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THE LIMNOLOGY AND PRODUCTIVITY OF THREE CALIFORNIA COLDWATER RESERVOIRS[1]

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Three Sierra Nevada coldwater reservoirs, Lake Spaulding and Icehouse and Beardsley Reservoirs, were studied to determine relationships between chemical and physical characteristics, primary production, zooplankton standing crop, and game fish yield. No direct relationships were found among these parameters. All three reservoirs are oligotrophic, exhibiting high Secchi disk transparencies, low alkalinities, and pH values near 7.0. Lake Spaulding had the lowest mean daily net primary production (119 mgC/m^2) and Icehouse Reservoir the highest (314 mgC/m^2). Spaulding also had the lowest mean annual game fish yield (0.75 kg/ha), while Beardsley Reservoir was highest (6.71 kg/ha).

Comparison of observed data with predicted "productivity indices" suggests that the potential yield of game fish from these reservoirs is not being realized. Lake Spaulding, because of its low temperature and high flushing rate, was lowest in overall productivity, and would benefit most from proper management activities. Net primary production, taken by itself, was not a satisfactory index to game fish yield.

INTRODUCTION

In 1961 the California Department of Fish and Game began a study of California's numerous coldwater reservoirs. The purpose was to find the best means of enhancing fishing quality in these waters. An important portion of the study involved investigations of the limnology and productivity of three such reservoirs situated on the western slope of the Sierra Nevada: Lake Spaulding in Nevada County, Icehouse Reservoir in El Dorado County, and Beardsley Reservoir in Tuolumne County (Figure 1).

The objectives of our investigations at these three reservoirs were (i) to obtain more complete basic limnological data from California coldwater reservoirs, (ii) to attempt to evaluate the characteristics of coldwater reservoirs that might affect game fish yield, and (iii) to decide whether primary production measurements would be useful in predicting game fish yield. This report summarizes the findings of these investigations.

STUDY RESERVOIRS

Definition of a Coldwater Reservoir

In this study a coldwater reservoir is defined as an impoundment in which (i) the dominant species of game fishes are salmonids, (ii) game fish are not restricted in space for an appreciable length of time by temperature at their upper tolerance limits, and (iii) at least 50% of the maximum storage volume is the result of a man-made dam. This definition allows for the brief occurrence of surface waters of limiting

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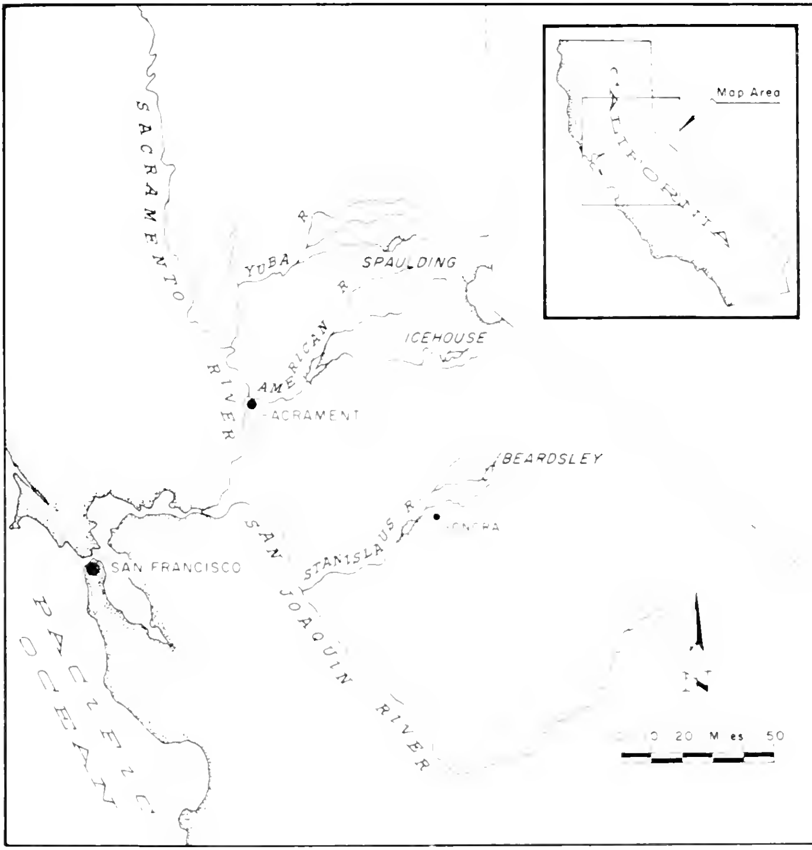

FIGURE 1—Map of study area, showing location of reservoirs.

temperature, but is meant to exclude reservoirs with temperature conditions that prevent salmonids from occupying the epilimnion. The third requirement excludes impoundments that are essentially natural lakes with small dams that increase their storage capacity only slightly. Dissolved oxygen is not used as a criterion for determining a coldwater reservoir, for although limiting concentrations may occur below the thermocline in relatively rich, thermally stratified waters, the temperature regime might otherwise support coldwater game fish.

