fish of the muddy Colorado are rather soft and unpalatable to the white man, but the Mohave caught quantities and relished them."

It is of interest to note that the use of the harpoon for fishing—"* * * probably known to every group in California whose territory contained sufficient bodies of water"—was not known to the Colorado River tribes.

Modern

Although the accounts of individual fishes have included short statements as to the fishing methods used in their capture, a more extended discussion may be of interest.

Handline Fishing. This rather primitive method is legal in both states for taking game fish as long as the line is held in the hand or (in California) when it is closely attended. A few cases were noted where the sole equipment consisted of a line, sinkers, and baited hook.

Stillfishing. Almost any of the fishes may be taken in this way on bait, and any type of rod can be used. Usually bamboo, willow, or even tamarisk poles are used, and are either held in the hand or stuck or propped on the bank. Several poles may be set up by the same man. The author has seen as many as 6 in use at one time, and Mr. Leo Rossier reports seeing 9 used by the same fisherman.

The commonest baits for catfish are: chicken guts, shrimp, liver, or cut fish (often carp or mullet). Some fishermen compound rather intricate mixtures (cheese, blood and feathers, etc.) which are highly odoriferous.

Live bait fishermen often utilize small green sunfish and bluegills. The use of these game fish is sometimes considered illegal, although the author can see no objection to their use provided that they have been taken in a legal manner. In fact, the use of such a resident fish is far preferable to the use of fish brought from other waters. The latter might become established in the river and prove deleterious. Goldfish, carp, and mosquitofish are also utilized. Of considerable interest is the use of "mud-suckers" as live bait. These are marine gobies (*Gillichthys mirabilis* and perhaps others) which are caught on the coast and sent packed in "moss" to bait dealers along the river. These fish have a surprising tenacity of life and will live for some time in fresh water. They will not survive, however, hence their use (to the exclusion of other live baits) might well be promoted.

"Jugging" or "Bottle Fishing." "Jugging" does not appear to be used frequently in California, although it has been practised for many years in other parts of the country and is sometimes used on the Colorado. A baited hook and line is attached to a well-corked bottle, beer can or some other type of float and then thrown out from a boat or from the shore. Perhaps a dozen or more "jugs" will be used. They are then watched until their bobbing indicates that a fish has been caught, whereupon they are retrieved.

FIG. 79. A 3-pound largemouth bass taken from a drain ditch near Palo Verde. May 1942.

"Skittering." A form of simple bait casting for bass termed "skittering" or "spatting" was observed at Palo Verde Lagoon. To a very long cane pole (perhaps 20 feet in length) was attached a line of about the same length bearing a plug. This plug was then tossed or swung into likely places or "skittered" along the top of the water. Although used here on open water it offers its greatest advantage in weedy places or others from which it might be difficult to retrieve a plug cast in the ordinary fashion. Skittering may be done either from boat or shore. Although this method is not at all unique to the lower Colorado, it appeared to be the firm belief of a few residents that it had originated here.

Bait (Plug) Casting. Fishermen on the river employ it primarily for bass, and utilize the usual variety of artificial lures common to the sport. Deep-running plugs appear to have special favor particularly in the muddier areas. Occasionally channel catfish are taken on plugs. It is now well known that this species may be taken on a variety of artificial baits including plugs, spinners, and even flies.

Flyfishing. This style of angling is little practised on the lower river by residents, a fact emphasized by the paucity of this type of tackle to be found in local shops. Any of the game fish here can, of course, be taken on a fly rod and for some species its greater use would increase the enjoyment of the angler. The taking of such smaller fish as the bluegill or the crappies offers more sport on a flyrod than on the heavier rods or poles. Flies or small spinners are good lures for these fish. Exceptionally good fishing for bass may be enjoyed at times using large flies, spinners, or bass bugs.

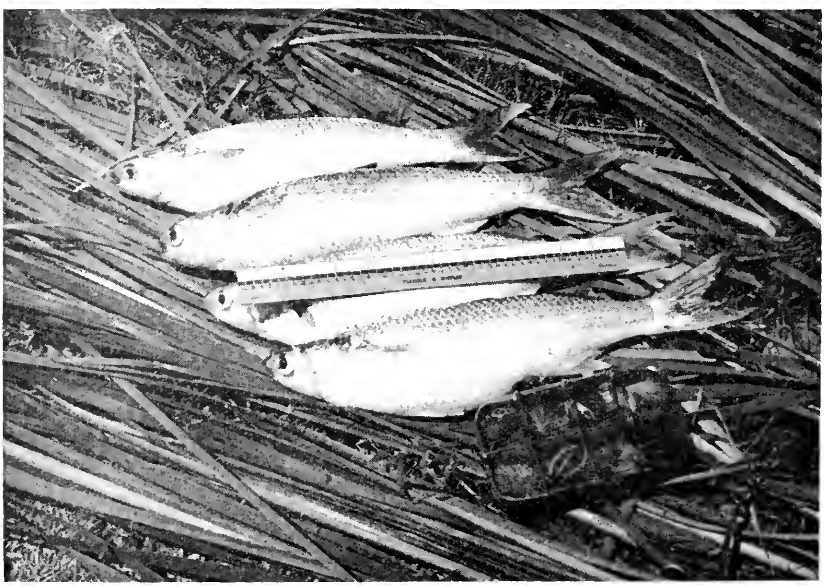

FIG. 80. Small mullet taken from a canal in the Yuma Project. May 1942.

Sport Fishing for Mullet. It seems to be rather commonly believed that mullet can not be taken on hook and line; and in the Imperial Valley, clubs and dip-nets of chicken-wire are often used in shallow water for their capture. It was of interest to find that a few people along the lower Colorado were acquainted with a method whereby this fish could be taken by angling. The hook used is small, about No. 10 or 12 in size, and is usually baited with a tiny piece of worm.[36] From about 8 to 18 inches above the hook a small cork is attached to the line. The line must be kept taut and the angler must strike as soon as the float exhibits the slightest movement.

Upon noting mullet feeding on bits of scum as they drifted down drainage ditches, Mr. Chester Woodhull and the author tried out another method, dry fly fishing. Small flies (No. 14) were cast upstream and allowed to float down over a school of mullet. Several were caught in this way and a number of flies were snapped off through striking too hard while using fine gut. (On the two occasions of experiment the fish did not respond unless a fine leader was used.) The fly seems to be ejected almost immediately, and a most rapid though delicate strike appears to be necessary.

It is believed that this method deserves a thorough trial. Even a small mullet puts up an excellent battle and thus warrants recognition as a potential sport fish along the Colorado and in its irrigation canals. Once taken on a flyrod, it will be remembered with respect. Since returning from the Colorado an article (Emery, 1943) has been noted which describes catching "grey mullet" on a flyrod at Gibraltar. "A tiny flake of bread, cast like a fly and allowed to float over the shoal, turns the trick * * *"

Other methods. Illegal fishing is still rather common along the Colorado. Several reasons for its prevalence are easily noted. Certain areas are so inaccessible that fear of apprehension is almost nonexistent. Then, too, especially in these jungle-like areas there often dwell a class of people to whom game laws mean nothing, and who live to a certain extent "off the country." A fairly large population of negroes and whites from the southern states (many of which have very lenient laws compared to those in California) contributes to this problem.

Among the methods used by "violators" are the following: set-lines, throw-nets, trapping, and even poisoning. Several cases of the use of throw-nets, mostly by Orientals, have been noted. Large hoop-nets of chicken-wire or woven willows, baited with ducks, mudhens, muskrats, or rabbits, have been successful in taking many fish. One of these traps taken from Palo Verde Slough in February 1941, by California game wardens was 10 feet long and 5 feet in diameter.

The drainage of irrigation ditches for repairs often brings out a crowd of people eager to wade into the mud and capture stranded fish. On one such occasion viewed in 1942 in the Imperial Valley there was a mad scramble of a dozen or more men, women and children for the spoils. Washtubs and sacks were quickly filled with small fish.

At Laguna Dam the periods of sluicing have brought about a somewhat similar enterprise. In order to wash out the accumulation of silt in

[36] Other baits described to me are: a pea, a raisin, a bit of lettuce, or shrimp. Goode and Gill (1903, p. 373) say, "It does not readily take the hook, but can sometimes be caught with a bait of banana, or one manufactured from cotton and flour."

FIG. 81. Arrowweed jungles line roads to fishing spots.

the channels leading to the canal heads, sluicegates are opened and the silt flushed out into the river below the dam. The withdrawal of a large quantity of water through the sluiceways causes a temporary diversion of water which would otherwise pass over the crest of the dam. At such times fish are stranded in potholes in the downstream talus. This has afforded a field-day for people who flock to capture these fish. Provided with spears, clubs, hooks, nets and barley sacks, they spread out below the dam for this fishing. One enterprising man even sewed fishhooks to his gloves to aid in capturing fish. It has been the practice of State game wardens to be present at such times to prevent illegal fishing.

PAST AND PRESENT FISHERIES MANAGEMENT

It can not be said that the present fishery of the lower river is in any way the outgrowth of a planned management program. With the help of a little sporadic initial stocking of exotic species, the changes in the physical aspects of the river have created its fishery.

Stocking

As has been related already the present stocks of fishes in the lower Colorado have undoubtedly had a multiple origin and may have arisen from plants in the waters of any of seven different states. Hence, there has been but little attempt here to trace their origin.

In recent years there have been but a few plants in the Arizona-California section. In 1938 more than 18,000 largemouth bass, 20,000 bluegills and an unknown number of crappie (only a few thousand at most) were planted by California in sloughs near Blythe and Palo Verde. In 1939, 3,000 more largemouth bass were stocked here. A plant of 5,000 largemouth bass and crappie was also made near Needles in 1939 by California.[37] There have been a few plants of bluegills in waters not connected directly with the river.

Bass were, of course, present before these recent plants; the abundance of bluegills and crappies before 1938 is unknown. Such additions may have served to increase or hasten the spread of these species, but, considering the vastness of the water areas, must be considered rather unimportant.

No reason is seen why any further stocking is at all necessary in the lower river. There is an abundant population of largemouth bass and channel catfish, the major game fish. Minor game fish (or pan fish) are represented by the numerous bluegills, and to a lesser extent by the green sunfish, and black and white crappies; there are also several species of bullhead catfishes (*Ameiurus*) to provide fishing for sport or food as well as the coarser fish. The author believes that the first three species are the only ones whose welfare should be furthered to any extent. The green sunfish may well be a competitor of the bass while offering but few compensatory attributes. Although the crappies are not yet common, several studies have indicated that they are severe competitors of bass, and their increase may prove to be undesirable. The bullheads are not very popular with fishermen now, and there is no obvious biological reason to augment their supply. Fishermen are often desirous of having a great variety of fishes with the idea that this will increase their total catch and "spice" their fishing. The latter premise may be granted. But, in general, the greater the variety of fishes present, the more complex are their interrelationships and the greater the chance of a poor fishery.

There is but little evidence to suggest that continued stocking of warm-water fishes in large bodies of water suitable for their natural reproduction and sustenance is of value. On the other hand, there is a gradually accumulating store of information which indicates strongly that such stocking is useless or at least inadvisable once a population has been established. The fecundity of these fish is high and under the present conditions and with suitable restrictions on catch we should expect them to reproduce just as fast, or faster, than they can be caught. Since the Colorado is now well supplied with desirable game fishes, why plant more? Even if their population should show a decline, it is probable that rehabilitation in ways other than by stocking would produce better results. If near-by waters (unconnected) are found which are suitable for fish and lacking or deficient in them, these can, of course, be planted.

The stocking of forage fish (minnows) has been suggested by a few people. However, there is no evidence to show that the present population is suffering from lack of food, and the addition of other exotic species to an already mixed assemblage might prove harmful.

Regulations

Since the lower Colorado forms the boundary line between Arizona and California, each State is in part responsible for its management, and uniformity in the regulations of the two States for this area is desirable. It is possible for the Arizona Commission to modify its general State laws so that they may be compatible with those of California. It is also possible

[37] In all probability these were all black crappie.

for California to modify its general State regulations but not to as great an extent. Table 7 shows the compromise between the general laws of the two States which is now in effect.

TABLE 7

Colorado River Fishing Regulations, Bordering the States of Arizona and California

Parker Dam (Havasu) Lake, Imperial Dam and the Colorado River Bordering the States of Arizona and California

Regulations with reference to fishing in Havasu Lake, Imperial Dam and the Colorado River where these waters border the two States have been made to coincide; the seasons and bag limits as follows:

Bass:

May be taken all year. Bag limit, 10 fish, providing total weight is not more than 15 pounds and one fish per day or in possession. Legal length 9 inches.

Channel Catfish:

May be taken all year. Bag limit, 10 fish, providing total weight is not more than 15 pounds and one fish per day or in possession. No length limit.

All other game fish:

May be taken all year. Bag limit, 20 in the aggregate not to exceed 20 pounds and one fish per day or in possession.

Licenses Required for Fishing in Colorado Waters Bordering the States of Arizona and California

Licenses of either Arizona or California are honored on both sides of the Colorado River, Havasu Lake and Imperial Dam where these waters border both States.

Section 698.1 of the California Fish and Game Code (1943-1945) says that in this area, "* * * the season and bag limit on black bass, spotted bass, bluegill perch, crappie and catfish may be fixed by the commission in conformity with such agreements that it may make with the proper authorities in the State of Arizona." The limitations of this section are obvious. It would be highly desirable for it to be changed so that the California Commission could also regulate size limits and fishing gear and make any other regulations which would cover all fish in the Colorado River as well as those specifically mentioned. Unless and until this section is amended, several of the recommendations for change made in this report can not be accepted.

Attempts at the conservation of fish by passing laws is one of the oldest forms of fish management. From simple beginnings with rather broad restrictions on the take over large areas, such restrictions have been increased in number and in such complexity that the fish and game codes of some States swell fat volumes. The laws relating to fish in Arizona are relatively few in number and rather broad. California, on the other hand, has evolved a complex system. Some of these laws have been passed, at least ostensibly, to agree with the biological requirements of fish in local areas. Others seem unjustifiably complex, and seem to place an undue burden on even the most conscientious sportsmen and to lead to quibbling by "fish lawyers."

The author believes that the area along the Colorado is well enough defined and has enough special characteristics to warrant its designation as a special district in both Arizona and California. He does not believe that the number of laws governing the take of fish here need be large. And he is most aware that even with the best facts at hand, the laws must be somewhat arbitrary.

The Colorado River District

The citizen of Arizona living at Yuma is as likely to wish to fish on the California side, say at Laguna Dam, as in Arizona. Many residents of the Imperial Valley in California enjoy the fishing at Martinez Lake in Arizona; and although they drive many miles to reach this point, consider it a local fishing area. For this reason the two States have agreed that the licenses of either State, " * * * are honored on both sides of the Colorado River, Havasu Lake and Imperial Dam where these waters border both States." There has been some confusion regarding the exact limits of the area in which both licenses should be honored. For example, a strict interpretation of the rule might prohibit an Arizona license-holder from fishing below the Pilot Knob Wasteway (Mullet Bay) in California only a few miles from Yuma or in the drainage ditches near Winterhaven.

In a desire to allow the fishermen of both States to prosecute their angling in Colorado River waters close to their homes, the following definition of the area in which dual use of licenses be allowed is suggested.

The Colorado River District shall include the Colorado River from the Arizona-Mexico boundary to the Nevada-California boundary; the district to include all reservoirs on the river itself. To include also the following areas: On the California side all of that portion of the Alamo Canal within California; only that portion of the All-American Canal from Pilot Knob Wasteway to Imperial Dam, and all waters lying between this section of the canal and the river; all waters in the Palo Verde Valley which drain into or out of the Colorado River; and all waters above here as far north as the California-Nevada boundary which drain into or out of the Colorado River, exclusive of any part of the Colorado River Aqueduct and its reservoirs east of the intake at Lake Havasu. On the Arizona side to include all waters draining into or out of the river, exclusive of the Gila River, as far south as the Arizona-Mexico boundary.

Seasons

At present there is an open season on all fish in the Colorado River District throughout the year. In other parts of Arizona the open season for fish, except trout, also extends throughout the year. In California there is no closed season for catfish, but except in a few special areas the season for bass, crappies, and sunfishes is open only from May 29th to October 31st, inclusive.

It has already been pointed out that while the practicable fishing season on the Colorado might be considered long because of climatic conditions, the same climatic conditions make the really effective fishing season much shorter. The population of fish here is large. The angling intensity is relatively light. For these reasons a long open season seems advisable.

