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1. THE ABALONE INDUSTRY IN CALIFORNIA

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With Three Text-Figures.

The abalone is a marine snail which is of great importance because of its beautiful shell, polished as an ornament or manufactured into many kinds of novelties and jewelry. Pearls may be secreted around foreign particles accidentally or designedly introduced between the mantle and the nacreous layer of the shell. The mollusk Pholas may bore through the shell and cause the formation of the blister pearl or we may bring about the same result by inserting a prepared form. Then the meat, either fresh or dried, is of such food value that upon this part alone a great industry might be built up. Under our present laws the abalone is being exterminated. If we are to save an industry capable of a development and expansion scarcely dreamed of by our citizens, we must enact laws that will do away with the piratical robbery of the sea and substitute therefor a protected aquaculture. This report will not include a discussion of the anatomy and life history of the abalone but will be confined to matters of production, manufacture and preservation.

1.1. COLLECTING ABALONES

In the commercial fishery of abalones one or more crews are employed, generally made up of Japanese, but sometimes of Chinese or American fishermen. The boat containing a crew is either rowed or driven by motor from the camp to the fishing grounds. The crew consists of the diver and his six assistants. When over the right bottom the diver is clothed with his suit, the helmet is screwed upon the brass collar, the heavy lead breast and back weights are adjusted, and the air pump is manned. One man takes the diver's signal rope, another the hose from the air pump, and the diver, with a net attached to a rope and his "shucker" in hand, is assisted over the side, climbs down the short ladder, and then drops down through the water. If he finds the abalones plentiful, work is continued in water from twenty to sixty-five feet deep, in four hour shifts. The man on the boat with the signal rope in hand, follows the course of the diver by the constant stream of air-bubbles rising to the surface. When the kelp is thick one man has a knife on a long pole, with which he cuts the sea-weed and keeps the air-tube clear.

The diver finds it an easy task to detach the abalone from the rock if he pushes the "shucker" under the expanded foot before the animal is alarmed. If, however, the diver hesitates and the abalone contracts its

muscular foot a powerful pressure is exerted. One or two cases have been reported of the drowning of Chinese fishermen, who having had their hands caught by the abalone were thus held until overcome by the rising tide.

I have gone down in a diving suit, in company with a Japanese diver; the sudden plunge to a depth of sixty feet gave me a number of unusual sensations, and an attack of caisson-sickness followed the submarine journey, but the experience was wonderful. The bottom of the sea seems made of grains of gold and silver, shimmering in the penetrating

Diver prepared to descend.

rays of sunlight. Upon the face of a precipice, large specimens of the green and corrugated abalones rest. The shell of each is covered with a luxuriant growth of algæ, hydroids and tentacled tube-worms, which mask the creature from its enemies. All about are large fish which swim close and peer through the glass window of the helmet. An enormous stingray drifts indifferently by. One has a fellow feeling with these denizens of the deep in the fascination of observing their behavior under natural conditions.

The diver secures a net full of abalones, gives the signal, and the mollusks are hoisted aboard the boat and stowed below. I have seen the diver send the net up, filled with about fifty green and corrugated

abalones, every six or seven minutes. During his shift below the diver gathers from thirty to forty basketfuls, each containing one hundred pounds of meat and shell, or altogether one and one half to two tons.

Sometimes a crew is composed of six divers who work without diving suits up to a depth of twenty feet; some of them remain under water for as long as two minutes. These expert swimmers protect their eyes with glasses and wear cotton in their ears. They pry off the abalones with a "shucker," often filling their arms on the way to the boat. Every two hours they return to the launch to be warmed at the fire. It takes the united efforts of these six men to equal the catch of one diver in a suit.

1.2. THE ABALONE AS FOOD

Preparation of Fresh Abalone.—The meat is removed from the shell by cutting away the large central muscle, the attachment of which to the

Cooking and drying green and corrugated abalones.

shell forms the rough iridescent scar. The visceral mass and the mantle fringe are trimmed off from the muscle, which is then cut transversally into slices. Each of these small steaks is beaten four or five times with the flat side of a meat cleaver and when fried it is tender and delicious. The abalone is also made into a chowder.

This mollusk may be shipped across the continent; for when individuals are placed one on top of the other, in a sort of living nest, they will

survive for as long as six days without water, and seem to eat the organisms and organic slime covering the shells upon which they rest.

Preparation of the Dried Abalone.—The method of preparing and preserving the abalone in a dried state involves the following processes:

Gathered from the rocks by the diver.	1.
Removed from the shell.	2.
Salted for two or three days, in order to remove the pigmented mantle fringe and to preserve the meat.	3.
Washed in tubs by means of wooden paddles.	4.
Cooked for one half hour in water almost at the boiling temperature. This is said to give the desired round shape to the meat.	5.
Laid in trays and placed on frames in the sunshine. The abalone is dried four or five days or even longer, according to the temperature.	6.
Cooked in water for the second time; about one hour.	7.
Smoked in charcoal smoke from twelve to twenty-four hours.	8.
Placed in boiling water for the third time; mainly for rinsing.	9.
Dried upon the trays for six weeks.	10.
A final cleansing bath in lukewarm water.	11.
Shipped to market, having lost nine tenths of the original weight.	12.

Commercial Value of Dried Abalone.—A camp of fourteen Japanese fishermen gathers thirty tons or more of the fresh abalone in a month. When dried the meat brings from twelve to fourteen cents a pound for the green and corrugated species, and from eight to ten cents for the black abalone. In 1870, at Avalon, the meat sold at five cents a pound. Most of the dried abalone goes to China and there finally, at retail, brings seventy-five cents per pound. There is considerable business in canning abalone for the local California markets, as well as for New York and Honolulu. A case of four dozen cans sells for four dollars and fifty cents, wholesale.

1.3. MANUFACTURE OF CURIOS AND JEWELRY FROM ABALONE SHELLS

Shells.—The familiar polished abalone shells have gone all over the world and everywhere are highly esteemed as ornaments. The shell is polished by first grinding it on a carborundum wheel until the desired colors are reached; it is then surfaced by a wheel of felt sprinkled with carborundum dust glued to the wheel; and finally, it is polished with a wheel made of many layers of cotton, on the edges of which tripoli has been rubbed. This wheel is revolved about 2,200 times per minute. The quality of being easy or hard to grind and polish is spoken of by the manufacturers as the "texture of the shell."

The shells are sorted into two classes, but ordinarily classes one and two are mixed together. At Avalon, in 1870, when the meat sold for five cents a pound, the green shells brought eighty dollars a ton. At the present time, the green shells are sold at one hundred and twenty-five to one hundred and eighty dollars a ton, the black, at eighty to one hundred

dollars a ton, and the red at forty to seventy-five dollars a ton. The black shells, with especially good pearly centers, bring from three hundred to five hundred dollars a ton. Owing to the increasing scarcity of good green shells, there is a growing tendency to use the centers of the red shells for jewelry.

When the shells are cut into ornaments, as many as fifteen pieces, including one scimitar-shaped paper-knife made from the rim, or lip, may be cut from one shell of about twenty-two inches in circumference. At an average price of fifty cents for each of these pieces, the shell would realize seven dollars and fifty cents.

Blister Pearls.—The blister pearls are more or less extended elevations of the inner, pearly layer of the shell, formed by the secreting cells of the mantle in defense of the invading, boring mollusk, Para pholas californica. They occur mostly in the red abalone, with only one in about a thousand shells of the green species. A crab, which infests the abalone at certain seasons, may be the cause of blister pearls; one examined by the writer exhibited the complete outline of such a crab. Frequently the blister pearl is formed over sea urchin spines, chiton or razor clam shells, pebbles, and other foreign bodies retained beneath the mantle.

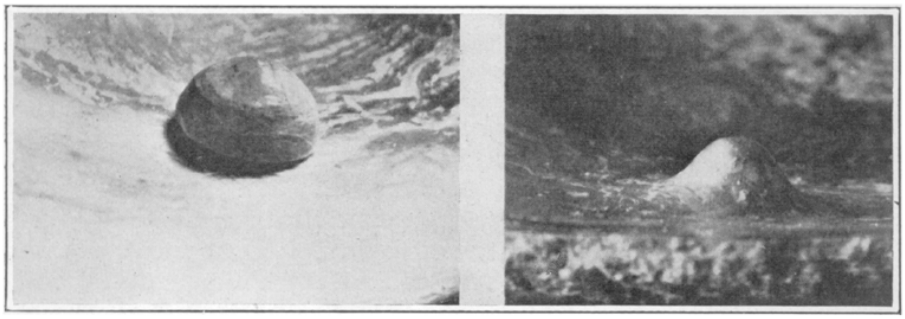
Free Pearls.—The pearls have the color of the inside layer of the shell, varying from white to green or pink, according to the species. They sell from fifty cents, for the smaller ones, to one hundred and twenty-five dollars, for one of twenty-five grains, and at even higher prices for rare specimens. Occasional pearls are so large and of such fine quality as to sell for five hundred dollars or even more. The free pearls are frequently found within the stomach.

Culture Pearls.—It is well known that for a long time in Japan and China artificially induced pearl formation in the pearl oyster, and some allied species, has been commercially successful. The nature and cause of pearl formation has been discussed and investigated for many years, but only within recent years, has the mystery been solved. In 1852, De Fillippi, an Italian, attributed the pearls in fresh water mussels to the presence of parasites in the mantle of the mollusk. Other naturalists—Kuchenmeister, 1852; Mobias, Kellart and Humbert, 1858; Thurston, 1894; and Girard, 1897—have confirmed this theory. In 1902, Dubois made a thorough investigation of this matter upon the European edible mollusk (Mytilus edulis). In this species, and probably in others, a little parasitic worm, about one-fiftieth of an inch long, encysts itself within the mussel toward the beginning of August, to remain there until the following summer. The worm is covered by calcium carbonate in minute particles, until an envelope of lime results, in which the parasitic pearl nucleus is a distinctly visible yellow body. The surface then becomes polished, or "takes the orient," and is opaline and nacreous, reflecting the tinted lights so much prized in these gems. In 1885, in the laboratory at Roscoff, France, Boutan succeeded in producing culture pearls in the abalone found near that coast.

1.4. EXPERIMENTS IN THE PRODUCTION OF BLISTER PEARLS AND FREE PEARLS

In our red abalone, a boring mollusk, (Para pholas) penetrates the shell from the outside. It files its way by means of sharp teeth on its shell and possibly by the secretion of sulphuric acid. The burrow enlarges as the Para pholas, growing in size, digs its way in. When near the inner pearly layer of the abalone shell, the host resists the oncoming Para pholas by secreting more nacreous matter. Thus the defensive wall, eaten by the Para pholas, grows inwardly as a moundshaped projection—the blister pearl.

In imitation of this natural process, I drill a hole into the abalone shell and insert, from the inside, a pearl form with a head lying against the pearl secreting mantle. This form has a shank which projects from the outer surface of the abalone shell and is there made fast by aluminum wire, to which a metal tag bearing the serial number is attached. The black abalone has been used in most cases, although a few experiments have been made upon the green abalone. Various parts of the shell have been bored into, and different numbers of forms inserted.



Pearl form inserted in shell; and culture blister-pearl in green abalone, secreted in 231 days.

In addition, spherical forms, without shanks, have been placed beyond the mantle cavity near the visceral hump, to become the nucleus of free pearls. Unless thrown out by the animal, I have succeeded in raising abalone culture pearls in 133 days. These pearls, however, are thin layers of nacre, formed over a horny basis, which is the first material to be secreted. In the natural process of continued deposition they increase in thickness and solidity and consequently in value. One produced in a green abalone in seven months shows good form and color.

Mr. C. B. Linton of Long Beach has succeeded in growing similar culture pearls. He drills a hole through the shell center, pushes in a round ball, made from shell, and fills the outside end of the hole with beeswax and some cement.

