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AN EVALUATION OF TROUT PLANTING IN LAKE TAHOE[1]

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Experimental plants of various strains of rainbow and cutthroat trout *(Salmo gairdnerii and S. clarkii)* made in Lake Tahoe from 1960 to 1963 were evaluated for both immediate and long-range contributions to the sport fishery. None of the plants was considered as successful as was desired. Lahontan and Yellowstone cutthroat *(S. c. henshawi and S. c. lewisi)* contributed least to the fishery. Estimated total harvests of various Kamloops rainbow *(S. g. kamloops)* plants were never greater than 4%. However, they showed some potential for providing a long-range or premium fishery. Domestic rainbow contributed relatively few premium fish to the creel, but had the highest immediate returns (3 to 36%). The majority of those caught were recaptured within 60 days of release. An occasional Kamloops and domestic rainbow survived in the lake for as long as 3 to 4 years. To demonstrate other characteristics (e.g., movements, growth, etc.) of trout stocked in Lake Tahoe, returns from plants made over a 9-year period (1956-1964) were used. Kamloops and Williams Lake rainbow (a wild strain from Idaho) distributed themselves widely in Tahoe's limnetic zone, and the Kamloops commonly entered its tributaries. Domestic and Pyramid Lake rainbow (a wild strain from Nevada) tended to remain in the lake in shallow, rocky areas. Initially, planted trout grew at a rate of about 0.4 inch per month and then gradually tapered off to about 0.1 inch per month after 30 months in the lake. The largest premium trout came from plants of domestic rainbow trout. Lack of an adequate food supply, mortality associated with life in the tributaries, and predation by lake trout *(Salvelinus namaycush)* appear to be the factors most responsible for the poor survival of stocked trout. Put-and-take plants of large (10- to 14-inch) domestic rainbow made from the shore during summer months appear to offer the best means of improving fishing through stocking, particularly for anglers fishing from the shore or from piers.

INTRODUCTION

The California and Nevada Departments of Fish and Game initiated the cooperative Lake Tahoe Fisheries Study on July 1, 1960. The basic goal of this study was to improve fishing at Tahoe. A large-scale experimental trout planting program was one method used. Evaluation of the plants was made possible by marking the fish and conducting intensive creel censuses by boat (referred to hereafter as "boat census") and at the Cave Rock public boat landing. A detailed evaluation of the planting program is presented in this report.

The primary objective of the planting program was to establish a premium trout fishery by releasing artificially propagated trout. We

[1] Submitted for publication September 1967. This work was performed as part of Dingell-Johnson Projects California F-21-R and Nevada F-15-R, "Lake Tahoe Fisheries Study", supported by Federal Aid to Fish Restoration funds.

were especially anxious to improve the success of shore and pier anglers fishing in the summer months, since their success was considerably lower than that of anglers in other categories (Cordone and Frantz, 1966). We hoped to find a species or strain of trout that would survive for an extended period and return to the angler as large, virtually wild fish. At the same time we would obtain information on the characteristics of any put-and-take fishery that might develop, although planting practices and regulations were designed to reduce the immediate take of planted trout. To test the feasibility of developing a premium fishery, trout of various sizes were released at different times of the year and in different locations in the lake. Trout surviving longer than 180 days (about 6 months) were considered premium fish, since by then they would have taken on the coloration and probably the behavior of wild trout, and would have increased in size. Almost all fish stocked during the study were subcatchable-sized [2] or larger, and of various strains of rainbow and cutthroat trout.

METHODS

Most trout planted were reared at hatcheries in California and Nevada, with the remainder reared in several other western states. In general, standard production and planting methods were employed. Most trout were stocked from trucks directly into shoreline locations, while some were barged into the limnetic zone before release.

Trout were marked by the excision of various combinations of fins and maxillary bones. All fish were anesthetized with chlorobutanol or tricaine methanesulfonate (MS-222) before marking. Special care was taken to remove the entire fin or maxillary bone to reduce regeneration. The relatively large size of the experimental trout helped minimize the regeneration problem. Examination of numerous marks in the field and on fish held in a pond at project headquarters near Tahoe City indicated that regeneration seldom occurred and, when it did, was easily recognizable.

After marking, fish were held at the hatcheries for a period of a few days to several weeks before release. Mortality during this period was negligible. Except on two occasions, mortality following transportation was also very light. We have no information on long-term marking mortality of planted trout.

Pertinent data regarding angler-caught planted trout were recorded principally during the Cave Rock and boat censuses. Creel census methods are described by Weidlein, Cordone, and Frantz (1965) and Cordone and Frantz (1966). Some planted trout were also recorded during censuses on the tributaries and in collections from the lake by means of gill nets, traps, and rotenone. Trout were measured to the nearest 0.1 inch fork length and weighed to the nearest 0.01 pound.

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[2] For our purposes, "fingerlings" are fish 5.2 inches or smaller (16.0/pound or less), "subcatchables" are fish from 5.3 through 7.3 inches (15.9 to 6.1/pound), "catchables" are fish from 7.4 through 9.9 inches (6.0 to 2.6/pound), and "large catchables" are fish 10.0 inches or larger (2.5/pound or more). It should be remembered that in hatcheries the growth of domestic rainbow is much faster than that of wild strains. Thus, wild-strain fish could be from 6 to 12 months older than domestic fish of the same size. "Domestic" fish are progeny of various hatchery brood stocks.

RAINBOW TROUT HABITAT

Limnological characteristics of Lake Tahoe make it one of the world's most fascinating lakes. It ranks fifth in mean depth (1,027 feet) and tenth in maximum depth (1,645 feet) in the world (McGauhey et al., 1963, p. 58). The great depths are largely responsible for a very restricted littoral zone, although the paucity of shoreline irregularities is also important. Its chemical and physical characteristics, coupled with its morphometry, make Tahoe one of the world's most oligotrophic lakes. Goldman and Carter (1965) describe its extreme light penetration and low primary productivity. Its surface area is 193 square miles.

Unpublished fish sampling data revealed that rainbow are largely confined to shoreline areas at depths less than 25 feet. However, netting in the limnetic zone showed that rainbow occur in this area also, but at a lower density and usually within 10 feet of the surface.

Our observations plus results of the sampling program indicate that rainbow prefer shallow rocky areas. Rainbow also frequent the larger piers, particularly the rock-filled type. Small rainbow (catchable-sized and smaller) appear to be more closely tied to this rocky shoreline habitat than larger specimens, which move more widely and also invade shallow, sandy habitat.

At Tahoe, sandy beaches are common. The largest beach covers the entire south end of the lake from the mouth of Cascade Creek to Elk Point (see Cordone and Frantz (1966) for a map of Tahoe showing important landmarks). Crystal Bay and Agate Bay also contain large, sandy beaches, and many smaller ones are scattered around the remainder of the lake. Gravel, rubble, and boulder beaches are common along the east and west shores. However, they do not extend very far into the lake and are replaced by sand at depths from 5 to 50 feet. Consequently, in relation to its size Tahoe contains little of what might be considered prime rainbow trout habitat.

With its restricted drainage basin (326 square miles), Tahoe has relatively small tributaries. There are about 30 to 40 that probably sustain spring migrations of rainbow from the lake. Most of these, however, cease flowing or have low or intermittent flows in late summer, autumn, and winter. They are generally precipitous and, according to our observations, support small runs of rainbow. The larger streams flow through meadows and maintain larger runs of rainbow. These include the Upper Truckee River and Trout, Taylor, Blackwood, and Ward creeks. All but Ward Creek also support runs of mountain whitefish *(Coregonus williamsoni)* and brown trout *(Salmo trutta)*. Kokanee salmon *(Oncorhynchus nerka)* spawn each year in Taylor Creek. Spawning runs of cyprinids and suckers enter many of the tributaries. Resident populations of eastern brook trout *(Salvelinus fontinalis)* are found in nearly all of them, especially in their upper reaches. The tributaries are not only small in relation to the size of Tahoe, but also many of them are in poor condition because of man's activities. We hypothesized that planted trout might successfully substitute for natural recruitment.

FISHING REGULATIONS

In Tahoe, game fishes may be taken only from 1 hour before sunrise to 2 hours after sunset. The bag limit is five fish: either trout, kokanee salmon, or whitefish in any combination and irrespective of weight and length. Fishing is open all year. To protect spawning game fish, both states maintain certain tributary closures. In California, all tributaries to Tahoe and their mouths within a 200-yard radius are closed from October 1 through the Friday preceding July 4. In Nevada, the lower sections of Third and Incline creeks, including a 200-yard radius around their mouths, are closed all year. Nevada's smaller tributaries are open all year. An area surrounding Logan Shoals Harbor is closed to fishing from March 1 through October 31. It is here that the Nevada Fish and Game Department releases most of its trout.

LAKE TAHOE PLANTING HISTORY

Since the late 1800's, millions of fingerling trout and salmon of a variety of species and strains have been planted in Lake Tahoe. During this period, the native Lahontan cutthroat trout disappeared, and the introduced lake trout became established as the dominant game fish. While providing good fishing for anglers using specialized gear, the lake trout is seldom caught by the average angler (Cordone and Frantz, 1966). In a major effort to improve fishing, about 14 million trout and kokanee salmon [3] were released during the 15 years from 1950 through 1964 (Table 1). The bulk of these comprised about 10 million domestic rainbow fingerlings stocked in the first 10 years of this period.

Although quantitative evidence is lacking, the large-scale fingerling planting program apparently failed to improve fishing materially. However, these fish were unmarked, and so it is possible that what is considered a "wild" rainbow fishery in Tahoe may actually be the result of these releases. The "wild" rainbow fishery is small, with only about 4,000 fish caught annually, yet the quality of the fish and their fighting ability makes them very popular with anglers. We have reason to believe that virtually all of these fish are the result of natural reproduction. First, creel census results (some of them unpublished) indicate that the wild rainbow fishery was very stable from 1960 through 1965. If the rainbow plants supported this fishery, angler success rates should have started to decline markedly by 1963, since the final large plant of fingerlings took place in 1959. Second, what most likely were wild rainbow were commonly observed or captured by various collecting methods during the 1960–1965 period. For example, observation of many tributaries during spring months revealed rainbow spawning runs. Subsequently, large numbers of rainbow fingerlings were seen in these tributaries during the summer months. In late summer, fingerlings were common along the lake shore. Finally, small unmarked rainbow were regularly taken by shore, pier, and boat anglers. Because of their size, these very likely were the result of natural reproduction.

When the study began in 1960, it was becoming increasingly obvious that domestic fingerling rainbow plants were not significantly improving fishing success. However, the Nevada Fish and Game De-

[3] Results of the kokanee plants will be considered in another report.

TABLE 1

Numbers of Trout and Kokanee Salmon Planted in Lake Tahoe From 1950 Through 1964
(Not Including Plants in Tributaries; F = Fingerlings, S = Subcatchables, C = Catchables, LC = Large Catchables)

Year	Domestic rainbow[1] Fingerlings	Domestic rainbow[1] Subcatchables	Domestic rainbow[1] Catchables	Domestic rainbow[1] Large catchables	Kamloops rainbow	Lahontan cutthroat	Eastern brook	Kokanee salmon	Other species and strains	Yearl totals
1950	296,770	0	0	0	0	0	0	500,300 (F)	0	797,070
1951	460,006	0	0	0	0	0	0	392,064 (F)	0	852,070
1952	394,530	0	0	0	0	0	0	623,585 (F)	0	1,018,115
1953	615,180	0	0	0	0	0	4,610 (F)	176,810 (F)	0	796,630
1954[2]	146,869	0	1,500	0	0	0	0	308,565 (F)	0	456,934
1955[2]	535,000	0	0	10,404	0	0	0	78,720 (F)	0	624,124
1956[2]	2,620,902	0	12,164	5,317	20,522 (F)	763,406 (F)	6,860 (S) 2,800 (C) 1,400 (LC)	0	0	3,433,371
1957[2]	1,999,690	0	15,583	0	0	0	11,040 (S) 18,886 (C)	0	0	2,045,199
1958[2]	1,437,000	0	12,610	4,839	0	1,714 (F)	0	0	0	1,456,163
1959[2]	1,570,366	9,921	33,326	1,159	0	0	0	0	0	1,614,772
1960[3]	0	2,914	133,494	7,841	16,750 (F)	0	0	0	0	160,999
1961[4]	0	0	55,128	1,554	91,967 (C)	80,174 (S)	0	0	28,403 (S) Yellowstone cutthroat 1,339 (C) Pyramid Lake rainbow	258,565
1962[5]	0	0	8,032	2,043	25,769 (S) 105,842 (F)	48,009 (F) 29,658 (S)	0	0	12,345 (C) Yellowstone cutthroat 511 (LC) Brown trout 14,742 (S) Pyramid Lake rainbow	246,951
1963[5]	0	0	15,755	0	98,368 (S)	0	0	0	14,981 (C) Williams Lake rainbow	129,104
1964[5]	0	0	6,719	6,220	5,260 (LC)	0	0	0	5,260 (LC) Steelhead rainbow[6] 4,300 (C) Williams Lake rainbow 17,141 (S) Williams Lake rainbow	44,900
Totals	**10,076,313**	**12,835**	**294,311**	**39,377**	**364,478**	**922,961**	**45,626**	**2,080,044**	**99,022**	**13,934,967**

[1] From various domesticated brood stocks maintained by state and federal agencies and private parties.
[2] From 1954 thorugh 1959, only 47,532 domestic rainbow were marked (none of fingerling size).
[3] All marked except 30,703 domestic rainbow catchables and the Kamloops fingerlings.
[4] All marked except 6,624 domestic rainbow catchables.
[5] All marked.
[6] *Salmo gairdnerii gairdnerii.*

partment had been testing domestic rainbow catchables in Tahoe since 1954 and there were indications that success was possible. Corlett and Wood (1958) state, "Return to the angler has been greatest immediately following planting, but recent recoveries indicate that long-range returns from some of the plantings are just starting to show up well." Therefore, in an endeavor to develop a premium fishery, it was decided to test large domestic trout along with wild strains on a large-scale basis.

TRIBUTARY PLANTS

Numerous fish representing several species have been stocked in Tahoe's tributaries by California and Nevada. Before 1956, fingerling rainbow and eastern brook trout and kokanee salmon were planted. Since then, releases have consisted mostly of catchable rainbow and both fingerling and adult Lahontan cutthroat trout. From about 50 to 400 ripe, adult cutthroat, captured from the spawning run at Heenan Lake, Alpine County, California, were planted annually in Taylor Creek and the Upper Truckee River from 1956 through 1964. Creel census data show that these and the fingerling plants (58,944 from Heenan Lake and 25,000 from Summit Lake, Nevada) had virtually no impact on fishing in the lake. Each year between 20,000 and 25,000 domestic rainbow catchables are planted in California tributaries. All 25,000 catchables stocked in 1962 were marked. In 1962 and 1963, only two were checked during boat census and five at the Cave Rock public boat landing. Thus, relatively few of these fish move downstream and enter the lake fishery. We believe the heavy fishing pressure exerted on the tributary plants during the summer greatly reduces their contribution to the lake fishery. Numerous catchables are planted annually in the Truckee River. However, an unladdered dam at its outlet from Tahoe restricts movement of fish from the river into the lake. During most years, water released under high pressure at the dam also prevents upstream movement.

RESULTS AND DISCUSSION

Contribution of Planted Trout to the Tahoe Sport Fishery

Lake trout clearly dominate the Lake Tahoe sport fishery (Cordone and Frantz, 1966). They comprised about 56% of the total catch, with planted trout and wild rainbow trout contributing 23 and 18%, respectively. The remaining 3% consisted largely of brown trout and mountain whitefish. Eastern brook trout and kokanee salmon were caught rarely.

Total catch estimates showed that planted trout comprised 4,880 or 24.7% of the total catch for 1961, 3,365 or 16.8% for 1962, and 9,471 or 38.4% for 1963. Of the total planted trout caught in these years, 59.1% were taken by shore anglers, 17.1% by pier anglers, 23.4% by topliners, and only 0.4% by deepliners.[4]

Contribution of planted trout to success rates for Tahoe anglers, exclusive of deepliners, was substantial during the period June through November for 1961, 1962, and 1963 (Table 2 and Figure 1). For these

[4] All boat anglers using metallic line of any type were considered deepliners, while boat anglers using nonmetallic line were termed topliners.

TABLE 2

Contribution of Planted Trout to the Lake Tahoe Sport Fishery, Excluding Deepline Effort, Based on Boat Census for Combined 1961, 1962, and 1963 Unexpanded Data

	January	February	March	April	May	June	July	August	September	October	November	December	All months
Total anglers	630	372	361	847	810	2,212	2,758	1,803	827	390	353	750	12,176
Total angler hours	1,168.00	721.00	616.50	1,690.25	1,569.25	3,971.50	4,762.00	2,817.00	1,304.50	613.25	592.75	1,212.75	21,106.75
Total game fish	107	50	39	162	175	426	648	451	127	118	111	177	2,621
Total planted trout	12	14	6	15	13	156	416	360	54	74	57	50	1,227
Total catch/hour	0.092	0.069	0.060	0.096	0.112	0.107	0.136	0.159	0.097	0.192	0.238	0.146	0.121
Planted trout catch per hour	0.010	0.019	0.009	0.009	0.008	0.039	0.087	0.126	0.041	0.121	0.096	0.041	0.058
Planted trout c/h as percentage of total	10.9	27.5	15.0	9.1	7.1	36.1	64.0	79.2	42.3	63.0	10.3	28.1	16.8

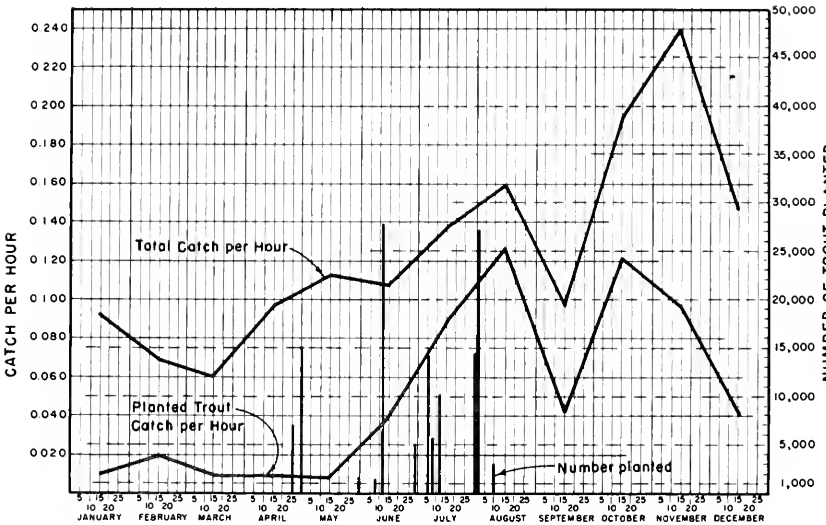

FIGURE 1—Contribution of planted trout to the Lake Tahoe sport fishery (excluding deepline effort), based on cambined 1961, 1962, and 1963 boat census data. Number af trout planted during this period includes only those plants whose estimated percentages harvested were greater than three. When release of a given lot of traut required more than one day, the total number is shown on the first day of release only.

months, the contribution of planted trout to the total catch per hour ranged from about 35 to 80%. Percentages were highest in July, August, and October. Beginning in December or January, their contribution started to decline, reaching a low of about 8% in April and May. In general, this pattern can be attributed to a put-and-take fishery created by spring and summer releases of domestic rainbow trout.