It is true that large numbers of bass may be removed during the spawning season, and this undoubtedly means a loss to the river of young bass which are destroyed when their parents are taken. This is not, however, equivalent to saying that this is harmful to the fishery. It may be. But if the number of bass taken during the remainder of the year is relatively low, sufficient escapement of spawners probably results. It may be noted that Moffett (1943) recommends the continuance of a year-round open season on Lake Mead until such time as circumstances warrant its shortening. He believes, " * * * that fishing is not heavy enough to remove the annual yield of the Lake and restriction of it would encourage the increase of the bass population to a point disproportionate to its food supply." It is not claimed that conditions in the lower Colorado and its lakes are entirely similar to those in Lake Mead. Instead, the preliminary study indicates that the food supply of the lower river may be much superior to that in Lake Mead. But an abundance of food encourages spawning in centrarchids under certain conditions so it is entirely possible to maintain a large population in the face of heavy fishing. Several authors, in fact, have maintained that fairly heavy fishing is necessary for the best management of warm-water fisheries. And while there is a considerable sentiment among both sportsmen and fisheries biologists against fishing during the spawning season, it may also be noted that both groups have members who can see no harm in it. (See, for example, the remarks of Langlois, Wiebe, and Swingle in Tarzwell, 1941, p. 221.)

No general rule can be laid down on this point. In other localities, closure during the spawning season of bass, either with or without other protective measures, may be the best method. But the author is inclined towards an all-year-round open season on the lower Colorado until such time as a change can be shown to be necessary. And if depletion ever becomes evident, he recommends consideration of other changes, such as an increase in the size limit, before ordering a closed season.

Bag Limits

The establishment of bag limits is a very old form of management, and is one of the most direct methods of restricting the catch. In its ideal form, the bag limit or catch limit is a seasonal one and is a total one, i.e., including the catch of all fishermen. If it could be shown, for example, that a certain body of water would produce a definite quantity of fish (a certain poundage) which could be cropped each year without harm to the brood stock, then a total annual limit could be authorized. When that limit had been attained, then fishing for that season would stop. Such a system has been used with success in the Pacific halibut fishery. This is, apparently, one of the best of all methods for the protection—or better, management—of a fishery. However, it is also the most difficult one. It requires such a thorough knowledge of the species to be fished that its exploitable limits (with best returns to the fisherman) can be predicted. And, equally important, it demands a full control of the expendable fishing effort.

In a sport fishery such a system can rarely be used. In its place, recourse is had to the establishment of a bag limit of an arbitrary nature. It is arbitrary in that bag limits have to be daily ones. Fishermen come and go. They do not enter checking stations, nor do they carry a record showing just what their seasonal catch has been to date. Nor do we have, or expect to have, wardens or checkers to collect these statistics—outside of certain small or experimental areas. Except, then, in that a daily bag limit (when adhered to) acts as a general deterrent to over-fishing, it has but little value in determining the amount of the total annual catch.

One man may fish once during the year and catch his "limit"; another man might fish every day of the year and take this limit each time.

In general, then, we must simply guess at what a bag limit should be. There is no very clear conception of its upper limits except that: (1) It should not be so high that it furnishes a chance (collectively) for the total annual take to exceed safe numbers. The author refuses to guess what this would be. (2) It should be high enough so that the fisherman will derive the maximum enjoyment from his outing. The formulation of such a limit can be in no way exact, nor can it satisfy all fishermen. The quality of the fishing, the precedent of past regulations, the character of the individual, the state of his pocketbook, the time he has available for fishing—all influence his choice.

With full recognition that these are arbitrary choices, the author recommends a continuance of the present bag limits for largemouth bass and channel catfish. In each case, the limit is 10 fish per day, providing the total weight is not more than 15 pounds and one fish per day or in possession. It is believed that these limits have the following advantages. (1) They provide an angler with enough fish for both good sport and food. (2) In connection with the other regulations advised and with what is known of the fishery's production and its exploitation they provide a reasonable check on over-fishing. (3) They have the virtue of being known to and accepted by the residents already. (4) These limits agree with those now in effect in other parts of Arizona; and, except for the weight limit, with those for bass in California. It is true that there is no bag limit on catfish in most districts of California. However, channel catfish are rare outside of the Colorado River area.

It is suggested, however, that the limit on sunfishes, crappies, bullheads and other fishes which possess qualifications as game, pan, or fine fishes be raised so that their bag limit is 40 in the aggregate, not to exceed 20 pounds and 1 fish per day or in possession. This may encourage fishing for such species, and it is believed that a reduction in their numbers should be advantageous to the fishery as a whole.

No bag limit is recommended for carp or mullet taken by angling, or for any other coarse fishes such as goldfish or buffalofishes, which may be found to be established in the river. In this way any residents who need fish for food should not be unduly harmed by the restrictions on the take of game fishes. A certain measure of control of harmful or obnoxious fish (carp) can be exercised by increased angling.

Size Limits

In general, the imposition of minimum size limits on fish are considered to have three functions. (1) To allow a fish to spawn at least once and thus perpetuate itself before it is captured. (2) To allow a fish to complete a large portion of its period of efficient or rapid growth before being captured. It has been stated, with specific reference to the striped bass, that such a measure "* * * means that fish should be allowed to grow [without being caught] as long as the gain from growth is adding more pounds of fish to each brood than are being lost by [natural] mortality." (Anon., 1939.) The determination of the ideal minimum size limit for such a purpose can not be realized without a most detailed study. However, at least partial fulfillment of the complete purpose is possible in many instances by increasing the size limit somewhat conservatively. (3) To insure the fisherman an adequate supply of fish of "desirable size," either for sport or food. In Illinois, Bennett, Thompson, and Parr (1940) have defined desirable size for several species which are also found in the Colorado River, and their minimum sizes are of interest. "Among the pan, or fine, fishes the minimum size for sport or table use should be at least 0.2 pound. Converted into total lengths, this weight is about 6 inches for bluegills and other sunfish, 7 inches for bullheads, 7 or 8 inches for crappies and 10 inches for channel cat." They also seem to imply that largemouth bass of 10 inches in total length or a little over one-half pound are of desirable size.

Such purposes (the second and third) are more or less similar, and all of them may bring about some of the same results: a larger stock of spawners; a total increase in poundage; a larger number of big fish in the catches. It may be pointed out that an increase in the number of large game fish (if they are piscivorous) should result in a better utilization of the coarse fish and sunfishes as forage. This may be beneficial in reducing the amount of competition afforded by the latter fishes.

The necessity for size limits, especially those based on the presumption that each individual should be allowed to spawn at least once, has been questioned, and it is true that their imposition complicates the enforcement problem. In general, however, their application can constitute a very effective tool of management—one which protects a fishery from depletion and actually increases the angler's enjoyment. Especially, since a long season has already been advised, the application of size limits is suggested for the Colorado. It is recommended, however, for only two of its fishes, largemouth bass and channel catfish.

It is true that fairly large numbers of sunfishes are taken in some waters along or near the Colorado, especially in the Imperial Valley. But here, bass are not common and the gear used by many of the residents is better fitted for taking other fish. From some of the catches seen in such areas one is inclined to believe that any fish of any size would be considered desirable, and that a fish stew or fish soup would be the only way in which the small fish caught could be utilized. Mr. Leo Rossier's field notes (1941-42) record numerous observations such as "a 3-gallon bucket full of channel catfish 3 to 6 inches long." Where such catches are composed largely of channel catfish, such occurrences may provide additional reasons for believing that a size limit on this species would be helpful. It seems doubtful, however, if size limits are desirable for the sunfishes even in these areas of fairly heavy fishing. The bluegills and green sunfish examined from the Colorado mature at a small size—well below "desirable size" for food or sport. The setting of size limits exceeding their length at first maturity would therefore have a tendency to allow them to spawn even more than once. Because of their present abundance and their known fecundity it is difficult to see how they could demand much protection. Fisheries workers, in general, do not advocate any stringent protection of these sunfishes. Conversely, several have gone on record as advocating the removal of many restrictions on their take by angling, and even actual reduction in their numbers by netting or poisoning, in cases where their overpopulation has damaged the fishery through stunting, predation, and competition. (See, for example: Langlois, 1941; Beekman, 1941; the remarks of Bennett, pp. 327-328 in Van Oosten et al., 1942.)

The largemouth bass and channel catfish are the only fish which are exploited to a marked degree at present. They are the ones which should be accorded the most protection and at the same time be so managed that they will give the maximum yield to the angler. The preliminary study of the largemouth bass in this area indicates that it does not ordinarily spawn until it is three years old at which time its average length is 13 inches to fork of tail. If this should hold true in the future (which is not a certainty) the present size limit could be increased at least several inches with an expectancy of a greater and better yield to the fisherman. Pending further study of this problem, it is suggested that the size limit be raised to accord with Arizona's State regulation of 10 inches (total length).

In view of the scanty knowledge of the size at first maturity and growth rate of the channel catfish, we can not point out a minimum size limit which is based on these factors. We can, however, recommend a minimum size of 10 inches. This will protect the fish to a more desirable size, be favorable to production, and be in accord with the established limit in Arizona.

Closed or Restricted Areas

Two types may be considered here: (1) Those closed to fishing because excessive concentrations of fish render their capture too easy; (2) those closed as nursery grounds or spawning sanctuaries.

In Arizona, fishing is prohibited near the dams on some of its lakes, but there is no general State provision preventing it in all waters.

FIG. 82. A check on a canal in the Palo Verde Irrigation District. Fish congregate at such points. May 1942.

In California, "It is unlawful to take any fish within * * * 150 feet of the lower side of any dam * * *" (Fish and Game Code, 1943-1945, Sec. 485.) The ostensible purpose of this section is to prevent the taking of fish from areas where they may be heavily concentrated. For example, trout or salmon whose upward migration in a stream is blocked or impeded by a dam may be easier to catch by angling (or snagging) than if the dam were not present. The catching of these fish might perhaps be so easy that, even if bag limits were not exceeded, the run could be depleted by the intensity of fishing.

At present, this provision is enforced at dams on the California side of the Colorado River. It has even been suggested that any obstructions in artificial conduits, such as the checks in canals or wasteways, should be considered "dams" in this area.

The author can not agree that such regulations are necessary on the Colorado River. There is no run of any important species which might concentrate immediately below a dam. It is true that there may be a concentration of fish here and this includes such game fish as bass, sunfish, and catfish. The same is true at places such as headgates, checks or drops in canals. Many areas along the river possess but little easily fishable water except at dams, and this is much truer in canals or drainage ditches. It is only at points where the water is slack enough to afford resting places, or has fast currents (perhaps feeding areas) close to slow water that fish congregate in numbers. And unless there is some concentration of fish it is a hopeless job for the fishermen. If fishing is not permitted at such points we are simply letting a resource go to waste, i.e., uncaptured.

In the absence of migrating game fishes, it is recommended that fishing be permitted as close to any type of obstruction in either natural or artificial channels in the Colorado River District as the angler desires.

The suggestion that fishing be forbidden in certain areas of the river or at certain times in these areas because they constitute spawning grounds may be a good one. In Connecticut, for example, the bass spawning areas in lakes over which the State has the necessary jurisdiction are located and posted as closed to all fishing prior to the completion of the spawning season. According to Thorpe et al (1942) this single measure has given gratifying results in many bass lakes. The establishment of such sanctuaries appears to meet with favor even by biologists otherwise disinclined to believe very strongly in closed seasons during the spawning period. This would still permit fishermen to fish for other species and for bass outside the closed areas. The taking of bass which are not protecting nests does not result in the same loss which occurs when an unguarded nest is left at the mercy of predators.

If further protection to Colorado River fish should be deemed necessary, therefore, the author recommends the establishment of such closed areas during the spawning season. We should close only those areas which are found to be the ones selected by the fish themselves. It should also be noted that in waters which are not yet stabilized (as in the lakes above Imperial Dam) the spawning areas may change from time to time.

Restrictions on Fishing Gear

Restrictions of this type are common in sport fisheries. Their usual purpose is simply to cut down the number of fish which a man can take easily. In other words some very efficient methods of catching fish are often prohibited. It is the writer's personal belief that a considerable leniency should be permitted in the choice of gear commonly described as "sport fishing tackle." In general this would permit most methods in which the fish is captured on a hook (or hooks) attached to a line which is closely attended, and which will not harm fish which are caught but not retained by the fisherman.

The following suggestions are made for the Colorado River District:

(1) All fish in the river to be caught by angling only.

(2) Angling is defined as the taking of or the attempt to take fish by hook and line. The line may or may not be attached to a pole or rod. The line or pole must be held in the hand or closely attended.

(3) Each fisherman to be limited to the use of one line or one pole and line.

(4) The total number of hooks (regardless of whether they are simple or compound hooks) on any one line to be limited to 3 when bait fishing. No limit to the number of hooks on any artificial lure.

(5) All other devices or methods whereby fish can be taken or killed to be prohibited. Among such devices or methods are: explosives, poisons or stupefacients, nets of any kind, traps, spears, gaffs, gigs, clubs, etc.

(6) No fresh-water fish which are not now resident in the Colorado River District to be used for bait or released in the waters of this district. (The list of fishes given in this report should suffice to indicate what fishes are now residents of the Colorado.) This would limit allowable types of live bait fish to species now resident in the river (whether native or exotic); marine fishes, such as gobies (*Gillichthys*); game fish (such as sunfish) if taken legally.

The only reason that the number of lines or poles and lines and hooks is limited is because the use of multiple equipment is an approach to large scale fishing, and readily lends itself to practices of violation well known to wardens. Few bait fishing methods (and these are the only methods other than trolling in which more than one line can be used very successfully) are specific enough to guarantee that only one species of fish will be captured. Therefore, the use of one line is recommended even when the fisherman is attempting to catch only unprotected or coarse fish. The removal of fish considered to be obnoxious or harmful can be carried on better by allowing higher bag limits, or by special fishing by the States or commercial interests with commercial gear. There is a possibility that the general rules allowing fishing only by angling might be amended in certain sections of the district to allow the taking of mullet (admittedly difficult to take with hook and line) by some other methods, such as by dip-net or spear. This subject is now under consideration.

It can not be seen how any of the recommendations made here can do any harm to the fishery, and it is believed that they should benefit it. By a slight extension of existing powers, it will be possible for the California and Arizona commissions to attain complete conformity in their regulations for this district. It will then be possible for the fisheries' administrators of the two States to establish a marked degree of control over the fishery and to change their policies quickly and with a minimum of effort whenever it appears advisable.

CONCLUSIONS

In a study such as this it has not been possible to collect or analyze enough data to justify detailed conclusions as to the general economy of the Colorado River and the many processes involved in the production and utilization of food by its aquatic population. The Colorado has always been a changeable river, and is still in a process of change. Floods, droughts, shifts in the channel, plant succession—all have played important roles in its configuration and its habitats for wildlife. The new dams have further altered such basic physical factors as flow, clarity, temperature, and even water chemistry. The introduction of exotic species, both vertebrates and invertebrates, has brought further changes; in fact, the last few years have witnessed what may be a major biological revolution.

With but incomplete factual data and with the realization that the river and its fauna are still in a state of flux, it is none the less possible to make certain general statements. Inadvertently, man has improved most of the physical conditions for game fishes on the Colorado; and fortunately he had already introduced some fishes (bass, catfish) which, while they may have caused the decline of the native species, were well fitted to take advantage of these physical changes and to create a sport fishery where none had existed before.

He has also created some new hazards. He has introduced species (the carp, for example) which may have been detrimental to his own interests. He has constructed diversions which cause some fish loss. He has built roads and boat landings; has created resorts; has held "prize fish contests," advertised the sport on the river, and otherwise increased the exploitation of its fishery. It must be admitted however that these are all legitimate enterprises, and that up to a certain point his capture of fish is not only not destructive to the fishery but actually beneficial.

When we speak in terms of "beneficial" or "detrimental" we usually think only of those changes which seem to affect us personally. Therefore, it must be agreed that the "new Colorado" has been benefited by its changes and that the sum total of these changes far outweighs such losses as have occurred and may continue to occur. It seems certain that the entire biological production of the river (whatever its components may be) has increased tremendously.

A biologist must regret that a limited but interesting natural assemblage of species has had so many additions that its original nature has been destroyed. He must also regret that some species appear to be verging on extinction, at least in the lower river. But he must also admit that the rise of the new population of exotic fishes has brought recreational and utilitarian values which exceed those of distant days. The value of some sport fisheries of California and Arizona (trout, for example) must be measured mainly in terms of the pleasure and relaxation they bring to the angler; or it can be reckoned, to the merchant, in terms of the business created by sales to the fishermen. In the valleys of the Colorado the value of the game fish as food is also an important one. There are many families whose subsistence in part on fish serves to alleviate their condition.