My average time for drilling a hole in the abalone shell, inserting the form, and wiring it in place with the numbered metal tag, is eight minutes. This working time might be decreased by an expert laborer

doing nothing else, so that the business of raising pearls would be one of interest and value. I have found that abalones will take kelp from one's hand, consequently the feeding of these mollusks is a simple matter.

1.5. ESTIMATED VALUE OF ABALONE MEAT AND OF ARTICLES MANUFACTURED FROM ABALONE SHELLS

Based upon the fact that each ton of abalone shells represents a certain value of manufactured jewelry and novelties, it is possible to estimate the value of the abalone industry during the past year. For the region centering in San Pedro and Long Beach the shipments have been made by Mr. C. B. Linton, who has kindly given me the data.

Shells of the black abalone are sorted into two classes. Each ton of those with fine, pearly centers will make novelties and jewelry worth. at retail, $4,000.00. The class known as button shells, with plain mother-of-pearl surface, represents a final value of $1,000.00, and the shells of the green abalone $3,000.00. For the year ending July, 1912, the following shipments were made, representing the given valuations in manufactured products:

13.3 tons of pearl center, black abalone shells	$53,200 00
39.9 tons of button black abalone shells	39,900 00
14.2 tons of dried abalone meats at $200 a ton	2,840 00
Total	$95,940 00

The data for the red abalone was secured through the courtesy of Mr. G. W. Luce, freight traffic manager of Southern Pacific Railway Company, and represents the shipments made during the fiscal year ending June 30, 1912. During this period neither shells nor meat were shipped from Santa Barbara, and from San Luis Obispo only 200 pounds of shells of the red abalone, representing a valuation of $200.00. The region about Monterey furnished approximately one and one half tons of red shells and one ton of meat, representing values of $3,000.00 and $200.00 respectively. These figures from the region of the red abalone speak eloquently of the urgent necessity for the conservation of the abalone and the reëstablishment of this fishery upon a basis which would guarantee great returns to the people.

1.6. PROTECTION AND COLONIZATION OF ABALONES

Much has been said recently in the newspapers concerning the threatened extermination of the abalone. That this is a real danger and not an idle theory, is apparent to any one familiar with the facts. For instance, near Avalon, Santa Catalina Island, not more than twenty years ago, the green abalones were so thick that they rested upon one another four or five deep, all over the rocks. After much searching in this locality, I was unable to find a single specimen. The same thing is true of many other places where the abalone was formerly abundant. The large individuals of legal size are taken and it is probably true, as in the case of the American lobster, that in this manner the most prolific breeders are sacrificed.

We do not yet know anything about the breeding habits and embryology of any species of abalone and therefore are not certain as to the best months for a closed season. It is my hope that before long we shall be able to artificially propagate abalones, as has been done with oysters, clams, lobsters, and other useful animals.

It would be very advantageous to establish a number of protected reservations, similar to those at Monterey Bay and at Venice, at regular intervals along the coast. In this manner, and in these places, colonies of abalones would be established, which would not only insure us against their future extermination, but would afford greater opportunity for the study of their life history and commercial utilization. The government breakwater at the mouth of San Pedro harbor has become a natural reservation. The black abalones creep back under the great stone blocks and thus many escape the gatherers who are stripping every accessible niche and cranny along the coast at each low tide.

The establishment of proper laws for the regulation of aquaculture and the concomitant protection of marine and fresh water organisms is of primary importance for the lasting benefit of the State. We should enact laws similar to those of Germany, for the Elster River pearlmussel bed; of France, for the mussels; and of Connecticut, for oyster farms; then our citizens could profitably engage in various lines of aquaculture. The State should lease the marine farming bottom and waters and legally protect them. The formation of reservation districts for absolute closure during successive periods of years, within which we may have, every five or ten miles, smaller perpetual biological reservations for breeding centers, will solve the problem of preservation in a better manner than the present laws for closed and open seasons.

In order that the preservation of our abalones may be insured, the legislature should declare a general closed season of at least two years. At the same time, the importation of abalone shells should be made allowable to meet the needs of manufacturers.

1.7. CALIFORNIA SPÉCIES OF ABALONES

The following six species of abalones and one variety are given in "Keep's West Coast Shells":

Green Abalone (Haliotis fulgens) Phil.

Among the rainbow colors of the nacreous layer many tints of green are particularly noticeable, giving the center a resemblance to the pattern in the feather of a peacock's tail. The shell is about six inches long and an average of six holes remain open. In deep water this shell is smaller, and more convex, and of brighter tints. Up to the present time the shells of this species have been the most largely used in the manufacture of shell jewelry. The green abalone is most abundant south of Santa Barbara, but is occasionally found as far north as Monterey. The texture of this shell is tough and soft, and so it does not hold the polish as long as a harder shell does, but the color is superior to all other kinds except the Eros. The green shell is especially subject to

boring worms, which follow the loosely formed layers, winding in and out, often entirely through the whole shell.

The green abalone inhabits water from the low tide limit to a depth of sixty-five feet, where it creeps on the faces of submarine precipices or over great boulders upon the ocean bottom.

Haliotis fulgens, var. walallensis Stearns.

This variety is said to occur at Gualala, Mendocino County, California, and is described as being more elongated and flattened than its species, with the nacre of a paler color. Because of the great variation noticeable in shells from different localities, it is possible that this variety may not stand the test of more extended investigation.

Red Abalone (Haliotis rufescens) Swains.

The edge and parti-colored inner layer of the shell are characterized by predominant tints of red. The shell is flattened and may reach nine inches or more in length and often has considerable thickness, even up to one inch. There is an average of four large holes open, with a range from one to five. The texture of this shell is hard and brittle, the layers being very dense and compact, since an unusual amount of material is secreted at each period of growth. The external red layer is especially thick. The center is hard, admitting of a high polish, which is permanent, and the spots of the spots of the mottle are large.

The red abalone occurs among the northern Santa Barbara Islands and along the coast of the mainland to the northward, in about the same depths as the green form. It is especially abundant around Point Lobos, Monterey Bay, where the largest specimens are obtained.

Black Abalone (Haliotis cracherodii) Leach.

The nacre is pearl-colored but iridescent, while the back of the shell is generally smooth and ranges from bluish or greenish to reddish brown. Individuals are found of all sizes up to six inches in length, with an average of seven to eight holes open. The shell is slightly flexible, and its texture is very dense. This shell is largely used for buttons, which resemble those made from the pearl oyster. The center is the most valuable of all the pearl shells because of its hardness and opalescent colors. In fact, it is often called the "opal" pearl.

The black abalone lives in crevices of the rocks, exposed at low tide. In places relatively inaccessible to tourists and beach-walkers they occur in such numbers that one person may gather from fifty to one hundred in an hour. It is the most widely distributed species, being found all along the coast.

Corrugated Abalone (Haliotis corrugata) Gray.

This form resembles the red abalone in size and color, except that its shades are lighter, so that it is called the pink abalone. The shell has a higher arch and the back is fluted, or corrugated, with only two or three holes remaining open. The outside layer is very thick and hard. The color varies widely and so it is unsatisfactory in the manufacture of

novelties and jewelry. It brings about one fourth the price of the green shell.

Its habitat is similar to that of the green abalone, together with which it is taken by the Japanese divers, but in larger numbers.

Threaded Abalone (Haliotis assimilis) Dall.

The shell, which is thick and compact, is silvery within, while the back is reddish and marked with threads like tapestry. The length is four inches, the breadth three and a quarter inches.

This form is found in deep water from Monterey to San Diego.

Japanese Abalone (Haliotis gigantea) Chem.

This native of Japan has emigrated along the course of the ocean current flowing by the Aleutian Islands and has reached the central part of California. In spite of its specific name and primitive size our specimens do not measure above five inches long. The shell is elongated, narrow, and with a more prominent spire, and four open holes. The nacreous is pearl-colored and iridescent.

1.8. DISTRIBUTION OF CALIFORNIA ABALONES

It is possible, from data in hand, to roughly indicate the present distribution and frequency of occurrence of the various kinds of abalones of commercial importance.

San Clemente Island.—During the years from 1898 to 1907 the Japanese fishermen gathered so many black abalones that the rocks of this island are cleaned off, except in a few localities. The green and corrugated abalones have been taken by Japanese divers from Howlands, at the northwest end of the island, to the northeast extremity. Thus virtually the whole of the north side has been denuded, and this is also true of the south end. From the southeast point to near the southwest end there are not enough green and corrugated abalones for a profitable fishery.

Santa Catalina Island.—The southeast part of Santa Catalina Island, around Avalon, has been stripped of black, green and corrugated abalones within twenty years. Now the shells brought up by the divers of the glass-bottomed boats and eagerly bought by the tourists are previously placed in position by the enterprising management. From the isthmus around the northwest end of the island and along most of the southwest side, black, green and corrugated abalones are found in considerable numbers, especially along the more inaccessible, steep, rocky cliffs.

San Nicholas Island.—Formerly, the black abalones were abundant upon the rocky coast of this island; but within the last five years, nearly all of commercial size have been removed. During the period of the occupation of this island by white men, neither green, corrugated, nor red abalones have been found. Large shell heaps of red and black shells show clearly that the ancient Indians gathered large numbers of

the mollusks. Some of these shells measure twenty to thirty inches in circumference.

Santa Barbara Island.—Black abalones are found only in the less approachable parts of Santa Barbara Island. The green and corrugated abalones have all been removed from these waters, except within the half mile on the southwest point of the island, which is almost inaccessible. A Japanese crew began fishing at this point this year, but gave up the attempt because it was too rough to work with success.

Santa Cruz Island.—Most of the black, green and corrugated abalones had been taken from Santa Cruz Island by about 1898. In 1911, the Japanese diver, Yokayama, worked here fourteen days and was obliged to retire from the field because of the lack of abalones. There are now many small black abalones around this island.

Santa Rosa Island.—Santa Rosa Island is owned by Vail and Vickers, who raise cattle and lease the abalone fishery to Chinese crews. Black abalones are taken, but only a few of the red species are to be found at the northern end of the island.

San Miguel Island.—There are many black abalones of commercial size along the north side and the northwest end of San Miguel Island, but this coast is too rough for the landing of fishing boats. The abalones gathered must be carried across the island and thus the fishing here is not profitable. In 1909, there were numerous black abalones, of from four to ten inches in circumference, along the south side of San Miguel. There are only a few red abalones along the south and northwest coasts and it is too rough for collecting.

Mainland.—There are only a few remote localities along the rocky cliffs skirting San Pedro Hill, between Redondo Beach and San Pedro, in which black abalones are found in such abundance as was the rule along the coast a quarter of a century ago. Some of the more favorable places are the rocky points between Portuguese Bend and Point Vincente, along the rocks of a great ranch closed to outsiders and thus not often visited by beach walkers.

The government breakwater at the entrance to San Pedro harbor is well stocked with black abalones. In Orange County, where local laws have protected the abalone, many are still to be found. Off San Juan Point the green abalones are in such numbers as to constitute a valuable fishery. They are gathered in water from eighteen to fifty feet deep.

To the northward of the Santa Barbara Islands many red abalones are gathered from the sea—near Santa Barbara, San Simion, Cuyucos and Monterey. The localities near these ports have been denuded by Japanese fishermen, until now they work in the deeper and rougher waters of the more inaccessible places.

Many persons connected with the abalone fishery and manufacture have shown me courtesies. I wish to thank all of them and especially to mention my indebtedness to Mr. C. B. Linton and Mr. J. A. Yeomans of Long Beach and Mr. J. H. Oliver of Los Angeles.

2. THE TOWING OF SALMON AND STEELHEAD FRY FROM SACRAMENTO TO THE SEA IN A "LIVE CAR"

By N. B. SCOFIELD, *Special Assistant.*

The experiment of carrying salmon and steelhead. fry from Sacramento to the sea in a "live car" was made chiefly to determine whether or not there is any condition of the water at or below Sacramento that will prevent the safe planting of young fry at the Sacramento station. Upon one occasion salmon eggs were placed in river water at Sacramento and they promptly died; it was therefore feared by some that fry liberated at the same point would share a like fate.