Total Harvest Estimates for Individual Plants

Estimates of the total harvest of individual lots of stocked trout are derived from data gathered during the coordinated boat and Cave Rock censuses which took place from September 1960 through December 1963. Estimates were calculated only for those releases made from August 28, 1960, through August 1963.

Weidlein et al. (1965) and Cordone and Frantz (1966) describe the methods used to obtain estimates of total angler hours at Lake Tahoe. The figures obtained are point estimates for which no confidence limits could be calculated. Possible biases were examined and, although none was found which precluded the use of the method, they resulted in underestimates of total use and catch. In our judgment, this was not serious and the values obtained are reasonably accurate.

To obtain total angler hours for shore, pier, and topline anglers combined, estimates of the total deepline angler hours were subtracted from total angler hours for each month.[5] By multiplying these total

[5] Deepline effort was excluded because during 3 years and 4 months of boat census only 6 planted trout were found among the 2,531 deepline-caught trout examined. These anglers use specialized gear and catch lake trout almost exclusively.

monthly "surface" angler hours by the monthly catch per hour for each plant for the same angler categories combined, it was possible to obtain estimates of total monthly catches for the individual plants.

Harvest estimates are minimal, since they are based only on returns from Tahoe itself. Some strains were caught in the tributaries and the Truckee River and from waterways of the Tahoe Keys, which were not in the census area. For strains that range widely, like the Kamloops, this might, at most, double the harvest estimate, but probably would little influence estimates for other strains.

Harvest estimates varied considerably from species to species and for different releases of the same species (Table 3). However, we believe that in most cases there was sufficient replication of the test plants to assess their success in providing either a short-term (put-and-take) or a long-term (premium) fishery. In general, for a given species, trout released in the limnetic zone were compared with those released from shore, and releases made in rocky shoreline areas compared with those made in sandy shoreline areas.

Lahontan cutthroat trout (mostly subcatchables but some fingerlings) gave the poorest returns of all the strains tested, with none checked from the 1961 release of 80,174 fish and an estimated harvest of about 0.2% of 77,667 fish released in 1962. Yellowstone cutthroat trout gave only slightly higher returns; the three plants of subcatchables and catchables totaling 40,748 fish made in 1961 and 1962 gave total returns of only 0.1, 0.2, and 0.8%

In 1961, 1962, and 1963, six marked groups of Kamloops rainbow trout were released in Lake Tahoe. The plants totaled 321,946 fish from the British Columbia and Diamond Lake, Oregon, strains. Design of these tests did not permit a comparison of the strains and the time of release. Kamloops catchables were planted in the autumn of 1961 and fingerlings and subcatchables were released in the spring of 1962. In both of these years, plants made at Lake Forest in shallow rocky habitat yielded substantially higher returns (1.4 and 3.9%) than those made at the sandy beach at Kiva (0.1, 0.1, and 0.8%) and the 1961 McKinney Bay limnetic plant (0.4%). In August 1963, 98,368 Kamloops subcatchables were released in 12 areas around the lake representing a variety of habitats, and gave an estimated return of 3.0%. Since returns were still coming in when the boat census was terminated at the end of December 1963, the total harvest for this plant was probably closer to 5%. A group of Kamloops fingerlings on a special diet to reduce premature ripening in the hatchery also gave poor returns (0.1%).

Two additional strains of wild rainbow trout were tested in Lake Tahoe: the Pyramid Lake, Nevada, strain and the Williams Lake, Idaho, strain. Harvest figures for both were considerably higher than those for Kamloops and similar to those for domestic rainbow trout. Harvest estimates of rainbow from Pyramid Lake stock were 18.7% for a plant of 1,339 catchables made in 1961 and 9.2% for 14,742 subcatchables released in 1962. The 1963 plant of Williams Lake rainbow catchables yielded an estimated harvest of 14.0%. Two plants from this strain were made in 1964. Although no harvest estimates for these were calculated, one plant appeared to give about the same return as the 1963 plant, while the other seemed to return at a much reduced rate.

TABLE 3

Harvest Estimates of Trout Planted in Lake Tahoe [1]

Mark	Species or strain	Egg source	Number planted	Dates of release	Area of release	Mean fork length (inches)	Actual percentage checked	Estimated percentage harvested
RV	Domestic rainbow[2]	Idaho, private brood stock	4,000	Aug. 28, 1960	Zephyr Cove, limnetic[5]	10.5	1.27	21.0
An-LV	Domestic rainbow	California, Hot Creek brood stock	29,920	Sept. 16, 19, 21, 1960	Off Tahoe City	7.5	0.15	8.0
An-RV	Domestic rainbow	California, Hot Creek brood stock	30,129	Sept. 12, 14, 16, 1960	Off Al Tahoe	7.5	0.77	13.1
Ad-An	Domestic rainbow	California, Hot Creek brood stock	30,024	Sept. 13, 15, 17, 20, 22, 1960	McKinney Bay, limnetic[6]	7.5	0.16	2.5
LM	Domestic rainbow[3]	Utah, private brood stock	13,374	Apr. 26, 29, 1961	Logan Shoals	8.0	0.58	5.6
LP and jaw tag	Domestic rainbow[2]	Idaho, private brood stock	1,554	May 30, 1961	Zephyr Cove, limnetic[5]	14.5	2.90	29.8
An-LP	Domestic rainbow	Utah, private brood stock	14,524	June 6, 7, 19, 22, 28, 1961	Logan Shoals	8.4	1.57	15.8
An-RP	Domestic rainbow	Utah, private brood stock	27,230	Aug. 2, 9, 14, 16, 24, 29, 1961	Logan Shoals	8.0	0.25	3.5
LP	Domestic rainbow[2, 3]	California, private brood stock	2,043	June 12, 1962	Off Kiva, limnetic[5]	11.5	0.69	7.9
D-RMax	Domestic rainbow	Utah, private brood stock	4,974	June 29, 1962	Logan Shoals	9.6	1.89	22.6
D-LMax	Domestic rainbow	Washington, private brood stock	3,058	Aug. 9, 1962	Logan Shoals	8.9	0.49	4.7
RV-LP	Domestic rainbow	Idaho, federal brood stock	5,666	July 8, 9, 10, 11, 1963	Logan Shoals	9.4	1.75	35.8
LP-LM	Domestic rainbow	Utah, private brood stock	10,089	July 12, 1963	Logan Shoals	8.7	0.77	15.4
D	Kamloops rainbow	British Columbia	29,586	Sept. 25, 26, 27, Oct. 3, 1961	Lake Forest	7.7	0.15	1.4
LV-RP	Kamloops rainbow	British Columbia	30,794	Sept. 18, 20, 25, Oct. 5, 1961	Kiva Picnic Area	7.7	0.07	0.8
D-LV	Kamloops rainbow	British Columbia	31,587	Sept. 18-28, Oct. 3, 1961	McKinney Bay, limnetic[6]	7.7	0.05	0.4
LV-LMax	Kamloops rainbow	Diamond Lake, Oregon	25,769	June 12, 1962	Lake Forest	5.5	0.28	3.9
LV-RMax	Kamloops rainbow	Diamond Lake, Oregon	71,570	June 12, 1962	Kiva Picnic Area	3.8	0.01	0.1
Ad-RMax	Kamloops rainbow[4]	Diamond Lake, Oregon	34,272	June 12, 1962	Kiva Picnic Area	4.3	0.01	0.1
LV-LP	Kamloops rainbow	British Columbia and Diamond Lake, Oregon	98,368	Aug. 5, 7, 12, 14, 16, 1963	12 areas around lake	6.0	0.12	3.0
Ad-LMax	Pyramid Lake rainbow	Pyramid Lake, Nevada	1,339	June 8, 1961	Sand Harbor	7.8	1.94	18.7
D-RP	Pyramid Lake rainbow	Pyramid Lake, Nevada	14,742	Aug. 1, 2, 4, 7, 9, 1962	Logan Shoals	7.2	0.63	9.2
LP-RP	Williams Lake rainbow	Williams's Lake, Idaho	14,981	Apr. 30, 1963	Logan Shoals	8.2	0.71	14.0
D-RV	Lahontan cutthroat	Heenan Lake, California	26,766	Sept. 28, 30, Oct. 3, 1961	Lake Forest	6.5	0.00	0.0
RV-RP	Lahontan cutthroat	Heenan Lake, California	26,743	Sept. 29, Oct. 1, 5, 11, 1961	Kiva Picnic Area	6.9	0.00	0.0
An	Lahontan cutthroat	Heenan Lake, California	26,665	Oct. 3, 4, 5, 6, 9, 11, 1961	McKinney Bay, limnetic[6]	6.7	0.00	0.0
RV-RMax	Lahontan cutthroat	Heenan Lake, California	48,009	June 12, 1962	Lake Forest	4.3	0.002	0.03
RV-LMax	Lahontan cutthroat	Heenan Lake, California	29,658	June 12, 1962	Kiva Picnic Area	5.7	0.03	0.4
RM	Yellowstone cutthroat	Montana, federal brood stock	14,886	Apr. 21, 1961	Logan Shoals	6.8	0.03	0.2
D-An	Yellowstone cutthroat	Montana, federal brood stock	13,517	May 26, 1961	Logan Shoals	5.4	0.01	0.1
D-LP	Yellowstone cutthroat	Montana, federal brood stock	12,345	May 22, 1962	Logan Shoals	7.1	0.06	0.8

[1] Includes estimates for only those plants made from August 28, 1960, through August 1963, except for a group of 511 brown trout released in June 1962. Because of the small number planted and a single recorded return, a meaningful harvest estimate was not possible.

[2] Purchased by private sportsmen's groups, either the South Tahoe Rod and Gun Club or Lake Tahoe Fisheries, Incorporated. All other fish were either reared or purchased by the California and Nevada Departments of Fish and Game.

[3] Relatively high mortalities noted at time of release.

[4] These Kamloops were fed a special diet to eliminate premature ripening.

[5] Fish transported by boat to widely scattered open water areas.

[6] Fish transported by boat to an open water area about 2 miles northeast of Homewood.

Domestic rainbow trout generally gave the highest returns to the angler. Annual plants of large catchables made in 1960, 1961, and 1962 by private sportsmen's groups yielded estimated harvests of 21.0, 29.8, and 7.9%, respectively. All fish were released by scattering them in the limnetic zone. The relatively low return of the 1962 plant was probably due to the poor condition of the fish at the time of release.

Harvest estimates of catchable domestic rainbow are based on 10 separate plants made in 1960, 1961, 1962, and 1963. Only three groups were released in areas other than Logan Shoals Harbor. These totaled 90,073 fish of the Hot Creek strain released in 1960 at Al Tahoe in shallow sandy habitat, at Lake Forest in shallow rocky habitat, and in the McKinney Bay limnetic zone. Harvest estimates were 13.1, 8.0, and 2.5%, respectively. The offshore release again gave the poorest return while, in contrast with the results of the Kamloops plants, the release in the inshore sandy area at Al Tahoe was higher than that in the inshore rocky area at Lake Forest. This was probably due to higher immediate returns of the Al Tahoe plant, since the release site lies close to several large and popular fishing piers.

Harvest estimates for groups of domestic rainbow catchables released at Logan Shoals ranged from 3.5 to 35.8% and averaged 14.8%. The release site is only about two shoreline miles north of the Cave Rock public boat landing, the most popular boat launching and shore fishing area at Lake Tahoe. This probably accounts for the relatively high returns, which provided largely a put-and-take fishery.

There were obvious differences in harvest rates among the various species and strains planted in Lake Tahoe. The Lahontan and Yellowstone cutthroat virtually disappeared after planting, while the Kamloops yielded harvests of less than 5%. The harvests of the remaining strains (Williams, Pyramid Lake, and domestic rainbow) ranged between approximately 5 and 40%. Much of the variation among species and strains may be attributed to differences in behavior, particularly regarding movements and distribution following release.

Other factors influencing the degree to which stocked trout return to the angler were not as apparent. The releases of Kamloops and domestic rainbow made in the limnetic zone generally gave substantially lower returns than comparable plants made in shoreline locations. However, no firm conclusion could be drawn between the relative merits of rocky versus sandy release locations. The large variation in returns of the 7 plants of domestic rainbow catchables released at Logan Shoals is difficult to explain, but probably reflects the interaction of time of release, size of fish at release, variations in the quality of the hatchery product, and genetic differences among the several brood stocks involved.

Harvest estimates for each of the 13 plants of domestic rainbow released in Tahoe were compared with the number released per plant, the time of year of release, and the size of fish at release. No clear-cut relationships were evident. However, according to Cave Rock census data, returns from several plants of domestic rainbow made in March and April of 1960 gave indication of lower harvests than plants made from May through September. The relatively high returns of the large catchables, despite the fact that they were released in the limnetic zone, suggest that higher yields to the angler of fish of this size could be expected by releasing them along the shore. Corlett and Wood (1958) noted that plants of eastern brook trout 9 to 13 inches long gave greater immediate returns than plants of 6½-inch fish.

Longevity of Planted Trout

The length of time the various species and strains of planted trout were able to survive in Lake Tahoe was also based on data from the boat and Cave Rock censuses. Although none of the releases produced a worthwhile premium fishery, such information may very likely have application to other waters, and possibly in the future to Lake Tahoe should substantial changes take place in its ecology (e.g., eutrophication, establishment of exotic food organisms, etc.). This analysis is based on actual numbers of each plant checked, and not on expanded catch estimates for the plants. The numbers checked were those observed during boat census from September 1960 through 1963 and Cave Rock census from 1963 through 1966. (Several 1964 plants were included in this analysis, i.e., two lots of Williams Lake rainbow catchables and one group of domestic rainbow catchables all released at Logan Shoals.) The values obtained are approximations, but are adequate to permit comparisons among the different strains. More refined estimates of survival were not considered feasible because of small sample sizes in most instances, the short life span of most groups stocked, and complications caused by several changes in creel census sampling levels.

In general, domestic trout showed little potential for providing long-term or premium fisheries (Table 4). Of the domestic rainbow eventu-

TABLE 4

Percentages of Planted Rainbow Trout Censused During Various Time Intervals Following Release [1]

Time period at liberty	Kamloops rainbow	Williams Lake rainbow	Pyramid Lake rainbow	Domestic Hot Creek catchables	Domestic large catchables	Domestic catchables released at Logan Shoals
Less than 6 months	70.6	91.0	95.0	99.0	95.4	93.7
More than 6 months	29.4	9.0	5.0	1.0	4.6	6.3
6 months to 1 year	19.9	6.5	3.3	1.0	2.8	4.8
Less than 1 year	90.5	97.5	98.3	100.0	98.2	98.5
More than 1 year	9.5	2.5	1.7	0.0	1.8	1.5
Less than 2 years	96.4	99.7	99.2	100.0	100.0	99.6
More than 2 years	3.6	0.3	0.8	0.0	0.0	0.4

[1] Returns from plants of the same strain were combined.

ally censused, about 95% were taken within the first six months of release, with about 70% returning within the first two months. Wild trout strains demonstrated potential for surviving in Tahoe for extended periods, but there was substantial variation among strains.

Returns of Lahontan and Yellowstone cutthroat were so few that an analysis of their contribution as premium fish was not possible. Only a few long-range returns were checked. The record Lahontan cutthroat was at liberty for only 256 days; one Yellowstone cutthroat survived for about 3 years and another just over 4 years.

In general, Kamloops showed the most potential for providing a premium fishery. An average of nearly 30% of the fish eventually recorded had survived longer than 6 months, with 10% surviving more than 1 year, and 4% more than 2 years. For five of the individual plants, the fractions checked after 6 months ranged from 20 to 30%, and the remaining two values were 0 and 61%. Several Kamloops survived for about 3½ years, the longest survival time recorded for this strain. We believe that the factor most responsible for the superior long-range returns of the Kamloops is their tendency to invade a variety of habitats, in both Tahoe and its tributaries.

Pyramid Lake rainbow manifested little ability to survive for long periods in Tahoe. About 5% of those checked were recorded after 6 months in the lake, less than 2% beyond 1 year, and only a single specimen was known to survive longer than 2 years. This fish was at large almost 3 years. Although from wild stock, the low survival of this strain was not unexpected, since it is adapted to the fertile, highly alkaline Pyramid Lake, a water wholly unlike Tahoe. Williams Lake rainbow were intermediate between Kamloops and domestic rainbow. About 10% returned after 6 months and 2.5% after 1 year in the lake. A single fish was at liberty about 2 years.

Domestic rainbow catchables from California's Hot Creek brood stock exhibited the poorest long-range returns. About 92% of those observed in the creel returned during their initial month in the lake, while 99% came back within the first 6 months. The final 1% returned during the second 6-month span. The record was a fish returning after about 1 year in the lake. The remaining plants of domestic rainbow catchables, representing a variety of brood stocks, had superior long-range returns. About 6% of those checked lived longer than 6 months and 1.5% more than a year. There was considerable variation among plants made in different years, but relatively minor variation among plants made in the same year. Survival beyond 6 months averaged 3% for the 1961 plants, 19% for the 1962 plants, and 5% for the combined 1963 and 1964 plants. A few fish surviving in Tahoe for as long as 3 and 4 years provided the maximum long-range returns. These lots were all released in Logan Shoals, which is closed to fishing part of the year. This apparently reduces the initial high angler take, since schools of planted trout were observed in the harbor from 1 to 2 days to as much as a month after release. From this point they scattered north and south along the rocky shoreline. The influence of the closed area on survival of trout is definitely felt for 2 or 3 months after release, but apparently does not materially increase the percentage surviving longer than 6 months. Based on several plants of domestic rainbow made in March and April of 1960, this appears to hold for trout stocked during periods of low angler pressure compared with those released during the high use months of May through September.

Large catchables of the domestic rainbow strains gave somewhat the same pattern of returns as the domestic catchables released at Logan Shoals. About 5% of those checked came back after 6 months in the lake and 1.8% after 1 year. However, none which had survived over 2 years was checked.