Characteristics of Study Reservoirs

Reservoirs differ from typical coldwater Sierra lakes in several general features. Most apparent is age. Lake Spaulding, the oldest of the three studied, was created in 1913 (Table 1). Sierra Nevada lakes were mostly created by glacial action, which ended about 10,000 years ago. Furthermore, most coldwater reservoirs are considerably larger than natural lakes. Few Sierra Nevada lakes exceed 16 ha (40 acres) in surface area, whereas the majority of coldwater reservoirs are much greater than 16 ha, and the three in this study are greater than 243 ha (600 acres).

TABLE 1

Location and Description of Study Reservoirs

	Spaulding	Icehouse	Beardsley
Location	lat. 39°21′N long. 128°38′W	38°19′N 120°21′W	38°13′N 120°1′W
County	Nevada	El Dorado	Tuolumne
Elevation (m)	1,524	1,657	1,026
River drainage	S. Fk. Yuba R.	Silver Cr., trib. to S. Fk. American R.	M. Fk. Stanislaus R.
Drainage area (km^2)	311	72	803
Mean depth (m)	34	21	16
Max. depth (m)	79	10	91
Max. area ($m^2 \times 10^6$)	2.73	2.74	2.63
Capacity ($m^3 \times 10^6$)	91.88	56.69	120.26
Mean annual flushing rate[1]	6.0	1.1	3.3
Shoreline development (D_L)	2.30	2.54	2.24
Year storage began	1913	1959	1957

[1] Annual discharge ÷ capacity.

All three reservoirs are typical of the majority of Sierra reservoirs in their mode of operation. From the point when snowmelt runoff reaches its peak in May or June, the water level of the reservoir gradually declines as water is drawn off for various uses. Withdrawal continues to exceed inflow until late winter (February, March), when the reservoir reaches low pool. The reservoirs experience a large annual fluctuation in water level. Spaulding has an average fluctuation of 20.0 m, Icehouse, 23.2 m, and Beardsley, 23.3 m.

Generally, snowmelt runoff is sufficient to cause water to spill through the spillway. Withdrawals, however, are made through outlet structures usually located near the base of the dam. Spaulding has two outlet gates that draw water at depths of 17.0 and 48.5 m above the bottom. Icehouse also has two, located at 7 and 8 m above the bottom, while Beardsley has one, at 8 m above the bottom.

Of the three reservoirs, only Icehouse has no upstream storage or diversion structure on its tributaries. Beardsley has two such structures, Donnells Reservoir (174 ha) and Relief Reservoir (92 ha) on its principal tributary, which are used for power production and water storage. Spaulding also has two, Fordyce Reservoir (282 ha) on Fordyce Creek and Lake Van Norden (155 ha) on the South Fork of the Yuba River, both designed for power production and water storage. In addition, Spaulding also receives water through a conduit from Bowman Reservoir (334 ha) on nearby Canyon Creek in the South Fork Yuba River drainage.

The Fisheries

Fisheries are maintained in most coldwater reservoirs by annual introductions of large numbers of fingerling[3] rainbow trout (*Salmo gairdnerii*) and occasionally brown trout (*S. trutta*). Fingerling trout are planted on the assumption that they will be able to utilize the basic "productivity" of the reservoir and be caught by the angler in sufficient numbers to sustain a fishery. In some waters where fingerlings

[3] In California's hatchery program fingerlings include all trout weighing 1 oz. (31.1 g) or less.

have not been successful, catchable-sized [4] trout are planted to provide fishing.

In addition to planted trout, all three reservoirs contain populations of wild rainbow and brown trout, with kokanee salmon (*Oncorhynchus nerka*) present in Icehouse Reservoir as a result of annual stocking of fingerlings beginning in 1961. The most abundant nongame fish species include the hitch (*Lavinia exilicauda*) and western sucker (*Catostomus occidentalis*) in Beardsley, and the introduced smelt (*Hypomesus transpacificus nipponensis*) and Sacramento squawfish (*Ptychocheilus grandis*) in Spaulding. Icehouse contains the golden shiner (*Notemigonus crysoleucas*). The relative abundance of these species is not known.