The experiment also furnished an opportunity to hold the fry for some time in salt water and thus determine whether they can exist in full strength sea water continuously, without its being necessary for them to return occasionally to water less salt before they finally remain at sea.

A small "live ear" was constructed from a pine box, 20 by 32 inches, and 16 inches deep. The bottom and two sides were open, and covered with wire netting; the top had a tight cover. After placing the car in the water, we put in 400 Quinnat salmon fry, averaging 1# inches in length, and 100 steelhead trout fry, averaging 1# inches in length, and started from Sacramento at 11 a. m. on May 10, 1912.

From Sacramento to Rio Vista we drifted mostly with the current. From Rio Vista down we had to tow the car on account of windy weather and rough water.

The first brackish water was encountered near Army Point, Suisun Bay, on May 12th. At night on that date, at Vallejo entrance, the salinity of the water was 2 per cent of a saturated solution, at high tide.

On May 13th, near Rodeo, San Pablo Bay, the salinity increased to 3 per cent. The temperature of the water after leaving Sacramento had fluctuated between 61° and 63° F.

At Point Pinole, at 12 m., the salinity of the water was 5 per cent. In the tide rifts off Point San Pablo, at 1:15 p. m., the salinity varied between 6 and 8 per cent. West of Red Rock, at 2 p. m., it was 9 per cent, and in Raccoon Straits, at 3 p. m., it suddenly increased to 10 per cent, while the temperature dropped from 61° to 57°. At Tiburon, at 6 p. m., salinity 11 per cent, temperature 58°; at 9:45 p. m., at about high tide, the salinity was 10 per cent and the temperature of the water 56°.

On May 14th, at Tiburon, at 7 a. m., salinity 10 per cent, temperature of water 56°; at 9:30 a. m., salinity 11 per cent, temperature of water 58°, at nearly high tide. At Sausalito, at 10 a. m., salinity 13 per cent, a few minutes later dropping to 11 per cent. Off Point

Diablo, salinity 14 per cent, temperature of water 54°; off Point Bonita, at 11.40 a. m., salinity 13 per cent, and the tide beginning to run out.

The return to Sausalito was made, towing the "live car" against a rough "weather" tide. At Sausalito the car was kept tied to a mooring until June 15th. The water during all the intervening time varied from 10 per cent to 13 per cent of a saturated solution. The fry were fed ground liver or beef twice each day after leaving Sacramento.

During the one month that the fry were held in salt water, the total loss from all causes was 9 per cent for the salmon and 55 per cent for the steelhead. Most of the loss of steelhead (about three quarters) occurred during the night of the 14th of May. One half of the loss of salmon fry occurred during the first two days, in fresh water.

The average length of the salmon fry at the start was 1# inches. On June 15th they averaged 2#, a gain in the month of nine tenths of an inch. This gain is greater than occurs among salmon fry in the upper Sacramento River.

The steelhead averaged at the start 1# inches and at the end of the month their gain was slightly less than one half an inch.

On leaving Sacramento the membranous flap of the opercle, or gill cover, of the salmon fry did not quite cover the gills. At the end of the month in salt water the gills were entirely covered, and the fry strong and apparently healthy in every way. Fry taken to Brookdale Hatchery by Mr. F. A. Shebley, and kept in fresh water, also recovered from this exposed gill condition within the month.

The salmon fry had been marked by removing both ventral fins. In only one case did the fins start to regenerate. In this one case three inner rays of one fin grew out.

In the trip down the river and bays a gauze tow net was used to determine what kind of food there was present for fry to feed on. A plenteous supply of land insects was found floating on the surface of the water, and they were especially abundant on Suisun and San Pablo bays. So it was evident that the fry would not be obliged to change their habit of surface feeding until well out in salt water. In Suisun Bay and as far down as Vallejo "channel" small crustaceans, especially young shrimp, were numerous, swimming on the surface of the water. Quantities of these were given to the fry and they devoured them greedily. The crustaceans that exceeded one inch in length were too large for the fry to eat. The fry would strike at them repeatedly as they swam about on the surface, but they could not catch them in the mouth. These small crustaceans were not observed in San Pablo Bay, nor were they found after passing through it, either swimming upon the surface or below it.

3. THE PROBLEM OF THE SPINY LOBSTER (Panulirus interruptus)

By BENNET M. ALLEN, *University of Wisconsin.*

Four years ago the spiny lobster supply of our waters had become so seriously depleted that the legislature passed a measure prohibiting the capture of the spiny lobster for a period of two years. During that time our markets were supplied from Mexican waters. On September 15, 1911, the capture of spiny lobsters was again permitted by the terms of a measure passed at the preceding meeting of the legislature. According to this law, the open season lasts from September 15th to February 15th, a duration of five months.

The purpose of the two-year closed period had been to permit the spiny lobster to increase unchecked, in order to replenish the supply. Apparently this object was attained, because spiny lobsters were very plentiful during the season 1911–12. It is difficult to make any kind of estimate regarding the amount of increase in supply because we have no data regarding the catch prior to the closed period. Market quotations and the general opinions of both fishermen and dealers point, however, to a decided increase in the catch in 1911–12, as compared with the catch in 1909–10. A disturbing element in our comparison is found in the fact that with the reopening of the spiny lobster fishery, the size limit was changed from the older limit of 11 inches to 9½ inches, *i. e.,* while in the older law fishermen had been prohibited from taking spiny lobsters less than 11 inches in length, our present measure prohibited the capture of those less than 9½ inches in length. As a result of this change it will be seen that a large part of the increased catch was due to the change in the law permitting the capture of smaller spiny lobsters than before. This is well illustrated by consideration of certain typical catches, as shown in the accompanying table:

	Per cent of total.
Catch 1.	
Anacapa Island, November 6, 1911. 24 spiny lobsters.	
Total weight of catch, 34.2 pounds.	
Weight of specimens under 11 inches, 12.8 pounds	37.5
Weight of specimens under 10½ inches, 8.4 pounds	24.6
Number of males over 14 inches, 0, 0.0 pounds	0.0
Number of females over 13 inches, 2, 4.5 pounds	13.2
	37.8
Catch 2.	
Santa Barbara, November 12, 1911. 84 spiny lobsters.	
Total weight of catch, 179.0 pounds.	
Weight of specimens under 11 inches, 20.7 pounds	11.7
Weight of specimens under 10½ inches, 11.4 pounds	6.4
Number of males over 14 inches, 11, weight 49.8 pounds	27.9
Number of females over 13 inches 9, weight 25.3 pounds	15.3
	49.6

Catch 3.

Soledad Bay, Lower California, Mexico. 66 spiny lobsters.

Total weight of catch, 88.8 pounds.

Weight of specimens under 11 inches, 55.7 pounds	62.7
Weight of specimens under 10 ½ inches, 30.5 pounds	34.3
Number of males over 14 inches, 0, weight 0.0 pounds	0.0
Number of females over 13 inches 2, weight 5.3 pounds	6.1
	40.0
Total number of spiny lobsters recorded	174

In order to understand the decided difference in these three tables, it may be well to state that catches one and three were made in shallow water. They consequently show a large percentage of medium sized and small specimens. Catch two, on the other hand, was made in deeper water, of from 15 to 25 fathoms depth. As a rule large spiny lobsters are more common in deep water than in shallow water. These tables show how different the range of sizes may be in different catches. The high percentage of small specimens shown in catch three is often equaled or exceeded on our coast, for instance at San Juan Point and around San Clemente Island.

While these observations are too few to give us an accurate idea of the degree to which the increased catch of the past season is due to the lowering of the size limit, they at least are strongly suggestive of the part played by this factor. Since the greater part of the fishing operations are carried on in water less than 12 fathoms deep, it would be fair to conclude that from 30 to 40 per cent of the increased catch was due to the lowering of the size limit.

The natural increase of the spiny lobster during the closed season, together with the reduction of size limit and the extensive fishing operations, induced by the high expectations of the fishermen, combined to glut the market. The result was that fishermen and dealers made no more money on the catch than usual, and that many inexperienced fishermen suffered serious loss because of the ruinously low price offered. The price ranged from three to nine cents per pound to the fishermen, while it had ranged twice as high before the closed period had been established.

While this condition of the market was favorable to the consumer, the benefit will be short-lived because of the depletion of the supply that is entailed. The spiny lobster is essentially a luxury. Our supply must be carefully conserved. *This should be done steadily and consistently rather than by alternate drastic and mild legislation.*

I recommend that the minimum size limit be raised to 10 ½ inches; *i.e.*, that it be made illegal to take spiny lobsters less than 10 ½ inches in length exclusive of legs and feelers.

I further recommend that a maximum measurement be set, in order to protect such individuals as may have grown to exceed that limit. It has for years been a matter of common observation among fishermen that

the amount of spawn carried by a female is directly proportional to its size. A few careful observations of my own verified this view:

Length of spiny lobster.	Weight of spawn.
8 inches	5.115 gr.
9 ¾ inches	13.422 gr. (average of 3 specimens)
13 ½ inches	52.930 gr.
14 inches	67.845 gr.

A more extensive series would be very instructive, but these show sufficiently that the larger spiny lobsters carry many times more eggs than do the small ones. The three 9 ¾ inch specimens, from which the average was made, carried almost equal amounts, the difference coming under one gramme. This line of argument would probably apply to the males as well as to the females. We do not yet know what proportion of males must be preserved in order to insure proper fertilization of the eggs. In nature the sexes occur in practically equal proportion, as shown by extensive records of the catch.

Reference to a preceding table will show in catch two a larger number of males 14 inches and more in length than of females 13 inches in length. So few specimens that had attained these measurements were included in catches one and three, that they have no value in this connection. It is common knowledge among all who have handled the spiny lobster that the males attain much larger size than do the females. Large spiny lobsters are not easily marketed. Dealers aver that they can not handle these large specimens in any considerable number; they would much prefer not to handle them at all; the public does not want them.

I recommend that it be made unlawful to take spiny lobsters exceeding 13 ½ inches in length exclusive of legs and feelers. The recommended change in the minimum size limit and the imposition of a maximum size limit would thus reduce the catch by 40 to 50 per cent of its present amount, as will be seen by referring to the table of catches. Such a reduction would not be injurious to the market because it would exclude only the less desirable grades of lobsters.

The following table of sizes and weights, having been compounded from records of the weights and the lengths of 150 spiny lobsters, will be of value in this connection:

Average Weights as Compared with Size.

Length.	Male.	Female.
9½ inches	⅞ pound	⅞ pound
10 inches	1⅛ pound	1 1-16 pound
10½ inches	1¼ pound	1⅛ pound
11 inches	1½ pound	1⅜ pound
11½ inches	1¾ pound	1⅝ pound
12 inches	2 pounds	1¾ pound
12½ inches	2¼ pounds	2 pounds
13 inches	2⅝ pounds	2¼ pounds
13½ inches	3 pounds	2½ pounds
14 inches	3½ pounds	2¾ pounds
14½ inches	4 pounds	3 pounds

It will be seen that the females do not weigh quite so much as do the males of the same length. The parallel lines drawn across this table indicate the limits in size, between which it is suggested that the capture of the spiny lobsters should be made lawful. Observations have shown that only about one third of the gross weight of the spiny lobsters is made up of edible meat.

The lessening of the supply by the imposition of further limitations upon the size, would not materially affect either fishermen or dealers because of the increase in price that would be certain to follow; it is the consumer that would be directly affected. These recommendations are made with chief regard for the ultimate interests of the consumer. A continuance of the heavy catch of last season must inevitably soon make it necessary to again impose a closed period of two years or more, to enable the fishery to again rehabilitate itself. The public would then be forced to depend upon the supply from Mexico, which can be bought only at a very heavy increase over the price for the catch of our own waters.

In France, Spain and Italy, where allied forms of the spiny lobster occur, and where formerly lobsters were very abundant, they sell at much higher prices than have ever been asked for them in this country. The true lobster of our Atlantic coast has had a similar history; once extremely abundant and very cheap, it is now quite the reverse.