Distribution and Movements of Planted Trout

Information on the distribution and movements of planted trout was gained through the boat census, occasional censuses on certain tributaries and the Truckee River, and from fish collected by a variety of sampling gear. Fish recovered during the period from September 1960 through December 1965 are included in this section, although analysis of recovery by lake area was necessarily limited to the period of boat census.

Corlett and Wood (1958) maintained that trout planted from sandy beaches tended to disperse widely while those released along rocky shorelines remained in the area for a long time. An analysis of our planted trout returns by seven major lake areas revealed that trout planted along the rocky east shore tended to remain on that side of the lake while those planted elsewhere moved more widely (Table 5). This dispersal pattern agrees with the findings of Corlett and Wood, although not all strains were planted in both rocky and sandy areas. All strains of domestic and wild rainbow trout planted on the east shore at Logan Shoals, Zephyr Cove, and Sand Harbor tended to remain along the east shore, with occasional fish caught at the north and south ends. In contrast, trout released at Kiva, Lake Forest, and in McKinney Bay (all Kamloops except for one group of large catchables released at Kiva) usually returned from five or six different areas, without concentrated returns from any one. However, there appeared to be a strong tendency for Kamloops to enter Emerald Bay even when released at Lake Forest and McKinney Bay.

Domestic rainbow appear to be largely restricted to the littoral zone. Plants made from 1960 through 1963, inclusive, returned only four fish from the Truckee River (all from the 1960 release at Tahoe City), and none from the tributaries or the limnetic zone. Six fish were taken in gill nets set on the bottom in relatively shallow water: one at 16 feet, three at 25 feet, and one each at 65 and 100 feet. The great majority of domestic rainbow apparently remain in the littoral zone, where they are caught by shore, pier, and topline anglers. This distribution pattern apparently holds for Pyramid Lake rainbow, since the only recoveries were made by anglers in these same categories.

Distribution of fish in Tahoe's large limnetic zone was determined with monofilament gill nets. Forty sets, usually with two nets, were made in widely scattered locations in open water. Nets were usually set for 2 or 3 days and nights. Each net was about 400 feet long, 22 feet deep, and contained 8 panels with mesh sizes from 1 to 5 inches, stretch measure, in ½-inch intervals (excluding a 4½-inch panel). One net was usually set at the surface and the second hung below it, fishing either the 50- to 72- or the 100- to 122-foot depth zones. However, occasional double surface sets were made. The nets were set so that they did not come close to the bottom. They were set each month in 1964.

The monofilament nets captured 423 fish of which 73, or 17%, were planted rainbow trout. Most of the remainder were wild rainbow trout, kokanee salmon, and tui chub (*Siphateles bicolor*). Stocked trout were strongly surface oriented throughout the sampling period, during which time surface temperatures ranged from 42 to 67 F. Fifty-

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TABLE 5

Area of Capture of Planted Trout as Reflected in Percentage Contribution by Area of Each Planted Group to Total Catch Per Hour[1]

Strain of trout	Year of plant	Release locality	Area 1 Stateline to Dollar Point	Area 2 Dollar to Sugar Pine Point	Area 3 Sugar Pine to Eagle Point	Area 4 Emerald Bay	Area 5 Eagle to Elk Point	Area 6 Elk to Deadman Point	Area 7 Deadman to Stateline Point
Domestic rainbow catchables	1961, 1962, 1963	Logan Shoals	1.6	0.6	0.0	0.0	2.0	81.8[2]	14.0
Pyramid Lake rainbow catchables	1961	Sand Harbor	0.0	0.0	0.0	0.0	0.0	0.0	100.0[2]
Pyramid Lake rainbow subcatchables	1962	Logan Shoals	2.8	0.0	0.0	0.0	0.0	85.4[2]	11.8
Williams Lake rainbow catchables	1963	Logan Shoals	0.0	0.0	0.0	0.0	0.0	71.3[2]	28.7
Domestic rainbow large catchables	1961	Zephyr Cove, Immediate	0.0	0.0	0.0	0.0	3.6	88.1[2]	8.3
Domestic rainbow large catchables	1962	Off Kiva, Immediate	25.0	0.0	20.0	0.0	15.0[2]	30.0	10.0
Kamloops rainbow subcatchables and catchables	1961, 1962	Lake Forest	29.0	44.6[2]	2.5	8.3	0.0	1.5	14.1
Kamloops rainbow fingerlings and catchables	1961, 1962	Kiva	0.0	2.0	2.3	87.0	5.1[2]	2.5	1.1
Kamloops rainbow catchables	1961	McKinney Bay, Immediate	22.6	25.8[2]	0.0	11.9	0.0	3.2	6.5

[1] Derived from boat census catch-per-hour data for 1961, 1962, and 1963 combined. These were used as a measure of the relative density of planted trout in each area. The percentages are based on the portion each area contributes to the summation of the catches per hour for each strain for all areas combined. Data for 1960 plants were not used because boat census did not cover the entire lake.

[2] The area which includes the release locality.

three (73%) were found within 10 feet of the surface, 14 (19%) within the 11- to 14-foot depth zone, and 4 (5%) between 16 and 20 feet. The remaining two fish were caught 52 and 54 feet below the surface. However, nets were not fished between 22 and 50 feet.

Kamloops and Williams Lake rainbow trout dominated the catch of planted trout in Tahoe's limnetic zone. Kamloops comprised 48% of the total caught, with the 1963 release making up the highest percentage (29%) of any individual group. Virtually all were from 10 to 16 inches long. If we eliminate the 1964 plants from consideration,[6] Kamloops and Williams Lake rainbow were the only stocked trout caught in the limnetic zone. The former made up about 83% and the latter 17%, with the 1963 Kamloops plant alone contributing 58%. However, since the number of Kamloops planted in 1963 was over six times larger than the 1963 Williams Lake plant, the latter were relatively more abundant. Although fewer domestic than wild rainbow were released, the complete absence of the former (except for two from the 1964 plant) in the limnetic zone seems significant.

Stocked trout caught in the limnetic zone were colored like wild rainbow trout from the same habitat. (Several weeks are apparently required for planted trout to lose the typical "hatchery" coloration.) These fish are known locally as "silvers" and are highly prized by anglers. Their sides are intensely silver, grading into creamy white ventrally and deep blue to emerald green along the back and head. Body spotting is absent or inconspicuous, but when present is found along the dorsal body surface and on the dorsal and caudal fins. At times we observed the presence of many small, sharp teeth, and on some specimens the scales were deciduous. The fins tend to be more pointed and the caudal fin more deeply forked than for rainbow taken in the littoral zone or the tributaries. These features generally conform to those of the probably nominal royal silver trout (*Salmo gairdnerii regalis*) described by Snyder (1917). While still somewhat silvery, the shallow-water rainbow, both planted and wild, tend to be darker, more heavily spotted, and may possess typical lateral rainbow hues. Fish with this appearance were rarely taken very far from shore.

Of all the strains planted, Kamloops rainbow showed the greatest tendency to enter streams tributary to Lake Tahoe. No Williams Lake rainbow were recovered from streams. Only fragmentary information is available, since census effort and collections occurred only on certain tributaries and spawning runs were not sampled. Creel census on July 1, 1962, and July 4, 1964, on Ward, Blackwood, and Taylor creeks recorded 41 Kamloops: 5 from the 1961 releases, 31 from 1962 plants, and 5 from the 1963 plant. Nine additional Kamloops were recorded from Third Creek, the Truckee River, and the small stream adjacent to the old Tahoe Fish Hatchery near Tahoe City (Hatchery Creek). Six Kamloops spawners from the lake (5 from the 1962 and 1 from the 1961 plants) were dip netted from Hatchery Creek in May and June of 1965. Runs of Kamloops spawners probably entered other tributaries, also. This indicates that Kamloops may spawn successfully and thus contribute to the wild rainbow fishery. Since rainbow spawn-

[6] All 1964 plants were made in June or July, in the middle of the sampling year. Their capture in the limnetic zone is probably the result of wandering which planted trout undergo for a short period following release.

ers commonly return to the lake before the July opening of trout season, we would not expect to check them during stream census.

In October 1961, 103 planted trout were seined from Taylor Creek. These included 93 Kamloops and 10 Lahontan cutthroat from the 1961 plants, of which about 90% were ripe males. Numerous small redds were seen. This represented an instance of premature ripening quite distinct from the spring spawning of adults noted earlier. Other Kamloops from this plant tended to remain schooled for several weeks after release and commonly entered harbors and marinas. In several instances we noted schools of small trout containing both Kamloops and wild rainbow. Although it was not part of the regularly censused area, a spot check of anglers fishing in the Tahoe Keys on April 22, 1962, revealed 52 Kamloops in the creel. It is apparent that Kamloops are capable of utilizing all of Tahoe's surface waters as well as its tributaries.

Growth of Planted Trout

We assessed the growth of the various strains of rainbow trout planted in Lake Tahoe by combining data for individual lots of the same strain and then plotting monthly mean lengths for all fish taken by anglers and in sampling gear. Data were available for plants made as long ago as 1956. Returns of cutthroat and certain rainbow strains were too few to permit analysis. Results for fish at large more than 6 months tended to be highly variable because of small sample sizes, precluding a more quantitative description of growth. Extreme variation occurred in the Kamloops data because some fish grew little, if any, after release. Up to 12 months following planting, anglers were still taking a few 6- to 9-inch Kamloops from shore and piers. To minimize the influence of these fish, all Kamloops at large more than 6 months and less than 10.0 inches long were eliminated.

Growth rates for the various strains appeared relatively uniform, with the domestic rainbow showing some superiority (Figure 2). Best growth was recorded during the first 12 to 18 months in the lake, when planted trout increased about 0.4 inch per month. Growth then declined to approximately 0.2 inch per month and, after 30 to 36 months, finally tapered off at 0.1 inch per month. Using values for October, the domestic rainbow averaged about 10.0, 15.5, 18.5, and 20.0 inches in their 1st, 2nd, 3rd, and 4th years in the lake, respectively. Similar figures for the Kamloops were about 8.5, 13.0, 15.0, and 16.5 inches. Growth for domestic rainbow appears asymptotic between 19 and 21 inches and for Kamloops between 16 and 18 inches.

Of the trout recaptured after 6 months at liberty, domestic rainbow catchables returned relatively more large fish than wild rainbow strains. Kamloops returns consisted mostly of small fish and returns of Williams Lake rainbow were intermediate (Figure 3). Considering 1961, 1962, and 1963 plants only, the 10 largest domestic rainbow observed ranged from 17.5 to 21.0 inches, while the 10 largest Kamloops ranged from 16.5 to 17.8 inches.

Mortality Factors

The low returns to the angler of trout planted in Lake Tahoe demonstrate that large numbers are being lost through natural causes. In gen-

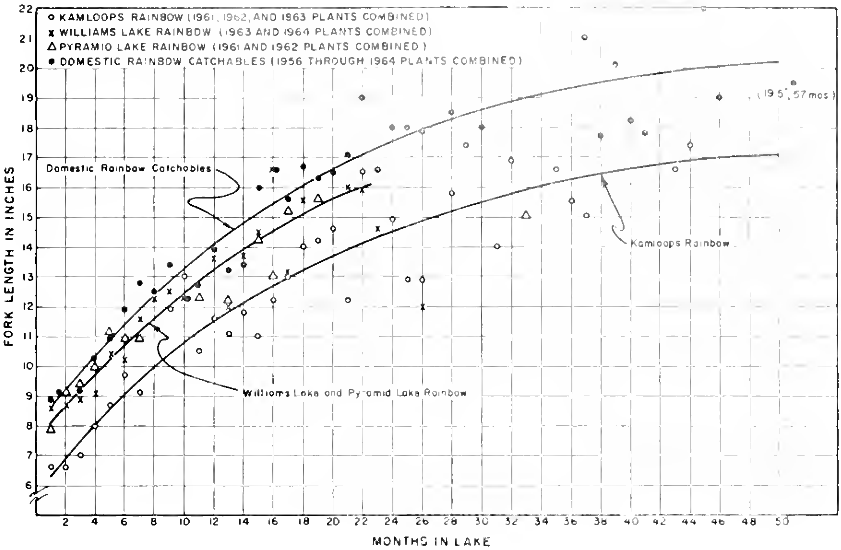

FIGURE 2—Growth of rainbow trout planted in Lake Tahoe as shown by monthly mean lengths. Returns are combined for fish taken from the lake by any method from 1959 through 1966. Curves fitted by inspection.

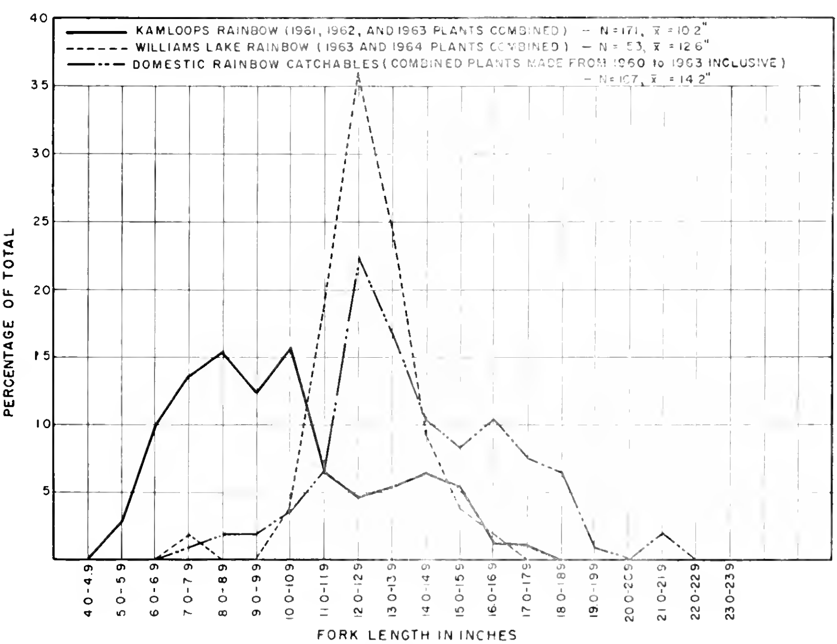

FIGURE 3—Size composition of planted rainbow trout recovered from Lake Tahoe after 6 months at liberty. Returns are combined for fish taken from the lake by any method from 1961 through 1965.

eral, planted trout arrive at Tahoe in good condition. However, weak and distressed fish were noted on occasion and premature ripening was common in some lots. Although probably such factors, and perhaps the removal of fins or mixillary bones, reduce survival, we don't believe they are as important as certain other factors. Although much of what is presented here is speculation, there is some factual and observational evidence.

The inclination of Kamloops to enter tributaries, apparently for prolonged periods, must result in high natural mortalities. Almost all tributaries are subjected to wide fluctuations in flow, with the low flow period extending from late summer through winter. Winters are normally severe and, in conjunction with low flows, no doubt take their toll of trout. Competition for food and space is severe and probably critical, especially in summer and autumn. Mammalian and avian predators on trout occur along the tributaries and undoubtedly take some trout, especially under reduced flows. The belted kingfisher *(Megaceryle alcyon)*, American bittern *(Botaurus lentiginosus)*, and common merganser *(Mergus merganser)* appear to be the most serious. Resident brown trout found in the larger tributaries most likely prey heavily on planted trout.

Murphy (1963) conducted a short-term study in late summer of trout survival in a 295-foot screened section of Taylor Creek. A plant of domestic rainbow fingerlings (47 per ounce) yielded a 1-month survival of only 10.6%, and wild rainbow trout-of-the-year had an 11.7% survival for the same period. To help explain the low survival, he mentioned the presence of a 20-inch brown trout, a bittern, ducks, and western garter snakes *(Thamnophis ordinoides)*, plus the lack of stream shade and shelter. His sampling in the experimental section also revealed a very abundant population of nongame fish.

Planted trout which remain in the lake are also subjected to various conditions which reduce survival. Competition for food and space in the restricted littoral habitat is probably severe during the critical summer and autumn months, when this area is populated by large numbers of nongame fishes (Baker, 1967). In addition to Tahoe's unusually low basic productivity, which can be expected to produce low densities of potential food items, this may be responsible for the poor survival of planted trout. The condition of planted trout recovered after 6 months in Tahoe reflects less than optimum conditions for growth and survival. Condition indices of planted trout at the time of release ranged from 40 to 45. Indices for those recovered after 6 months declined to a mean of 35.8 for 149 Kamloops, 38.0 for 48 Williams Lake rainbow, and 38.1 for 100 domestic rainbow. Also, we commonly observed that wild and planted rainbow trout shorter than 18 inches had a slender appearance. This was especially true of rainbow taken in the limnetic zone.

The behavior of planted trout in the lake probably results in reduced survival. We noted that Kamloops and domestic rainbow very often formed large schools upon release. Sometimes they entered marinas and harbors, where they remained several weeks. Apparently they were not actively foraging at such times. In addition, such compact schools provided a ready food supply for certain predators such as common mergansers, which frequent Tahoe.

That the lake trout is abundant in Lake Tahoe may be surmised from data presented by Cordone and Frantz (1966). The piscivorous habits of the lake trout are well known and, therefore, predation on planted trout may be expected. In 1962, 1963, and 1964, 1,150 stomachs from lake trout longer than 15.0 inches were examined (Lake Tahoe Fisheries Study, unpublished data). Lake trout of this size are fully capable of ingesting planted catchable-sized trout. Those longer than 30 inches could probably consume large catchables, but such large lake trout constitute only a small fraction of the population. In 30 stomachs (2.6%), we found 123 possible planted trout. Ninety-eight were definitely planted trout and the remainder were either wild rainbow or planted trout. Recently planted Lahontan and Yellowstone cutthroat seem to be especially vulnerable to lake trout predation. The 98 planted trout included 75 Lahontan cutthroat, 18 Yellowstone cutthroat, 4 Williams Lake rainbow, and 1 Kamloops rainbow. Stomachs from eight lake trout (19.6 to 24.7 inches) taken in gill nets set at a depth of 40 feet, and about 1½ miles from the location of a release made 2 days earlier, contained 74 Lahontan cutthroat. One stomach had 20 and another 19 cutthroat. We believe that lake trout predation is the primary cause of the failure of the two cutthroat species. Unlike rainbow strains, which occupy the littoral and shallow limnetic zones, cutthroat apparently range along the bottom into deeper water, where they are particularly vulnerable to the lake trout. This attribute may be an advantage, however, in large, deep lakes not containing lake trout.