METHODS AND MATERIALS

Limnology

Physical and chemical data were obtained at approximately 1- to 2-week intervals at Icehouse from July through October 1961, and June through November 1966; at Beardsley from May through September 1962, June through November 1964, and May through November 1965; and at Spaulding from June through December 1963, April through October 1964, and June through October 1965. In addition, samples were taken once a month at Beardsley from January through April 1965 and at Spaulding from January through March 1964.

Sampling was restricted to one station in approximately the center of the reservoir. On each sampling date, water samples were taken and analyzed for pH, total alkalinity, and dissolved oxygen following methods outlined in *Standard Methods* (American Public Health Association, 1965). In addition, a temperature profile was obtained and the Secchi disk transparency was observed. Primary production was measured by the C-14 method of Steemann-Nielsen (1952), as outlined by Goldman (1963) for use in fresh water. Primary production data were analyzed with the aid of a special computer program written by graduate students under the supervision of Dr. Charles R. Goldman of the Department of Zoology, University of California, Davis, California.

Zooplankton

Zooplankton samples were collected at the same station and on the same days that limnological data were obtained from Icehouse, from June through November 1966. In addition to the offshore station at Beardsley and Spaulding, one shallow-water (15 m) station near shore was selected in both reservoirs for additional plankton sampling. Samples were taken in these reservoirs also on the same days limnological data were collected, but only during August, September, and one day in October 1965. A standard Wisconsin net was used to take three vertical hauls at each station. Each sample was analyzed for total centrifuged volume, wet and dry weights, and numbers of organisms. The percentage which each group of organisms composed of the total sample was computed and the number of each group per m^2 and per m^3 was estimated. Dry weights were obtained by baking the sample in a drying oven at 50 C for 24 hr.

[4] Catchable-sized trout are defined as those which are 7½ inches (191 mm) or longer.

Creel Census

Creel censuses were conducted from 1962 through 1966 at Spaulding, from 1961 through 1963 at Icehouse, and from 1962 through 1967 at Beardsley. At Spaulding and Beardsley two or three weekdays and both weekend days were censused each week throughout the entire season, with 100% and 90 to 100% of the angler effort sampled each day, respectively. At Icehouse census was conducted intermittently throughout the season, with an unknown percentage of the angler effort sampled. Details of census methods will be presented in a later paper.

Diet

Stomach samples of game fish were obtained during the creel censuses at Beardsley and Spaulding in 1962, 1963, and 1964. Stomach samples were also collected during the 1967 creel census at Beardsley. No stomach samples were collected at Icehouse. The method of collection and analysis followed that recommended by Borgeson (1963).

RESULTS

Limnology

The mean pH and alkalinities of the three reservoirs for the month of August (Table 2) closely approximated the average annual values calculated for these parameters. Surface temperatures were at their highest in July and August in Spaulding and Icehouse, and August and September in Beardsley. The highest average surface temperatures occurred in Icehouse in all months except September, when Beardsley had the highest average temperature (Figures 2, 3, and 4). Otherwise, Beardsley had the second highest average temperatures and Spaulding the lowest. High temperatures were never observed to be limiting for

TABLE 2

Some Physical and Chemical Characteristics of the Study Reservoirs for the Month of August, All Years Combined

	Spaulding	Icehouse	Beardsley
Mean temperature (C)			
0 m	17.9	22.2	21.8
30 m	15.2	7.3	11.6
Max. temperature (C)			
0 m	19.1	23.1	22.7
30 m	16.0	7.4	12.6
Mean dissolved oxygen (ppm)			
0 m	8.0	7.5	7.2
30 m	8.0	4.4	8.8
Mean pH			
0 m	7.1	6.8	7.2
30 m	6.7	6.1	7.0
Mean alkalinity (ppm)			
0 m	10.2	8.0	22.6
30 m	8.7	7.9	20.0
Mean Secchi disk transparency (m)	9.9	7.2	9.2

trout at any of the study reservoirs. Thermocline formation was lacking in Spaulding Reservoir during the years of the study, at least to a depth of 30 m (Figure 2). In Icehouse, a thermocline existed from June through October at 5 to 20 m (Figure 3), and in Beardsley the thermocline ranged from 3 to 7 m from June through early September (Figure 4). Thermal stratification was strongest in Icehouse.