It has not been many years since the spiny lobster was sold by the fishermen along our coast for one cent per pound; now they will not catch them for less than three cents. Interesting accounts are given of their former abundance. The supply has become greatly depleted, this being especially evident in some places. Santa Catalina Island furnishes a good example of how a coast splendidly adapted as a habitat for these crustaceans, and formerly abounding in them, has become so depleted by intensive fishing that the fishery is no longer profitable there.

It is to be expected that the further restriction in the size limit here recommended would make it appear that the species was being rapidly depleted. This would be especially marked in the course of three or four years, when the depletion due to the fishing operations would have made spiny lobsters of legal size relatively scarce. In that short time the protection of large spiny lobsters for purposes of propagation would not have had any visible effect. It would probably require eight or ten years for these measures to vindicate themselves.

Wise, consistent conservation of the supply will, in the long run, benefit the consumer. Exactly the same principles apply to the conservation of our fish as to the conservation of our forests. This is peculiarly true of such a strictly localized shallow water animal as the spiny lobster. While a few may escape the range of fishing operations by frequenting deeper water than usual, isolated patches of rocky bottom, or the coasts of islands exposed to heavy winds, the great bulk of them are especially liable to capture.

3.1. EXTENT AND LIMITS OF THE OPEN SEASON

It would work a decided hardship upon the fishermen to shorten the open season. There are over 200 men engaged in the spiny lobster fishery. A large proportion have little other remunerative work, being in a sense specialists in this one line of fishing. It is a calling that requires a considerable amount of skill and experience. The complete prohibition of the capture of the spiny lobster for a term of years would be a great hardship for many of these men, and should be imposed only as a last emergency measure after all other measures have failed. A reduction of the open season differs from complete abolition only in degree.

The cost of outfitting for a fishing season is quite considerable. The fisherman must procure a tent or shanty and provisions and bedding must be provided. The lumber for the construction of his traps and boats is expensive, and the labor of constructing them is a large item. (An able bodied man can make two or three traps per day.) Each trap requires from 60 to 100 feet and often 150 feet, or even more, of three quarter or one inch rope; so that if the fisherman has, say, 25 traps, the rope, too, is a heavy expense. Usually both traps and ropes must be provided anew each year; often they must be transported for quite a distance; thus it seems that the present season of five months is, at best, but short to justify this extensive outlay of money and labor, by way of preparation. I, therefore, emphatically protest against any suggestion towards shortening the open season.

Certain changes should be made in the dates set for the beginning and the end of the open season. The season opens while the spiny lobsters are in shallow water. According to the accounts of practically all the fishermen, there is later a movement into deeper water. During the first two weeks of the 1911–12 season the catch was very large, much larger than the markets could handle. Many dealers turned away tons of spiny lobsters, to be dumped back into the water, or, as was more frequently the case, they held them in crates until they died. Useless waste of this kind cannot be too strongly condemned.

This surplus was due to the ease of capture and to the relatively small demand. It is just about the beginning of the open season that a large number of non-residents who have spent the summer in the State are returning to their homes, while the general movement of travelers to spend the winter here has not yet commenced. It is certainly not suggested that changes in the law be made for the benefit of these non-residents of the State; at the same time, it is true that our markets have difficulty in handling the catch of the first two weeks; and it is the lessened demand combined with the heavy supply that produces this difficulty.

One of the factors in the case of this over-production is the entrance into the work of a class of inexperienced "fair weather" fishermen who carry on their operations for a few weeks, to be later driven out by the first storms of winter.

Another disadvantage in the early opening of the season is found in the fact that the spiny lobsters die during shipment much more easily in warm than in cooler weather. I therefore recommend that the season open October 1st and extend to March 1st. This would make a more even balance between supply and demand, and would, in a large measure, prevent the destructive waste at the opening of the season.

A very few spiny lobsters are found to carry spawn during the month of February; but such cases are exceptional, the real spawning season not commencing until May. I recommend, however, that these few spawn bearing females be protected by law.

3.2. MIGRATORY MOVEMENTS OF THE SPINY LOBSTER

During the season of 1911–12, I carried on experiments in the vicinity of Santa Barbara and of Santa Cruz and San Clemente islands, to determine the directions and distances that the spiny lobster would traverse in a given length of time. While certain specimens were caught in the same place after a period of two months, others were caught at considerable distances from the points where they had been released. The maximum distance traversed was in the case of one individual that moved 9½ miles in twenty-eight days. Another went at a more rapid rate, having covered 6 miles in fourteen days. These results show how depleted fishing grounds may become replenished, and suggest the scheme of establishing permanent state preserves at different points along the coast. It would be premature to undertake such a measure at this time. I feel that other measures will suffice for the present. It may be found necessary to temporarily close the lobster fishery along certain ports of the coast. After replenishment had taken place in a district so treated, the fishery could be reopened there and closed at other stretches of the coast. This plan might simply serve to concentrate the many fishermen in the stretches of coast where fishing was permitted. It is not suggested that such a measure be adopted at present.

3.3. IMPORTATION FROM MEXICO

The proof of fairly extensive movements of the spiny lobster has suggested to some the idea that by prohibiting the importation of the spiny lobster from Mexico we would thus exclude it from our markets, where practically all the catch of Lower California is marketed. This would destroy the business of the concessionaires who operate the fisheries of that coast, and would thus result in the almost total cessation of the fishery there. According to this view, rather widely held, our own supply would be increased by migration from the Mexican coast. We shall not consider the question from the standpoint of our relation to Mexico, as we well might, but shall look at it from the standpoint of our own interests.

In the first place, is it probable that appreciable numbers of spiny lobsters migrate across the line from the Mexican coast into our own waters? It seems hardly likely that they would traverse the distance of

14 miles of sandy shore intervening between the mouth of San Diego Bay, the most southerly point where spiny lobsters are caught in our waters, and the Mexican line. They would readily work along such a space of *rocky* coast. We should expect it. The bottom along this stretch of coast, however, is free from rocks and would be quite unattractive to the spiny lobster.

There is a better reason, however, for considering measures prohibiting the importation of the spiny lobster unwarranted; that is, the fact that there is only one fishing camp of the Mexican company within 40 miles of the American line, namely, on the Coronado Islands. It is not at all likely that spiny lobsters would cross from the islands to the mainland, because of the depth of the intervening water. It must be admitted that spiny lobsters might now and then wander from Mexican waters into our own, but this must be of rare occurrence and no practical value should be attached to it.

The greatest practical argument in favor of the admission of spiny lobsters from Mexico is the fact that our markets can be supplied in no other way during the closed period. It would be unfair to deprive our consumers of their supply upon the problematic assumption that we might gain advantage from the migration of a few spiny lobsters into our country; then, too, a number of our citizens are each year employed by the Mexican company in its operations. We could find justification for excluding the Mexican variety only in case it could be shown that substantial quantities of spiny lobsters caught in our waters were illegally sold in our markets as Mexican spiny lobsters. Our present regulations are so stringent that it is almost impossible for this to be done without detection. Careful inquiry upon this point has failed to bring any such cases to light.

I recommend that there be no change in our law regarding the importation of spiny lobsters from Mexico, and that it be continued in force as at present.

3.4. LIMITING THE NUMBER OF TRAPS

Some fishermen operate a very great number of traps. This is especially true of aliens, particularly of Italians and Portuguese. A group of three or four men with a gasoline fishing boat will operate from 150 to 300 traps on a stretch of coast several miles in extent. This practice is very strongly condemned by fishermen and dealers who have the best interests of our fishing at heart.

Few American fishermen use more than 25 traps each, and this number is often used by two partners. It is difficult to operate properly a greater number of traps.

The problem of devising legislation to limit the number of traps would not be an easy one. It would be necessary for each fisherman to inform the fish and game commission of the general location of all his traps, and each buoy that indicates the situation of a trap should be plainly marked with the license number of the owner and a number indicating the position of the trap in the series. Stringent penalties should

be imposed to enforce the marking of the traps, also, that reasonable provision be made to insure the floating of the buoys upon the surface of the water. Sometimes the current or the kelp may carry the buoys under. The fishermen should not in all cases be held accountable for such accidents. Each fisherman operating traps should be required to state how he travels from his place of residence or camp to his traps. If he lives aboard a boat he should so state, giving the name of the boat. If he travels in the same boat with other fishermen, he should state their names. With these requirements to make the enforcement of the law possible, a proper patrol of the coast should be effective.

Each fisherman working alone should be permitted to use no more than 25 traps. Two adult licensed fishermen using the same boat should be limited to 40 traps. A party of men habitually traveling within 3 miles of their traps, in the same boat, should not be allowed to use in the aggregate more than 60 traps.

3.5. RECOMMENDATIONS FOR FUTURE WORK

I strongly urge that the scientific study of the spiny lobster be continued. The situation that confronts this fishery is a serious one; it involves the conservation of one of our best sea foods and the maintenance of an industry estimated to have a yearly money value to the State of over a quarter of a million dollars. Serious depletion of the supply will cause irretrievable injury to the industry. Not only should stringent regulation of the fishery be maintained, but means of artificial protection and propagation should be devised.

It will be well at this time to outline the lines of scientific investigation that should be followed in the work upon the spiny lobster.

1. Last summer a good start was made in experiments upon the artificial propagation of this animal. The greater part of the time was spent in the construction of necessary apparatus and the breeding season was very far advanced before any experiments could be carried on. These first few trials were unsuccessful but we hope to be able to carry them to a successful issue next summer. The problem is a very difficult one but must certainly be solved in time. The practical artificial propagation of the true Atlantic lobster (Homarus) was only worked out after nine years of experimentation. The problem that confronts us is similar in many ways, so that we can profit from this previous work. At the same time, the life history of our spiny lobster differs very greatly from that of the true lobster and we shall have to greatly modify the methods of artificial propagation. Prof. William E. Ritter, director of the Scripps Marine Biological Laboratory of the University of California, situated at La Jolla, has very kindly given us permission to carry on this work in the University laboratory. This laboratory is splendidly equipped for such work, and we shall have ideal conditions for the continuance of these investigations.

2. The experiments upon the movements of the spiny lobster in the vicinity of Santa Barbara and the neighboring islands should be extended along all the coast south to the Mexican boundary and to the

cutlying islands. Such extended work will not only give us a clearer idea of the movements of this animal, but will give other valuable information as well. The method followed is to affix numbered tags to captured spiny lobsters and to return them to the water. Arrangements are made with the fishermen for the return of these tags, with a report as to the date and place of capture whenever such lobsters are re-caught. Twenty-six reports of this kind were made last year in connection with our work at Santa Barbara. By this means we would be enabled to roughly estimate the number of spiny lobsters in our waters from year to year, and could determine whether our supply is diminishing or increasing as a result of legislation passed. This estimate can be made by determining the proportion of tagged lobsters caught and computing the total number at large by applying this ratio to the total catch of the season.

3. It is very necessary that we have accurate data from year to year regarding the size of the catch.

4. The exact limits of the breeding season should be determined. We have not sufficient data in regard to the commencement of the breeding season, nor the time when it is at its height.

5. Experiments should be made to determine the proportion of males and females necessary to insure fertility of the eggs. This could be done easily by confining different proportions of the sexes in large live-crates at the beginning of the breeding season.

6. There is a strong belief among fishermen that the spiny lobster has special breeding grounds. A study of this question should be made, and, if feasible, such sections should be mapped out, and measures taken to prevent fishing in such localities.

7. Scientific work should be carried on through a period of years, to determine the rate of growth of the spiny lobster.

8. The spiny lobster does not thrive north of Point Concepcion. It would be of very great importance to determine whether the temperature conditions are equally unfavorable to the larval and adult stages of life. If they are unfavorable only during larval development, it might be possible to greatly extend the scope of our commercial fishery by introducing to the coast north of Point Concepcion young fry artificially propagated in hatcheries south of that point. Such measures might prove to be of large commercial value, since food conditions along the northern coast are certainly favorable.