CONCLUSIONS

Under present conditions, it does not appear that a premium trout fishery can be developed in Lake Tahoe by stocking domestic rainbow or wild strains of rainbow and cutthroat trout. Some species such as Lahontan and Yellowstone cutthroat yielded little or no return to the angler. Kamloops rainbow showed the greatest potential for providing a premium fishery. However, returns of premium fish were too few to justify the expense involved. Other species have been planted in Tahoe and while data are not available to compare with those presented here, it is evident that they also did not furnish a premium fishery. This includes eastern brook trout planted in 1956 and 1957, steelhead rainbow and domestic rainbow of the Mt. Whitney (California) strain planted in 1964, and silver salmon *(Oncorhynchus kisutch)* planted in 1966. No doubt there are other promising species and strains of trout and salmon which might be tested. However, there is little reason to believe they would be successful when Kamloops and other wild strains failed. We suspect that the lack of an abundant and readily available supply of food limits the growth and survival of planted trout. Should the introduced opossum shrimp *(Mysis relicta)* and/or Bonneville cisco *(Prosopium gemmiferum)* establish dense populations in Lake Tahoe (see Linn and Frantz, 1965; Frantz and Cordone, 1965), it would be advisable to repeat tests with Kamloops and possibly steelhead and silver salmon.

Using domestic rainbow catchables, it would be feasible to develop a put-and-take program at Tahoe in which 90% or more of the fish would be caught. This could be done by releasing the trout in shoreline locations which are readily accessible to the public, by publicizing the plants and, if necessary, by using some type of enclosure to prevent planted fish from moving away from the area of release. Obviously, such an approach is much too artificial, creating undesirable concentrations of anglers, and is not recommended.

Based on the plants described in this report, and unpublished results from returns of trout planted in Tahoe in 1964 which were tagged with $5 reward tags, a put-and-take fishery for domestic rainbow catchables could be developed which would probably yield harvests of about 40%, with one for large catchables providing harvests of about 70%. This could be done by summer plants in harbors and marinas closed to fishing, such as at Logan Shoals, or by scattering smaller lots of fish in suitable locations around the lake. Under such a program occasional undesirable concentrations of anglers could still be expected, but on a much reduced scale.

Considering costs alone, it would be more economical to plant catchables rather than large catchables. Based on records from trout production hatcheries of the California Department of Fish and Game, it costs $0.874 per pound to rear and plant these trout (Ward, 1967). Each catchable (mean length and weight = 8.0 inches and 0.23 pounds) costs about $0.20 and each large catchable (mean length and weight = 12.0 inches and 0.75 pounds) costs about $0.66. If we wanted to double the present take by Tahoe "surface" anglers of 4,000 wild rainbow, we would have to plant enough fish to provide an additional take of 4,000 trout. This could be done with either 10,000 catchables costing $2,000 or 5,714 large catchables costing $3,771. The cost per trout in the creel would be $0.50 for the former and $0.94 for the latter. Despite the cost differential, a planting program utilizing large catchables seemed more suitable for Lake Tahoe. Substantial plants of catchables are already made annually in a number of lakes and streams in the Tahoe Basin. Thus, to provide greater diversity of fishing opportunities in the Basin and to enhance fishing for Tahoe "surface" anglers, we recommended an annual plant of large catchables. In 1964 the California and Nevada Fish and Game Commissions approved a proposal to plant 26,500 large catchable rainbow trout annually, and the program was initiated in 1965 on a routine management basis.

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STUDIES ON THE EPIZOOTIOLOGY OF THE MYXOSPORIDAN *CERATOMYXA SHASTA* NOBLE [1]

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Epizootics of *Ceratomyxa* devastated stocks of rainbow trout *(Salmo gairdnerii)* at Crystal Lake Hatchery, California, in 1948, 1949, 1962, and 1963. Wild rainbow trout, eastern brook trout *(Salvelinus fontinalis)*, brown trout *(Salmo trutta)*, and silver salmon *(Oncorhynchus kisutch)* were more resistant to the disease. Springs in the area appeared free of the disease but most streams and impoundments examined were infected. Changing the source of the water supply at Crystal Lake Hatchery in 1965 apparently eliminated the disease from this installation. Information is included on distribution of the disease, its seasonal occurrence, symptoms, and transmission, and resistance of various fishes to it.

Crystal Lake trout hatchery is adjacent to Baum Lake at the outlet of Crystal Lake, about 10 miles northeast of Burney, Shasta County. The altitude is about 3,000 feet. The surrounding area is of volcanic origin, characterized by geologically young lava flows, extensive diatomaceous earth deposits, and many springs.

A serious loss of rainbow trout caused by *Ceratomyxa* resulted in the temporary closure of Crystal Lake Hatchery in 1963 and prompted the 4-year study of the disease summarized in this paper. This study was greatly enhanced by and would not have been possible without the cooperation and assistance given by the employees at the hatchery and especially the manager, D. A. West.

Ceratomyxa shasta, or a closely related species, has been reported from king salmon *(Oncorhynchus tshawytscha)*, silver salmon, and steelhead trout *(Salmo gairdnerii gairdnerii)* in anadromous fish hatcheries in Oregon (Conrad and Decew, 1966), from king salmon and silver salmon in Washington (James W. Wood, pers. comm.), and from adult king salmon at Trinity River Hatchery in California (Richard Haley, pers. comm.).

Crystal Lake Hatchery was completed in 1947, and supplied with approximately 20 cfs of water by a ditch from Crystal Lake. Ponds were stocked with rainbow trout in October 1947. In June 1948, J. H. Wales observed *Ceratomyxa* in these trout and this myxosporidan eventually caused total mortality (Wales and Wolf, 1955). E. R. Noble described the organism as a new species and the first record of the genus in fresh water (Noble, 1950).

The hatchery ponds were sterilized with chlorine (HTH) and restocked with rainbow trout in the fall of 1948. The following June the disease recurred. Crystal Lake, the source of water for the hatchery, was first treated with rotenone and then chlorinated with 7,500 pounds of liquid chlorine in July 1949. The ponds were restocked but the dis-

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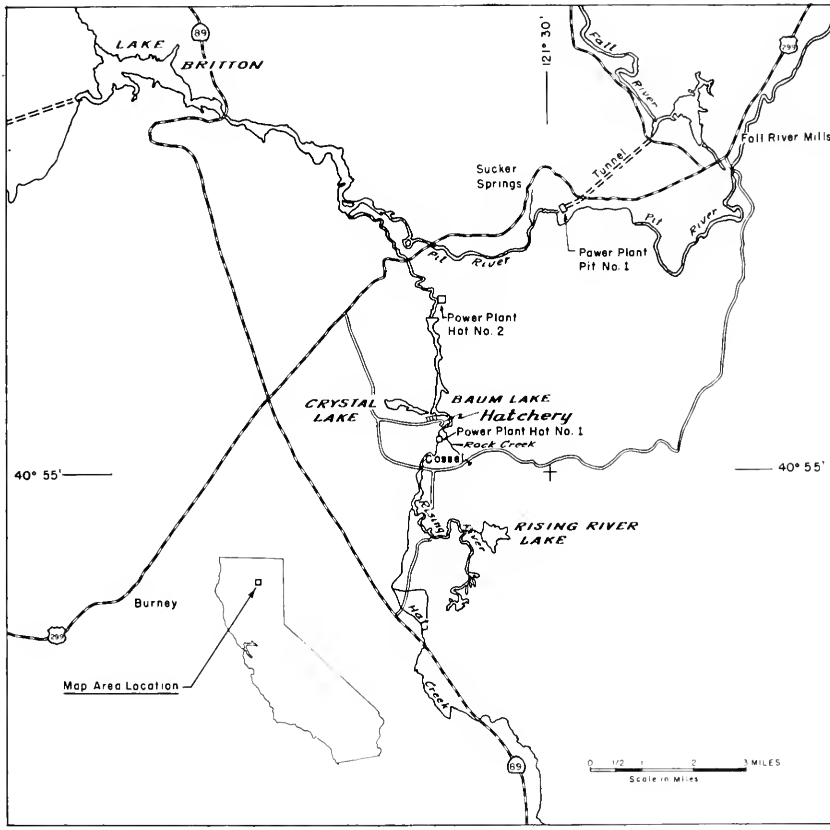

FIGURE 1—Location of the study area, showing the waters investigated. *Drawing by Cliffa Corson.*

ease reappeared in September 1949. All rainbow trout died in each outbreak. To make use of an alternate water supply, a diversion dam, 24-inch pipeline, and ditch were constructed in 1950 to bring water from nearby Rock Creek to the hatchery. This pipeline crossed Baum Lake through an inverted siphon. Subsequently, *Ceratomyxa* occurred only sporadically in a few fish over a 12-year period.

During these years experiments were conducted with various small groups of salmonids in Crystal Lake water in the old supply ditch. In 1958 and 1959, silver salmon were reared successfully, but in 1960 they became infected with *Ceratomyxa*, although the mortality was light. In 1961, brown trout were reared and found to be infected, also with slight loss.

Ceratomyxa reappeared in the hatchery in late June 1962. Because of the severity of infection, all rainbow trout were destroyed. A group of fingerling Eagle Lake trout *(Salmo gairdnerii aquilarum)* transferred to Crystal Lake Hatchery on June 18, 1962, did not become diseased. However, a similar group of Eagle Lake trout transferred from Crystal Lake Hatchery on the same date and returned on June 26 did incur the disease. This indicated that the infection occurred before June 18. Rock Creek, the hatchery water source, was rotenoned and chlorinated and as many fish as possible were collected and examined. The only diseased fish were rainbow trout found in the open ditch between the pipeline and headflume of the ponds.

The hatchery was restocked in August 1962 with 80,000 brown, 120,000 eastern brook, and 180,000 rainbow trout. On June 4, 1963, *Ceratomyxa* was found in all three species. Samples indicated a 20% infection in the brown trout, a 70% infection in the rainbow trout, and a 90% infection in the eastern brook trout. However, tissue damage in the brown and brook trout grossly appeared less severe than in the rainbow trout. All brown trout and brook trout were held for further observation. One pond of rainbow trout was also held for observation, and all other rainbow trout were destroyed.

By August 1, 1963, all of the retained rainbow trout were dead. The brown trout had suffered a loss of 0.5% (340 fish) and the brook trout a loss of 3.0% (3,000 fish). Of 90 brook trout examined at this time, two aberrant appearing spores in one fish were the only evidence of *Ceratomyxa*. No evidence of it could be found in the brown trout. Surviving brook and brown trout were planted in the watershed. During August, production at Crystal Lake Hatchery was stopped to make all hatchery facilities available for studies to develop control measures.

After the disease appeared in 1963, live cages had been placed in Rock Creek at the upper diversion (domestic supply), at the lower diversion (pond supply), and in the open ditch below the pipeline. Cages were also put in Crystal Lake, Baum Lake, and Hat 1 powerhouse forebay. Each cage was stocked on June 12, 1963, with one hundred 1-ounce rainbow trout from Moccasin Creek Hatchery, Tuolumne County. Ten fish from each cage were examined weekly during July. Fish in cages from Crystal Lake, Baum Lake, and the powerhouse forebay were found to be infected with *Ceratomyxa* 29 days later, on July 11, 1963. Fish in the cages in Rock Creek water did not show any evidence of the disease during 1963.

These results suggested that leaks in the siphon under Baum Lake were the probable source of infection. Live-cage tests proved that particular part of the lake to be highly infective, and several small holes were found in the siphon when it was removed in 1965.

Experiments in the hatchery itself during 1964 had been unproductive because the disease did not occur there that year, even though live-cage tests confirmed that Baum Lake water was again highly infective. Baum Lake's surface level was significantly lower that year, and the flow through the pipe was reduced. Either factor would tend to reduce the entry of lake water into the pipe, and their combination probably prevented entry of lake water.

Early in 1965, a new pipeline bridging the lake was built, and carried water directly from the major spring source of Rock Creek a half-mile to the hatchery. Since then the disease has not reappeared in the hatchery.

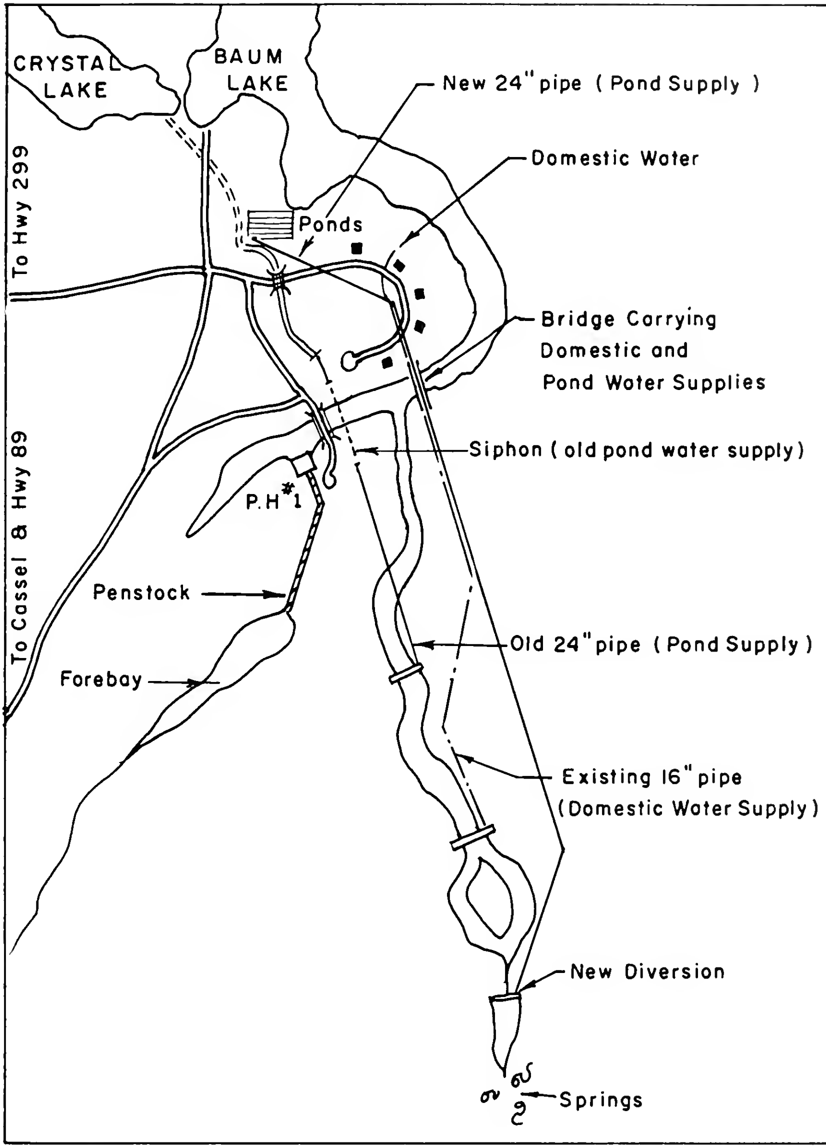

FIGURE 2—Location of diversions and pipe lines to hatchery from Rock Creek. *Drawing by Cliffa Carson.*

DISTRIBUTION

The distribution of *Ceratomyxa* in the Pit River drainage is under investigation. Results at present indicate that the ground waters (springs) are free of the disease. *Ceratomyxa* has been found in spring-fed lakes (actually large spring pools), their outlet streams, streams accepting the outflow, and impoundments on these streams. Spring-originated streams which do not have large pools and standing water have not been infective.

Live cages containing rainbow trout were used in the following waters to determine if *Ceratomyxa* was present.

Crystal Lake

This is a 37-surface-acre lake with a maximum depth of 14 feet. It is fed by many subsurface springs and has an outflow of about 250 cfs into Baum Lake.

Rainbow trout in all areas of this lake became infected except when held directly in the emerging water of the springs. In one experiment, a live cage constructed by screening both ends of a 2-foot section of 36-inch-diameter steel pipe was placed vertically over a spring in 5 feet of water in Crystal Lake. Rainbow trout held in this cage did not become infected even after a 90-day exposure.

Rock Creek

This spring-fed stream, approximately ¾ mile long, has an average flow of 24 cfs. It has a moderate gradient and normally would flow into Baum Lake. Most of the water is now diverted to the hatchery.

Ceratoxyma could not be found in any of the fish collected above the hatchery diversion by chemical treatments in 1962 and 1963, nor has it been possible to infect rainbow trout held there in live cages.

Baum Lake

This 80-acre impoundment was formed for hydroelectric purposes. It operates on a stream-flow basis, with minor fluctuations.

Ceratomyxa occurs in all areas of the lake.

Rising River Lake and Rising River

This 100-surface-acre spring-fed lake has an outflow of approximately 200 cfs. It resembles Crystal Lake in most respects. Rainbow trout held in the outlet are infected with *Ceratomyxa*.

Rising River is a series of pooled springs gradually merging into a stream. It flows about 300 cfs for about a mile before joining the outlet from Rising River Lake. About 2 miles downstream, Hat Creek enters and the combined flows are diverted at Cassel and enter Baum Lake through Hat 1 powerhouse. Infection occurs above and below the junction of Rising River and the Rising River Lake outlet. *Ceratomyxa* is believed to occur throughout the river.

Hat Creek Above Rising River

This spring-fed stream starts 10 miles northeast of Lassen Peak and flows for about 25 miles to the northeast. In late summer much of its flow is diverted for irrigation. It has not been possible to infect rainbow trout in Hat Creek 100 feet upstream from its junction with Rising River, and the disease is therefore assumed to be absent there.

Hat Creek Below Baum Lake

This stream of approximately 700 cfs flows for about 3 miles from the Hat 2 powerhouse to join the Pit River at the head of Lake Britton. It carries the accumulated flows of Hat Creek Rock Creek Rising River, Rising River Lake, and Crystal Lake. *Ceratomyxa* infection occurred in live cages in this stream near the Highway 299 crossing (approximate midpoint of stream section).

Sucker Springs

This spring-fed stream, approximately a half-mile long, flows about 40 cfs into the Pit River about 1 mile below Pit 1 powerhouse. It has not been possible to infect rainbow trout with *Ceratomyxa* in this stream.

Pit River

Rainbow trout placed in a live cage in the Pit River between Sucker Springs and Fall River became infected with *Ceratomyxa*.

Fall River

This slowly moving, spring-fed stream flows south on the west side of Fall River Valley. About 1,800 cfs is diverted through a tunnel to Pit 1 powerhouse and discharged into the Pit River. Fall River drains Big Lake, Eastman Lake, Tule River, Lava Creek, Spring Creek, and Bear Creek, a complex of waters much like the Rising River, Crystal Lake, Baum Lake, Hat Creek system. Infection occurred at the Pit 1 tunnel intake structure and is assumed to originate from the upstream lakes.

Lake Britton

This hydroelectric impoundment of about 1,264 surface acres in the main channel of the Pit River diverts water through a tunnel to Pit 3 powerhouse. Infection occurred at the tunnel intake near the dam.

SEASONAL OCCURRENCE

Wales and Wolf (1955) found *Ceratomyxa* in the fall and winter at Crystal Lake Hatchery, presumably because the ponds were then stocked with trout during the summer and fall. Actually, it is infective when water temperatures exceed 50 F. January, February, and March are non-infective months. April and December can be infective, depending on water temperatures. Infection occurred regularly from May through November.