At present the sport fishery of the river appears to be in a healthy condition. Naturally, the success of angling varies from season to season and in different spots along the stream. To a certain extent this appears to be correlated with variations in flow and turbidity which are a consequence of man's attempt to harness the river, and there is little that the fisherman or his conservation agencies can do or say to control such changes. In general, the resident fishermen are well satisfied with the present fishery.

It is not felt that we can or need to institute any elaborate form of management which will improve it. The addition of new species, either game or forage fishes, to an already complex assemblage is not recommended. Nor is it believed that the fishery could be benefited by further stocking of its existing game fishes. On the other hand it is believed that a reduction in numbers of some species might be of value. This can be accomplished to some extent if the angler will turn his attention towards the capture of fishes which he now largely ignores. In time, it may be of value to institute either commercial fishing or State control of undesirable populations. In this territory of great water areas such control will probably be difficult.

No program of stream or lake improvement can be suggested nor can it yet be seen how such an attempt could be easily carried out or be of material value to the fishery.

The fishery, which is still embryonic, has great potentialities. It should be studied to as full an extent as possible with the reminder that other areas of California have much more pressing needs for investigation. Meanwhile, the only major form of management suggested is the continued acceptance of a set of regulations which are uniform in both Arizona and California. The ones suggested here differ somewhat from those now in practice in this district, and are in some respects more lenient than those now in vogue in other parts of California. As far as is possible they are based on what is known of the biological requirements of the species considered, and are as compatible as possible with the expressed desires of the fishermen and the precedents which have already been established. Since our knowledge of individual life histories is still slight and the interrelations of fish to fish and fish to fisherman still not well known, it is emphasized that the suggested forms of management are only tentative. They should be changed as our knowledge of the fishery grows.

SUMMARY OF RECOMMENDATIONS

District

A clearly defined district along the lower Colorado River in which the dual use of Arizona or California licenses is permitted. See p. 197.

Stocking

None, either of game fishes or forage fishes.

Fishing Season

Open season throughout the year for all fish.

Bag Limits and Size Limits

Largemouth bass: 10 fish, not to exceed 15 pounds and 1 fish daily or in possession; minimum size limit 10 inches (total length).

Channel catfish: 10 fish not to exceed 15 pounds and 1 fish daily or in possession; minimum size limit 10 inches (total length).

All other game fishes (crappies, sunfishes, bullheads and any other fish listed as game fish by the laws of Arizona or California): 40 fish in the aggregate not to exceed 20 pounds and 1 fish daily or in possession; no size limits.

Mullet: no bag limit nor size limit when taken by angling.

Carp and all other non-game fishes: no bag limit; no size limit.

Closed Areas

None. Fishing to be permitted in all areas and at all points on the river and on the reservoirs and artificial waterways within the district.

Fishing Gear and Methods

Sport fishing to be by angling only and subject to such limitations as listed on p. 203.

Commercial Fishing

To be allowed in any area within the district if believed desirable by the State commissions. To be conducted under permit and under such regulations as the two commissions shall formulate with respect to the species taken, quantity, gear, etc.

It is also recommended that a study of the growth rate and size at maturity of the largemouth bass and the channel catfish be made in order that suitable minimum size limits for these species can be determined.

It is further recommended that a study of bass spawning areas and a closer determination of the bass spawning season be made in the event that a closure of certain areas during the peak of the spawning season is believed desirable.

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EDITORIALS AND NOTES

DESTRUCTION OF SURFGRASS, *PHYLLOSPADIX*, IN SOUTHERN CALIFORNIA IN THE SUMMER OF 1943

In view of the importance of *Phyllospadix* as a food of diving waterfowl it seems worthwhile to record an instance of destruction of this plant on the Pacific Coast in the summer of 1943. About July 1, in front of Scripps Institution of Oceanography, La Jolla, California, loose strands and balls of surfgrass started to appear on the sandy beach in more than usual numbers. By July 18th, 50 to 100 tons of surfgrass had accumulated, some of it in piles 4 feet deep. The piles were composed about 90 per cent of surfgrass and 10 per cent of marine algae. After the middle of July only scattered fragments of fresh surfgrass appeared on the beach, and wave action gradually covered the windrows of dead material with sand. In December, the cycle was reversed and sand started to wash away, exposing the blackened but intact masses of surfgrass.

These observations were made along a beach approximately one mile in length between Camp Callan and La Jolla. No observations were made elsewhere. In the experience of several long time employees of Scripps Institution the accumulation of dead surfgrass in 1943 was markedly greater than in other years.

The surfgrass did not appear to be discolored or to show outward evidence of disease. Many of the plants were complete, including roots. No explanation is offered as to the reason for its destruction.—*Victor B. Scheffer, U. S. Fish and Wildlife Service, March, 1944.*

FIG. 83. Piles of surfgrass on beach near La Jolla, July 18, 1943.

TWENTY-FIVE YEARS AGO IN CALIFORNIA FISH AND GAME

"California Trout" by Barton Warren Evermann and Harold C. Bryant, a 30-page article accompanied by four fine color plates from paintings by Charles B. Hudson, was the outstanding feature of the July, 1919, issue of CALIFORNIA FISH AND GAME. Twice since then our trout have been given the place of honor in this magazine, the last time in 1940 with "The Trouts of California" by John O. Snyder, a revision of an earlier paper by the same author published in CALIFORNIA FISH AND GAME in 1933.

One of the questions which vex anglers is specifically dealt with by Messrs. Evermann and Bryant. "The name *trout*," they say, "a word of French origin, is in Europe applied only to species with black spots, while in America it is more loosely used and is applied not only to the true trout (those with black spots), but also to the chars (or those with red or orange spots)." The chars found in California are the native Dolly Varden and the introduced eastern brook. It should be noted that the introduced brown or loch leven, a "true trout," has, in addition to its black spotting, other spots which range from brown through orange to red, depending on the individual.

The steelhead-rainbow problem is treated by the authors as follows: "The fact that most ichthyologists and many anglers regard steelheads simply as sea-run individuals of rainbow trout has not escaped our minds, and we ourselves are inclined to accept that view. Nevertheless we know that in some places they are entirely distinct and easily distinguishable. At any rate, we deem it best for our present purposes to treat the steelhead as a distinct species."

While this is an undeniably sensible point of view, the majority of students 25 years later consider that there is only one species, called by most *Salmo gairdnerii*, of which there are both sea-run forms and those that remain in fresh water. In fact, the trend is toward "lumping" all the rainbow-steelhead series, so carefully distinguished in earlier years as Kern River trout, McCloud River trout, Shasta trout, etc., into this same species, and giving them at most subspecific rank. Whether this should be applied also to the California golden trouts is doubtful, but in any case it is pretty well accepted that at least one of the species set up by Evermann, *Salmo roosevelti*, the Volcano Creek Golden Trout, is not valid, and that this fish properly belongs with its close neighbor, the South Fork of Kern Golden Trout, in the species *Salmo agua-bonita*.

The tendency toward lumping is also apparent in the present treatment of the cutthroats, most of which are now considered subspecies of *Salmo clarkii*, and this includes the Colorado River Cutthroat, not mentioned by Evermann and Bryant, which is now generally called *Salmo clarkii pleuriticus*. A notable omission from their paper is a cutthroat offshoot which had not yet been discovered 25 years ago, the Piute Trout, named *Salmo seleniris* by Dr. Snyder in 1933 for its fancied resemblance to a moon-rainbow in coloration.

It is of interest that no additional trout has been introduced in the past 25 years. The mackinaw still holds its own in Lake Tahoe, where it has flourished without outside help since its introduction there in 1895, and is also found in a few other waters. The eastern brook still makes an important contribution to fishing in our high mountain lakes, and the brown trout or loch leven—indistinguishable now, if they ever were distinct species, through artificial hybridization,—has its place in certain waters to which it is particularly suited; but in our California hatcheries neither of these two species plays anywhere near as important a part as it did in earlier years. The rainbow now holds the center of the stage.—*Brian Curtis, Editor, California Fish and Game.*

IN MEMORIAM

MILTON S. CLARK

Milton S. Clark, a retired employee of the division, passed away April 1, 1944, at his home in Stockton. First appointed in August, 1911, he served in the Patrol Bureau until his retirement December 1, 1942. A former Pinkerton man, Milt, as he was known by all his friends, was well qualified to work in the metropolitan area where at the time of his employment there were many violations of the State conservation laws by game and fish dealers. It was largely through evidence secured by him that certain well-organized transfer companies were shown to be dealers in game, incorporated merely to evade the law. Through his work the sale of ducks in San Francisco dropped from hundreds of thousands to almost nothing.

Clark's most dangerous experience occurred in Marin County in 1913 while arresting fishermen for the illegal taking of striped bass. In the arrest Deputy Ernest Reynaud and one of the fishermen was killed. Clark was knocked overboard but was rescued by a passing boat. One of the fishermen was tried and sent to San Quentin.

Detailed to work in various parts of the State but mostly in the Bay region, Clark made hundreds of arrests and very seldom lost a case.

Reaching the retirement age of 70 in 1942, he and his wife moved to Stockton to be nearer their daughter, Mrs. Norma Ford. To his wife and daughter, we extend our sincere sympathy.—*J. S. Hunter, Chief, Bureau of Game Conservation, California Division of Fish and Game, April, 1944.*

REPORTS

FISH CASES

January, February, March, 1944

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalones: closed season, undersize, no license, remove from shell below high tide, fail show license on demand	21	$555 00	
Angling: illegally taken fish, false statement to secure license, using trout roe for bait, night fishing, closed area, fishing from fish ladder	28	572 00	
Bass: night fishing, more than one rod	4	80 00	
Bass, black: closed season	1	40 00	
Bass, striped: no license, more than one rod, overlimit	24	325 00	
Catfish: closed season district 4	2	60 00	
Clams: overlimit, undersize, no license	27	485 00	
Commercial: using trammel net district 2, using gill net district 2, seining district 1	8	700 00	
Fishing district 101: no license, use set lines	8	330 00	
Lobsters: undersize	2	45 00	
Salmon: no license, using snag hook	1	25 00	
Spear: closed area, 300 ft. of stream, using gaff hook	4	80 00	
Trout: closed season, overlimit, no license, closed stream, snagging with "spanish liver," taking steelhead other than in tidewater	31	890 00	
Totals	161	$4,187 00	0

GAME CASES

January, February, March, 1944

Offense	Number arrests	Fines imposed	Jail sentences (days)
Deer: taking 2 deer in a 1-deer district in special season, hunting in refuge, firearms in refuge, female deer, using artificial light at night, closed season, no license, no deer tags, unplugged gun, early and late shooting, fawn, allowing hounds to run deer during closed season	87	$4,280 00	40
Deer meat: closed season, illegally taken	20	935 00	
Ducks: unplugged gun, late shooting, shooting from power boat, hunting in refuge, no license	48	1,375 00	
Elk: overlimit, cow	2	200 00	
Geese: overlimit, hunting in refuge, no license, barrying geese with car	12	477 50	
Hunting: no license	4	60 00	
Mudhens: no license	1	10 00	
Non-game birds and meadow larks	3	100 00	
Pheasant: failing to tag, trapping hen, closed season, no tags, shooting from auto, no license	28	950 00	
Quail: closed season	2	50 00	
Sage hen	1	25 00	
Shore birds	2	20 00	
Swan	1	10 00	
False statement to secure hunting license, failure to show license on demand	2	25 00	
Taking birds with trap	1	25 00	
Trapping muskrats for profit, no license	3	20 00	
Totals	217	$8,562 50	40

SEIZURES OF FISH AND GAME

January, February, March, 1944

Fish Cases:	
Abalones, red	88
Abalones, black	11
Bass, black	30
Bass, striped	17
Bluegill sunfish	2
Catfish	23
Clams	88
Clams, Pismo	34
Crappie	5
Lobsters, spiny	72
Lobster traps	92
Lobster receiver	1
Perch	4
Trammel nets, pieces	11
Trout, rainbow	27
Trout, steelhead	49
Game Cases:	
Deer	23
Deer meat, lbs.	682½
Doves	4
Ducks	33
Elk	1
Geese	18
Pheasant, cock	22
Pheasant, hen	14
Quail, valley	1
Sparrows	12
Squirrels, tree	12
Swan	2

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(Continued from inside front cover)

BUREAU OF ENGINEERING

JOHN SPENCER, Chief — San Francisco
Clarence Elliger, Assistant Hydraulic Engineer — San Francisco
Samuel Kabakov, Junior Civil Engineer — San Francisco

BUREAU OF LICENSES

H. R. DUNBAR, Chief — Sacramento
L. O'Leary, Supervising License Agent — Sacramento
R. Nickerson, Supervising License Agent — Los Angeles
Lorraine Atwood, License Agent — San Francisco

ACCOUNTS AND DISBURSEMENTS

D. H. BLOOD, Departmental Accounting Officer — Sacramento

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CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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TABLE OF CONTENTS

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36534

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Killed in Line of Duty

Byron Sylvester
Arthur [illegible]
Richard DeL[illegible]

THE PRONG-HORNED ANTELOPE IN CALIFORNIA[1]

By Donald D. McLean

Bureau of Game Conservation, California Division of Fish and Game

The accepted scientific name of the prong-horned antelope, *Antilocapra americana* (Ord), dates from 1818 (Journal de Physiologie, LXXXVII, p. 149). An earlier name, *Antelope americana* Ord 1815 (Guthrie's Geography, 2d. Am. ed., II, p. 292, desc. on p. 308) was displaced by the former.

The genus name *Antilocapra* was compounded by Ord from the Latin *antilope*, meaning antelope, and *capra*, meaning goat. *Americana*, of course, means American. The genus has only one species.

Some other local names are prong-buck, prong-horn, antelope, and loper, which is English. Le cabrit is French-Canadian. Ah-pi-chee Ah-tik is Cree meaning small caribou, Tah-cha-chis-teen-ah is Yankton Sioux meaning small deer, and Ogallala Sioux is Tah-keen-cha Sanla meaning little pale deer. The Mexican term is berrendo meaning pinto.

The family *Antilocapra* is strictly North American and is peculiar in that it combines the features of several other families. It has two hoofs on each foot like the giraffe; a gall bladder similar to a goat; hair resembling that of a deer, with an undercoat of fine, woolly hair; and four teats. It has hollow horns on bony cores like a goat, but unlike the goat the external horn is shed each year.

The scent glands are numerous and are distributed as follows:

1 postmandibular	2
1 ischial	2
1 inter-digital	4
1 hock, present in pairs	2
1 median on lower back	1
Total	11

The general color and pattern of the pelage in the adult buck is a bright reddish tan with pure white on the sides of the head, breast, belly, rump, and the two front bands on the throat (Fig. 84). The patch under each ear, the top of the nose, and the mane are generally black. The entire animal has the appearance of being patched tan and white rather than spotted. The female appears similar except the black areas are less extensive and the tan is paler. The entire pelage is shed twice a year, once in the fall and again in the late spring.

The young are unspotted and are grayish brown at first, with a paler but not white rump and underparts. They acquire the adult colors early in the first autumn.

[1] Submitted for publication, July, 1944. All illustrations and maps by author.

2—36534

Early Records

There are many records among the notes and logs of early explorers and travelers in North America. A few of these are listed below as seeming to be of worthwhile importance.

In 1540, antelope were described by Coronado.

In "Torquemada's Monarquia Indiana" published in 1723, a hunt was described as taking place in 1540 in southwestern Hidalgo in honor of the Viceroy Antonio Mendoza.

Lewis and Clark mentioned them in the annals of their trip westward in 1805 and 1806.

Bidwell used them as a source of food in 1841.

During the 1850's, John Converse shot antelope for the Stockton and San Francisco markets on the plains of the San Joaquin Valley where the City of Merced is now located.

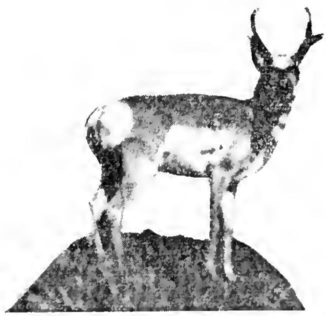

Fig. 84. Adult buck antelope. Lassen County. September 10, 1941

General Range of Prong-Horned Antelope

Originally antelope were found over a large part of western North America, principally on the high, open plains. In Texas and California, they ranged down to and even below sea level. The original range covered over 2,000,000 square miles and had an estimated population of 40,000,000.