There are very many other less directly practical investigations that should be made; as, for instance, a study of the parasites and enemies; study of the length of time that intervenes between the periods of shedding the shell; and many points regarding habits and structure. Some of these questions might prove, too, to be of great practical value.

It is very obvious that the investigations outlined above would demand the continuous work of a trained scientist through a considerable period of years. In view of the serious outlook for the future of the fishery, and its large commercial importance, appropriations for such investigations are imperatively called for.

4. INVESTIGATION OF THE CLAMS OF CALIFORNIA

By DR. HAROLD HEATH,

Department of Zoölogy, Leland Stanford, Junior, University.

In response to conflicting and usually unfavorable reports concerning the cultivation of claims of economic importance, an investigation has been in progress during the past eighteen months, during which time practically all of the beds of the State have been examined. The several elements comprised within this inquiry are (*a*) the extent of the clam beds, (*b*) the nature of the bottom, temperature, salinity, etc., (*c*) the food supply and the factors affecting it, (*d*) the breeding habits and season, (*e*) rate of growth and (*f*) enemies.

Each species of clam is adapted to a fairly definite set of surroundings; for example, the Pismo claim (Pachydesma stultorum) flourishes in open sandy beaches, while the soft shell or mud clam (Mya arenaria) is at home in sheltered muddy bays, and it may be added that this fact must be kept in mind if transplanting is to be made a success. Furthermore, the food of all clams, mussels, oysters and their kind consists invariably of microscopic animals and plants or minute fragments of larger organisms, which are borne within the shell. It thus becomes apparent that while the wastes discharged from cities and towns may not directly seriously disturb clams or fish, they may destroy the much more delicate organisms on which these larger animals subsist and so vitally affect the fishing industry. Without much doubt this is now an important factor in various localities.

Generally speaking, the California molluscs of economic value breed in the spring and summer. The resulting young are for a time free-swimming organisms, of microscopic size, that by means of tidal currents are usually distributed over wide areas. It thus may happen that beds perfectly adapted for certain species of clams may remain untenanted because of unfavorable currents. Under such circumstances transplanting may be done readily and profitably. If the fully developed clam belongs to a freely moving species any size may be used, but if it is a sedentary type, such as the mud clam, large individuals require to be planted with care, though the young, an inch or less in length may be sown broadcast like grain.

Constant digging up of clam beds probably does not injure freely moving species, but in the case of the mud clam or any species with a fixed abode, great damage may be done. These sedentary types have very slight powers of locomotion, and when buried by spade or boot heel very frequently are smothered before they are able to open communication through the mud. The value of systematic digging under such circumstances is obvious.

The rate of growth of molluscs, a very important item in the intelligent administration of the clam industry, has been found to vary enormously. Chiefly it depends upon the food supply. On certain experimental beds the Pismo, soft-shell and Tomales Bay (Tapes staminea) clams (the

last sometimes termed "cockle"), with artificially marked shells have been under observation for nearly three years. During the first year the Pismo clam attained an average circumference of 4 inches, which increased to 6 during the second year and to 8.25 during the following eleven months. While the evidence is not wholly conclusive, it indicates that this species is four years of age before it attains sexual maturity. The Tomales Bay clams showed a growth of 2.85 inches in circumference during the first year, of 4.75 during the second, while 1.6 inches were added during the next eleven months. It appears to breed at the close of the second year, though further observations must be made to settle the question. Experiments made on the east coast show that the mud clam may reach a length of three inches and breed within one year when favorably located. Judging from beds at various points in San Francisco Bay, the usual rate is about two thirds as rapid, so that the animal becomes sexually mature and of marketable size during the second year. Several other species are under observation.

It is well to keep in mind that these figures are not final; that another year's observations may increase or reduce them; but they do serve to show that considerable time is required to develop marketable clams, and that wholesale, irresponsible digging is probably largely accountable for the depleted condition noted in the case of many of the clam beds of the State.

In a state of nature favorable beaches may become so crowded with clams that these develop imperfectly; on the other hand, beds may be dug so relentlessly that the clams are in danger of extinction. Between these two extremes there is an optimum that is usually maintained where the land is owned by or leased to responsible parties who consider the future as well as the present. Since this policy cannot be carried out with clam lands in general, protection should be afforded the young clam through at least one breeding season. This secures the species against complete annihilation. Then, again, if the beds are the property of the State, the general public is entitled to the benefits. Granted that such is the case, the placing of a limit of 200, for example, on the daily catch of clams of legal size, insures the distribution of the annual catch among a larger number of people than where no limits are imposed. When such limitations are placed it does not appear necessary, for the present at least, to declare a close season.

In conclusion it may be said that the reports of a diminution in the size of many of the clam beds and in the number of clams on each is based on fact. A gratifying exception is found in the case of the mud clam, introduced years ago from the east, which is steadily gaining ground in San Francisco Bay. As the number of people within the borders of the State is constantly increasing, a proportional demand will be made for marine food products. Under such circumstances the protection of such animals is a necessity in many cases. This is certainly now true of the clams. With wise laws, and their just administration, there is no apparent reason why these animals should not continue to be a valuable asset of the people of the State.

5. INVESTIGATION OF THE LIFE HISTORY OF THE EDIBLE CRAB (CANCER MAGISTER)

By F. W. WEYMOUTH,
Leland Stanford Junior University.

I have the honor to submit the following report, consisting, first, of a statement of the work in progress; second, of a recommendation in regard to the extent and time of the closed season.

5.1. 1. PROGRESS OF THE INVESTIGATION

The present report can be regarded as only preliminary in character, as practically all of the work undertaken is still far from complete. Since December, 1910, when Mr. J. P. Babcock, then Chief Deputy of the California Fish and Game Commission, asked me to undertake an investigation of the life history of the edible crab, I have been engaged in following out this work; but with the exception of the summer of 1911, I have been able to devote to it only such time as was available from my University duties. Since at the inception of this work no data whatever was available in regard to the life history of the crab, the task has proved a considerable one, and the time at my disposal has been inadequate for its completion. I hope to present a full account of the various problems taken up at some future time, either in this or in other publications. At present only a brief summary of the work in progress can be given.

5.2. 2. IMPORTANCE OF THE CRAB FISHERY

The crab fishery of California is an industry of considerable importance, employing at San Francisco during the present year (1912) about 150 men during the open season of eight months and representing a net wholesale value of about $150,000 a year.

To the Californian who purchases his crab at twenty to thirty-five cents, it is a hint of the possible fate in store for his delicacy, that through depletion of the supply the price is already about three times what it was in 1880. Unless protected, the future history of the crab may be but a repetition of that of the lobster of New England, once more abundant than our edible crab, now so scarce that even with artificial propagation it brings thirty cents a pound in the shell.

5.3. 3. STUDY OF FISHING METHODS

It was thought advisable first to make a study of the methods of fishing and of the fishing grounds at various points on the coast; and to this end the writer accompanied some of the Sausalito crab fishermen (to whose coöperation he owes any measure of success he may have had in this direction) on fishing trips, at intervals of two to four weeks throughout the year 1911. In addition, a trip was made to Eureka in the spring of 1911; and Anacortes, the chief crab fishing port of Puget

Sound, was visited during a trip to Washington, in the fall of the same year. As a result, a considerable amount of data, including numerous photographs of boats, tackle and fishing operations, has been accumulated, and will be included in the final report.

5.4. 4. PRESERVATION OF MATERIAL

Since the inception of the work a series of specimens taken at short intervals has been preserved. The work of examining these, with the purpose of determining as far as may be the food, breeding season, molting or casting season, and similar information, is now under way.

5.5. 5. HABITS OF THE CRAB

The habits of the crab are difficult of direct observation, as these animals are found only in fairly deep water, and since at the present time no adequate aquarium facilities are available, the problem has had to be attacked by less direct means.

During the present summer the writer has been working at the laboratory of the United States Bureau of Fisheries at Woods Hole, on species of crabs related to the edible crab of the Pacific coast. A considerable series of experiments on the senses taking part in food-getting—smell, taste, sight and touch—has been carried out on several forms. These, supplemented by some observations made in San Francisco Bay, throw considerable light on the behavior of the crabs in entering baited nets, and have direct bearing on the kind of bait used.

Other habits having considerable importance in food-getting and protection from enemies, as burrowing and the peculiar manner of respiration necessitated by this habit, have also been studied.

5.6. 6. TAGGING EXPERIMENTS

Experiments in tagging and releasing crabs in order to study their movements, though only partially carried out, have given rather unexpected results. More striking than the movements recorded is the large percentage of tagged specimens recapturd. Of a total of 159 released crabs, free for less than a year, seventeen have been retaken by the crab fishermen. No more striking illustration of the exhaustive fishing near San Francisco is needed than this fact—one out of every ten of the tagged crabs has been recaptured in less than a year, although this period includes a closed season of four months. A little consideration of the significance of this fact will convince any one that the supply of crabs is far from inexhaustible.

5.7. 7. HATCHING EXPERIMENTS

Some experiments have been carried out and a study made of the methods used in lobster hatching in certain of the eastern states, with a view to determining the practicability of hatching the edible crab; and it is hoped that experiments may be prosecuted in the future on a larger scale, as the present trials have given promising results.

In connection with this, a study was made of the larval forms, a point

of considerable importance in view of the fact that it is probably in the early larval stages that the greatest destruction of crabs takes place, and that we know nothing of the habits, food, or enemies during this period. The two youngest larval stages—protozœa and first zœa—were obtained by hatching, and some specimens of a later—megalops—stage were obtained from floating driftwood. It is hoped to complete the series at a future time.

5.8. 8. RATE OF GROWTH

The allied question of the rate of growth of the crab has been studied in a series of small individuals which were reared through several molts, and though we still cannot tell the age at which a crab becomes of marketable size, yet the information thus obtained, together with observations on the young at various times of the year in San Francisco Bay, promises an early solution of this important question.

5.9. 9. MOLTING SEASON

Some interesting observations on the time and length of the molting or casting season were made in the fall of 1911, when a large number of catches of individual fishermen were tabulated as to the number of males and females, hard, soft and undersized individuals. It was found that in spite of the exclusive fishing of the males, brought about by protection of the females, the numbers of the two sexes were almost exactly equal. In this year it was found that by November 4th, the soft crabs, which on August 25th made up 77 per cent of the catch, had practically disappeared. This point is further considered in the recommendations for protective legislation.

5.10. 10. RECOMMENDATIONS FOR PROTECTIVE LEGISLATION

In making recommendations for protective legislation in regard to the crab it must be borne in mind that these suggestions are only preliminary in nature. Only about a season and a half of field work has been possible, and conditions vary from year to year. Nearly all of the work has been done on the San Francisco fishing grounds, and though this is the most important port, other localities should not be ignored. An even more serious defect is the lack of accurate statistical information in regard to the crab fishery. Unless we know exactly the state of the crab fishery—the amount of the annual catch, its value, the number of fishing boats and the amount of fishing gear,—not only for one but for a series of ten or twenty years, we are not in a position to know whether the fishery is being exhausted or not, and all statements of the condition are in the nature of guesses. Baird, the first United States Commissioner of Fisheries, and the man responsible for the farsighted plans on which is founded the national Bureau of Fisheries, after which most state fish commissions are modeled, says:

"Accurate statistical information is the one essential foundation upon which protective legislation must rest." I cannot too strongly urge that statistics, not only of this, but of all branches of the California fisheries, be collected, in order that in the course of time we may have

some firm basis on which to calculate the effect of protective measures. It is evident that since the considerable development of the fishery, a period of perhaps fifteen or twenty years, there has been a marked decrease in the abundance of the crab, though by intensive fishing both as regards a greater amount of gear and a greater number of men, the catch has not only been maintained but greatly increased. The growing scarcity is further shown by the increase in price. In 1880 the average wholesale price was 60 cents a dozen; in 1912, $1.50 and $2.00. For the current years, however, though as stated, exact figures are not available, there seems to be no alarming decrease. The fact shown by the tagging experiments, that crabs marked and released are recaptured at the rate of 11.4 per cent, or that more than one in every ten are taken in the course of a year, shows conclusively that we cannot afford to relax any of the protection now given to the crab. If further proof is needed we have only to consider the history of the lobster fishery of New England.