Even though infection does not occur at temperatures below 50 F low temperatures will not stop an established infection. However lowered temperatures slow the rate of development. For example, rainbow trout infected in late November did not die from the disease until February or March.

SYMPTOMS AND COURSE OF DISEASE

Noble (1950) described *Ceratomyxa shasta* and the gross pathology of this parasite in rainbow trout. Wales and Wolf (1955) also discussed the gross pathology and some symptoms of the disease. Additional information follows.

The first symptoms of *Ceratomyxa* in domestic rainbow trout (held in water with an average daily temperature 54 F (52-56 F) usually occur about 25 days after infection. Lack of appetite, listlessness, and redistribution to the slack water are early indications. The fish darken. Casts of intestinal epithelium and mucosa often appear on the screens and pond bottom. The abdomen may swell if the visceral cavity fills with ascites. Exophthalmia (popeye) also accompanies this dropsy.

The first internally observed changes are small, whitish, opaque areas which begin to appear in the tissue of the large intestine about 20 days after infection. As the disease progresses, the entire intestine becomes swollen and hemorrhagic.

All domesticated strains of rainbow trout which have been tested have died after being infected. For example, in 1961, six groups of 100 rainbow trout (2 per ounce) from Moccasin Creek Hatchery were placed in live cages in Crystal Lake at 2-week intervals and all died of *Ceratomyxa*. The average time from infection to mortality was 41 days. The first group survived 42 days at a water temperature range of 51 to 53 F, and the last group survived 38 days at a range of 53 to 61 F.

The earliest stage of *Ceratomyxa* so far recognized in rainbow trout is found about 18 days after infection. Fresh preparations of scrapings from the junction of the large and small intestine examined with a phase-contrast microscope reveal a few granular, multinucleate, nonameboid schizonts.

Approximately 25 days after infection, active, binucleate, ameboid trophozoites can be found readily in the opaque areas occurring in the intestine.

From 30 to 35 days after infection, ameboid pansporoblasts with developing spores occur throughout the intestine but still are less numerous than the trophozoites.

From 38 to 42 days after infection, the fish die. Spores, pansporoblasts, and trophozoites then occur throughout the visceral cavity. These pansporoblasts and trophozoites degenerate soon after the death of the host.

TRANSMISSION

Throughout the infective season, rainbow trout repeatedly have been infected by *Ceratomyxa* during a 2-hour exposure in Baum Lake. Infection has occurred in no more than 15 minutes. A 2-hour exposure assured infection of all fish. For these tests, noninfected rainbow trout were exposed in a live cage in Baum Lake and then moved to a holding tank supplied with Rock Creek water, a noninfective source, for observation. Control fish not exposed in Baum Lake showed no evidence of the parasite.

Infection does not appear to depend on the ingestion of food organisms. Sixty rainbow trout (at 1 per ounce) were starved for 72 hours at Darrah Springs Hatchery, Shasta County, and transported on May 13, 1964, to Crystal Lake Hatchery. Ten of these trout were put in a holding tank supplied with Rock Creek water as controls. The other 50 trout were put in a live cage in Baum Lake. Groups of 10 trout were removed from the live cage at intervals of 2, 5, 8, 18 and 24 hours of exposure. Three trout from each sample, including the controls, were killed and the stomach and intestinal contents were examined. The remaining fish in each sample were fin-clipped and transferred to the holding tank with the controls. All trout that had been in Baum Lake, regardless of the length of exposure, were diseased when examined 28 days later, on June 10, 1964. No evidence of *Ceratomyxa* could be found in the controls, even though they had been in the same tank with the exposed groups. The three stomachs examined from the 2-hour exposure sample were empty except for a tendipedid larva found in one stomach. This experiment has been repeated on a 2-hour basis from 7 a.m. to 11 p.m. with the same results.

In another test, rainbow trout exposed for 2 hours in Baum Lake in a wood-frame live cage covered with "Nytex 44", a nylon material with threads spaced approximately 44 microns apart, were infected with *Ceratomyxa*.

Hoffman, Putz, and Dunbar (1965) suggest that aging of myxosporidan spores *(Myxosoma)* may render them infective. To explore this possibility, an experimental tank was stocked in November 1964 with 10 rainbow trout (at 4 per pound) infected with *Ceratomyxa*. These fish died and decomposed and the tank was not disturbed through the winter period. Normal-appearing spores were recovered in pipetted samples from the bottom of this tank on April 21, 1965. Fifty noninfected rainbow trout (at 1 per ounce) were put in the tank and held through August 1965. No evidence of *Ceratomyxa* was found in any of these trout.

The disease has been transferred by inoculating ascites (containing schizonts, trophozoites, and spores) from infected rainbow trout into the visceral cavity of noninfected rainbow trout. Autopsy of the inoculated trout after 20 days revealed a possible regression of stages. The visceral cavity contained spores and early schizonts and the intestinal tissue had been invaded by schizonts. No trophozoites or pansporoblasts were found.

Fish-to-fish transmission by all other methods tried has failed. Association of noninfected rainbow trout with infected rainbow trout in the same tank in noninfective water has not transmitted the disease. Force feeding of infected viscera containing schizonts, trophozoites, and spores has not been successful.

The mode of transmission is still unknown.

RESISTANCE

All of the waters found to be infective contain "wild" rainbow trout. These fish are presumably resistant to *Ceratomyxa*, but occasionally an individual is found dead or dying from the disease. Healthy fingerling rainbow trout trapped from spring areas in Crystal Lake become infected with *Ceratomyxa* when held in Baum Lake. Perhaps these "wild" rainbows, like eastern brook and brown trout, are more resistant to the disease than domesticated rainbow.

The experience with brown trout in 1961 and brook and brown trout in 1963 suggested that they are resistant to the disease. Therefore, in 1964 fingerling resistance was tested in a concrete flume supplied with approximately 6 cfs of Crystal Lake water and screened into three consecutive sections. On July 16, 1964, the upper section was stocked with 1,000 brown trout (20 per ounce), the middle section with 1,000 brook trout (20 per ounce), and the lower section with 1,400 rainbow trout (28 per ounce). On August 28, 1964, *Ceratomyxa* was found in samples from all three groups. The rainbow trout had all died by October 16, 1964. The brown trout had suffered a loss of about 11% (115 fish) and the brook trout loss was about 24% (239 fish) when the experiment was terminated in January 1965. No evidence of *Ceratomyxa* was present in the survivors.

Silver salmon are also resistant to *Ceratomyxa shasta*, some strains more so than others. In 1963, the following seven strains of silver salmon were exposed to the disease to test the assumption that a change in the strain used had caused the 1960 outbreak:

1) Quilcene River, Jefferson County, Washington
2) Klaskanine River, Clatsop County, Oregon
3) Lower Columbia River (Eagle Creek National Fish Hatchery), Cowlitz County, Washington
4) Alsea River, Benton County, Oregon
5) South Fork Eel River (Benbow Dam), Humboldt County, California
6) Pudding Creek, Mendocino County, California
7) Noyo River, Mendocino County, California

On April 16, approximately 200 fish (70 per ounce) of each strain were placed in separate live cages in Crystal Lake water. Equal numbers of rainbow trout (at 1 per ounce and 80 per ounce) served as controls. The experiment ended on February 20, 1964. All rainbow trout had died. *Ceratomyxa* infections in the silvers had been found only in the South Fork Eel River, Pudding Creek, and Noyo River strains. Losses were minor. The usual site of infection in these silvers was in the eye, rather than the intestine.

CONCLUSIONS

The available evidence suggests that the life cycle of the Myxosporida is completed within a host. Presumably, spores produced as the terminal product of infection in the host are the infective agent. Transmission may occur by ingestion of spores and subsequent release of an amoebula (sporoplasm) which penetrates the gut and migrates to a tissue of choice and a new infection is started. However, no one has been able to demonstrate experimentally that this occurs.

The knowledge gained in this study even suggests that the spore may not be directly infective to fish. For example, although many spores were probably shed in the hatchery ponds during the 1962 and 1963 epizootics, no additional infections occured in these ponds after construction of the new pipeline, which eliminated infective waters from the water supply. Similarly, neither close association of infected and noninfected trout nor force feeding of tissue containing spores transmitted the disease. Careful examination of many stomachs and intestines of trout infected by exposure in a live cage never uncovered spores or remnants such as spore shell halves, even though intact spores can be recovered from inoculated fish.

Many invertebrates and vertebrates from Crystal Lake and nearby areas were examined for *Ceratomyxa*, always with negative results. These included sponges, hydras, planarians, rotifers, annelids, cladocerans, copepods, ostracods, amphipods, mites, insect larvae and nymphs (orders Plecoptera, Ephemeroptera, Odonata, Hemiptera, Trichoptera, and Diptera), snails, limpets, clams, frogs, prickly sculpins (*Cottus asper*), and tui chubs (*Siphateles bicolor*). Since the infective agent is small enough and abundant enough to infect fish held in a 2-cubic-foot live cage with a 44-micron screen which tends to foul rapidly in 500 cfs in 2 hours, some of the invertebrate fauna would presumably be ingesting this agent. The problem may therefore be one of recognition.

It therefore seems probable that *Ceratomyxa* infects trout in some form other than the spore so far recognized as the terminal product of infection.

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MORTALITY, GROWTH, AND YIELD PER RECRUIT FOR PISMO CLAMS[1]

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Utilizing data collected from protected populations of Pismo clams, *Tivela stultorum*, evidence is presented to show that Pismo clams have an increasing survival rate with age. A function is given to represent survival when natural rate of decline is decreasing exponentially with time. Total mortality is estimated from data collected from unprotected populations. Weight-at-length and length-at-age data are used to present estimates of weight at age. Estimates of mortality and growth are combined to estimate yield per recruit. Age at entry for maximum yield is compared favorably with a 4.5-inch size limit.

INTRODUCTION

For more than 40 years, with few exceptions, the California Department of Fish and Game has conducted annual sampling (Fitch, 1952, 1954, 1955; Baxter, 1961, 1962; Carlisle, 1966) of the Pismo clam, *Tivela stultorum*, population at three sites (Pismo Beach, Oceano, and LeGrande) near Pismo Beach, California. By removing and aging all clams from a standard unit of area, it has been possible to demonstrate year-class strength and to gain an understanding of mortalities. These data have been useful in forming management policies. Therefore, it is of interest to compare such policy (e.g., the size limit) with results of predicting yield per recruit.

Ricker (1958) provided a useful method for determining yield per recruit. Paulik and Bayliff (1967) describe Ricker's method and present a computer program useful for solutions.

Since Ricker's method requires knowledge of mortality and growth, estimates of mortality and growth determined from data collected during the annual Pismo clam censuses are presented. Estimates of yield per recruit are also given.

MORTALITY

Generally, the rate of mortality (Z) at any instant is the sum of instantaneous fishing mortality (F) and instantaneous natural mortality (M).

NATURAL MORTALITY

Natural survival in fish populations is most often described so that the rate of decline is a constant times the number of survivors.

That is, with an initial population of N_0 having survivors N_t at time t,

$$N_t = N_0 e^{-Zt} \text{ or } dN_t/dt = -ZN_t \qquad (1)$$

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Studies of data collected from protected populations of Pismo clams indicate that this model (1) does not give a satisfactory prediction of natural survival unless the unit of time is small. Empirical examination of the data indicates that natural rate of decline is exponentially decreasing with time. The data suggest that a possible solution is,

$$dN_t/dt = (\alpha + \beta\rho^t)N_t; \quad \begin{cases} O < \rho < 1 \\ \beta > O \\ \alpha > O \end{cases} \qquad (2)$$

Solving the differential equation in (2) yields the model,

$$N_t = N_O e^{KR^t - K - Ct}; \quad \begin{cases} O < R < 1 \\ K > O \\ C > O \end{cases} \qquad (3)$$

When $K = O$, equation (3) is equivalent to equation (1).

Equation (3) was fitted to data using a computer program prepared by Gales (1964). Gales' program is in FORTRAN II and was adapted, in part, to FORTRAN 63 for this study. The program is useful for fitting many nonlinear equations by least squares. Some difficulty was encountered in that no easy way was found to control the conditions on parameters R, K, and C.

Natural survival was predicted (Table 1) using equation (3) and data from five year classes (LeGrande 1929, 1931, 1935 and Oceano 1945, 1946). While these data represent protected populations, some fishing mortality probably did exist (Fitch, 1950) and may have been high enough to cause my estimates of natural survival to be low.

The natural mortality rate apparently decreases with age (Table 1) when no fishing is allowed. In estimating yield per recruit, the natural mortality rate was assumed to be constant, equation (1), for a one-fourth year period. The results of fitting equation (3) were used to determine values of N_o and N_t for each quarter.

An estimate of the instantaneous natural mortality rate (M) for the quarter is given by,

$$M = -\log_e(N_t/N_O).$$

The values of M used to compute yield per recruit were averages for the five year classes (Table 1) and decreased from $M=0.67$ (age 1.5 to age 1.75) to $M=0.04$ (age 9.75 to age 10.0). Empirical evidence for a low M at older ages is the number of older clams, one reaching an age of 53 in an unexploited population (Fitch, 1965).

FISHING MORTALITY

Estimating fishing mortality proved to be troublesome because very few clams over age 6 appeared in the samples from fishing areas. Age frequency within a sample is of no help, since recruitment is not constant.

Data for ages 4.5 through 8.5 were combined from 13 year classes (Oceano 1929, 1930, 1931, 1932, 1933, 1952, 1957, 1958, 1959, and Pismo Beach 1929, 1930, 1931, 1932, 1933, 1947, 1951, 1952, 1953, 1954, 1957, 1958, 1959) and used to predict survival during fishing (Table 2).

TABLE 1

Observed and Estimated Natural Survival in Pismo Clams

Sample site and year class		Age t 0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	Estimated parameters for $N_t = N_0 K R^t$ $K = C^t$ N_0	K	R	C
Oceano 1946	Obs.	329	145	97	77	41	61	*	50	38	32	*				
	N_t	329	147	93	71	60	52	47	13	39	36		619.8	2.07	0.5093	0.0823
	M	1.17	0.64	0.36	0.23	0.16	0.12	0.10	0.09	0.09	0.08	0.08				
Oceano 1945	Obs.	*	115	60	31	27	39	29	*	18	37	13				
	N_t	604	116	55	39	33	29	27	26	25	23	22	2708	4.31	0.4316	0.0472
	M	2.69	1.19	0.54	0.26	0.14	0.09	0.06	0.05	0.05	0.05	0.04				
LeGrande 1935	Obs.	151	89	44	39	36	29	19	*	*	*	*				
	N_t	152	83	54	39	31	26	23					222.4	2.59	0.7292	0.0011
	M	0.73	0.53	0.39	0.28	0.21	0.15	0.11	0.08	0.06	0.04	0.04				
LeGrande 1931	Obs.	174	106	22	*	29	31	21	*	*	*	*				
	N_t	177	76	45	32	26	23	21					320.0	2.87	0.6300	0.000001
	M	1.12	0.70	0.44	0.28	0.18	0.11	0.07	0.04	0.03	0.02	0.01				
LeGrande 1929	Obs.	106	36	12	14	21	10	8	*	*	*	*				
	N_t	106	33	19	14	12	11	10					289.8	3.05	0.4601	0.0427
	M	1.82	0.86	0.42	0.22	0.12	0.08	0.06	0.05	0.05	0.04	0.04				
Average	M†	1.50	0.78	0.43	0.25	0.16	0.11	0.08	0.06	0.05	0.05	0.04				

* Unreliable or not available.
† $M = -\log_e N_t / N_{(t+.25)}$

TABLE 2

Number of Pismo Clams at Age Used to Calculate Fishing Mortality

Age	4.5	5.5	6.5	7.5	8.5
Obs.	318	120	57	22	8
N_t	319	129	52	21	9

Equation (1) was fitted to these data and yielded $Z=0.91$. An average M for ages 4.5 to 8.5 was estimated to be approximately 0.09. This led to a decision to use a constant instantaneous fishing mortality (F) for all ages, since $Z=F+M$. $F=0.8$ was chosen as the present level of fishing intensity. Actually, larger clams should have a higher fishing mortality, since they present a greater surface area to the clam digger. Also, some diggers undoubtedly replace smaller clams if prospects for finding larger ones are good.

Much of the data used was collected many years ago and represents fishing mortalities as they existed then. Undoubtedly, fishing effort has increased and $F=0.8$ probably underestimates present fishing mortality.

GROWTH

Ideal growth data for use with Ricker's method would be observations of weight at numerous ages. The meaning of weight is seldom discussed, since it is more or less implied that usable weight is proportional to total weight. Since total weight in Pismo clams is mostly shell weight, I decided to subtract shell weight from total weight to produce usable weight. No direct measurements of usable weight at age were available, so a weight-length relationship was estimated from the model,

$$w = al^b \tag{4}$$

Parameters a and b were estimated from total weight and shell weight data presented by Weymouth (1923). The difference of these two equations ($\hat{w}_1 - \hat{w}_2$) represents non-shell weight at length. Equation (4) was fitted to ($\hat{w}_1 - \hat{w}_2$) at 16 different lengths. Further, non-shell weight-at-length was converted to non-shell weight-at-age by fitting a von Bertalanffy growth curve to length-at-age data (1965 and 1966 census) using a computer program by Abramson (1965). Predicted weights and lengths increased from 8.0 g (5.05 cm) at age 1.5 to 202.5 g (13.38 cm) at age 9.5 (Table 3).

The three weight-length curves and the length-age curve are:

$$w = 0.161 l^{3.164} = \text{total weight}$$
$$w = 0.123 l^{3.101} = \text{shell weight}$$
$$w = 0.041 l^{3.283} = \text{non-shell weight}$$
$$l = 14.45\{1 - \exp[-.272(t + .582)]\}$$

TABLE 3

Estimated Non-shell Weight in Grams and Lengths in Cm at Various Ages for Pismo Clams

Age	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5
Weight	8.0	27.5	56.0	86.5	117.5	146.0	167.0	184.5	202.0	215.0
Length	5.05	7.28	8.99	10.29	11.28	12.03	12.61	13.01	13.38	...

All weights (w) are in grams; lengths (l) are in centimeters; ages (t) are in years.

YIELD PER RECRUIT

Two different estimates of yield-per-recruit isopleth diagrams were calculated. The first was obtained by assuming that natural mortality decreased from $M = 0.67$ to $M = 0.04$ between ages 1.5 and 10.0 (Figure 1). The second was obtained by assuming that natural mortality leveled off at $M = 0.12$ for ages 6.5 and older (Figure 2). $M = 0.12$ was selected arbitrarily as a maximum, since $M = 0.11$ for age 6.5 was the maximum estimate. As mentioned earlier, the data available for estimating natural mortality are likely to contain some fishing mortality.