During the latter part of the last century, the increased amount of fencing and agricultural development forced them to work more and more into the lightly timbered areas. Now it is not at all unusual to find antelope in open, yellow pine timber and relatively dense stands of juniper, especially if these are on plateau type terrain. The antelope, because it could more easily adjust itself to the changing conditions, survived after a hard struggle, whereas the equally numerous bison or buffalo failed.

Present Range in California

The present principal range of the prong-horned antelope in California is in the northeastern part of the state, as may be seen on Fig. 85. Lassen County has the largest number, followed by Modoc. Siskiyou has a fair number, and several smaller groups are to be found in Plumas, Shasta, and Sierra counties. The original range of the species

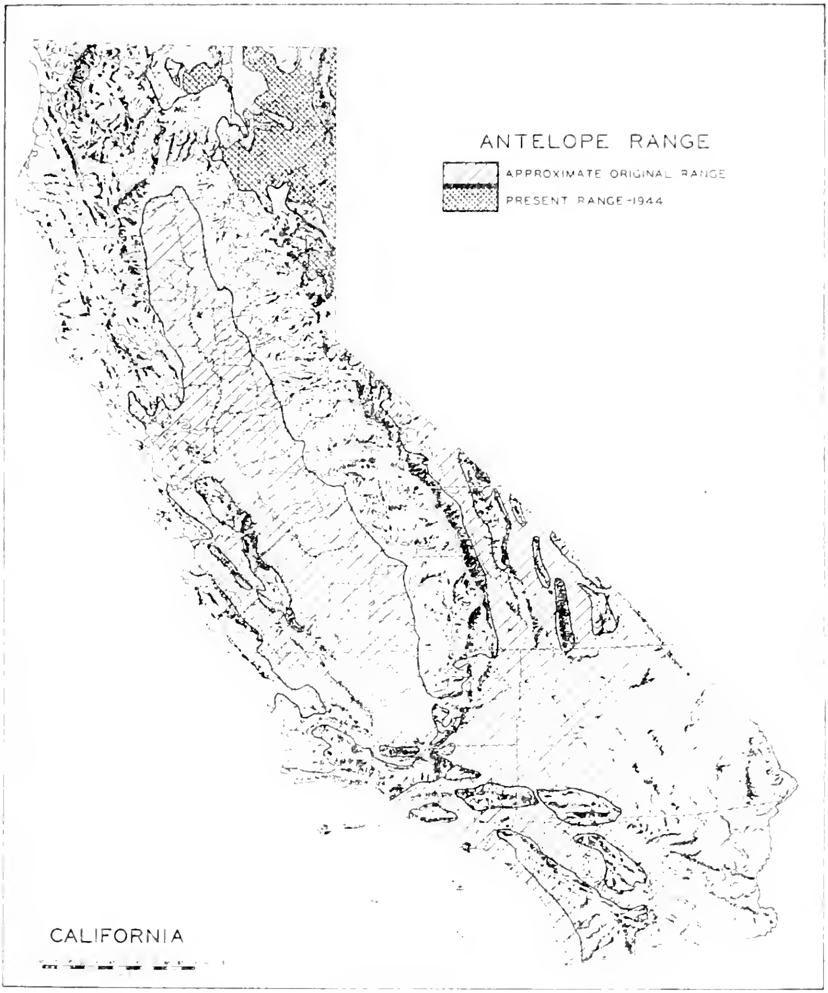

FIG. 85. Antelope range in California.

in this region has not as yet been repopulated, but this is gradually being accomplished as each year small bands invade new areas in the old habitat, sometimes to remain and in other instances to return again to the more heavily populated range. Such areas are Shasta Valley east of Granada, Siskiyou County; Hobart Mills, Nevada County; Mountain Meadows east of Westwood, Lassen County; Sierra Valley and vicinity in Plumas and Sierra counties; Hat Creek rim in Shasta County; and Dry Lake south of Stronghold in Modoc County. Apparently Shasta Valley, Hobart Mills, and Mountain Meadows are not permanently occupied as yet, but may become so. They do show that the antelope are gradually returning to their old range. Some of these movements were made in force, but in most instances the first animals were venturesome small groups or even singles.

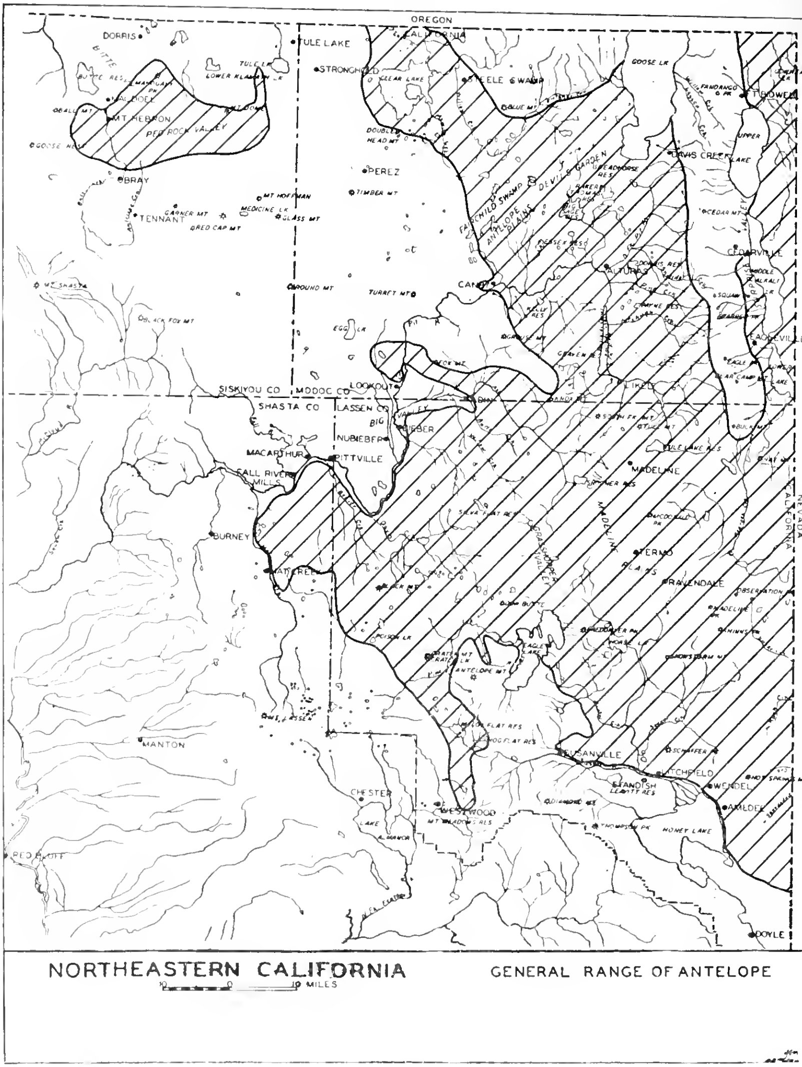

Fig. 86

Some of the incursions have necessitated the traversing of a considerable distance through timbered areas. More and more it has become evident that antelope are not averse to travelling through timber land even where it is quite heavy. They have been seen on a number of occasions well out in the open yellow pine and fir forests, particularly in that region northwest and west of Eagle Lake. In this area, it is often necessary for them to travel through timber to get from one open valley to another. Brushy cover is not to their liking and they make every effort to stay out of it, particularly if frightened.

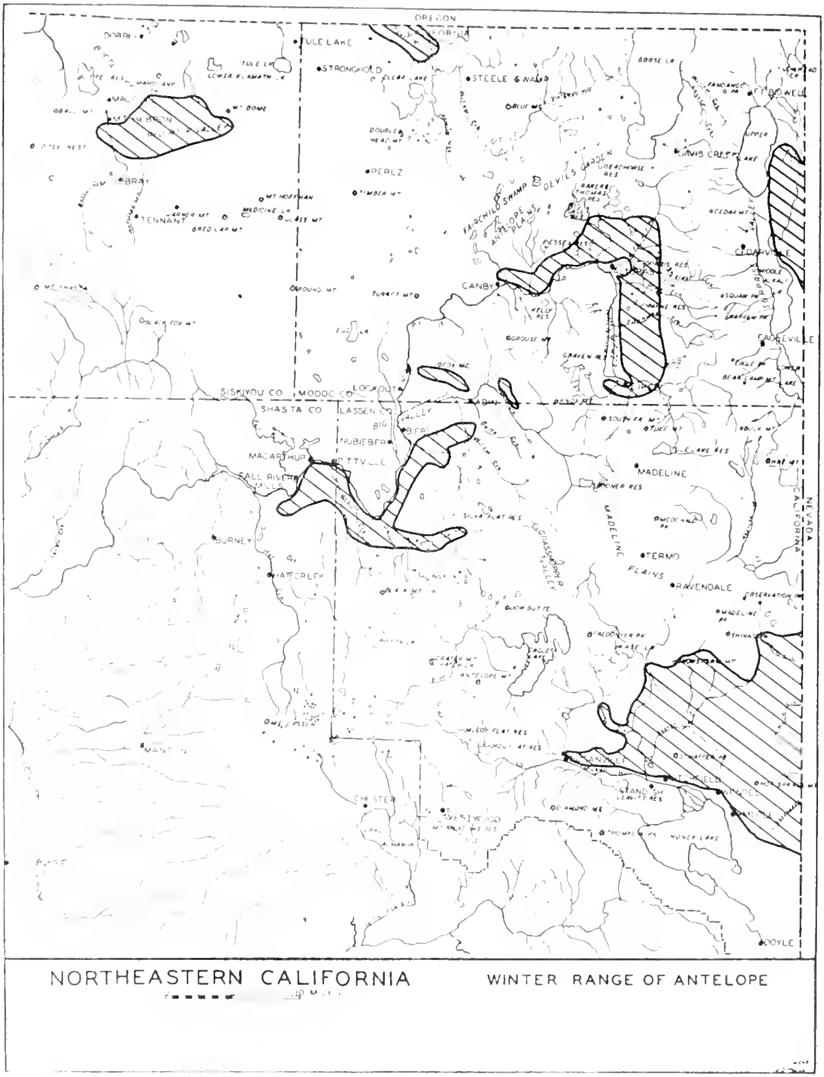

FIG. 87

Winter Range

Since the summer range is so much larger than the winter (See Figs. 86 and 87), groups of antelope tend to converge in migrating from their summer haunts to the wintering areas. At certain points along the migration routes there are concentration areas where smaller groups gather together into larger and larger bands before continuing to work along toward the winter range. A gathering point is generally situated in some flat valley where several drainage basins converge, or on a tableland.

3—36584

The winter range in southeastern Lassen County is an irregularly shaped area north and east of Honey Lake Valley. It extends a few miles eastward into Nevada, north to the upper Smoke Creek Basin and Snowstorm Mountain, and south to the edge of Honey Lake Valley. This area harbors the largest number of antelope in the state during the winter.

Some antelope winter in Dixie Valley and Big Valley in northwestern Lassen County.

In Modoc County there are several winter range areas: the tableland lying east of the south fork of the Pit River between Alturas and Likely; the slope and edge of the tableland lying north of the Pit River from the Indian agency northeast of Alturas to near Canby; the easterly side of the north half of Surprise Valley in eastern Modoc County (in hard winters they apparently leave this range and go into Nevada); and along Lost River north of Clear Lake where a small number winter along the California-Oregon line.

The winter ranges in Siskiyou County and Shasta County lie within the summer ranges but are smaller due to the fact that snow forces the antelope to concentrate at lower elevations.

It seems from the evidence of the annual counts that the same herds of antelope winter in the same sections of the winter range year after year. Spot maps show this quite plainly. Each herd has a relatively small area over which it moves.

Migration in California

The antelope of Modoc and Lassen counties usually occupy their winter range from November to early or middle April. This varies some from year to year because of weather. Early storms hasten the autumn migration and spring storms retard the return to the summer range. There is a gradual break-up of the large wintering herds commencing in the latter part of February, and these smaller groups often begin a gradual drift in the direction of their summer range, although they may not actually leave the winter range for some time.

The journey to the summer range is ordinarily carried on in a more leisurely manner than the fall migration. However, one of the longest and, as far as I know, one of the fastest migration trips occurred in April, 1937, when a band of antelope moved from near Bull Flat in eastern Lassen County to near Hayden Hill in north central Lassen County, a distance of about 60 miles, in about 11 hours.

A map of the principal migration routes in the northeastern part of the state is shown on Fig. 88.

Antelope Highways

During their migration from summer to winter range and in travelling from one area to another on either the summer or winter range, antelope ordinarily move over definite and well established routes.

Antelope from various valleys will converge toward the main travel line and upon reaching it all take the same route toward their ultimate destination. Some of these antelope highways are so well worn that they show up plainly even during the seasons when no antelope are using them. The trails are easily identified as those of antelope and not of deer. Deer go from one brush patch to another or from tree to tree, especially in the juniper area, whereas antelope keep to the open slopes and flats and their trails are much more direct and maintain a more even grade. Deer occasionally travel antelope trails, but antelope rarely travel deer trails. Antelope tend to keep together, often in single file, when traveling, whereas deer commonly spread out with stragglers along the sides of the band. Deer herds are always much more loosely knit than those of antelope.

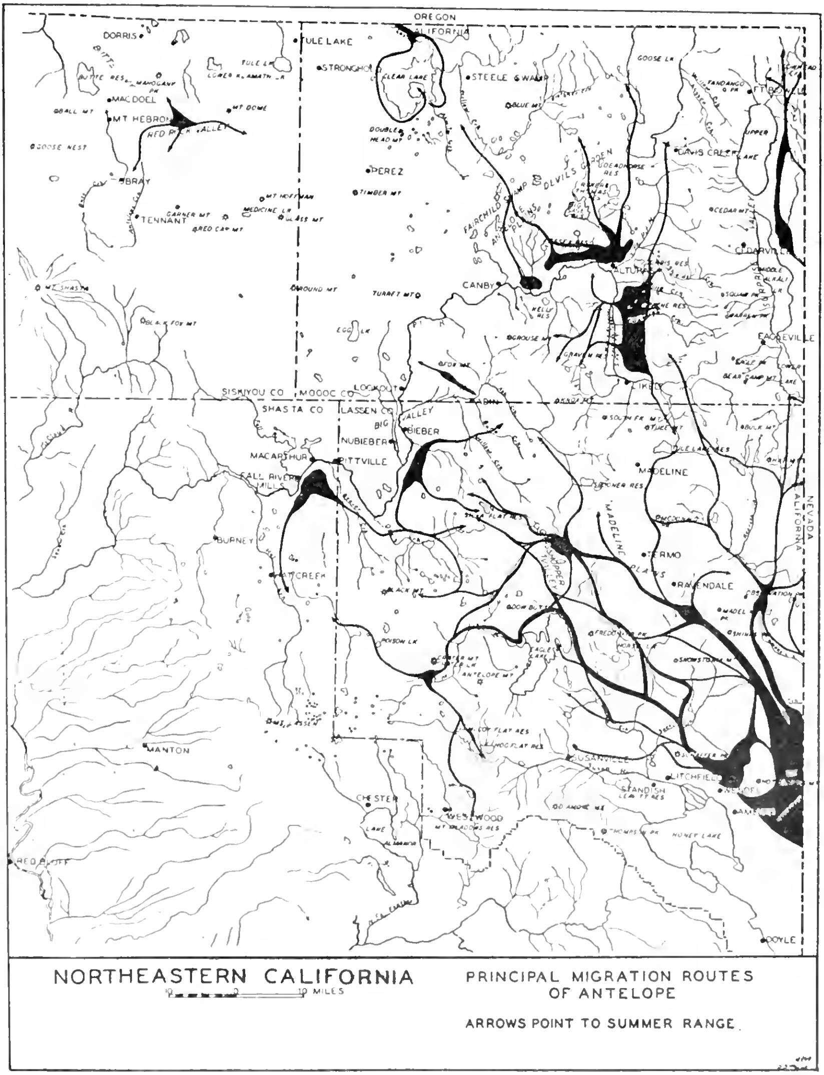

FIG. 88

Life History

Rutting Season and Gestation Period

In California, the rutting season begins in September and runs through October and part of November. The fawns appear from late April to mid-June, the bulk being dropped from May 5 to May 25. Apparently the gestation period is 7 to 10 days longer than that of deer, which is approximately 210 days.