We are still in the position of conserving a natural resource, a task of comparative ease when contrasted with that of restoring it after it has been exhausted. Let us maintain our favorable position.

Legislation for the protection of the crab usually falls under one of the following heads: restriction of fishing methods, gauge laws restricting the size taken, protection of females, or establishment of a closed season. All of these measures have for their object one of three things: first, the prevention of the capture of the animal at a rate out of proportion to its numbers and natural rate of increase, which must eventually deplete the fishery; second, the prevention of fishing which interferes directly with the natural rate of increase (chiefly the capture of females and interference with the breeding season); and, third, the prevention of fishing at such times and in such manner as shall cause destruction of animals without their becoming available for food.

5.11. 11. THE BREEDING SEASON OF CRABS

In regard to the prevention of interference with the natural rate of increase, I believe that we have adopted the wisest course in the complete protection of the female crab. In the case of the lobster only the "berried" or egg-bearing female is protected; but as the maturing of eggs with the lobster as well as with the edible crab is a process extending over more than a year, even before the external eggs are hatched, ovarian eggs are present to the full number, and are of a considerable size; so it is obvious that the protection given the lobster is inadequate, the destruction of a female at *any* time involving the destruction of a potential brood—in the case of the crab, of from 750,000 to 1,000,000 young. The complete protection of the female is the only way of meeting this question. The present size limit of seven inches also insures that some breeding animals are undisturbed, as both males and females breed before this size is reached.

5.12. 12. PURPOSE OF A CLOSED SEASON

The purpose of a closed season is commonly twofold: first, the prevention of interference with the breeding season; and, second, the prevention of the too rapid depletion of the animal by restricting the time during which it may be caught.

In the case of the crab fishery conditions are, however, somewhat different from those found in the protection of most animals. Because of the long season during which the eggs are matured, a closed season is inadequate to protect the females, and, as we have seen, this question has been met in another way. Here, as elsewhere, the restriction of fishing must be considered. For this a closed season at any time of the year would be equally efficacious; its value depending not upon its actual length but upon the proportion of the fishing of the year which it prevented.

5.13. 13. MOLTING SEASON

One other fact peculiar to the crab must now be considered. At certain times of the year the crab molts, or casts its hard outer shell, increases rapidly in size for a time, and gradually hardens a new outer covering. While the shell is soft the crab is particularly vulnerable. At this time there is more danger of injury in handling the females and small males which are thrown overboard. Many large males too soft to market are also liable to injury, and of those hard enough to be kept, a much larger percentage die in transportation, both in the fishermen's boats and live boxes and in shipment to the wholesalers, than is common with normal crabs. Crabs taken when soft or only partially hardened are of inferior food value. Owing to changes in the tissues, incident to the rapid growth and the production of a new shell, the crab is light in weight and the flesh is watery.

From these considerations it appears that the chief factor which should determine the closed season is the molting period, or more exactly, the period during which soft crabs would enter the nets. In regard to this point I have obtained the following information: molting occurs in the vicinity of San Francisco at least as early as the middle of June, since on this date I have found recently cast shells washed upon the beach. In 1911 few crabs of any kind were taken on the bar during June and July, but in the early part of August the catch became large, owing to the presence of many soft-shelled crabs. This was apparently due to the fact that, for a considerable time after molting, the crab is too soft to enter the nets. By the first week of August they appeared to have become hard enough to feed, and since they had been unable to obtain the normal amount of food and at the same time had had abnormal demands in the way of tissue formation, they entered the nets in search of the bait, in unusual numbers. In 1912 crabs were not absent from the fishing grounds near San Francisco at any time during the summer. Soft crabs appeared in

large numbers several weeks later than in the previous year, or during the last week of August.

During the period from the last of August to November, 1911, I tabulated the whole or parts of sample catches made by some of the crab fishermen, in order to determine the proportion of soft-shelled crabs, six trips being made and over 1,500 crabs handled. On August 25th, of the male crabs taken over seven inches in breadth, 77.4 per cent were soft; on October 14th this proportion had fallen to 13 per cent; and on November 4th none was taken. The percentage of the males, over seven inches, hard enough to be marketable had meanwhile risen from 5.7 per cent to 72 per cent. These facts may be more conveniently shown in the following table:

	August 25.	September 2.	September 9.	September 16.	October 14.	November 4.
Total number of crabs taken	584	274	205	239	149	70
Total number of males over 7 inches	146	56	51	44	46	51
Percentage of males over 7 inches, hard	22.6	35.7	56.8	65.9	87	100
Percentage of males over 7 inches, soft	77.4	64.3	43.2	34.1	13	0

As the soft-shelled crabs appeared about three weeks later this year, it is probable that they remained soft about that much later than they did last year, or until the latter part of November.

As far as we have information for the years 1911 and 1912, it would seem, therefore, that a closed season extending from August 1st to November 15th would cover the period during which the vast majority of crabs are soft-shelled.

5.14. 14. CONCLUSIONS

I would therefore recommend, taking into consideration the meager information at hand in regard to the edible crab, that for the present closed season, November 1st to March 1st, a period of not less than three and a half months be substituted, extending preferably from August 1st to November 15th. This change is recommended for three reasons: first, though slightly shorter, I do not think it will decrease the amount of protection now afforded the crab, as during the months of December, January and February stormy weather will considerably reduce the actual number of fishing days; second, placing the closed season at the time when the crabs are soft-shelled will prevent the females and young from being caught in the nets (as now) at a time when injury might result from handling them; and, third, it will prevent the destruction resulting from shipping soft-shelled crabs, which are thus taken from the total available supply and yet yield no food; also the placing on the market of inferior crabs, which are not only a loss to the fishery but have little food value.

In case action is taken at this time, I also recommend that the present law remain in force until the expiration of the current closed season (March 1, 1913); otherwise the crab would be fished continuously for a period of seventeen months, from March 1, 1912, to August 1, 1913.

6. A GENERAL REPORT ON A QUINNAT SALMON INVESTIGATION, CARRIED ON DURING THE SPRING AND SUMMER OF 1911

By N. B. SCOFIELD,
Special Assistant.

The object of the investigation was to gain additional knowledge of the life of the quinnat fry in the Sacramento River and the bays at its mouth, by which it might be possible to increase the number of adult salmon running in the river.

The main object of the artificial propagation of fish is to improve on nature and get a larger number of fish from the eggs than is possible in the natural state. Fish that have the habit of protecting their eggs and young deposit few eggs compared with the salmon, which deposits an average of 6,000 eggs per female. The salmon, instead of guarding its eggs or young, simply lays more eggs and trusts to change that enough hatch and escape, without protection, to perpetuate the species. Artificial propagation comes in and takes advantage of this great number of eggs per fish, and by giving protection, which in nature they do not get, strives to increase the production many fold. Hatching methods under skilled fish culturists have reached a high state of perfection and the hatcheries now turn as high as 90 per cent of the artificially spawned eggs into healthy fry. But the results of artificial propagation, *judged by the return of adult salmon to the river*, do not look nearly so good. It is a difficult matter to accurately determine the results of artificial propagation, but it can be shown that great accuracy is not needed to determine that the results are not what they should be.

Ten years ago Mr. Cloudsley Rutter of the U. S. Fish Commission, specially detailed to investigate the salmon of the Sacramento, made a report giving the results of all work up to that time. This report, entitled "Natural History of the Quinnat Salmon," was published by the U. S. Commission of Fish and Fisheries in 1903, and in it can be found about all that was known of the Sacramento salmon at that time. In speaking of the artificial and natural propagation of salmon, Mr. Rutter states what he thinks are the approximate values of natural and artificial propagation. Up to the free swimming stage of the fry he gives the natural loss as 99 per cent, with the loss under artificial propagation as 13 per cent. At the free swimming stage they are liberated from the hatchery. In the investigations which he reports, no appreciable loss of fry was discovered after the free swimming stage was reached.

In the days before salmon on the Sacramento were fished for by white men, the fish had probably reached a sort of balance and were holding their own. From each 6,000 eggs deposited by an average female, it would be only necessary, to preserve the balance, for one adult spawning pair to result. To be well within the truth we may say, if one egg in a thousand resulted in a spawning adult, the balance would be preserved.

We do not usually realize what a difference there is in a state of nature, between the number of eggs spawned and the number of resulting adults. If we do not bear this in mind we are apt to be misled when trying to determine the efficiency of artificial propagation. If only 1 per cent of the fry liberated from the hatchery return as adult salmon, the results would be several times better than if the process had been left to nature. This discrepancy between number of eggs and the number of adult salmon gives almost unlimited room for improvement. Further improvement will have to come along the line of better protection of the fry, either by holding them longer in protected captivity or by liberating them in such a manner that they will not be exposed to so many dangers. We will give artificial propagation the credit of producing as many adult salmon as are annually caught, and leave to natural propagation the credit of producing as many adults as escape the nets and are not caught. An error in this statement we believe is in favor of artificial propagation.

As near as we can get at it from statistics gathered as to the salmon catch, the number of adult salmon taken on their run up the Sacramento, and on Monterey Bay combined, is no more than 1 per cent of the fry liberated from the hatcheries. This does not mean that the artificial propagation of salmon is doing no good, as explained above, but it does show that there is room for improvement. If only 1 per cent more of the fry, being liberated, could reach maturity, the run of adults would be increased 100 per cent. So that any slight additional protection to the fry would be richly rewarded.

Obviously the field for improvement lies between the time the fry leave the hatchery and the time they are beyond our protection in salt water. Also it is evident that we can not intelligently give this additional protection without pretty thoroughly knowing the habits of the fry and their dangers after leaving the hatcheries. It was the object of the investigation to gain this knowledge. It is often argued that the Sacramento River is holding its own, or that the salmon in it are increasing in numbers, for the statistics show a gradually increasing catch. But statistics are apt to mislead us. Up to a certain point it is possible for the catch to increase while the total number of salmon running may be steadily decreasing. Within a few years the number of boats fishing for salmon, on our river, has more than doubled. The demand for salmon has increased, and the fishermen fish harder and better, and the number of fish that escape the nets is smaller than in years past. This is shown by the fewer salmon appearing on the

spawning beds. We can not be sure that the salmon is holding its own. So when it was realized that probably less than 1 per cent of the salmon fry liberated from the hatcheries return as adult fish, it was decided that the best method of improvement lay in finding out if some of this great loss did not occur in their trip down the river, and if such loss was found, to devise some means of overcoming it and getting them to salt water with as little loss as possible.

Our work as first outlined was:

First—To find out what we could about the fry in San Francisco and upper bays; and find at how early an age they could take the salt water. The object, to make use of knowledge gained to liberate the fry in the bay and thus cut out the river trip if thought necessary.

Second—To find out what loss there is, if any, through being devoured by other fish, especially by black bass on the lower river and by trout in the upper river.

Third—To determine the loss of fry resulting from their being swept into irrigation ditches along the route.

Fourth—To be prepared to investigate any other cause of loss that should come to our notice.

Our plans were materially changed in April, when we discovered that great numbers of salmon fry are lost during high water, by being caught in overflow ponds, where they become stranded as the water recedes. Our work was then confined to the overflow basins known as Yolo and Sutter basins. The American Basin and Butte Sink, which receive much water from the Sacramento in time of flood, were not investigated, for we had not the time or a sufficient force.

Another cause of loss discovered was the high temperature of the water. When the temperature of the water gets near 83 degrees F. the salmon fry die; so that even in the larger ponds and lakes where they are left by receding water, they cannot live until the next winter. There is probably a considerable loss of fry in the lower river itself on account of high temperature. The water in Sutter Basin reaches a temperature of 80 degrees F., or more, and the loss of fry within this basin may be very great. In isolated or land-locked ponds we could, on visiting them at intervals, observe the rapidly diminishing numbers of fry, and their complete disappearance as the water rose in temperature.