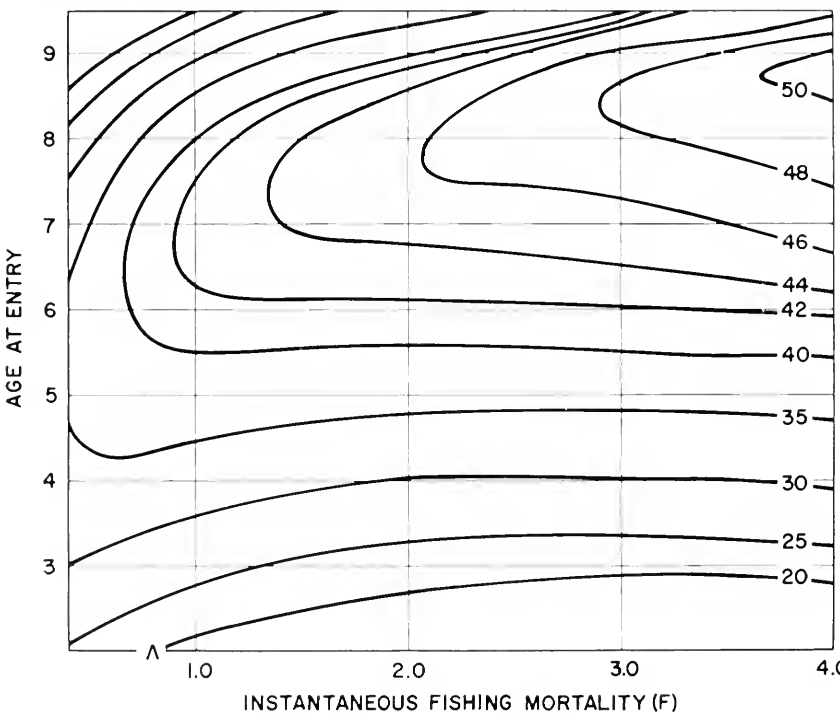

FIGURE 1—Yield-per-recruit isopleth diagram showing yield per Pismo clam recruited to age 1.5, when natural mortality (M) is calculated from fitting equation (3) to data in Table 1. Yields are in grams of non-shell weight. The present value of F is Λ.

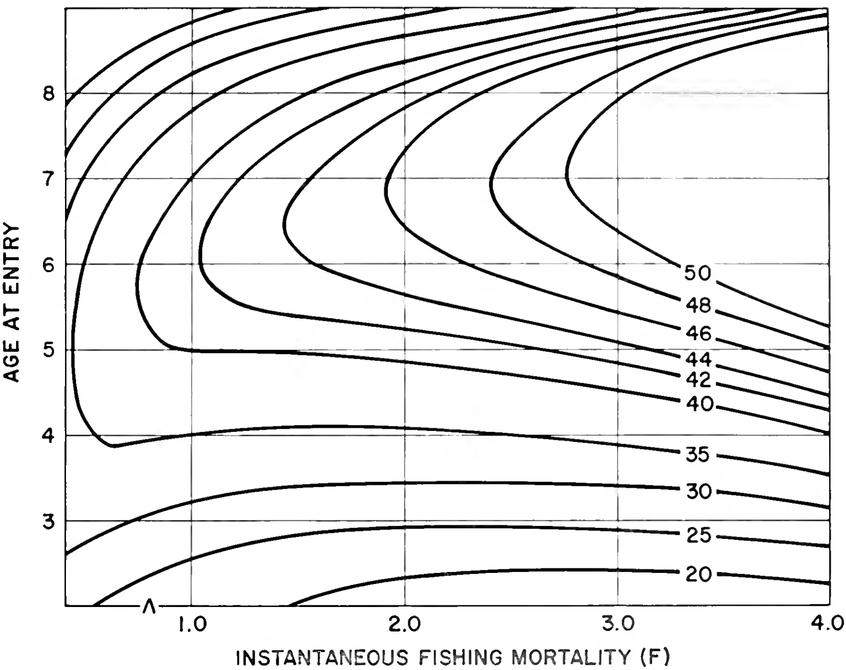

FIGURE 2—Yield-per-recruit isopleth diagram showing yield per Pismo clam recruited to age 1.5, when natural mortolity (M) is calculated as in Figure 1, except $M = 0.12$ for ages 6.5 and older. Yields are in grams of non-shell weight. The present value of F is ∧.

Changing M had a relatively small effect at $F = 0.8$, but at higher fishing intensities the difference becomes quite noticeable.

Assuming that M decreased after age 6.5 (Figure 1) produced a maximum yield per recruit of about 41 at entry age 6.5 ($F = 0.8$), while $M = 0.12$ after age 6.5 (Figure 2) produced a maximum of about 40.5 at entry age 5.75 ($F = 0.8$). At a higher intensity, $F = 2.4$, the difference is 47 at age 8.25 to 48 at age 7.0. At extreme intensity, maximums occur at about ages 10 and 7.5, respectively. My conclusion is that maximum yield per recruit occurs between ages 5.0 and 7.0 (4.25 inches to 4.85 inches) at present fishing intensity. It seems reasonable to select an age (size) in the lower part of this range to use as a size limit, since yield per recruit does not change much and this will insure larger numbers of clams in the catch. With the present size limit of 4.5 inches at Pismo Beach, it appears that clams slightly less than 4.5 inches are fully affected by fishing.

The present size limit of 4.5 inches is supported by this analysis of yield per recruit. However, if it can be demonstrated that fishing intensity is much higher than predicted or that M is smaller in the older ages, it may be advantageous to allow a longer protected life for the clams.

The computer program used for yield estimates is that of Paulik and Bayliff (1967) converted to FORTRAN 63 by the Inter-American

Tropical Tuna Commission. This program allows for a number of levels of fishing intensity and the yields produced are almost certain to cover the range of possible fishing rates.

DISCUSSION

Since this study relied heavily on estimates of weight at age, a few comments are necessary. The parameter *b* of the weight-length relation was not significantly different for total weight and shell weight. This implies non-shell weight is proportional to total weight and all computations can be made using total weight. This was done for total weight at age, using data from Weymouth (1923), and resulted in the same conclusion about entry age (size). It should be mentioned that non-shell weight contains unusable material such as sand (Fitch, 1965). In the future, it might be advisable to collect total weight-at-age as well as length-at-age data. This information could be utilized to advantage in future calculations of yields.

Length-at-age data contained a preponderance of young clams and did not lend themselves well to predicting length at age beyond age 5.5. The effect, if any, was to underestimate length at age and consequently weight at age for the older ages. If weight at age is to be well represented, clams that are aged should be weighed and additional older clams collected, even if they are not part of age-frequency sampling.

Since fishing intensity and natural mortality are still subject to doubt, sampling intensity should be increased in a single fishing area in order to increase the probability of older clams entering the sample, and an area where Pismo clams are protected should be included as a regular sampling station. These measures could be accomplished without increased effort by confining all fishing mortality sampling activities to a single site, such as Pismo Beach. It is doubtful that stations at Oceano and LeGrande are providing much additional information. The Pismo Beach site appears to provide sufficient data concerning long-term trends. Perhaps a particular section of beach might be closed for a long period of time to provide a site for study of natural mortality.

The question of recruit-stock relationship is also essential to interpretation of yield-per-recruit estimates. No analysis is necessary to conclude that recruitment is not constant. Whether recruitment is independent of stock size must remain an unanswered question, since a portion of the adult stock exists beyond the range of sampling and fishing. The importance of this unexploited stock to recruitment is unknown. However, the data suggest that no relationship exists between stock size subjected to sampling and number recruited into subsequent samples. No analysis was attempted, but I assume that recruitment is independent of total mortalities at present fishing intensity.

Throughout this paper, ages at time of sampling are given as 0.5, 1.5, . . . etc. All calculations are based on this age structure and, as such, it is only necessary to assume relative age with one year between ages. Data and analysis by Coe and Fitch (1950) indicate a sequence of 1.0, 2.0, . . . etc. would be more nearly correct.

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Calif. Fish and Game, 54(2): 108–114. 1968.

OBSERVATIONS ON THE BEHAVIOR OF THE BASKETWEAVE CUSK-EEL *OTOPHIDIUM SCRIPPSI* HUBBS[1]

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A collection of over 100 individuals of *Otophidium scrippsi* from shallow waters off Newport Beach, California, presented the opportunity for an analysis of feeding habits as well as observations of general behavior in aquaria. The basketweave cusk-eel was found to be a burrowing nocturnal form, feeding at night by a peculiar method, and exhibiting a number of interesting behavior patterns. There is a brief description of and comments on the function of the sexually dimorphic gas bladder.

INTRODUCTION

During the 1966–67 academic year, the Orange County School District initiated a pilot program utilizing a 52-foot vessel, the *Jet*, as a floating marine science laboratory to introduce junior high and high school students to marine biology and oceanography. A number of stations were established and sampling, using an otter trawl and other collecting gear, was carried out five days a week from August 1, 1966, to February 1, 1967. This continuous sampling program produced a record of fish species at various locations off the southern California coast.

On December 8, 1966, 63 specimens of the basketeave cusk-eel, *Otophidium scrippsi*, were trawled at a depth of 60 feet off Balboa Pier, Newport Beach, at 1400 hours. The following day, 50 more specimens were taken at the same locality. The sudden appearance of this species in the catch is of particular interest, since *O. scrippsi* is not reported as an abundant species. The basketweave cusk-eel was first described by Hubbs (1916) from a specimen dredged at a depth of 240 feet near Cedros Island, Baja California. Five specimens were collected during November and December 1948, off Point Arguello, California (Fitch, 1949), and three more specimens were collected in May and June 1949 near Santa Rosa Island (Fitch, 1950). All of these specimens were killed by explosives and were floating at the surface. Fossil otoliths of *O. scrippsi* and *O. taylori* were found in a Long Beach, California, Pliocene deposit (Fitch and Reimer, 1967).

We placed a number of the cusk-eels in the bait tank aboard the vessel, and later transferred them to an aquarium. Having been trawled at a depth of 60 feet, they were unable to equilibrate and floated at the surface for a period of 24 hours, at which time a hypodermic needle was used to remove the excess gas from the bladder. Four specimens survived this procedure and lived for five months in the laboratory. During this period, a number of observations on their behavior was made.

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OBSERVATIONS

When the cusk-eels were placed in the aquarium, which had only about 1 inch of sand in it, they displayed the "tail standing" behavior which Herald (1953) described for the spotted cusk-eel, *Otophidium taylori*. However, after watching this behavior for some time, it became evident that the fish were simply trying to bore deeper into the sand with their tails. The caudal fins showed extensive rupturing of the blood vessels from digging against the bottom of the tank. Nine inches of sand were then added to the tank, and the cusk-eels promptly dug down tail first until they were completely buried under the surface of the sand (Figure 1). The burrowing action was preceded by a re-

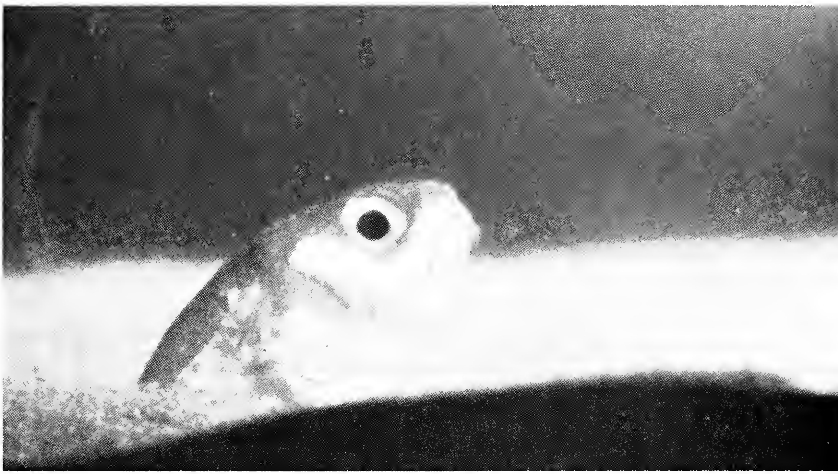

FIGURE 1—Basketweave cusk-eel, *Otophidium scrippsi,* burrowing into the sand. *Photograph by Jack Turner, December 1966.*

versal in swimming direction, so that the fish moved backward for several inches with accentuated anguilliform movements. The cusk-eels would then dig the tips of their tails into the sand, raise their bodies so that they were perpendicular to the surface of the bottom, and then burrow straight down into the sand. In some cases, a fish would stay completely buried for up to 5 minutes before coming to the surface and blowing the sand away with several bursts, giving the effect of a small volcano. The fish then remained with just the tips of their snouts protruding from the surface of the sand. Once sufficient sand had been added to the tank, the "tail standing" behavior was not again observed.

Throughout the daylight hours the cusk-eels remained with just the tips of their snouts above the sand; however, one-half to one hour after dusk, or after the lights in the laboratory were turned off, the fish emerged from the sand until half to three quarters of the body length was exposed. While in this position, the fish began to wave slowly from side to side. When food items such as small fish were introduced into the tank, the cusk-eels showed no interest whatsoever. Even when a mosquitofish, *Gambusia affinis*, was held by the tail with forceps very close to the head of a cusk-eel, the eel made no attempt to grab it, although it was within easy reach. However, as soon as a food item touched the body, or especially the barble-like pelvic fins, the cusk-eel instantly reached for it. After taking the food, the cusk-eel would come all the way out of the sand and begin swimming back and forth above the sand, dragging its pelvic fins along the bottom in search of food.

At first this type of feeding behavior seems unusual, for usually a fish does not remain in one place and wait for its food actually to come in contact with it. However, if this behavior is examined in terms of energy conservation, by waiting until the concentration of a particular food item is heavy enough to make contact with it, it becomes worthwhile for the fish to leave the sand and expend energy actively foraging for food.

In order to determine whether the types of food taken by cusk-eels correlated with this interpretation of their observed behavior, the stomachs of 68 individuals were examined. Thirty-seven were found to be empty. The various food items found in the others were separated into their respective taxonomic categories, counted, and the volume of water displaced by the members of each category measured to the nearest 0.1 ml. The relationship of each category to the total volume was determined and the frequency of its occurrence was also ascertained (Figure 2). Amphipods were the most abundant food item in numbers and percentage occurrence; nevertheless, in percentage volume they were only fifth in importance. Other important food items were crabs, shrimp, polychaetes, and flatfish. These are typically found along sandy bottoms. The number of similar items in a single stomach tends to support the idea that cusk-eels feed on concentrations of a particular species which moves into the area. On the other hand, it is also evident that the cusk-eels will take any food item they can find, including small sea urchins.

After observing the various behavior patterns exhibited in the laboratory, the reasons for this fish being uncommon in catches were evident. The cusk-eel is strictly nocturnal, being buried in the sand when trawling is usually carried out. This explains why fishermen occasionally catch a cusk-eel by hook and line from Newport Pier at night, and why they are sometimes taken by beach seines at night. Why, then, were these fish taken during a few days in December in midday? The time of capture followed a period of heavy storms; there was extensive runoff and the water was very turbid. Since the basketweave cusk-eel apparently responds to light intensity and does not appear to be on a biological clock schedule, when the light level dropped due to the turbid conditions the fish emerged from the sand to feed. Capture of 16 specimens in January after another stormy period certainly strengthened this hypothesis. In order to substantiate these ideas, a dive using SCUBA gear was made off Newport Beach during a storm in April. As anticipated, the cusk-eels were found at a depth of 25 feet, slowly waving back and forth. The visibility in this area was about 3 feet and the light intensity was low. No cusk-eels were located on successive dives on calm days.

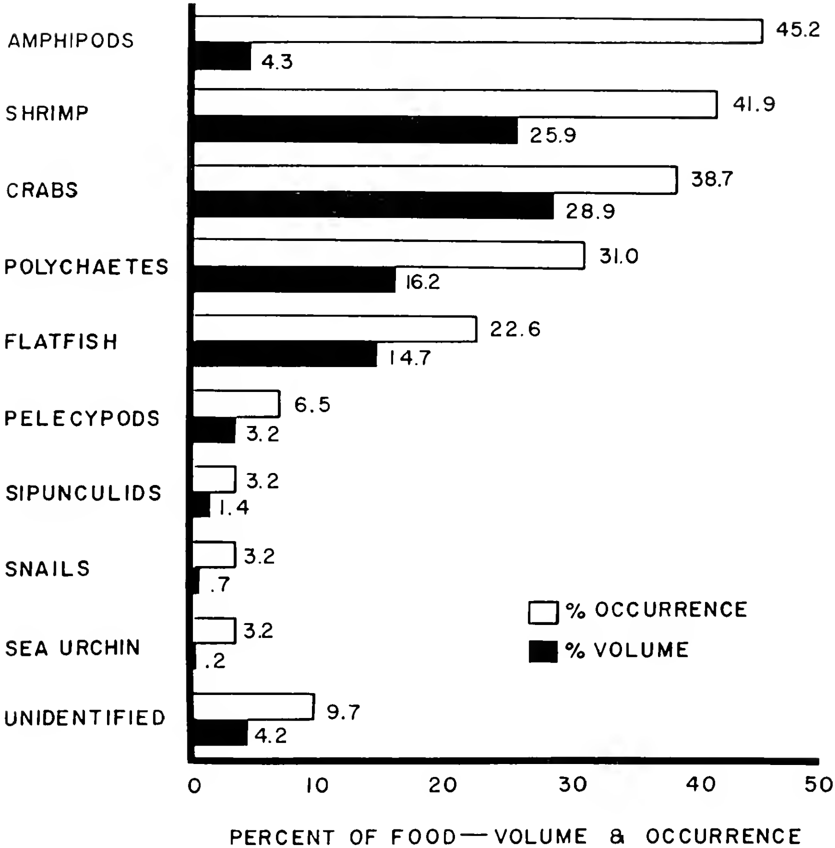

FIGURE 2—Relative importance of food items in basketweave cusk-eel stomachs.

As was the case in the laboratory, the cusk-eels in the field were very placid and were easily picked up by hand. This lack of an effective escape response certainly helps to explain why the cusk-eels are not found above the sand during the daylight hours, when predators could easily take them.

SEXUAL DIMORPHISM

Several types of sexual dimorphism occur in the basketweave cusk-eel. In my sample, the males were larger than the females (Figure 3), which is of interest because females are usually larger than the males in a number of species of cusk-eels (Robins, 1960). The males also outnumbered the females (41 to 27), while in some other cusk-eels females outnumber males. However, the more striking differences between the sexes are found in the gas bladders.