Other data on the rutting season and time of arrival of fawns are presented below for the sake of comparison:

Rut September through October	Colorado
Rut early September	Arizona; and Sonora, Mexico
Rut in September	Central area (according to H. E. Anthony)
Fawns late May to early June	Colorado
Fawns May 1 to June 20	Northern Nevada
Fawns May 29, 1935	Alberta, Canada
Fawns May 31, 1927	In Milwaukee Zoological Park
Fawns May 26, 1928	In Milwaukee Zoological Park

Does and Fawns

The unspotted antelope fawns are born in the latter part of April, through May, and even into early June. Most of them are born during the first 20 days of May in northeastern California. One, two, or three fawns are born, the average being about 1¾.

Antelope does travel with other does and immature antelope during the early spring and ordinarily do not leave the band until a few hours before the young are born. At fawning time a doe generally seeks seclusion in an area with open, but rather high brush. After she drops her first fawn, which lies perfectly still, she moves off 100 feet or so before she drops the other, which also lies still. The youngsters are not ordinarily seen together until they can run with the mother. She remains close by most of the time, except when going to water and then goes and returns promptly. She browses and grazes around the area where the young are bedded down, giving their location away to the careful observer by pausing now and then to look at the spot where each one is located. She scans the surrounding country for enemies and will fight or, if possible, lead away a coyote or dog that approaches. She is very clever in intercepting the intruder, running slowly across in front of him to induce him to chase her. She will almost let him catch her and then, after leading him to a safe distance, will simply leave him flat-footed or turn on him and drive him away. A single coyote is not a match for an angry doe antelope. I have seen two cases of a single doe running a coyote with her head down at the coyote's tail tip and striking him at every possible moment with her front feet.

During the first week of June, 1942, Ramon Somavia and I were at Big Springs near the head of Smoke Creek in eastern Lassen County when we saw two antelope running with their heads low and darting forward now and then as they struck with their front feet. We were unable to see anything in front of them for some time because of the brush, but finally we spotted a large coyote in noticeably bad shape that was being belabored from the rear by an old doe antelope and a yearling buck. He was definitely in bad condition, as he was limping and appeared to be injured in the lower back. They went on out of sight over a ridge and in about 20 minutes both antelope returned.

During the winter when the antelope are in large bands, I have never noticed that they pay any particular attention to coyotes; in fact, they hardly get out of a coyote's way. Of course, if snow were deep it might be different, but antelope make every effort to keep out of such situations.

Eagles hunt for young antelope and are clever enough to perch near a doe and watch for the young. However, I have never seen one actually get a fawn as the doe was generally on the job as soon as the eagle soared out over the area. The does stand up on their hind legs and strike toward the eagle. Eagles also attack single adult antelope on occasion.

Does feeding near their young will occasionally walk toward a fawn and stop. Whether the doe makes any noise or not, I do not know, but as the doe stops the fawn will stand up and then immediately lie down. As soon as the doe sees it, she begins feeding again. I have observed this on a number of occasions.

When going to nurse the young she cautiously walks around, feeding as she goes, but gradually getting close to the fawn until finally she stops directly over it. It then gets up, takes its meal, and lies down again, while she either goes to the other fawn or goes off feeding. She spends very little time actually with the fawns.

The fawns have a plaintive bleat that does not carry very far. The does have a barking bleat when calling to the fawns which I have heard only twice. Once when I put a fawn to flight accidentally, he ran pell-mell on a circuitous course through sagebrush about two feet high and directly past his mother. She bleated to him as he went by but he did not stop, going on into some dense *Atriplex* brush. On the other occasion a fawn was hidden in high meadow grass and apparently the doe had either lost the exact location of the fawn or it had moved. At any rate, when she bleated, it got up at least 100 feet away and came to her.

By the time fawns are 10 days old they can run with the mother but apparently are rather short-winded. Once they start following her, however, they do so much running and playing that by the time they are 15 to 20 days old, they can make long runs without showing much fatigue.

Bucks

Throughout most of the year the old bucks tend to remain by themselves, either singly or in small groups. Only during the rutting season are they to be found with the does in any numbers. Apparently some decadent individuals remain entirely alone throughout the year. The younger bucks generally mingle with the bands of does and fawns all the year around, although occasionally relatively large groups of young bucks may be found together.

Habits

The habit of racing first one way and then back is common in antelope, particularly when they are nervous or disturbed by something that they are unable to identify.

Many times when large bands are moving along undisturbed, I have seen individuals start from the rear of the band and race by the entire herd, whirl about, and dash all of the way to the rear, only to do the whole thing over again. Sometimes several will do this together.

Whether it is the desire for racing competition, exercise, release of pent up energy, or just because they are "antelope" and unpredictable, I do not know. Possibly it is to warm themselves, as I have generally noted it on cold days rather than warm ones.

This is not the only erratic habit of antelope, as I have witnessed many other unaccountable "stunts" on their part. One day Arthur Hensley and I were attempting to count a band of 975 head on the east side of Surprise Valley above Boyd Springs. They would not string out properly, but remained bunched in small groups, so it was impossible to get a count. They were "cornered" between us and deep snow that lay along the top of the ridge over which they would not pass. Finally Hensley started out to drive them past me, but they became interested and played hide and seek with him for several hours. Whenever he would get out of sight, they would hunt him up and then stand staring at him. Even by waving his arms and shouting, he was unable to frighten them. At last, they became tired, stopped in a solid mass in an opening in the junipers, and then walked and trotted past me in single file and were easily counted by both of us.

Another time when we were counting antelope, a small band of 26 was spotted about a half mile away across a valley. They were all watching us and just as we had finished counting them, they started running directly away from us. They ran up the slope of a hill, then put on a burst of speed and made a big curve back across the lower part of the valley and disappeared. In a few moments we heard a clatter of flying feet and here they came directly at us from behind and at about 100 yards distance. Suddenly they all swerved to the right, came around in a front facing us, and stopped. They stood thus with their rump hair on end for perhaps 20 seconds and then, with a snort from one or more, dashed off over a low ridge and back into the valley, stopped, and started feeding within a few yards of where we had first seen them.

On yet another occasion I spotted a large, lone buck lying dozing under a scraggy, dead juniper in Pete's Valley as I came down over a rim about 40 feet from him. He was facing the other way and did not see me. When I was about 25 feet distant, he apparently heard me as he quickly turned his head and saw me. He bounced straight up out of his bed about four or five feet in the air and landed with every hair standing on end, but did not run. He simply stood eyeing me intently. After what seemed at least a half a minute, he gave an extremely loud snort and ran with a bouncing gait for about 40 feet, then whirled about and stood facing me again only to snort and do it all over again. This continued until he was at least 200 yards away where he stood and watched me. I sat down on the side hill and watched him through the glasses. He finally moved under another juniper and pawed a bit and bedded down facing me. I then moved on but he only stood up until I turned away from him. The last I saw of him he was down again and chewing his cud, as I could see through the glasses. He certainly had very little fear of me. Like many nervous buck antelope, he urinated nearly every time he whirled to face me. This is most evident in late summer and fall.

I was very nearly run down by a large band of antelope near Horse Lake during the deer season of 1935. I had seen them off about a mile away in an open basin, but had paid no attention to them. Shortly after, I heard five shots on a mountain above them and glanced that way to see if I could see any deer running in my direction. There were half a dozen deer coming down the slope out of the mahoganies toward the antelope. Suddenly, as the deer got within about 150 yards of them, the antelope started pell-mell out of the basin. They left the deer behind immediately and came on straight toward me traveling at a terrific rate. I did not sense any possibility of danger until they were 150 yards or less from me. Finally I realized they were pretty tightly bunched and those behind were crowding those in front, so I stood up thinking they would turn, but they did not. When they had approached to within about 100 feet, I started waving my arms and hat. It was very evident that those behind did not see me, but those in front split, some going to my right and some to the left. By the time the last of the band had split, some of them were less than 20 feet from me and were nearly lying over on their ribs as they swerved away to either side.

Antelope Gaits

Antelope appear to be stiff, awkward walkers, but they can walk rapidly. When walking, their movements are jerky; in fact, they appear to limp. Everything about them appears angular and uneven at this gait.

When trotting, their actions are smoother but the appearance of a limp is often still there. When loping, they move still more smoothly, but show some bobbing and occasionally bounce a little, particularly when starting or coming to a stop.

The running gait seems to be their most natural. There is little or no bouncing. It is much like the run of a horse, but smoother. When antelope are running at high speed their bodies lie low to the ground and their backs rise and fall very little. Their bounds when going full speed are not as long as those of deer. From right hind foot to right hind foot of several different sets of tracks that I measured, I found that the average was 14 feet. They are capable of broad jumps of at least 27 feet, as I measured two such jumps in Lassen County where they cleared an open, mud-bottomed cut.

When they are traveling at high speed, they do not tear up the ground as do deer. In fact, their tracks are surprisingly light for animals with so much drive in their hind quarters. Most of their power seems to be generated in the hind legs, while the front ones keep the body off the ground and on an even keel. Striking a hole does not seem to bother them particularly as I have seen them running at great speed across flats which were full of wide cracks. Investigation of the tracks showed they had stepped in some of them, but that no particular trouble was evidenced in negotiating the area.

They do not like soft mud and make every effort to keep on dry and solid ground. In fact, after the thaws begin in early spring, I have seen them well up in the lava cliffs and rim rocks where one might expect to see big horn sheep. At this season they stay off the flats entirely. Perhaps the lack of dew-claws hampers them in mud.

When running over rough lava and loose rocks they injure their feet quite often. Some limp after such a run and blood may be seen in their tracks. These injuries are apparently only superficial in most instances.

Speed

Many estimates have been made of the speed of antelope, but it is difficult to arrive at a true figure because there is no way of knowing when one is doing its absolute best.

Following are some of these estimates:

Heller	32 m.p.h. sustained speed.
Seton	32 m.p.h. for 1 mile estimate.
DeVore	43 m.p.h. (in Seton).
O'Connor	50 m.p.h., whole herds.
	60 m.p.h. and crossed in front.
	70 m.p.h., possibly for barren doe.
	50 m.p.h.; bucks, particularly old, are much slower.
	45 m.p.h., one old buck could do no better.
	45 m.p.h. and young buck ran away from car.
McLean	53 m.p.h. for 300 yards and holding even—two bucks. Sped up noticeably when shots were fired. Apparently capable of 53 for nearly one-half mile.
	42 m.p.h. for one-half mile and then sped up to cross in front of car and ran another one-half mile at about the same speed—four does.
	45 m.p.h., good buck on dry lake bed for 5 minutes then to 40 and gradually down to 35, and then dodged off as evidently tired.
	35 to 40 m.p.h. at a rather long distance but will tire rather quickly if forced above this, as a conclusion.

The following details of my observations listed above are, I feel, fairly accurate.

Between Grasshopper Valley and Dry Valley in Lassen County, A. L. Brown and I saw two large buck antelope start racing the car as is often their habit. They were about 150 feet to our right and even with the car when they paralleled us, and as I sped up, they did likewise. The speedometer showed 53 miles per hour for about 300 yards and the antelope were still even, but closer to the car. Brown shot two revolver shots in the air, at which the antelope went still faster and pulled away. I was not able to drive faster because of the road surface. They finally stopped and turned around facing the road after running about one mile. The excessive burst of speed, following the shots, probably did not last more than 250 yards, but it was certainly evident that they were capable of at least 53 miles per hour for nearly a half mile.

On the Madeline Plains east of Ravendale, four antelope does ran along beside the car for about one-half mile at 42 miles an hour, suddenly put on a burst of speed and crossed directly in front, then raced along just ahead of the car for another one-half mile at about the same speed when they crossed over in front again and stopped about 100 yards from the road. These animals were certainly not particularly frightened. In fact, I think it was curiosity and the joy of a race that prompted them to stay by the car for such a distance.

On a flat, dry lake bed in northwestern Nevada, I chased one good buck that hit 45 miles an hour for about five minutes, then dropped to 40 and then to 35. I kept to the outside of the animal most of the time to keep him on the open lake bed. He evidently got tired, as all of a sudden he decided that he had had enough and dashed across in front of the car and went up a slope above the lake bed and on over the top of a ridge to the west. It is my opinion that an antelope can run between 35 and 40 miles per hour for a long distance, but will tire quickly at anything over that.

I have noted that shortly after gathering speed, most all of the antelope in a band open their mouths regardless of the temperature. This may be due, at least in part, to their small lung capacity. After a short sprint, they can be heard breathing heavily as they pass by, even above the clatter of their feet. In contrast to its relatively small lungs, the antelope has a large and extremely muscular heart for an animal of its size.

The hoofs are large compared with those of deer; in fact, a large buck antelope has bigger feet than a buck mule deer of more than twice his weight.

Vision

Of all mammals with which I am familiar, the antelope has by far the keenest vision, with the possible exception of the big horn sheep. Their noses are good and so is their hearing, but they depend primarily on eyesight to detect approaching danger. I have yet to show myself in full view of a band of antelope anywhere within a mile and a half without having some of the band spot me before I walked more than a few feet. They seem to see about as well as I can through 16 power binoculars—possibly better.

I am convinced also that they know their home terrain so well that anything unusual, however small, that appears in their field of vision is quickly spotted. One such instance occurred on Eagle Head Plateau south of Rush Creek in Lassen County. I slipped up to a rim rock and showed just the top half of my head over the edge. Below me and nearly 500 yards away was a band of about 90 antelope. Upon looking through the glasses, I saw at least 10 antelope gazing at me. They had picked up the movement of my head as it was pushed above the rim even at that distance. The wind was blowing toward me, so they had not gotten my scent first to put them on the alert. After I had remained there quietly for some time, some of them came toward me about 200 yards to investigate further.

I saw another band of about 200 in Upper Smoke Creek watching a coyote that was at least three-quarters of a mile away on a rocky slope.

Many times antelope will continue feeding and let on they do not see you or do not care. One large, close band continued feeding even when I was walking toward them across open ground. However, I could tell they were watching me even when their heads were down by the way they turned their heads and the fact that they gradually moved away. All of a sudden they all trotted off about 200 yards, then swept around in an arc, raced by me within about 50 yards and went over a hill only to reappear about 400 yards to the north and come back by me again at about the same distance as before. They all stopped on a little ridge and turned facing me, some of them snorting and running this way and that, but not going away from the rest of the herd.

Horns

Antelope have horns, not antlers as do deer. The horns are plainly made up of modified hair and can be separated out into individual hairs, particularly near the base. The fully grown horn is dark blackish-brown, some having ivory white tips for an inch or less. The outside sheath or covering is shed each year, leaving the core of the horn which is part of the skull. The new horn starts growing on the tip and sides of this core and gradually pushes the old horn up and off. Many of the record and near record sets of horns are a combination of new and old horns. The horns, even when fully grown and hardened, are not very securely attached to the core, as movement can be noted if the horn is twisted from side to side.

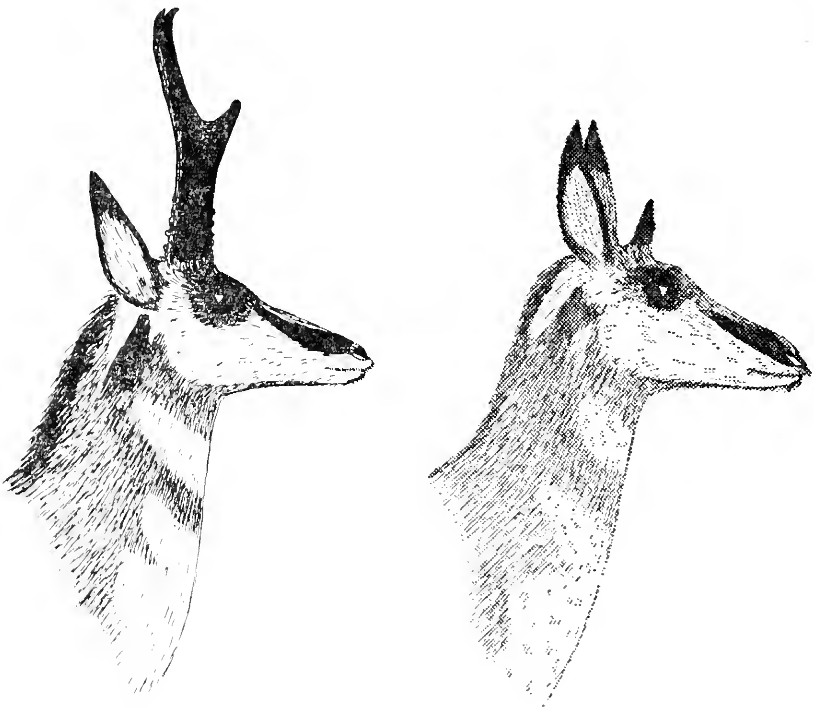

FIG. 89. Head and neck of adult buck antelope (left) and doe (right), showing horns and normal markings.