These great overflow basins receive most of their water from the river during the months of January, February, March and April, and occasionally for a longer period. The run of salmon fry down this part of the river, on their way to the sea, coincides almost exactly with the flooding of these basins. The floods began in January and reached their highest the latter part of February. The water gradually fell, but came up again about the first of April. The floods were not extraordinary, but about what is expected each winter.

We did not get on the ground until about the middle of April, after the main part of the fry had passed; but we were in time to find large

numbers still passing into the basins; and also to find ponds left isolated after the first and highest water, which still contained large numbers of fry. In the latter part of April and in May, as the water was receding, we found many fry being left in the ponds. We kept these ponds under observation and those that did not dry up entirely got so hot that the young salmon could not live.

6.1. DESCRIPTION OF THE BASINS WITH WORK DONE ON EACH

Butte Sink lies along the east side of the Sacramento River, extending north from the Marysville Buttes. It is 20 to 25 miles in length and 5 to 10 miles wide. While it gets a great deal of water from the back country through Butte Creek, it takes a large amount of water from the river during high water through what is known as Moulton's Break, about 12 miles above Colusa. At its lower end it drains into Butte Slough, which empties into the river a few miles below Colusa.

Sutter Basin joins on to Butte Sink at Butte Slough and continues sough along the east side of the river for over 40 miles, until the Feather River is reached at its junction with the Sacramento. This basin averages about 5 miles in width, and contains nearly 200 square miles of water during flood time. It takes water from the Sacramento through Butte Slough at its upper end, and through the Tisdale Weir located 6 miles below Grimes. Tisdale Weir is an easement built by the government to relieve the river by letting the water run into the Sutter Basin after a certain height is reached. This weir is 1,200 feet long and at the highest water in February the stream passing over it was over 6 feet deep. The water continued flowing over the weir, until the middle of June.

Butte Slough takes about as much water from the river as the Tisdale Weir, and water continued to flow through this slough until about July, when the river falling, water from Sutter Basin and Butte Sink began flowing back through the slough into the river again.

The basin is drained at its lower end by Sacramento Slough, which empties into the river less than a mile above the mouth of Feather River. During the time of flood Sacramento River is backed up by the floods from Feather River, so that its east bank in the neighborhood of Sacramento Slough is deep under water, and Sacramento Slough can only be located by an opening in the trees which line the banks at this place. While the Sacramento is high there is little or no water coming from the basin. As the river falls the water in the basin falls and finally the outlet is confined to the narrow Sacramento Slough, which is so small that before the lower end of the basin is drained the shallow water has become so hot in the sun that the fish are killed. Even the carp die by the thousands. We learned from fishermen and residents at Vernon, near by, that when the temperature of the water in the basin reaches sufficient height, fish are killed in myriads, and float out through the slough and down the river. Deputy Geo. Neale of Sacramento tells us he went into the slough at such a time and the stench from the dead

fish was too much to stand. This takes place annually in the first part of summer. We did not remain on the river long enough to witness it, as the temperature of the water at the time we left was already so high we were positive all salmon fry had perished.

About halfway up the Sutter Basin and near the town of Kirkville, on the river, there is a raised piece of ground crossing the basin, the western end of which is known as Cole Grove Point. As the water in the basin falls it ceases running over this raised part, and the whole north end of the basin is left a land-locked lake, with no outlet. The temperature of the shallow water increases rapidly and all fish that cannot withstand a high temperature perish.

We fastened our trap nets in Sacramento Slough, but could not find a single salmon fry coming out. With our nets we found that many fry continued to enter the basin by Tisdale Weir and Butte Slough as long as water flowed in. In ponds left along the edge of the basin in the vicinity of Butte Slough, Tisdale Weir and opposite Knights Landing, we found many salmon fry, all of which died as the temperature rose. In the deeper ponds or lakes left isolated in June after the water had receded still further, we found no salmon fry. It is our belief all fry had perished in the warm water before these lakes became isolated. We had expected to find great quantities of the fry in these larger ponds when the water receded so we could get at them, but we had not counted on the water draining off so slowly or the water temperature getting so high. We failed to get any absolute proof of loss of fry in the basins, outside of the ponds we first seined along the edges of the basins. The high temperature reached by the water was a factor we had not counted on. Such absolute proof will be hard to get, even now that we know much more what we have to contend against, for a fish on the first signs of distress would be picked up by the fish-eating birds that hang about these basins in large numbers—herons, gulls, shags and pelicans.

Yolo Basin lies on the west side of the river, and extends from Wood's Break, 3 miles above the mouth of Feather River, to Cache Slough, 3 miles above Rio Vista, a distance, in a straight line, of about 35 miles, and more than double that by the river. The basin, when flooded, contains between 300 and 400 square miles covered with water. It receives water from the back country, but when the river is in flood most of its water comes from the river. Beginning at the north end, it receives water through Wood's Break, three miles above the mouth of Feather River. This break is permanent and has been there for many years. It takes water from the river through the winter and did not stop flowing in 1911 until late in June. When the river is high it carries an immense quantity of water; and when the water from Feather River backs up, it takes much of the water descending the Sacramento at this point. Below this, Big and Little Butcher breaks, which have now been open several years, also divert an immense quantity of water from the river into Yolo Basin. Farther down and within 15 miles of Sacramento is the Elkhorn Weir, an easement put in by the Government. This is

about 900 feet wide and takes much water from the river. It ceased running about the middle of May. Below the Elkhorn Weir and in the vicinity of Elkhorn are six breaks, some of them quite large. They continued running until in June.

The Yolo Basin is drained at its south end principally by Cache Slough and tributaries. There is more of a current through this basin than in the Sutter Basin, and there is something of a defined channel through it when the water is low along the line of the old "Tule Canal," which was put in years ago to carry off the waters of Cache Creek.

We found great numbers of salmon fry being swept into this basin at the weir and the breaks. We also found large numbers coming out of the basin into Cache Slough. In June the temperature of the water in the basin reached a point too high for salmon fry to withstand. No fry could be found coming out of the basin after June 1st, although they continued to enter the basin at the upper end until the middle of June. Later we visited the Big Lake within the basin and seined it thoroughly, but could find no salmon fry. The temperature of the water was above 80 degrees F. It seems almost certain that large numbers of fry were destroyed within the basin by high temperature of water,—in addition to the fry caught in ponds.

Many fry were found in ponds that afterward dried up. Most of these ponds were in the vicinity of Wood's Break at the upper end of the basin. Others were found in ponds on the west side of the basin near the head of Haas Slough, a tributary of Cache Slough. Many were also found along the east side of the basin opposite Sacramento and near Elkhorn and Butcher Breaks, also in ponds inside Elkhorn Weir. The fry were evidently well distributed over the basin. The loss even in the small number of ponds that we were able to get at and seine, around the edge of the basin, was very great.

The larger lakes within the basin yielded nothing, for by the time they could be seined, the water was so hot there was no chance of any fish being still alive.

The American Basin, which takes much water from the Sacramento, lies on the east side of the river between the Feather and American rivers. This basin was not investigated, but we learned from fishermen that great numbers of all kinds of fish are caught in the large lakes in the basin, where they are later seined out for the market. There can be little doubt that large numbers of salmon fry are caught within this basin, where they die before the lakes have receded to the point where it is possible to seine them. So that the fact that small salmon are not found by fishermen is not evidence they were not caught in the lakes, for they are not able to survive temperatures that the black bass, striped bass, pike, carp and shad can stand.

A young salmon descending the river at time of flood, which is the time they do descend, would, if it kept out of the basins, have to escape first the Moulton Break, above Colusa; then, in order,—Butte Slough, Tisdale Weir, Wood's Break, the two Butcher Breaks, Elkhorn Weir

and the six breaks below this;—to say nothing of the American Basin and breaks in the levee that occasionally occur above Colusa. It would seem that the great majority of the fry must be swept into the flooded districts. There is pretty good evidence that the fry, especially the smaller ones,—which make up the greater number,—travel close to shore; which fact greatly adds to their chance of going through the weirs and breaks.

Loss of Fry at Sisson.—It was found that the fry liberated from Sisson Hatchery, at the free swimming stage, are eaten in great number by the trout and summer resident salmon. We learned that at Baird large numbers of fry are there destroyed by trout at the time of planting.

Loss by Ditches.—Salmon fry continued descending the river until in June, so that all water taken from the river for irrigation or other purpose, is sure to contain young salmon, unless small meshed screens are used; and screens have not been used. The naturally propagated fry make up a very large per cent of the fry descending the river, so even if all fry from the hatcheries be released below these ditches, the fry from the natural hatch need protection. We did not investigate any of the ditches after they began taking water. Some of them begin irrigating in April, and all use water by June. These ditches should be investigated to determine if the number of fry entering is large enough to need protection by screen or otherwise. The salmon fry travel near the surface, and it would be possible for these ditches to take the water from beneath the surface if screens cannot be used. Side streams from which water is taken for irrigation are all more or less important as spawning grounds for salmon, and ditches taking water from these should be investigated.

The latest proposal to build canals or by-passes within the overflow basins, so that they will be readily drained as the river falls, would be the saving of myriads of fish, and especially of salmon fry, and should be encouraged. Many adult salmon are annually lost at Tisdale Weir, before they can spawn, on account of the faulty construction of the top of the weir.

The work on the overflow basins was not complete. As stated before, the loss of fry in these basins came as a surprise and at first we had no plans for an investigation. The best work could have been done in February and March, but we were prevented from getting up the river earlier by the investigation of a legislative committee. To be complete the work should be carried on another winter on the river and within the basins and on the irrigating ditches. Also the fate of salmon fry planted after March at Sisson should be determined.

7. TROUT AND BLACK BASS PLANTING AND TRANSPLANTING IN THE SAN JOAQUIN AND SOUTHERN SIERRA DISTRICTS

By A. D. FERGUSON,
In Charge Fresno Division.

7.1. BLACK BASS

A trying problem in the preservation of black bass, which abound in the rivers of the valley section, early confronted the Commission in this division. During the time of the annual freshets, the swamp lands of the lower Kings and the San Joaquin rivers are inundated and vast numbers of black bass and other species of fish leave the main channels to take up their abode in the overflow waters. When the flow in the rivers becomes normal, millions of these fish are cut off from the main channels and, unless rescued, must eventually perish when the flooded area again becomes dry.

It has been found practical, and not unduly expensive, to take up the bulk of these stranded fish and return them to living water. This is accomplished by seineing, at the proper season, the potholes and small ponds and in cans or tank wagons, returning the rescued fish to living waters. When the distance which the fish must be carried is short, all stranded fish, regardless of species, are taken up. When the distance from the main channel is 3 or 4 miles, only the black bass and Sacramento perch are saved. As many as 500,000 stranded black bass have, by this means, been saved from destruction in a single season. The proportion of black bass to all the other species thus taken up is about 10 per cent.

7.2. TROUT

Natural conditions in the Sierra region of the counties of the San Joaquin Valley have afforded an ideal opportunity for demonstrating the practical benefits of the Commission's trout distribution work. Flowing westward from the high Sierra region to the trough of the valley, the main channels of the typical rivers of this section lie in deep cañons and offer no obstructions to the free movement of ascending fish. In these few main channels rainbow trout have always been found in abundant numbers. The tributary waters, however, almost invariably come into the main channels over a succession of falls which present impassable barriers, and as a general rule, no fish life was naturally to be found in the hundreds of streams and lakes which drain this vast watershed. Nor are these tributary streams necessarily of insignificant volume—many of them are small rivers, unfordable except at the

extreme low-water stage. The pioneers of the region early learned that native trout, if once planted above the falls in a barren stream, readily established themselves, and throve to a most gratifying degree.