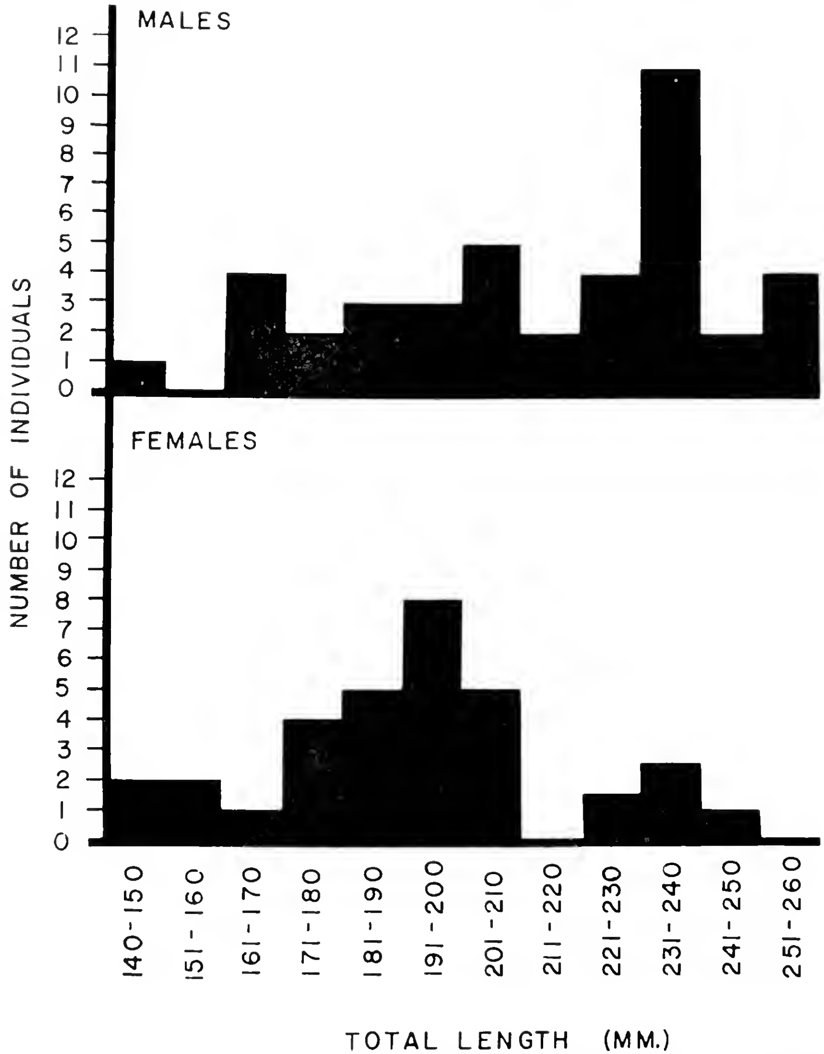

FIGURE 3—Length frequencies of the male and female basketweave cusk-eels in the Newport Beach samples.

The male basketweave cusk-eel has a large bladder, which has a ventral posterior tubular projection with a thin membrane across the end. This tubular projection was not present in males smaller than 144 mm TL, but develops first as a mere nipple, becoming progressively longer until it is fully developed in fish 230 mm TL and longer. The bladders in females are smaller and lack the tubular projection.

Harry (1951) recognized sexual dimorphism in the gas bladders of fishes in the family Ophidiidae. Herald (1953) mentioned the unusual male gas-bladder structure and suggested that the thin portions of the bladder allowed rapid diffusion of gases, enabling the cusk-eel to make rapid ascents to the surface. Briggs and Caldwell (1955) described and illustrated the structure of the male and female bladder in *Otophidium omostigmum*. Svetovidov (1961) described the gas-bladder structure for several genera within the family and discussed the functional significance.

Such an interesting structure immediately raises questions concerning possible functions. Svetovidov, while noting the absence of the tubular structure in the females, suggested that it is a mechanism for changing both bladder volume and the position of the gas within the fish to facilitate the burrowing habit. He further states that the males "are more adapted to digging into the ground". Four facts seem to argue against this conclusion. First, when the captured basketweave cusk-eels were placed in the aquarium in the laboratory, they were unable to rid themselves of the excess gas in the bladder, even after a period of 24 hours. However, compensation for changes less than 60 feet might be possible. Second, the tubular projection does not develop in the males until they reach a large size. Third, the digging speeds of females and males in the laboratory indicated that the smaller females are the more rapid burrowers. Finally, and perhaps most important, if there is a selective advantage for rapid burrowing due to the modified gas bladder structure, it is difficult to see how natural selection would favor this development in males but not in females. It must be noted, however, that the ratio of males to females would argue against this point. Perhaps other factors are responsible for the sex ratio.

The anterior portion of the basketweave cusk-eel's bladder has a number of modifications similar to those described for other members of the family (Svetovidov, 1961). The ribs from the anterior vertebrae are modified, extending down to the antero-dorsal portion of the bladder, where they attach to a bony plate which appears to be an ossification of the wall of the gas bladder. There are also strong muscles attached to the anterior portion of the bladder which run forward to the cranium, attaching near the sacculus. These muscles are much thicker in the female than in the male.

In the male, there is a definite median horizontal band on the bladder which runs forward and separates from the wall of the bladder to form a free, curved projection on each side. These free projections are poised over a thin triangular window in the anterior portion of the bladder.

Since the cusk-eel is a nocturnal animal, it seems that these bladder modifications might be for the purpose of sound production related to mating behavior, as suggested by Breder and Rosen (1966). The intricate structure of the bladder, and the close association with the labyrinth, suggest this as a more plausible function than volume adjustment for digging.

ADDENDUM

On November 17, 1967, seven basketweave cusk-eels, ranging from 53.3 to 71.4 mm TL, were taken while trawling at night off the entrance to Newport Harbor.

ACKNOWLEDGMENTS

Glenn M. Farrell Coordinator of Science, Orange County School District, and Clyde Gillum, skipper of the *Jet*, were most helpful in obtaining live specimens of the cusk-eel. Jack Turner prepared the illustrations, while David M. Wildrick and James W. Wiley assisted in both field and laboratory work

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VARIATION IN THE PINK SEAPERCH, *ZALEMBIUS ROSACEUS* (JORDAN AND GILBERT), AND EXTENSION OF ITS KNOWN RANGE TO THE GULF OF CALIFORNIA[1]

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The occurrence of the pink seaperch in the Gulf of California is reported. A series of specimens from the Gulf is statistically compared with series from three widely separated Pacific Coast localities. Results indicate that the Gulf population is distinctive, and suggest that effective gene exchange with the Pacific Coast populations must be limited or absent. This reinforces evidence from trawl collecting that the Gulf population is disjunct.

INTRODUCTION

The Gulf of California is part of the Panamic Faunal Province of the eastern tropical Pacific; almost three-fourths of the fish species occurring there have the principal part of their distributional ranges to the south (Walker, 1960). One interesting non-Panamic element is composed of San Diegan (warm-temperate) types which are common along the outer (Pacific) coasts of southern and Baja California, and in the northern parts of the Gulf of California, but which do not occur in the intervening region around extreme southern Baja California. Walker listed 24 such San Diegan types and Hubbs (1960) mentioned eight more genera in this category. Two additional genera were added by Lavenberg and Fitch (1966). The discontinuities in the distributions of these temperate types is probably due to the higher water temperatures prevailing in the southern regions throughout the year (Roden and Groves, 1959). Colonization of the upper Gulf presumably occurred during periods of Pleistocene cooling, when isotherms were displaced southward (Hubbs, 1948; 1960).

The Gulf disjuncts show varying degrees of differentiation from outer coast forms. Overall, morphological differences do not appear to be pronounced, but a comprehensive analysis of the situation has never been undertaken, and the taxonomic status of many of the Gulf forms has never been critically examined.

Additional examples of disjunct distributions will undoubtedly be found as more extensive collecting is undertaken in the middle and upper Gulf. Recently (1965) nine specimens of the pink seaperch, *Zalembius rosaceus* (Jordan and Gilbert), were collected in the Gulf of California (Bahía Santa Inez) by an expedition of the Scripps Institution of Oceanography (SIO)[2]. This species has been previously

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[2] Supported by National Science Foundation Grant GB-4408.

recorded from Drakes Bay, California, to San Diego, California (Tarp, 1952). Additional specimens from the Gulf of California have been collected by the California Department of Fish and Game, and are in the fish collection of the Los Angeles County Museum of Natural History (LACM).

The Pacific Coast range of the pink seaperch is greater than previously documented. The SIO fish collection contains a number of specimens from the vicinity of Isla Cedros, midway down the peninsula of Baja California, and one specimen from Bahía San Cristobal, 60 miles south of Cedros. The range can also be slightly extended to the north, to 38° 33.2′ N, 123° 20.9′ W, off Fort Ross (W. I. Follett, California Academy of Science, pers. comm.).

It seemed worthwhile to determine how different the Gulf population of pink seaperch may be from the outer-coast form. In order to determine the amount of variation between areas along the outer coast, where the pink seaperch is presumably continuously distributed, specimens were selected from three widely separated outer-coast localities. Each of these samples was treated separately, and compared individually with the Gulf sample. These outer-coast samples also were compared with one another, thus making all of the six possible comparisons between the four samples. An unambiguous criterion for distinctiveness was chosen: the Gulf sample would be considered distinctive in any character the mean value of which differed significantly from comparable values for each of the three outer-coast samples, as well as from the mean value for the lumped outer-coast samples.

METHODS

Nine morphometric and six meristic characters were selected for comparison. Most counts and measurements were carried out in accordance with Hubbs and Lagler (1958). Exceptions to their methods were as follows:

Head length—measured from the tip of the upper lip to the most distant point on the operculum excluding the opercular membrane.

1st dorsal–1st anal—Measured from base of 1st dorsal spine to base of 1st anal spine.

Pectoral rays—the single upper rudimentary ray was included in the count.

Collection localities for the four series, each of which included 39 specimens, were:

Gulf of California

Series A—Bahía Santa Inez (SIO65-305, 9 spec.; LACM 8836-2, 15 spec.), Bahía de las Animas (LACM 8824-1, 15 spec.).

Baja California

Series B—Isla Cedros (SIO62-91, 5 spec.; SIO62-92-47A, 12 spec.), Bahía Sebastián Vizcaíno (SIO64-701, 22 spec.).

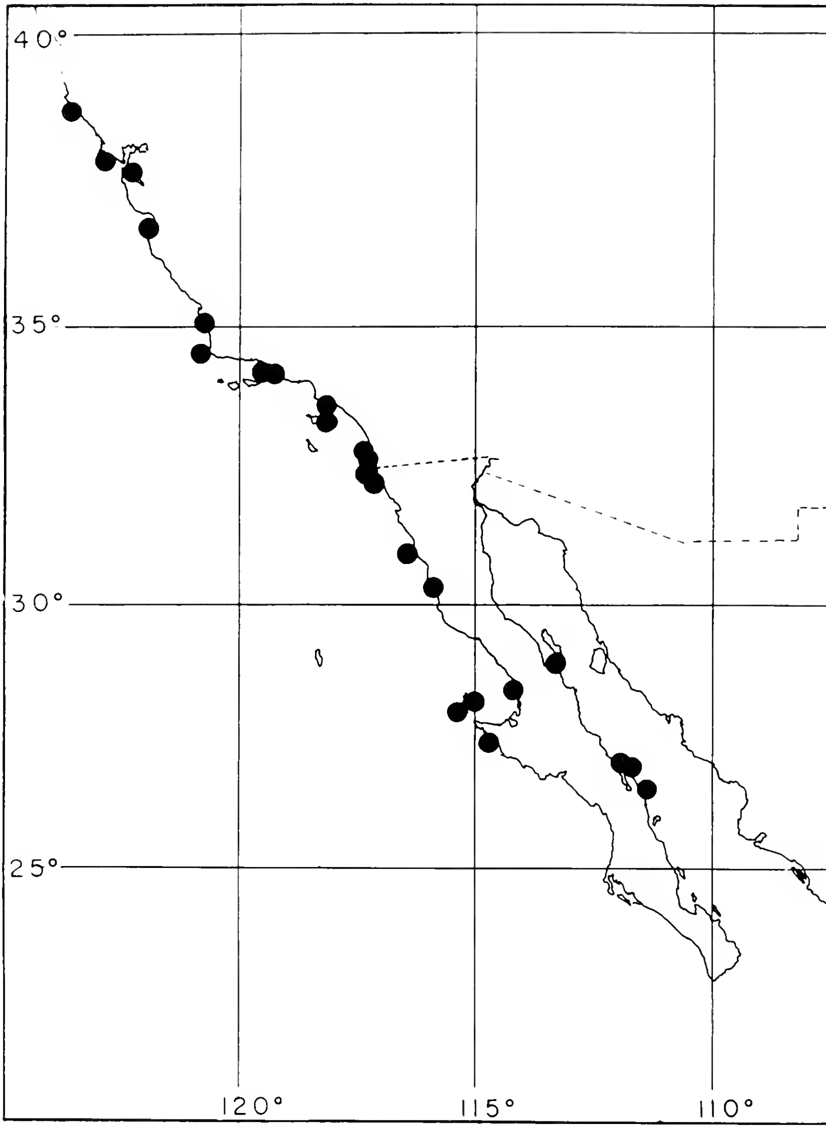

FIGURE 1—The known distribution of the pink seaperch, *Zalembius rosaceus.*

Southern California

Series C—San Diego (SIO54-14, 4 spec., SIO54-8, 9 spec.), Coronado Bank (SIO66-2-47A, 10 spec., SIO66-3-47A, 9 spec.). N. Coronado Island (SIOH50-255, 3 spec.), La Jolla (SIOH50-141-47A, 4 spec.).

Central California

Series D—Pt. Arguello (SIO63-1042, 32 spec.), Pismo Beach (SIOH 48-304-47C, 7 spec.), Pt. Sal (SIOH48-206, 1 spec.).

Body measurements were regressed on standard length by the Bartlett (1949) procedure and 95% confidence limits for the slope were determined. The slope of a morphometric regression is believed to be more independent of environmentally induced variability than is the intercept, hence more reliable as an indication of genetic relationship (Martin, 1949).

Meristic comparisons were made by the Tukey procedure (Steele and Torrie, 1960; Rothschild, 1963), which allows all possible comparisons between any number of means to be made by establishing an "allowable" difference (w) between means ($w = q_{\alpha}\ (p, n_2)\ S_{\bar{x}}$; where q_{α} is the upper percentage point of the studentized range at the chosen significance level α, p is the number of samples, n_2 is the error degrees of freedom, and $S_{\bar{x}}$ is the pooled sample error of the sample means). If w is exceeded by the difference between any two means compared, then these means are considered different at the level of significance. This procedure is preferred because it recognizes that multiple comparisons can not be independent of one another.

RESULTS

For most comparisons between the four samples, confidence limits for the slopes were found to be mutually overlapping; the few exceptions do not seem to indicate any consistent trend (Table 1).

The criterion for distinctiveness previously discussed was met by three of the meristic characters: number of dorsal spines, number of pectoral rays, and number of gill rakers. The Gulf sample means for these characters differed significantly ($p < .01$) from all three of the Pacific Coast sample means, and these did not differ significantly from one another (Table 2). However, one of the prerequisites for Tukey's procedure is that the variances of all samples compared be equal, and F tests established that this could be reasonably assumed for all comparisons except between dorsal spine means (due to the greater variance of the Gulf sample; see Table 2). Even though the propriety of Tukey's procedure is questionable in this case, the implication still appears to be valid; 19 of 39 Gulf specimens had 11 or 12 dorsal spines, whereas all the Pacific Coast samples together ($n = 117$) contained only 10 specimens with 11 dorsal spines and no specimens with 12 dorsal spines. The dissimilarity of these distributions was confirmed by a 2 x 2 contingency χ^2 test (adjusted $\chi_1^2 = 28.55$; $p << .0005$).

However, even though the Gulf sample means differed significantly from the Pacific Coast sample means for these three characters, the frequency distributions were broadly overlapping (Figure 2). There is no indication that the Gulf population should be given subspecific recognition.

DISCUSSION

There is good reason to believe that the apparent hiatus in the distribution of *Zalembius rosaceus* is indeed real. It is true that this species is always taken at considerable depths (50–70 fathoms) and lacks a pelagic larval stage (all embiotocods are viviparous) which

TABLE 1

Regression of Body Measurements on Standard Length

Measurement	Sample locality[1]	Y Intercept	Slope	Slope CI (95%)	Nonoverlap
Head length	A	1.313	0.327	0.308–0.345	A and C
	B	−1.235	0.333	0.291–0.372	
	C	3.891	0.276	0.256–0.293	
	D	1.988	0.297	0.281–0.313	
Eye length	A	1.874	0.089	0.080–0.098	A and C B and C, D
	B	−0.179	0.106	0.091–0.125	
	C	4.011	0.056	0.045–0.067	
	D	2.115	0.074	0.064–0.087	
Spinous dorsal base	A	−1.342	0.242	0.217–0.268	None
	B	−2.627	0.241	0.172–0.321	
	C	−2.313	0.229	0.207–0.253	
	D	−0.763	0.212	0.195–0.228	
Soft dorsal base	A	−0.062	0.262	0.246–0.278	None
	B	−0.980	0.281	0.232–0.336	
	C	−0.565	0.273	0.244–0.299	
	D	−1.241	0.279	0.258–0.297	
Anal base	A	7.569	0.126	0.103–0.146	A and B
	B	1.758	0.186	0.149–0.231	
	C	4.575	0.147	0.128–0.164	
	D	3.469	0.159	0.132–0.188	
Snout—1st anal	A	−5.492	0.753	0.723–0.781	None
	B	−3.073	0.721	0.625–0.828	
	C	−4.553	0.733	0.699–0.777	
	D	−1.715	0.702	0.653–0.751	
Snout—1st dorsal	A	1.739	0.404	0.378–0.430	None
	B	3.529	0.371	0.307–0.427	
	C	7.191	0.344	0.254–0.416	
	D	0.865	0.395	0.361–0.423	
1st dorsal—1st anal	A	−1.259	0.513	0.489–0.538	None
	B	0.383	0.490	0.445–0.539	
	C	−3.100	0.513	0.488–0.542	
	D	−0.368	0.488	0.456–0.515	
Caudal Peduncle	A	2.661	0.082	0.071–0.093	None
	B	−2.057	0.120	0.089–0.151	
	C	1.155	0.087	0.073–0.100	
	D	−0.167	0.096	0.082–0.111	

[1] A—Gulf of California
B—Outer coast, Baja California
C—Southern California
D—Central California

TABLE 2

Comparison of Meristic Means by Tukey Procedure [2]

Count	Sample locality[1]	$\bar{x}$	S^2	α	w	$\bar{x}$s differing significantly
Dorsal spines	A	10.538	0.368	0.01	±0.292	A from B, C, D (< .01), but validity questionable (see text)
	B	10.128	0.158			
	C	10.026	0.079			
	D	10.026	0.079			
Dorsal soft rays	A	17.513	0.474	0.05 0.01	±0.417 ±0.506	A from B (< .01) B from C (< .05)
	B	18.179	0.684			
	C	17.692	0.421			
	D	17.872	0.474			
Anal soft rays	A	20.103	0.895	0.05 0.01	±0.461 ±0.559	A from B (< .01) B from C (< .05)
	B	19.795	0.632			
	C	19.256	0.553			
	D	19.667	0.447			
Pectoral rays	A	19.538	0.368	0.05 0.01	±0.350 ±0.424	A from B, C, D (< .01)
	B	18.564	0.368			
	C	18.410	0.342			
	D	18.487	0.368			
Lateral line scales	A	50.286	10.56	0.05	±1.521	None
	B	50.343	6.18			
	C	51.457	4.56			
	D	50.371	6.24			
1st arch gill rakers	A	20.051	0.842	0.01	±0.618	A from B, C, D (< .01)
	B	18.667	0.500			
	C	18.458	0.895			
	D	18.487	0.842			

[1] A—Gulf of California
B—Outer coast, Baja California
C—Southern California
D—Central California

[2] $\bar{x}$—sample mean
S^2—sample variance
α—level of significance
w—"allowable" difference between means; if w is exceeded by the difference between any two means, those two means are different at the chosen level of significance.