The horn normally has an upwardly directed main shaft with the one prong projecting forward and braced with a heavy web against the main shaft. The prong plays a definite part in the protection of the buck from injury to the face and head when fighting. The opponent's horn or prong is caught on the hook of the prong and this keeps him from gouging with his horn tips. The curved-in, sharp-ended points on the horns are excellent gougers and when brought in contact with the side of the head or neck are hooked in and ripped, making the hair fly and probably cutting into the skin and flesh on occasion. While looking over a number of antelope capes, I noted many had scars showing on the inside of the skin on the cheeks and neck that looked as if they had been made in this way.

Freak horns of various shapes are not uncommon among antelope. Some are wide-spread, some straight up and parallel, some tipped forward, some with double prongs; in fact, most any type you could imagine. There was one four-horned buck that we saw for a number of years near the Horn Ranch at the southeastern end of the Madeline Plains. He had one normal set of horns and another set of about equal size growing between the first set. Several were killed during the 1942 and 1943 seasons with cock's-comb shaped horns on the bridges of their noses. This was attached to the skin over the base of the nasal bones.

The time of shedding the outside horn sheath seems to vary considerably. I have seen large, old bucks that had shed by October 10, and I have seen smaller bucks that still had their horns on December 1. It appears that larger bucks in good condition shed first. Shed horns disintegrate very rapidly and are nearly all gone by the following year. This is probably due to their structure which allows water to soak in between the fibrous parts. Freezing then forces the horn apart into a ragged mass which soon disintegrates, its remnants resembling pieces of dried rootlets. The hard tips sometimes last for several years.

Does' horns are small and barely show an indication of the prong in some instances. I have not seen a doe's horns over three and a half inches long, although I have heard of two a little over four inches and one about seven inches.

Male fawns at birth have a small bump over each eye. The horns break through the skin in the fall and are loosely attached to the skin. They ordinarily grow to about an inch in length by January, when they are shed. The following fall they are shed a little later than those of the older bucks, and when two and a half years old, they are dropped at the same time as the others.

Census Methods

Formerly antelope were estimated or counted by crews of picked men working from horseback or on foot. About six or seven men generally made up a crew, working in twos or threes in most areas. Occasionally, however, all joined to form one crew in places where large numbers of antelope in a limited area had to be counted at one time to avoid the possible duplication that might occur if they were not all counted in one day. Because of soft ground and rocky terrain, most of the counting had to be done on foot. In order to count the two counties, Modoc and Lassen, properly, each man of a six-man crew had to walk or ride about 600 miles—about 26 days of effort per man.

The extensive use of the airplane was started in the late winter of 1941-42. This first airplane census was carried on under the Federal Aid in Wildlife Restoration Act as part of Project California 12-R, "Aerial Survey of Big Game in Northeastern California and in Owens Valley." James D. Stokes of the Division of Fish and Game was the observer and A. L. Reese the pilot during the 1941-42 survey. The 1943 and 1944 censuses were made with regular Division of Fish and Game funds, with D. D. McLean as observer and John Allen as pilot. This method is far superior to the old from the standpoint of speed, accuracy, and expense.

The system normally used in counting is to cover the area in strips of one-half mile or less in width. During the winter season when the counts are made, the sun is low and in the south, so the counters work back and forth from east to west and vice versa, beginning at the south side of the area to be counted and working north so the sun is always at the counters' backs. The normal altitude of flight for best results is from 400 to 800 feet.

When a herd is sighted, it is counted as soon as possible by the observer, or observers, and the pilot independently. Small bands can be counted quickly, whereas larger herds must be circled, crowded together, flown over at low altitude to start them off in a string, and then passed from the rear and counted while passing. This sounds difficult, but one group of 1,155 was counted by three of us in this manner, independently, with less than 3 per cent difference. The average of the independent counts is used as the final figure unless there is more than 5 per cent difference, in which case they are recounted. No effort is made to separate sexes, as the counters do not have time. Counts on large herds are made from greater distances than those made on small bands. Often we move off to the side about 1,000 feet for counts of the larger groups. Photographic counts were tried but found to be of little value as one missed picture would upset the whole count.

As against the foot and horseback method, which often missed antelope that happened to be on the other side of a knoll, the airplane is flown high enough to see over such obstructions giving the observers an open, uninterrupted view of all the terrain.

Bad flying weather is the only real problem during the winter range counts. Extended stormy periods sometimes make the counting difficult. Because of this, it is necessary to count a complete block of winter range at one time so as not to count the same antelope a second time at a later date. It is also difficult to count antelope against a background of snow, particularly when bare ground alternates with patches of snow.

There are a few short-comings in the use of the airplane. If a large, radial motor is used, making a high obstruction in front of the observer, an occasional herd of antelope is passed over directly under the plane. Best results are secured with a plane that cruises under 125 miles per hour, but it is necessary to have sufficient power to get out of bad situations that regularly arise due to air currents and rough terrain. The type of flying required is extremely dangerous because of the low levels flown. If anything went wrong there would be little chance of gliding to anything but a crash landing. It is, therefore, extremely important to have a pilot of long experience and with the ability to land a plane on a side hill or lava bed and still be able to walk away from the crack-up. This requires a complete mastery of the plane so as to be able to ''stall'' it in at the slowest possible speed.

It requires about 35 hours of flying to properly cover the winter range area at 120 miles per hour. Even at the present high rate of airplane rental, this is much less expensive than the old horseback and foot method.

The counts for the three years, 1942-44, are shown in Table 1. The progressive growth in the yearly totals is perhaps due in part to the growing efficiency in the methods of carrying out the census, which has reduced the number of animals missed when making the count. However, there is no doubt that it reflects in part the fact that, regardless of the open hunting seasons of 1942 and 1943 (to be discussed in the next section), the antelope are increasing in number. The species being polygamous, enough bucks are left by the hunters to carry on the breeding; the fawn crop bears this out.

TABLE 1

Details of Three Years of Antelope Count

Modoc County

	1942	1943	1944
XL Ranch	224	124	82
Likely Tables	420	364	389
Clear Lake	----------	71	----------
Surprise Valley	----------	152	376
Rattlesnake Creek	----------	377	256
Cloverswale Creek	----------	----------	64
West of Adin	----------	10	----------
East of Adin	12	5	----------
Modoc County totals	656	1,103	1,167

Lassen County

	1942	1943	1944
Spencer Creek	271	530	----------
Skeedaddle Creek	255	1,214	874
Bull Flat	158	----------	----------
Shaffer Mountain	317	610	545
Mud Flat	242	100	1,904
Little Mud Flat	300	66	----------
Brubeck Spring	27	----------	----------
Rush Mountain	389	----------	----------
Rush Creek	87	----------	----------
Three and Five Springs	437	208	140
Rice Canyon	103	201	52
Smoke Creek	----------	374	435
Snowstorm Mountain	----------	143	530
Pete's Valley	----------	159	----------
Willow Creek Valley	----------	26	8
Big Valley	15	33	----------
Dixie Valley	60	67	16
South of Constantia	----------	14	----------
Tule Mountain	----------	46	----------
South Slope Hot Springs Mountain	----------	171	----------
Hog Springs	398	----------	----------
Lassen County totals	3,050	3,962	4,504

Siskiyou County

	1942	1943	1944
Mount Dome	*37	273	305
Grand totals	3,752	5,338	6,147

* Observer was certain that two large herds were missed.

NOTES:

In Shasta County, near Fall River Mills, 171 head were found in 1944.

The counts in 1942 and 1943 were made during January, February, and March. The count in 1944, under better weather conditions, was made from February 2d to February 15th.

Open Seasons

From the information gathered during these surveys it has been possible to endorse the limited open season authorized by the Legislature. Claim was made that antelope were beginning to damage crops. Two seasons have now passed with a maximum allowable kill of 500 buck antelope with horns longer than the ears. Five hundred licenses have been issued annually under a lottery system in which application is made and a number given to each application. These numbers are drawn until 500 has been reached, then 500 alternates are drawn in

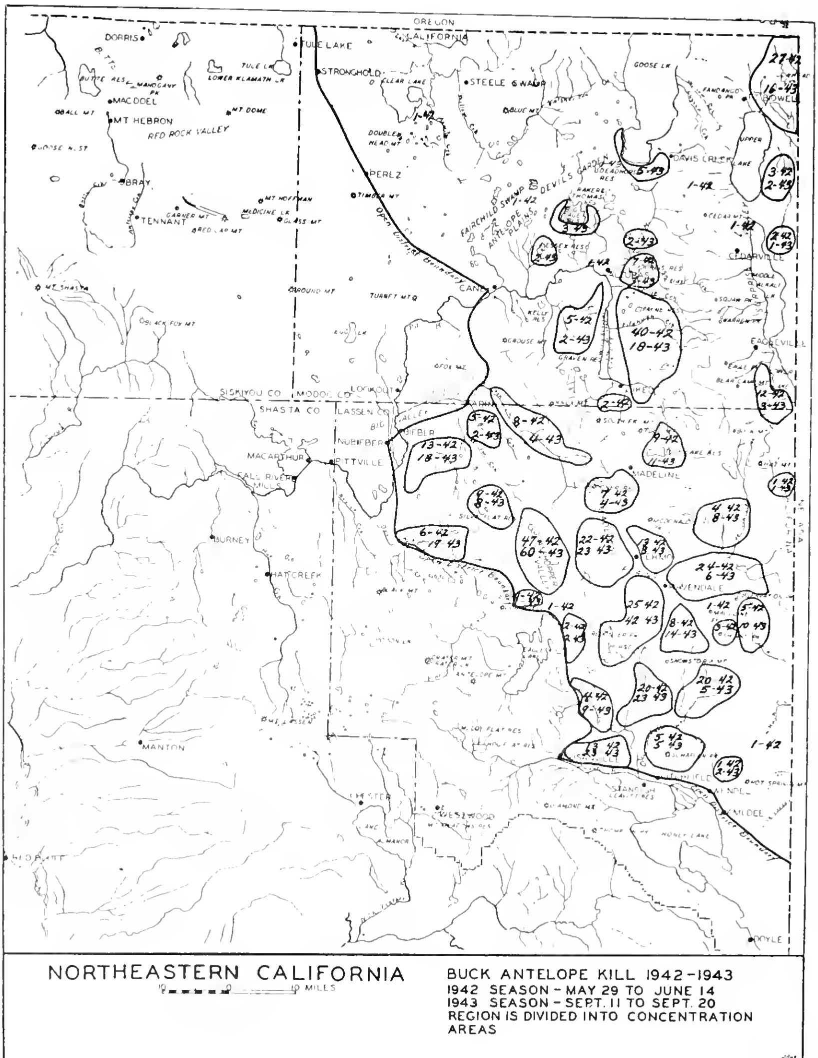

Fig. 90

case some of the original applicants are not able to secure the five dollar license or are unable to hunt.

During the 1942 season, 452 hunters took 405 antelope. During the 1943 season, 452 hunters took 362 antelope. In 1942 there were 47 hunters who were unlucky and in 1943 there were 90. During both years there were 48 prospective hunters who found they were unable to go at the last minute because of sickness, gas shortage, tires, etc.

Strategically located checking stations were set up each season where the hunters were checked in on arrival and out at the completion of the hunt. Here the antelope were weighed, measured, and checked as to condition of the animal, pelage, diseases, and parasites. Each animal checked had a separate sheet and the data thus secured are summarized below.

TABLE 2

Comparison of Live and Dressed Weight of Antelope

Live	Hog dressed	Loss	Per cent loss	Time killed
Lbs.	Lbs.	Lbs.		
140	112	28	20	2:00 P.M.
130	100	30	23	7:00 P.M.
125	100	25	20	10:30 A.M.
123	102	21	17	10:00 A.M.
120	88	32	26.6	4:30 P.M.
120	96	24	20	6:30 P.M.
117	98	19	16.2	2:00 P.M.
114	93	21	18.4	9:00 A.M.
112	98	14	12.5	12:00 P.M.
110	95	15	16.6	5:00 P.M.
100	86	14	14	5:00 P.M.
95	75	20	21	8:45 A.M.
94	80	14	14.8	10:00 A.M.
90	78	12	13.3	9:00 A.M.

Average loss	18.17%
Average actual dressed weight of 308, 1942 season	82.1 lbs.
Average actual live weight of 26, 1942 season	114.7 lbs.
Average actual dressed weight of 244, 1943 season	92.2 lbs.
Average actual live weight of 41, 1943 season	111.6 lbs.

TABLE 3

Average Measurements of Various Anatomical Features

Average total length of 275	57.46 inches
Average tail length of 251	4.40 inches
Average length of hind foot of 251	17.67 inches
Average length of ear of 359	6.42 inches
Average spread of horns of 377	11.45 inches
Average right horn base circumference of 345	6.34 inches
Average left horn base circumference of 345	6.28 inches
Average right horn length outside curve of 384	11.64 inches
Average left horn length outside curve of 384	12.56 inches

TABLE 4

Ten Best Heads by Length of Beam

1942

Length		Prong		Spread	Tip to tip	Base	
Right	Left	Right	Left			Right	Left
17	16¾	4¼	4¼	15½	12¼	7¾	7¾
16⅝	16	5⅜	5⅜	11¼	6½	8¼	7⅝
16¾	16¾	3	3	13	7	7	7
16¾	16	4	3¾	12¼	4½	7½	7¼
16½	16½	5½	5½	10½	6	7¾	7¾
16½	16½	5⅛	5⅛	10½	1¼	7½	7½
16½	16½	3½	3½	11	8⅜	8⅝	8⅝
16¼	16½	4	4⅜	15	9	7½	7⅜
16½	16⅛	4¾	4½	13⅜	6⅝	7⅛	7⅛
16¼	16¼	4	4	11	3		

1943

Length		Prong		Spread	Tip to tip	Base	
Right	Left	Right	Left			Right	Left
16⅞	16½	2½	3⅝	14⅛	9⅛	6½	6⅜
16⅜	16	5½	5	20¾	16¾	6¾	6¾
16⅜	15½	2½	2½	10⅝	3½	6⅝	6⅜
15⅛	16⅜	3¾	3⅜	12¾	3⅝	6¼	6¼
16	16	5⅛	5¼	17	12⅝	7⅝	7¾
16	16	5	5	15	6½	8½	8½
16	16	4¼	4¼	9	1½	8	8
16	14	4¼	4¼	8⅝	1¼	7	7
12⅛	16	3½	3½	22½	20½	5¾	7
15¾	15¾	3¾	2⅞	15¾	5¾	7	6¾

TABLE 5

Ten Best Heads by Extreme Spread

1942

Spread	Length		Prong		Tip to tip	Base	
	Right	Left	Right	Left		Right	Left
19⅛	14½	15	2⅜	2⅜	18	6½	6½
19	15⅛	15⅛	4⅛	4⅛	15¼	7	7
18½	13¼	13½	3⅛	2½	16	7⅛	7⅞
18	15⅜	15	3¼	4	13¾	7⅛	7⅛
17⅞	14⅛	14⅛	5⅝	5⅛	8⅝	6⅝	6⅝
16⅞	14⅞	15⅛	3⅞	4	11½	6⅞	6⅞
16½	14	14¾	3½	3	9½	6	6
16¼	14⅞	14⅞	3	3		7¼	7¼
16	12¼	12¼	3	3	12⅜	5¼	5¼
15¾	13	13	6	6	10¾	7	7

1943

Spread	Length		Prong		Tip to tip	Base	
	Right	Left	Right	Left		Right	Left
22½	12⅛	16	3½	3½	20½	5¾	7
20¾	16⅜	16	5½	5	16¾	6¾	6¾
19¼	11½	13	3	2½	16⅞	6	6
19¼	13	13	2	2	19¼	5½	5½
19	14½	14½	4¾	4¾	6¾	5¾	5¾
17½	14¾	14⅜	3½	3⅛	11⅜	5¾	5½
17	16	16	5⅛	5¼	12⅝	7⅝	7¾
17	15½	15½	3½	3½	12	7	7
17	15¼	15¼	2¼	2¼	14	6½	6½
16¾	14½	14¾	2¾	2⅛	8⅝	6	6

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THE FUR CATCH IN CALIFORNIA 1940-1941[1]

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For the past 23 years the California Division of Fish and Game has received catch reports from licensed fur trappers. Each year these reports have been summarized and used by the Division as an aid in understanding fluctuations in the fur supply. They have been helpful in indicating the importance of commercial trapping, but always there has been doubt regarding the *total* number of trappers actually at work each year and the *total* fur take in the state.