Supplementing the most laudable efforts of public spirited individuals, authentic instances of which have been traced as far back as 1874, the Commission, through its Fresno office, shortly after its establishment, undertook on a systematic scale to reach and plant with desirable varieties of trout all of the barren waters of the mountainous sections of the Fresno Division. It should be understood that the region described is public domain of the Forest Reserve, and that none of the waters therein are privately controlled or can ever come under private ownrship. The Forest Reserves, as distinguished from National Parks, are free of access to the public and without any restrictions with regard to hunting and fishing, except such as are provided by the state fish and game laws. Nor should the impression be formed that this work is only of local value. Fine public highways, built and projected, will bring the trout waters of Tuolumne and Mariposa counties within easy access of the people of the bay section and of the lower Sacramento and the San Joaquin valleys. A railroad about to be built into the heart of the mountains of Madera County, a railroad recently completed into the mountains of Fresno County, and the Kings Cañon State Highway, near the boundary line between Fresno and Tulare counties, now in course of construction, will enable many thousands of people to reap the benefits of the Commission's efforts toward making this magnificent public "outing" ground doubly attractive.

Because of the heavy snows which annually fall in this region, the trout planting work can be prosecuted only during the summer months. Well equipped pack-horse trains in charge of experienced deputies are engaged in the distribution work from about July 1st to the latter part of October of each year.

To reach the source of many of the streams often involves infinite labor on the part of the deputies and precarious going for the pack animals. Especially designed fish cans for pack-horse work are used; they are of 10 gallons capacity, oblong in shape, and thoroughly braced to stand hard usage. The cans are covered with burlap, which is kept saturated with water in order to keep down temperatures within the cans. When it becomes necessary en route to hold the fish, as over night, screens are placed across the mouths of the cans, which are then put into a running stream where the water can flow directly into the cans. By this method fish have been carried successfully for eight consecutive days, over the roughest part of the Sierra Nevada Mountains.

In planting the barren waters of the back country, many hundreds of thousands of trout fry of various species from the Sisson Hatchery have been used. In addition, adult rainbow and golden trout have been taken up from their native habitat and distributed to suitable new waters. By reason of the fact that the tributary streams to the main feeders of the rivers have also falls in their lower courses, it has been

possible to bring about a condition whereby there will be none but native rainbow trout in a certain stream; none but eastern brook trout in a nearby stream; Loch Leven trout in a third; and thus on to the high summit streams, where none but the far-famed golden trout will be planted.

To provide a supply of stock fish for the golden trout work, a deputy of the Fresno office, in September, 1910, brought from Volcano Creek, by a six days' pack-horse trip over an arduous and circuitous route, 179 adult golden trout, which he planted with a loss of only seven fish, in the headwaters of the West Fork of Roaring River. In this stream the golden trout should have sufficiently multiplied by the summer of 1913 to permit the taking of a sufficient supply for distribution throughout the summit region northward for a hundred miles.

An important feature of the trout planting operations is the stocking of many of the almost innumerable small lakes, or tarns, which dot the higher altitudes of the Sierra region. Since trout grow large in the waters of a lake, the addition to the food supply will prove no small item. While rainbow trout and several other varieties, will thrive in a lake which has a well defined inlet that the fish may ascend to spawn, the typical lakes of this region are not adapted to these varieties, for the reason that these lakes are fed by melting snows which percolate through loose rock, without establishing well defined inlet channels. In such lakes, Loch Leven and eastern brook trout have been introduced with great success. Much planting has been done with Loch Leven trout, which readily reproduce the species within the waters of the lake itself. They attain large size and are rapidly becoming locally famous for their gameness as well as for their table qualities.

Beginning with the more accessible waters, the fish planting operations have been annually extended to the more remote regions,—a system which works automatic relief to the streams which would otherwise become depleted.

Already attracted by the fishing which the region now affords, many thousands of people from the adjacent valley section, as well as hundreds of tourists from remote sections of the State, and from other states, annually seek these mountains for their summer's "outing." Naturally, as the drain upon an easily accessible stream becomes too great, these people push farther back in search of better fishing waters; thus they relieve the strain upon the nearby streams before endangering the future supply.

The results obtained from stocking these barren waters of the high Sierra have proven most gratifying, not to say marvelous. Finding in their new environment an abundance of natural food, the transplanted trout grow to large size and multiply with remarkable rapidity. An eighteen mile stretch of the South Fork of the San Joaquin River, a big and splendid stream, stocked some years ago with less than 50 adult rainbow trout was within four years found to be literally alive with trout of all sizes up to 5 ¾ pounds. Four-inch rainbow trout

from the South Fork of Kings River, placed in the barren waters of Roaring River, a tributary of the South Fork of Kings River, grew within three years to 19-inch fish, weighing three pounds. Had these fish remained in their native environment, they probably would never have attained a length of over 13 inches nor a weight of over one pound, since trout of greater size are seldom found in the section of the river where these stock fish were taken.

Loch Leven fry, planted in Weaver Lake, at 10,000 feet elevation, in September, 1911, had grown by July, 1912, to 10-inch fish, although the intervening period, because of low temperatures, was the period of comparatively slow growth.

While there have been practically no failures in these fish planting operations, it should be borne in mind that not every stream is equally adapted to supporting fish life. Once stocked, these Sierran streams will annually provide as many fish as food and water conditions will permit. A short, tumultuous stream devoid of stretches of comparatively quiet water, and with but few large pools, may have its finny inhabitants swept out by freshets. A stream which occupies a cañon in the granite of the higher mountains, and which is devoid of meadows along its banks, and unfed by streams which flow through a meadow country, will contain but very little natural fish food; consequently, such a stream will never become good trout water. Once stocked, it would be a waste of money and effort to annually plant fry in a stream where there is insufficient food to properly support the natural increase. A third condition which sometimes causes comment or disappointment occurs in streams where favorably high water prevails only during the time of melting snows, but where the channel becomes dry or practically dry in the late fall. Since a stream of this type naturally carries its best volume of water during the summer months, the time when most people see it, the public may easily be deceived as to the real reason for its being devoid of fish life. Fortunately, streams of the three types mentioned are the exception rather than the rule, and the fishing waters where none but favorable conditions prevail are numbered by the hundreds.

7.3. GOLDEN TROUT

A notable example of successful pack-train transportation occurred in September, 1911, when the Fresno office organized an expedition to go to Volcano Creek, in the Whitney range of eastern Tulare County, to take up golden trout (Salmo roosevelti) for experimental propagation work at the Sisson Hatchery.

The expedition was in charge of Deputy A. D. Ferguson of the Fresno office, assisted by Deputies S. L. N. Ellis, F. A. Bullard, and K. L. Hughes. The golden trout (Salmo roosevelti) were carefully taken up and carried over and down the mountains to Lone Pine Station, where, in accordance with a date arranged three weeks previously, the commission's fish distribution car awaited them. A small number of the

big golden trout of Cottonwood lakes was added to the consignment on route. These golden trout, 1,216 in number, ranging in size from 3 inches to 19 inches in length, were successfully delivered to the Sisson Hatchery, only 3 small fish being lost in transit.

Many previous attempt to secure a supply of golden trout by the state as well as by the Federal Fish Commission had resulted in ultimate disaster. This lack of success was due partly to the hazard of transporting such delicately constituted fish on pack-mules and partly to the smallness of the number secured.

Regarding the question as to whether or not the golden trout can be successfully introduced into new waters, the following extracts from a special report submitted by the writer are given:

"If, as has been held by some eminent ichthyologists and by most laymen, the golden trout of Volcano Creek, of South Fork of Kern River, and of Soda Creek and two nearby streams, which are the only natural habitat of the golden trout, owe their brilliancy of coloration to the presence of suspended minerals in the waters and to the colors of the beds and banks of these streams, and that under different environment the fish will revert to the rainbow type, then no profit would accrue from transplanting them to new and remote waters. But, if on the other hand, the type is fixed, the golden trout will retain their wonderful characteristics in waters far remote from the Kern-Whitney region, and the opportunity offered for wide distribution of this most beautiful of all trout through artificial propagation is ample justification for almost unlimited effort.

"With all due deference to the authorities, but from personal observation and experience I am led to believe that while it is probable that the golden trout are descended from the rainbow trout of Kern River (Salmo gilberti) and that the highly colored volcanic formation through which Volcano Creek and South Fork of the Kern flow, coupled with the fact that falls in the lower waters prevent any fish from the Kern ascending to interbreed with the fish of the upper streams, is responsible for the departure from the rainbow type; at the same time, the process of natural selection, through countless generations, has fixed the type. And if golden trout are not, in fact, a distinct species, they will not, under different environment, revert to the rainbow type for a great many generations, if ever."

After describing the golden trout of Volcano Creek, Salmo roosevelti, and those of South Fork of Kern River, Salmo agua-bonita, which are but slightly dissimilar and inhabit streams which were evidently at one time connected, the report continues:

"On the morning of September 13th we proceeded with our precious cargo toward Lone Pine Station, over the "Hockett" trail. Arriving at Cottonwood Creek in mid-afternoon, we held our fish after the manner previously described, until the morning of the 15th, that we might investigate the reported presence of golden trout of large size in Cottonwood lakes, our particular object being to observe what changes, if any,

had taken place in the appearance of these transplanted fish, under conditions dissimilar to those which surrounded them in their natural habitat.

"The Cottonwood lakes, of which we visited six, lie in a chain connected by Cottonwood Creek, directly under the summit ridge east and south of Sheep Mountain, or "Old" Whitney; thus their location is on the opposite side of the range from Volcano Creek. Their elevation is about 12,000 feet. They are in the granite formation of the Sierra summit, and there is no evidence of any mineral whatsoever within many miles of them. The history of the presence of golden trout in these lakes, as we gleaned it from residents of Lone Pine, briefly, is as follows: “Sometime in the early seventies Mr. Samuel Mulkey, a one time sheriff of Inyo County, carried golden trout from the South Fork of Kern River to Mulkey Creek. Thereafter, about the year 1876, Colonel Stevens and two companions carried a number of the fish from Mulkey Creek across the divide to Cottonwood Creek. Some four or five years later the fish in Cottonwood Creek, having become quite numerous, Mr. E. H. Edwards of Lone Pine, accompanied by a "Spaniard" named Diaz, picked up about 100 fish and carried them up to the lower tier of the Cottonwood lakes.”

"We found an abundance of golden trout in Cottonwood Creek, and they are to all appearances identical with those of the parent stock. And at Cottonwood lakes we found that with added size the golden trout had taken on very much more brilliant coloration. We found new colors, particularly purples, commingled with the orange and gold and yellow of the original agua-bonita, in the Cottonwood lakes fish, and the coloration, with added brilliancy, extends over the whole body of the fish. While we took no accurate measurements, there appeared to be, in the large specimens of the lake fish, a structural departure from the gilberti type, in that, the weight of the fish being equal, the head of the golden trout is much smaller and more delicately formed than that of the Kern River rainbow. It is hard to imagine anything in the piscatorial world half so brilliant as a three pound golden trout from one of these Cottonwood lakes; and this brings up my reason for the statement made in the opening paragraph of this report.

"From the fact that the transplanted fish in Mulkey Creek, in Cottonwood Creek, in the Cottonwood lakes, in Rock Creek, and in the North Fork of the Kaweah River,—all being waters in granite formation without any trace of mineral,—have apparently retained their characteristics, there is decided encouragement for the belief that the type is fixed, and that many waters in far distant locations may be stocked with golden trout, with a reasonable degree of assurance that they will not quickly revert to the rainbow type. In any event, results in the waters mentioned are sufficient justification for the effort to introduce these most beautiful of all fishes into new waters.

"The fact that Cottonwood lakes, where the most brilliant of all the

specimens are found, lie within the limit of perpetual snow, might indicate that low temperatures have much to do with the coloration of the fish."

Of some 30 plants of adult golden trout made since 1909, in waters tributary to the Kern, Kings, and Kaweah rivers, the Commission has only good reports.