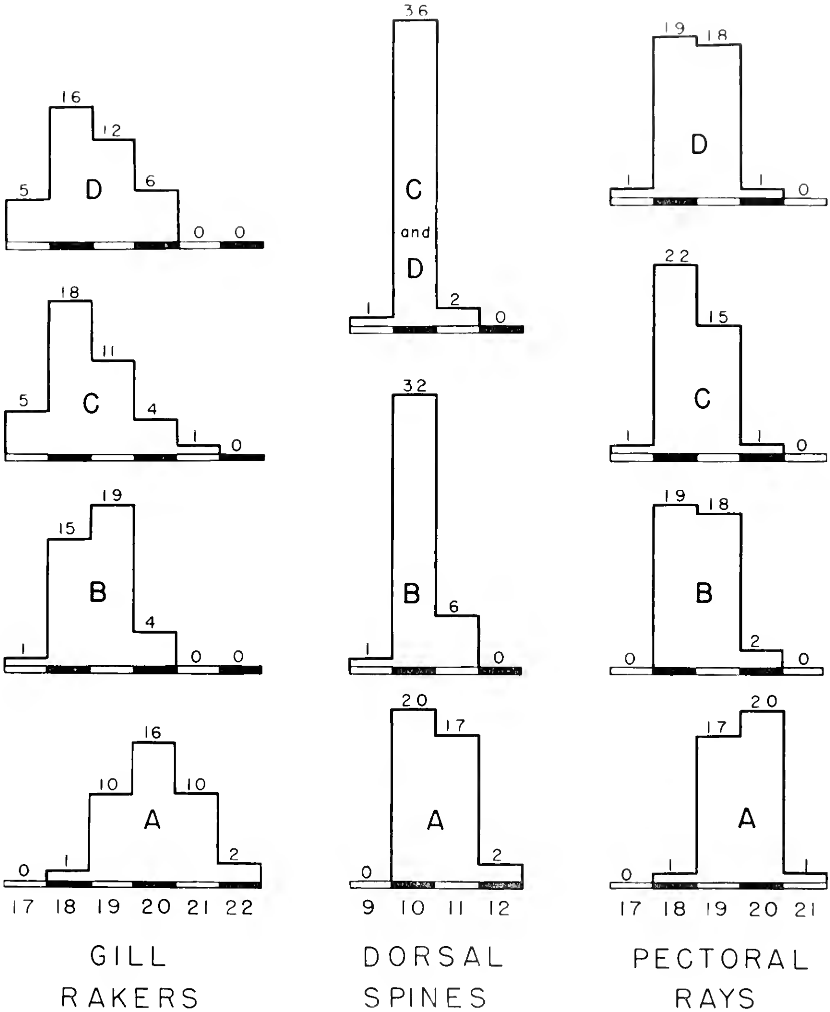

FIGURE 2—Frequency distributions for gill raker, dorsal spine, and pectoral ray counts of *Zalembius rosaceus* from four regions (dorsal spine count distributions identical for samples C and D). A, Gulf of California; B, Baja California; C, Southern California; D, Central California.

would be exposed to the higher and more variable surface temperatures. These factors would seemingly facilitate continuity in the range of the pink seaperch around southern Baja California. However, a half-dozen trawl stations at appropriate depths (40–80 fathoms) in the vicinity of Magdalena Bay on the Pacific side and a like number in the vicinity of La Paz on the Gulf side, from which material is deposited at Scripps Institution, have failed to yield this species.

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FOOD OF CALIFORNIA QUAIL ON BURNED AND UNBURNED CENTRAL CALIFORNIA FOOTHILL RANGELAND[1]

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Collections of California quail *(Lophortyx californica)* crops were made on an unburned range and on an adjacent site that was control-burned for range improvement. Results 2 months after the burn are reported. In general, little difference was found in the type of food eaten by quail. Legume seeds were the most important food on both burned and unburned range.

INTRODUCTION

Opinions about the effects of fire on wildlife run the gamut. To date, only a limited amount of research has been done on this subject. Howard, Fenner, and Childs (1959) concluded that most range fires do not directly destroy wildlife, but do alter its habitat. Lawrence (1966) found that after a burn some species dwindled in number while others increased, but none was eliminated. His field observations suggested that shrub-associated birds, such as quail, were not fire-killed; instead, they moved to an appropriate adjacent habitat where shrub cover was available. However, in areas with extensive rock outcroppings, shrub cover may not be as vital a factor as in the study area described by Lawrence.

In the summer of 1965, a control burn was held on a ranch next to the San Joaquin Experimental Range, in the central Sierra Nevada foothills, where a year-round study of quail food habits was underway. The burn provided an unusually good opportunity to study the effect of fire on quail food. We were able to compare the food habits of California quail which remained in the control-burned area with that of birds in an adjacent unburned area. We found that the type of food eaten by quail in the two areas did not differ drastically.

THE STUDY AREA

The San Joaquin Experimental Range, near O'Neals, California, is maintained by the Pacific Southwest Forest and Range Experiment Station. The burned area resembles the Range in topography and vegetation, and is separated from it only by a fence. Both ranges are fairly representative of the foothills of the Sierra Nevada's western slope. Glading, Biswell, and Smith (1940), Buttery and Green (1958), and Shields and Duncan (1966) have reported on the vegetation and quail food habits on the Experimental Range.

[1] Submitted for publication October 1967. This study was supported in part by Federal Aid in Wildlife Restoration Project California W-52-R, "Wildlife Investigations Laboratory".

Trees in the study area, except blue oaks (*Quercus douglasii*), were cut before the control burn. Many of the digger pines (*Pinus sabiniana*) had been cut in 1963. In the spring and early summer of 1965, many live oaks (*Quercus wislizenii*) had been cut for wood, and the stumps treated with 2,4,5-T.

The study area had been control-burned twice before, in 1951 and 1954. A preliminary burn, covering 100 acres, was made on July 22, 1965. On July 24, the main 1,100-acre burn was ignited. The day was hot; so was the burn. Rather light grazing, in anticipation of the control burn, and an unusually good vegetative production year resulted in a relatively heavy litter to carry the fire. The downed pine, piled brush, and much standing brush burned. Except in a few wet swales, where the grass was still green and relatively short from grazing, practically all herbaceous vegetation was consumed by the fire; exceptions were the still-green tarweed (*Hemizonia* sp.) and turkey mullein (*Eremocarpus setigerus*). Many Spanish clover (*Lotus americanus*) plants were also still green at the time of the burn and were scorched but not consumed by the fire. Most of the Spanish clover had formed some seed at the time of the burn, continued to grow, and produced more seed.

METHODS OF COLLECTION AND ANALYSIS

Quail were collected in August and September 1965 in unburned and burned areas. In the burned area, all collections were made at least a half-mile inside the fire line. Observations of the same groups of birds in certain spots at different times of the day indicated that the birds were staying within the burn, where crops of 11 birds were collected. Results were compared with 13 crops collected during the same time on the adjacent unburned range. All crops were analyzed by Bruce Browning and Walter Stienecker of the California Department of Fish and Game Wildlife Investigations Laboratory.

Contents were analyzed by standard procedure. Frequency of occurrence of each item was tallied and quantity measured by water displacement in a graduated cylinder. Volumes were converted to percentages and summarized by the aggregate percentage method described by Martin, Gensch, and Brown (1946). Thus, the results are directly comparable to those reported by Shields and Duncan (1966).

In addition to food samples, records of brood size, distance of birds from water, and distance inside the burn were kept for all birds collected in the burned area.

OBSERVATIONS

During the main burn, quail were seen flying back into the burned area and out ahead of the fire. Observations were somewhat limited by dense smoke, but there seemed to be no consistent pattern of quail or other birds flying away from the line of fire as it approached. It is doubtful that any adult birds were killed by the fire. Howard et al. (1959) reached similar conclusions in a report on an earlier fire.

Because many quail broods hatched late in 1965, we were interested in the effect of the fire on the survival of young quail. The day after the main burn, numerous broods of quail were seen in the burned area.

On subsequent collection trips in the burn, it became apparent that the fire had had little effect on even rather young quail. Brood size was about the same as that recorded on nearby unburned land at the same time.

Although quail were numerous in the burned area, they were hard to approach. After a few had been shot, the remainder became more wary and collection proved very difficult. Doubtless this difficulty was due to an almost complete lack of herbaceous cover, which enabled the quail to see an intruder at quite a distance.

Mourning doves *(Zenaidura macroura)* frequented the burned area to feed and to water at the ponds. Food taken by six doves shot in the unburned area in early September was almost exclusively turkey mullen seed, an important dove food in other areas of the State (Browning, 1962).

Cottontail rabbits (*Sylvilagus audubonii*) seemed to be fairly numerous and scattered throughout the burn. Whether as many of these animals were in the area after the burn as before is problematical. The ease of observation on the burned area could very well have made it appear that there were as many in the burned area as in adjacent unburned area.

Redtail hawks (*Buteo jamaicensis*) were seen on numerous occasions, but they are a common resident of the area. Cooper's hawk *(Accipiter cooperii)*, present in limited numbers in the general area, and a known predator on quail, was not observed in the burned area. No unusual predation was noticed.

RESULTS

We found little difference in the main food items taken by quail on burned and unburned range in August and September 1965 (Table 1). Because of high preference plus availability, 66 to 80% of the stomach contents of birds in both areas consisted of legume seeds. The most important legume seeds eaten by quail were *Lotus americanus*, *Lupinus bicolor*, and *Trifolium* sp. Legume seeds seem always to be a preferred quail food when available, and 1965 was a favorable year for legume growth. The same range areas reported by Shields and Duncan (1966) to have a vegetative composition of 3 or 4% legumes in 1959–1961 had a composition of about 10% legumes in 1965.

With the exception of the amount of turkey mullein, the proportions of important food items were similar in burned and unburned areas, considering the intensity of the fire and the virtual elimination of all herbaceous material in the burn. More swale or wetter soil areas were present in the unburned area than on the burned site. These areas normally have more turkey mullein than upland sites; thus, the larger intake of turkey mullein seed may be explained partially by availability.

Birds in the burned area ate more filaree (*Erodium* sp.) and clover (*Trifolium* sp.) seed than those in the unburned areas. These seeds were plentiful in both areas, but were probably much more accessible in the burned area. The presence of one minor item, ryegrass *(Lolium multiflorum)*, that appeared in the food of quail in the burned area was explained when we consulted the landowner. A few days before the ryegrass appeared in the quail diet, "hotspots" of white ash in the burn were seeded with ryegrass. Only three birds were found with ryegrass seed.

TABLE 1

Food of California Quail on Burned and Unburned Range, Madera County, California, August–September 1965

Food	Burned area		Unburned area	
	Volume (percentage)	Frequency of occurrence (percentage)	Volume (percentage)	Frequency of occurrence (percentage)
Lotus americana	11.4	100	56.9	100
Lupinus bicolor	23.6	100	7.3	85
Trifolium sp.	8.4	91	1.3	69
Lotus strigosus	1.3	73	0.7	69
Lotus subpinnatus	2.6	64	0.0	0
All legumes	**80 3**	**100**	**66.2**	**100**
Erodium sp.	8.1	100	1.9	85
Avena barbata	6.1	100	0.4	38
Plagiobothrys nothofulvus	0.8	54	5.5	38
Silene gallica	1.1	100	0.6	69
Lolium multiflorum	1.6	27	0.0	0
Centaurea melitensis	0.8	51	1.3	15
Hypochoeris glabra	0.3	100	*	69
Eremocarpus setigerus	0.3	45	23.5	92
Amaranthus sp.	0.0	0	*	8
Amsinckia sp.	0.0	0	*	23
Bromus mollis	*	9	*	8
Bromus rigidus	*	15	0.0	0
Calandrinia caulescens	0.0	0	*	31
Centromadia pungens	*	9	0.0	0
Cordylanthus sp.	*	9	0.0	0
Eleocharis sp.	0.0	0	*	8
Festuca sp.	*	9	0.0	0
Gilia sp.	*	9	0.0	0
Montia sp.	0.0	0	*	31
Phacelia sp.	*	9	0.0	0
Polygonum sp.	*	36	0 0	0
Quercus sp. (acorns)	0.0	0	*	8
Stellaria sp.	0.0	0	*	8
Forb leafage	*	18	*	8
Grass leafage	*	9	*	18
Insect fragments	*	9	*	69

* Less than 0.1%.

Several three-fourths grown quail were collected and their food examined separately from that of mature birds. Relatively little difference was found between food taken by young and old birds. In the burned area, total legume seeds for all birds collected comprised 80.3%, compared with 75.3% for young birds. On unburned range, there was even less difference; the diets of all birds and young were 66.2 and 66.1%.

Insect fragments were present in crops of all young birds on the unburned range. Although insect fragments made up only a trace of the total diet, they occurred in 69% of the samples in the unburned area. Insects appeared in only 9% of the samples from the burn.

Notes on brood size in the burned area were kept until mid-September, when young birds were practically full grown and could not be distinguished from older birds in field observations. Brood size in the burn averaged nine birds in August. This number is close to estimated brood size on adjacent unburned range at the same time.

The birds on the burned range concentrated around a permanent spring and two stockwater ponds. The collected birds were about 225 yards from water. A similar relation to water was observed on the unburned area. Proximity of birds to water sources had a definite effect on the distance inside the burn at which the collections were made. This distance averaged 0.6 mile.

DISCUSSION

The data indicate that even a "hot" burn did not vitally affect the food taken by quail in the burned area 1 to 2 months after the fire. This condition was especially true in the case of the hard-coated legume seeds. It is doubtful that quantity of seed was reduced sufficiently by the burn to cause any problems. Food was available and quail stayed in the burned area to use it.

A year-round food habits study under way and previous work (Duncan and Shields, 1966; Glading et al., 1940) suggest that once fall rains bring on general germination of the annual plants, quail quickly switch from a seed to a leafage diet. This pattern was doubtless followed in the burned area, although no collections were made at the time. The birds usually dispersed and no longer concentrated around water sources after the first major rains. Also, very little difference was found between food items taken by young birds and old birds by the time the samples were collected in August and September.

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IN MEMORIAM

Earl Leitritz

Earl Leitritz, former supervisor of California's fish hatchery program, died suddenly as the result of a cerebral hemorrhage on March 2, 1968, at the age of 62, while visiting the Great Barrier Reef in Australia.

Before his retirement from state service in 1961, Mr. Leitritz had a long and distinguished career in the California hatchery system.

He started regular work as an apprentice fish culturist at Mt. Shasta Hatchery on July 1, 1923. After completion of his apprenticeship, he continued as a fish culturist until 1931, when he was placed in charge of Fall Creek Hatchery and egg collecting stations on the upper Klamath River, in northern California.

In June 1939 he was appointed Superintendent of Mt. Shasta Hatchery, where he remained for a little over two years. In October 1941 he was promoted to Fish Hatchery Inspector for northern California, with headquarters in San Francisco. His title was changed to Assistant Supervisor of Fish Hatcheries in 1942.

Following a 31-month tour of duty with the U. S. Army from 1943 to 1945, he returned to state service.

In 1947 Mr. Leitritz was promoted to Supervisor of Fish Hatcheries, to direct all fish hatchery operations in California. He played a vital role in carrying out a $4,300,000 fish hatchery expansion and modernization program from 1949 through 1952. His many original innovations in hatchery design and layout established California as a leader in the field.

Mr. Leitritz is well known throughout fish cultural circles for his writings on hatchery subjects. He was a periodic contributor to *The Progressive Fish-Culturist*, *Outdoor California*, *California Fish and Game*, and *U. S. Trout News*, and some of his publications have been reproduced in England and France. He is best known for his definitive treatise, *Trout and Salmon Culture* (Fish Bulletin 107), which was first published in 1959 and has been reprinted three times since. It has received international acceptance and has been translated into Japanese and German. He also authored a yet unpublished history of fish culture in California. Upon retirement his services as a consultant were sought frequently.

Mr. Leitritz is survived by his wife, Madeline, to whom the deep sympathies of those who knew and worked with him are extended.—*Leo Shapovalov*.

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Notice is hereby given that the Fish and Game Commission shall meet on April 5, 1968, at 10:00 a.m. in the auditorium, Resources Building, 1416 Ninth Street, Sacramento, California, to receive recommendations from its own officers and employees, from the Department of Fish and Game and other public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to birds or mammals, or any species or variety thereof for the 1968 hunting season.

Notice is hereby given that the Fish and Game Commission shall meet at 10:00 a.m. on April 26, 1968, in the State Building, 1350 Front Street, San Diego, California, for public discussion of and presentation of objections to, the proposals presented to the Commission on April 5, 1968, and after consideration of such discussion and objections the Commission shall publicly announce the regulations it proposes to make relating to birds or mammals, or any species or variety thereof, for the 1968 hunting season.

Notice is hereby given that the Fish and Game Commission shall meet on May 31, 1968, at 10:00 a.m. in Room 115 Old State Building, 217 W. First Street, Los Angeles, California, to hear and consider any objections to its determinations or proposed orders in relation to birds and mammals for the 1968 hunting season, such determinations resulting from hearing held on April 26, 1968. This notice is published in accordance with the provisions of Section 206 of the Fish and Game Code.

FISH AND GAME COMMISSION
Monica Goodgame
Secretary to the Commission

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