There are several reasons why the reports of licensed trappers do not represent the total catch in the state: (a) Trappers for predatory animals need not buy a license and are not required to submit a report of catch; (b) those under 18 years of age need not buy a license nor report; (c) some trap illegally without a license, and (d) some licensed trappers fail to report. These trappers' reports, however, have been the only records readily available for consultation and much of the fur policy of the Division has been based on information taken from them.

In 1940, most of the 28 fur buyers in California were asked the question, "How many persons do you believe trap fur in this state

TABLE 1

The Fur Catch in California, 1940-1941

Species	From trappers' records		From buyers' records		Estimated total number of animals sold by all trappers	Estimated total price
	Number of animals	Value	Number bought by reporting dealers	Number bought by non-reporting dealers (computed)		
Opossum	1,485	$312 46	2,173	711	2,884	$591 97
Raccoon	7,265	9,672 45	9,464	5,457	14,921	19,241 64
Ring-tailed Cat	1,491	2,275 92	1,171	955	2,126	3,189 42
Marten	402	6,207 81	84	346	430	6,604 26
Fisher	5	183 50	3	2	5	209 24
Weasel	171	58 71	91	119	210	67 03
Mink	1,710	8,339 77	1,333	687	2,020	10,234 09
River Otter	26	173 37	9	21	30	189 00
Civet Cat	1,368	224 48	1,117	781	1,898	292 85
Striped Skunk	14,535	13,189 90	18,785	6,233	25,018	22,386 72
Badger	156	106 51	125	153	278	199 96
Grey Fox	5,047	5,619 47	4,423	2,519	6,942	7,471 08
Kit Fox	217	116 19	1,450	413	1,863	1,003 13
Red Fox	12	85 72	2	12	14	100 28
Coyote	3,285	7,113 93	2,613	2,125	4,738	10,229 35
Wildcat	2,776	4,665 69	2,297	1,941	4,238	6,698 59
House Cat	451	44 15	184	47	231	23 85
Muskrat	51,426	66,426 23	7,580	60,590	68,170	94,079 75
Sandrat	16,892	6,254 64	7,869	9,324	17,193	6,144 37
Totals	108,720	$131,070 90	60,773	92,436	153,209	$188,956 58

[1] Submitted for publication, April, 1944.

each year?" The estimates varied from 3,000 to 10,000. It was at this time that the Fur Project [2] of the California Division of Fish and Game conceived the idea of analyzing records of purchases by fur buyers so that by comparing these with the reports of licensed trappers an estimate of the total number of trappers and the total fur take could be prepared.

Twenty-three buyers cooperated by submitting their records of purchases for the 1940-1941 season. The records were transferred to punched cards and tabulated by the staff of the Bureau of Marine Fisheries. The statistical methods used in developing the final estimates of the fur catch are rather complex and are described at the end of this article.

In the year from July 1940 to June 1941, predatory animal trappers employed by the U. S. Fish and Wildlife Service and the State Department of Agriculture, in cooperation with various counties, caught 5,792 coyotes and 1,155 wildcats. Trappers hired by the Division of Fish and Game caught 3,178 coyotes and 1,009 wildcats. Only a small number of these were caught in the winter season and sold, but they would increase the total number of animals caught as follows:

Coyote:	4,738	estimated catch by commercial trappers
	5,792	catch by Federal, State, and County trappers
	3,178	catch by Fish and Game trappers
	13,708	total catch of coyotes
Wildcat:	4,238	estimated catch by commercial trappers
	1,155	catch by Federal, State, and County trappers
	1,009	catch by Fish and Game trappers
	6,402	total catch of wildcats
Totals:	153,209	estimated catch by commercial trappers
	11,134	catch by predatory animal trappers
	164,343	total caught by all trappers

In addition to the above mentioned trappers, there are predatory animal trappers hired with funds provided by certain counties and by stockmen. These records we have not been able to obtain. Their catch, in addition to the coyotes and wildcats occasionally killed by ranchers and hunters, we estimate would raise the total catch of coyotes to more than 16,000.

It would be easy to determine the total amount of fur sold in California if all trappers were licensed and required to report. It would be even easier if all fur were sold within the boundaries of the state. The problem is complicated by the fact that all trappers do not report their catch to the Division and also by the fact that it would be next to impossible to get records from the hundreds of fur buyers all over the United States of their purchases from California trappers. It was necessary to develop a method of making estimates of these missing records.

In the season of 1940-1941 California trapping licenses were taken out by 1,833 persons. Of these only 1,380 reported that they actually trapped and caught fur. Buyers in California reported that they bought

[2] Federal Aid in Wildlife Restoration, Project California 5-R, A Survey of the Fur Resources of the State of California.

fur from 895 licensed California trappers, indicating that the remainder of the 1,380 reporting licensees sold to buyers outside the State. Further, California buyers reported buying from 1,726 unlicensed trappers in California. To proceed with the estimate, it is now necessary to make the basic assumption that the same proportion of unlicensed as of licensed trappers sold fur out of State. This opinion is based on information from several sources, but mainly upon impressions gained from interviews with unlicensed trappers. Both out of State and California buyers use the lists of names of licensed trappers in the files of the Division of Fish and Game. It might be expected that boys would be more liable to sell to local buyers, but in checking the reports of 41 members of the Junior Game Patrol who specified where their furs were sold, it was found that more sold out of State than in the State (26 out of State, 15 in the State).

Returning now to our reported figures, and applying to them the proportion of our basic assumption, we have:

$$\frac{\text{Total of licensed trappers}}{\text{Number of licensed trappers selling fur in California}} = \frac{\text{Total of unlicensed trappers}}{\text{Number of unlicensed trappers selling fur in California}}$$

Letting x stand for the total of unlicensed trappers, and substituting the reported figures for the other factors in the proportion, we have:

$$\frac{1{,}380}{895} = \frac{x}{1{,}726}, \quad x = \frac{1{,}380 \text{ x } 1{,}726}{895}$$

or x, the total number of unlicensed trappers in California is estimated at 2,661. Adding this to the 1,380 licensed trappers, the total number of trappers in the State in the 1940-1941 season would be 4,041. Prices were comparatively low this year and few trappers were at work as compared with, for instance, the season of 1928-1929, when 6,482 were licensed to trap.

At first glance it seems strange that although there were nearly twice as many unlicensed as licensed trappers they caught only 44,489 pelts as compared with 108,270 caught by licensed trappers. The average income of the licensed trappers was $97.15, while that of the unlicensed trapper was only $20.58. We believe that these proportions are very nearly correct. Unlicensed trappers are largely minors who take only a few furs each season. Fur buyers tell us that the enthusiasm of most youngsters is short-lived and their average catch is very low. The ranks of unlicensed trappers must include a great many men who shoot or trap a predatory animal or two and rather than waste the fur send it in to a buyer. Licensed trappers are often professional trappers who take large amounts of fur. Muskrat trappers especially account for a large percentage of this catch.

Licensed trappers are required to report to the Division the animals caught, prices paid for each kind, and the buyer to whom sold. From these reports we can then determine the proportion of fur sold in the State and the proportion sold out of State. This proportion varied for each species. For example, trappers reported selling most of their marten to out-of-State dealers and most of their coons to California dealers (see accompanying table), so it was necessary to calculate each species separately. The proportion of fur sold out of State was applied to the buyers' reports. That is, the total amount of fur of each species bought by California buyers was increased by the proportion that licensed trappers reported selling out of State and the total number of each species sold out of State was thus obtained. These calculated figures are shown in the table.

A complication was encountered when one of the most important buyers in the State refused to cooperate in the project. The records of several minor buyers also were not obtained. Estimates of their purchases were made by considering them on the same basis as out-of-State buyers.

The problem was further complicated by the discovery that the total amount of fur reported sold to dealers by licensed trappers was 9 per cent more than the dealers reported buying from the trappers. This may have been because some dealers failed to report part of their purchases, or it could have been because trappers are inclined to exaggerate the amount of fur they trapped. To be on the conservative side, we assumed that the dealers' reports were accurate.

For the use of those who are interested in duplicating the procedure followed in this project, one animal (the raccoon) will be taken here as an example and the process applied to it will be explained.

A represents the number of pelts reported by trappers as having been delivered to reporting dealers. Coon = 2,823.

B represents the number of pelts reported by trappers as having been delivered to nonreporting dealers. Coon = 2,519.

C represents the number of pelts reported by 23 dealers as having been purchased from licensed trappers. Coon = 3,155.

D represents the number of pelts reported by 23 dealers as having been purchased from unlicensed trappers. Coon = 2,963.

$E = \frac{B}{A} \times C$, the weighted number of pelts for the nonreporting dealers purchased from licensed trappers. (This corrects the 9 per cent discrepancy.) Coon = 2,814.260.

$F = \frac{B}{A} \times D$, the weighted number of pelts for the nonreporting dealers purchased from unlicensed trappers. Coon = 2,642.996.

G = E plus F, the total number of pelts purchased by the nonreporting dealers. Coon = 5,457.

H = the total number of pelts purchased by reporting dealers. Coon = 9,464.

G plus H = the total number of pelts sold. Coon = 14,921.

The analyzing of dealers' records was first contemplated as an annual project. The great amount of labor involved precluded the undertaking of the job in 1942, but it is hoped that it can be done at least once again in a year when fur prices are high and more trappers are at work. In the meantime, we believe that the proportionate increase of the total catch over the reported catch in the 1940-1941 season can be applied to the reported catch of any year to give a rough estimate of the total take for that year.

Summary

A. A tabulation of the approximate total number of each species of fur animal taken by trappers in the season 1940-1941 has been made possible by the mechanical analysis of trappers' and fur buyers' records.

B. The catch was small, as fewer trappers than usual were at work because of low fur prices.

C. Calculations showed that approximately 153,209 furs were sold for a total price of $188,956.58.

D. There were approximately twice as many unlicensed as licensed trappers, but the number of furs caught by unlicensed trappers was less than one-third of the total catch.

E. Muskrats led the list with 85,363 furs sold, striped skunk followed with 25,018, grey fox was third with 6,942, and coyote fourth with 4,738.

F. Muskrats brought trappers the most money with a total value of $100,224.12; striped skunk brought $22,386.72; raccoon brought $19,241.64, and mink $10,234.09.

G. The number of coyotes caught and sold was 4,738; the number of wildcats 4,238. When the catch by government trappers is added, the total number of coyotes caught is increased to 13,708; the catch of wildcats to 6,402.

H. The computed total of trappers who sold fur in the season of 1940-1941 was 4,041.

I. It is believed that rough estimates of the total fur take for future seasons may be made by increasing the totals reported by licensed trappers to the Division of Fish and Game in the same proportions as shown in the above table.

EDITORIALS AND NOTES

TWENTY-FIVE YEARS AGO IN CALIFORNIA FISH AND GAME

In CALIFORNIA FISH AND GAME twenty-five years ago Carl Westerfeld, the executive officer, gave, in the course of an article dealing largely with other matters, the following brief description of this periodical:

> CALIFORNIA FISH AND GAME, a quarterly magazine devoted to the conservation of fish and game in California, contains
>
> 1. Numerous articles on game species, means of identifying them, their past and present status, and the means whereby they may be conserved.
> 2. Statistics bearing on the abundance of game species.
> 3. Reports of work accomplished by commission; activities initiated.
> 4. Financial reports.

That description would seem to fit rather closely still. And yet, comparing the issues of twenty-five years ago with recent ones, it becomes apparent that the emphasis has changed. To clarify this point, an excerpt from an editorial in the number following the one quoted above may be permissible:

> CALIFORNIA FISH AND GAME was started as a means of moulding public opinion, for it was believed that: "The effectiveness of game protection is governed by the interest of the people and the spirit of those who hunt and fish." The magazine has acted primarily in an educational and publicity capacity, but it also constitutes a record of activities and accomplishments which are of historical value.

That the magazine acts in an educational capacity is, we hope and believe, still true; but its publicity function can no longer be considered a primary one. For proof of this the mailing list alone suffices, for it contains less than 4,000 names. To be sure, the number of readers is greater, for it goes to many libraries, schools, colleges, and other organizations; but at best, the publicity value of a journal with so restricted a circulation can not be considered high.

Twenty-five years ago the number of copies printed was 5,200. That was not much greater than at present, but sights were already set on a far higher target. The circulation increased from year to year until the peak was reached in 1931 with a printing of 11,000 copies. One year later the number had dropped to 3,000. The reason for this phenomenal decline was simple: a suspicion was born that many of those receiving the magazine took it principally because it came gratis; to test this, a charge was made; and the number of those interested enough to pay was only a fraction of the original total. Having winnowed out what might be called the deadheads by the application of hard economic law, the effort was made, when the magazine was once more issued free, to restrict its mailing list to those genuinely interested and legitimately entitled to receive it; and this has been the aim ever since.

Publicity *per se* having in the course of this evolution ceased to be a mainspring, material of current and popular appeal such as might be expected to swell the mailing list gradually disappeared from the magazine. Material of this sort, much of which was printed in the earlier quarterlies under such headings as "Hatchery Notes," "Life History Notes," etc., still goes out from the Fish and Game Commission in the form of news releases to the press, through which it reaches a far greater number of readers than it could in any other way. CALIFORNIA FISH AND GAME has become principally a medium for the recording of the work accomplished by the Division of Fish and Game, and of the operations and investigations of others which affect the fish and game of the state. It is a sober record, at present, perhaps to some of its readers too sober, but it is difficult to be entertaining when presenting the results of original research—results which, to a greater or less extent, are true additions to the sum total of human knowledge. It is realized that accounts of scientific work written in a style to be interesting and informative to the non-scientist have a definite place in the magazine. It is also realized that reports of the work of the Division are at present not as complete as they should be. When the war ends, and our many absent workers return, expansion in both these directions can be looked forward to. "Conservation of wildlife through education" still stands on our cover; but where the educational effort was in earlier years to broadcast a great variety of information to a great variety of people, it is now to make available specialized information to people of specialized interests.—*Brian Curtis, Editor, California Fish and Game.*

IN MEMORIAM

E. CLARENCE MOORE

The Fish and Game Commission, meeting in Los Angeles July 14-15, 1944, unanimously passed the following resolution commemorating the death of Dr. E. Clarence Moore at Los Angeles July 10th. Dr. Moore was president of the Fish and Game Commission from February, 1935, to January, 1939.

WHEREAS, Dr. E. Clarence Moore who served the people of the State of California for five years as a member of the Fish and Game Commission has been called by death; and

WHEREAS, He is remembered with great affection by all who served with and under him for his kindliness, thoughtfulness, and consideration; and

WHEREAS, His training in the art of medicine taught him the necessity for sound, basic, scientific approach to the many problems confronting those who administer the wild life and fisheries of California; and

WHEREAS, He encouraged and fostered the training of the scientific staff in the Division of Fish and Game which has brought great credit to it; and

WHEREAS, His knowledge of and enthusiastic participation in the field of fish and game recreation endeared him to the sportsmen of the State of California while his quick grasp of the problems confronting California's great commercial fishing industry contributed greatly to its development; now, therefore, be it

Resolved by the Fish and Game Commission of the State of California, at its meeting in Los Angeles on July 14, 1944, that it realizes the loss of a great and understanding friend; and be it further

Resolved, That this resolution be spread upon the minutes of the meeting and that it be published in the Fish and Game Quarterly as an evidence of the respect and esteem in which it held Dr. E. Clarence Moore; and be it further

Resolved, That the Flag at all facilities of the Fish and Game Commission be flown at half staff on Sunday, July 23, 1944, out of respect for his passing.