Dissolved oxygen was never sampled at a depth greater than 30 m in Spaulding or Beardsley. In all three reservoirs, however, it was present to the greatest depths sampled (Figures 2, 3, and 4).

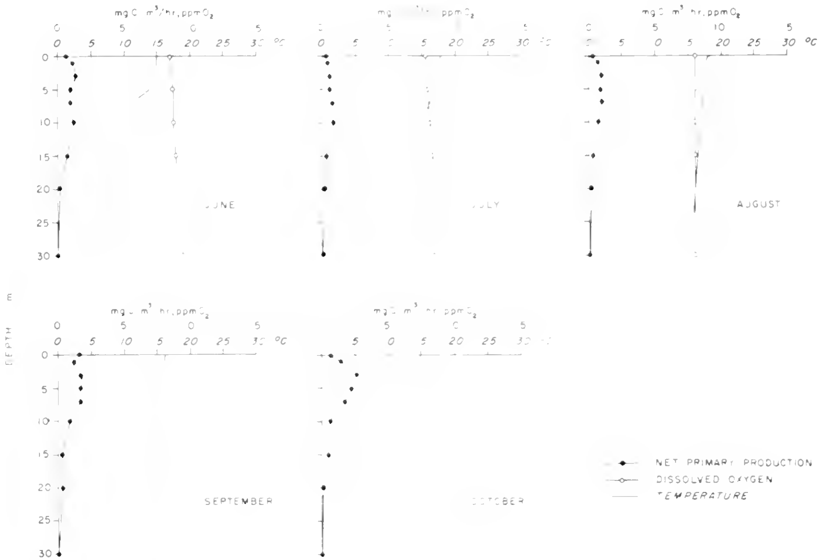

FIGURE 2—Mean net primary production, dissolved oxygen, and temperature profiles of Spaulding Reservoir, 1963–65 combined (dissolved oxygen data lacking for September and October).

Although no direct measurements of turbidity were made, the study reservoirs sometimes became highly turbid in the spring and early summer during snowmelt runoff. Occasional increased turbidity, of varying duration, was observed at other times of the year during and after rainstorms. Afternoon breezes, common during the summer, occasionally created turbid conditions along the shoreline through wave action. In general, Lake Spaulding tended to have the greatest Secchi disk transparency and Icehouse the lowest (Figure 5). Icehouse showed greatest transparency in July, while Spaulding and Beardsley were clearest in August.

The greatest primary production (photosynthesis) in most months occurred in the upper 10 m, with little or no production below 20 m (Figure 2, 3, and 4). In June and July, the oxygen maxima appeared to correspond with the carbon production maxima in Icehouse. Such a relationship was not observed in other months or in the other reservoirs. In nearly all months for each reservoir, primary production was inhibited at the surface. Depth of maximum carbon production also corresponded to the depth of the thermocline in June and July in

Icehouse, but occurred in the epilimnion in August, September, and October. In Beardsley, maximum carbon production appeared to occur always above the thermocline. The depth of maximum primary production was less distinct in Spaulding, except in October, when it was at 3 m.

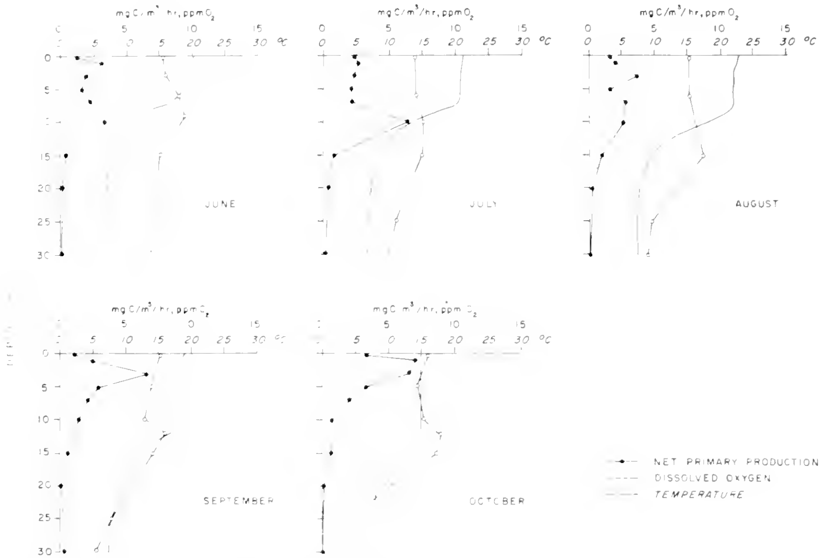

FIGURE 3—Mean net primary production, dissolved oxygen, and temperature profiles of Icehouse Reservoir, 1961 and 1966 combined.