REPORTS

FISH CASES

April, May, June, 1944

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalone: Undersize, removal from shell below high tide, overlimit, fail to show license and abalone on demand	105	$2,880 00	----------
Angling: District 101 no license, use gaff 300 ft. of stream, closed season, no license, near fish ladder, 150 ft. lower side of weir, game fish closed season, night fishing, more than one rod and line, taking fish other than angling, 150 ft. lower side of dam, failure to show license on demand, operating set line, using more than two attractor blades	138	2,413 50	----------
Bass, black: Closed season, no license, transport for sale	20	560 00	----------
Bass, striped: Failure to liberate from shad nets, use of more than one rod, taking with gill net Mokelumne River closed waters, no license, at night	34	815 00	----------
Catfish: Undersize, use of net to take catfish, closed waters	2	75 00	----------
Clams: Undersize, refuge	13	295 00	----------
Crappie: Closed season, no license, overlimit	2	70 00	----------
Commercial fishing: No license, refusal to show records and failure to fill out tags, no record kept of fresh fish bought from commercial fishermen, taking halibut with trammel net District 19-a	5	350 00	----------
Operating fish trap	2	200 00	----------
Perch: Closed season	3	85 00	----------
Salmon: Snagging, taking between sunset and sunrise, night spearing, taking on Sunday District 12b	33	1,285 00	----------
Sunfish: Closed season, no license	15	422 50	12
Trout: Closed season, no license, overlimit, using more than one rod, snagging, gaffing steelhead	87	2,107 50	----------
Totals	459	$11,558 50	12

GAME CASES

April, May, June, 1944

Offense	Number arrests	Fines imposed	Jail sentences (days)
Deer: Closed season, female, using artificial light, night hunting, illegal game, spike buck, no license, spotted fawn, killing doe	24	$1,830 00	----------
Deer meat: Closed season, illegal	9	875 00	----------
Doves: Closed season	1	25 00	----------
Ducks: Overlimit, after sunset, closed season	7	1,265 00	----------
Firearms: Refuge	5	85 00	----------
Hunting: Refusal to show license on demand	1	10 00	----------
Pheasants: Closed season, no license, shooting from public road, shooting from vehicle, no tags, hen pheasant	15	690 00	----------
Quail: Closed season, no license	2	75 00	----------
Shooting from car	1	25 00	----------
Squirrel, grey	2	100 00	----------
Trapping for profit: No license	1	25 00	----------
Totals	68	$5,005 00	----------

SEIZURES OF FISH AND GAME

April, May, June, 1944

Fish:	
Abalones	173
Abalones, black	142
Abalones, red	334
Bass, black	63
Bass, striped, pounds	77
Catfish, pounds	400
Clams	48
Crappie	43
Lobster traps	16
Perch, saltwater, pounds	50
Salmon	30
Shad, pounds	102
Sunfish	175
Sunfish, bluegill	35
Trout	554
Trout, rainbow	386
Trout, rainbow, pounds	35
Trout, steelhead	20
Trout, steelhead, pounds	1
Game:	
Deer	5
Deer meat, pounds	$175\frac{1}{2}$
Doves	2
Ducks	21
Ducks, drake mallard	2
Pheasants	4
Pheasants, hen	1
Pheasants, male	10
Quail	1
Rabbits, cottontails	11
Squirrels, grey	2
Woodduck	1

FINANCIAL STATEMENT—DIVISION OF FISH AND GAME

Revenue for the Period July 1, 1943, to June 30, 1944, of the Ninety-fifth Fiscal Year

Revenue for Fish and Game Preservation Fund:	
License revenue:	
1944 series—	
Angling	$303,397 50
Hunting	153 00
Trapping	1 00
Fish packer and shellfish dealer	255 00
Deer tags	17 00
Fish tags	2,540 00
Game tags	52 05
Market fisherman	64,640 00
Fish importers	65 00
Fish party boat permits	175 00
Fish breeder	205 00
Game breeder	2,795 00
Kelp license	50 00
Game management—Licenses	90 00
Game management—Tags	5 25
Total, 1944 series	$374,440 80
1943 series—	
Angling	$598,454 50
Hunting	551,553 00
Commercial hunting club	750 00
Commercial hunting club operator	205 00
Trapping	1,552 00
Fish packer and shellfish dealer	990 00
Deer tags	147,746 00
Fish tags	1,540 00
Game tags	66 81
Market fisherman	49,740 00
Fish importers	5 00
Fish party boat permits	60 00
Fish breeder	25 00
Game breeder	300 00
Kelp license	10 00
Game management—Licenses	20 00
Game management—Tags	4 29
Antelope permits	2,500 00
Pheasant tags	121,186 00
Elk permits	750 00
Total, 1943 series	$1,477,458 10
1942 series—	
Angling	$625 00
Hunting	14,027 50
Deer tags	73 00
Fish tags	20 93
Game tags	----------
Total, 1942 series	$14,746 43
Total, licenses, 95th fiscal year	$1,866,645 33
Other revenue:	
Court fines	$38,189 36
Deer meat permits	4,263 00
Lease of kelp beds	1,334 50
Publication sales	53 99
Fish packers tax	291,229 66
Kelp tax	1,057 30
Salmon packers tax	33,933 60
Miscellaneous revenue	18,826 32
Total, other revenue	$388,887 73
Grand total, revenue all years, Fish and Game Preservation Fund	$2,255,533 06

FINANCIAL STATEMENT—DIVISION OF FISH AND GAME

Expenditures for the Period July 1, 1943, to June 30, 1944, of the Ninety-fifth Fiscal Year

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
Administration:					
Education and public information	$3,435 00	$187 43			$3,622 43
Executive	7,379 92	3,715 93		$2 77	11,098 62
Library	2,255 00	74 03		339 09	2,668 12
Exhibits		96 59			96 59
Fish and game magazine		2,307 28			2,307 28
Office	10,274 00	70,705 95		332 22	81,312 17
Total Administration	$23,343 92	$77,087 21		$674 08	$101,105 21
Patrol and Law Enforcement:					
Cannery inspection	$21,439 82	$946 28			$22,386 10
Executive	16,755 00	2,626 50		$18 54	19,400 04
Land patrol	268,239 28	92,854 32		454 83	361,548 43
Marine patrol	47,501 03	25,628 39		5,228 18	78,357 60
Office	9,991 50	1,334 56		7 38	11,333 44
Pollution patrol	2,130 00	1,131 59			3,261 59
Total Patrol and Law Enforcement	$366,056 63	$124,521 64		$5,708 93	$496,287 20
Marine Fisheries:					
Central Valleys Water and Salmon Project	$11,175 50	$4,929 62		$92 61	$16,197 73
Executive	8,720 00	923 25		16 06	9,659 31
Fish Cannery audit		4,418 11			4,418 11
Laboratory	3,877 81	1,756 24		87 62	5,721 67
Mackerel	1,385 00	7 70			1,392 70
Office	8,569 94	588 27		59 92	9,218 13
Sardines	10,991 56	1,318 65			12,310 21
Shark investigation	3,425 00	4,981 54			8,406 54
Shell fish and miscellaneous	3,275 00	433 73			3,708 73
Statistics	18,567 66	8,275 68		7 38	26,850 72
Tuna	830 73	179 24			1,009 97
Total Marine Fisheries	$70,818 20	$27,812 03		$263 59	$98,893 82
Fish Conservation:					
Biological survey	$10,491 84	$809 43			$11,301 27
Executive	11,840 00	1,068 47			12,908 47
Field Supervision	3,780 00	689 96			4,469 96
Fish food unallocated		64,208 49			64,208 49
Fish planting	1,075 00	1,327 80		$21 53	2,424 33
Fish rescue	11,179 50	3,021 10			14,200 60
Office	8,862 95	425 72			9,288 67
Operating expense unallocated		235 15			235 15
Pollution inspection	4,080 00	861 84		33 31	4,975 15
Statistical		305 79			305 79
Structural maintenance		140 82			140 82
Alpine Hatchery	450 00	10 35			460 35
Arrowhead Lake Egg Collecting Station		31 30			31 30
Basin Creek Hatchery	5,813 34	982 94			6,796 28
Benbow Dam Experiment Station	1,422 50	212 66			1,635 16
Black Rock Springs Ponds		108 99			108 99
Bogus Creek Egg Collecting Station		85 00			85 00
Brookdale Hatchery	6,631 85	2,062 77		2 01	8,696 63
Burney Creek Hatchery	5,887 95	701 98			6,589 93
Central Valley Hatchery	4,685 00	2,440 33		5 41	7,130 74
Claremont	410 00				410 00
Copco Egg Collecting Station	104 88	91 18			196 06
Coy Flat	645 00	105 19			750 19
Fall Creek Hatchery	6,651 51	607 61			7,259 12
Feather River Hatchery	3,949 74	323 89			4,273 63
Fillmore Hatchery	16,498 78	8,084 13		648 69	25,231 60
Fishing Creek Hatchery		150 00			150 00
Hot Creek Hatchery	17,477 33	13,712 98		130 06	31,320 37
Kaweah Hatchery	4,422 30	1,728 64			6,150 94
Kern Hatchery	3,104 66	1,160 09			4,264 75
Kings River Hatchery	5,655 74	1,465 86			7,121 60
Klamathon Egg Collecting Station		4 32			4 32
Lake Almanor Hatchery	6,246 71	1,431 28		11 79	7,689 78
Mad River Egg Collecting Station	933 72				933 72
Madera Hatchery	1,251 14	543 45			1,794 59
Mt. Shasta Hatchery	43,478 61	11,528 56		71 11	55,078 28
Mt. Tallac Hatchery	2,178 34	2,193 21		23 10	4,394 65
Mt. Whitney Hatchery	20,979 94	14,756 29		51 63	35,787 86
Prairie Creek Hatchery	5,659 29	2,206 40		5 13	7,870 82
Rearing Reservoir		1 00			1 00
Rush Creek Egg Collecting Station	318 49	7 70			326 19

FINANCIAL STATEMENT—DIVISION OF FISH AND GAME

Expenditures for the Period July 1, 1943, to June 30, 1944, of the Ninety-fifth Fiscal Year—Continued

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
Fish Conservation—Continued:					
Salt Springs	$58 50				$58 50
San Lorenzo Egg Collecting Station		$115 56			115 56
Sequoia Hatchery	3,231 05	2,030 98		$148 21	5,410 24
Shasta River Egg Collecting Station	155 00	133 24			288 24
Snow Mountain Egg Collecting Station	2,165 33	326 06			2,491 39
Tahoe Hatchery	7,936 04	2,599 57		11 31	10,546 92
Yosemite Hatchery	4,769 99	724 99		2 31	5,497 29
Yuba River Hatchery	3,190 00	212 22			3,402 22
Total Fish Conservation	$237,672 02	$145,975 29		$1,165 60	$384,812 91
Engineering:					
Engineering	$6,112 20	$2,344 00		$4 61	$8,460 81
Executive	5,040 00	1,072 38			6,112 38
Inspecting fish screens	3,683 66	1,262 04			4,945 70
Office	1,860 00	77 07			1,937 07
Total Engineering	$16,695 86	$4,755 49		$4 61	$21,455 96
Game Conservation:					
Duck rescue	$495 97	$389 25			$885 22
Elk Refuge	1,070 00	620 77			1,690 77
Executive	11,220 00	2,487 24			13,707 24
Game management	8,279 49	4,904 73		$35 00	13,219 22
Grey Lodge Refuge	4,063 77	598 47		10 87	4,673 11
Honey Lake Refuge	1,129 02	1,112 46		482 47	2,723 95
Imperial Refuge	2,460 00	199 48			2,659 48
Los Banos Refuge	4,253 01	1,293 65		620 59	6,167 25
Office	4,586 68	300 73			4,887 41
Predatory Animal—lion hunting	5,745 00	6,231 96			11,976 96
Predatory Animal—trapping	49,779 37	16,305 40			66,084 77
Research	8,219 83	2,105 44		61 10	10,386 37
Statistics		8 19			8 19
Suisun Refuge	5,089 59	1,164 06			6,253 65
Winter feeding and salting of game		1,571 01			1,571 01
Total Game Conservation	$106,391 73	$39,292 84		$1,210 03	$146,894 60
Game Farms:					
Castaic Farm	$1,860 00	$151 42			$2,011 42
Executive	4,640 00	307 08			4,947 08
Fresno farms	3,334 79	1,446 21			4,781 00
Game Bird Distribution—Los Serranos		76 68			76 68
Game Bird Distribution—Yountville		81 30			81 30
Game management		38 44			38 44
Los Serranos game farm	9,905 24	5,770 06			15,675 30
Office	1,590 00	199 60			1,789 60
Redding farm	2,150 00	905 69			3,055 69
Sacramento State Farm	2,768 34	876 49			3,644 83
Willows	2,574 64	616 04			3,190 68
Yountville boarding house	355 48	251 90			607 38
Yountville game farm	14,545 62	8,719 64			23,265 26
Total Game Farms	$43,724 11	$19,440 55			$63,164 66
Licenses:					
Executive	$4,640 00	$146 10			$4,786 10
License distribution	21,389 71	101,213 43			122,603 14
Office	2,100 00	1,378 98			3,478 98
Total Licenses	$28,129 71	$102,738 51			$130,868 22
Grand total					$1,443,482 58

INDEX TO VOLUME 30

D

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X

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(Continued from inside front cover)

BUREAU OF ENGINEERING

JOHN SPENCER, Chief — San Francisco
Clarence Elliger, Assistant Hydraulic Engineer — San Francisco
Samuel Kabakov, Junior Civil Engineer — San Francisco

BUREAU OF LICENSES

H. R. DUNBAR, Chief — Sacramento
L. O'Leary, Supervising License Agent — Sacramento
R. Nickerson, Supervising License Agent — Los Angeles
Lorraine Atwood, License Agent — San Francisco

ACCOUNTS AND DISBURSEMENTS

D. H. BLOOD, Departmental Accounting Officer — Sacramento

BUREAU OF PATROL

E. L. MACAULAY, Chief of Patrol (absent on military leave) — San Francisco
L. F. CHAPPELL, Chief of Patrol — San Francisco

CENTRAL DISTRICT (Headquarters, Sacramento)

C. S. Bauder, Inspector in Charge — Sacramento

Northern Division

A. A. Jordan, Captain — Redding
Jos. H. Sanders, Captain — Sacramento
A. H. Willard, Captain — Rocklin
E. O. Wraith, Captain — Chico
L. E. Mercer, Warden, Butte County — Chico
Taylor London, Warden, Colusa County — Colusa
Albert Sears, Warden, El Dorado County — Placerville
E. C. Vail, Warden, Glenn County — Willows
Louis Olive, Warden, Modoc County — Alturas
Earl Hiscox, Warden, Nevada County — Nevada City
Nelson Poole, Warden, Placer County — Auburn
E. J. Johnson, Warden, Plumas County — Quincy
Charles Sibeck, Warden, Sacramento County — Sacramento
Earl Caldwell, Warden, Shasta County — Burney
Brice Hammack, Warden, Siskiyou County — Yreka
Fred R. Starr, Warden, Siskiyou County — Dorris
R. E. Tutt, Warden, Sierra County — Downieville
R. W. Anderson, Warden, Tehama County — Red Bluff
C. L. Gourley, Warden, Trinity County — Weaverville
C. O. Fisher, Warden, Yolo County — Woodland
R. A. Tinnin, Warden, Yuba County — Marysville
Wm. LaMarr, Warden, Placer County — Tahoe City
Rudolph Gerhardt, Warden, Butte County — Gridley
K. Langford, Warden, Sutter County — Yuba City
Walter Krukow, Warden, Shasta County — Redding

Southern Division

S. R. Gilloon, Captain — Fresno
John O'Connell, Captain — Stockton
R. J. Little, Warden, Amador County — Pine Grove
L. R. Garrett, Warden, Calaveras County — Murphys
F. A. Bullard, Warden, Fresno County — Reedley
Paul Kehrer, Warden, Fresno County — Fresno
Lester Arnold, Warden, Kern County — Bakersfield
C. L. Brown, Warden, Fresno County — Coalinga
Ray Ellis, Warden, Kings County — Hanford
H. E. Black, Warden, Madera County — Madera
Gilbert T. Davis, Warden, Mariposa County — Mariposa
Hilton Bergstrom, Warden, Merced County — Los Banos
Wm. Hoppe, Warden, San Joaquin County — Lodi
Geo. Magladry, Warden, Stanislaus County — Modesto
W. I. Long, Warden, Tulare County — Visalia
Roswell Welch, Warden, Tulare County — Porterville
F. F. Johnston, Warden, Tuolumne County — Sonora
Donald Hall, Warden, Kern County — Kernville

CALIFORNIA FISH AND GAME

"CONSERVATION OF WILD LIFE THROUGH EDUCATION"

Volume 30 San Francisco, January, 1944 Number 1

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(Continued on page 68)

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(Continued on page 108)

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(Continued on page 218)

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(Continued on page 262)

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Ralph Miller, Warden — San Francisco
T. W. Schilling, Warden — Terminal Island
G. R. Smalley, Warden — Richmond
T. J. Smith, Warden — San Diego
Carmi Savage, Warden — Santa Monica
R. C. Schoen, Warden — Terminal Island

POLLUTION DETAIL

Paul A. Shaw, Chemical Engineer — San Francisco

MARINE PATROL AND RESEARCH BOATS

Cruiser *Bonito*, Newport Harbor
Cruiser *Rainbow III*, Antioch
Cruiser *Shasta*, Redding
Launch *Shrapnel*, Suisun
Launch *Minnow*, San Rafael

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