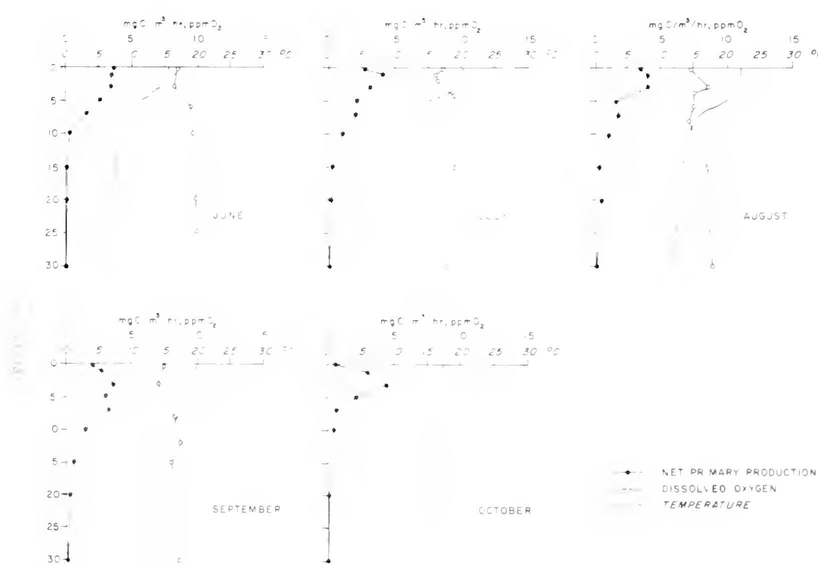

FIGURE 4—Mean net primary production, dissolved oxygen, and temperature profiles of Beardsley Reservoir, 1962, 1964 and 1965 combined (dissolved oxygen data lacking for October).

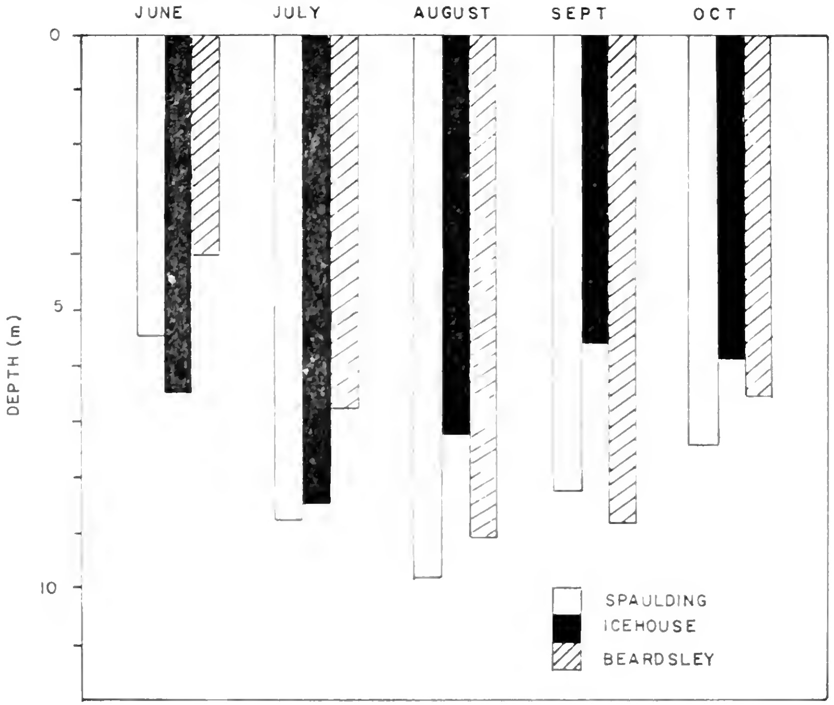

FIGURE 5—Mean monthly Secchi disk transparency in study reservoirs, all years combined.

Production

Although the "production" estimates that were obtained at three different trophic levels in each of the study reservoirs are not directly comparable, they do help provide a meaningful insight into the relationship between reservoir productivity and game fish yield (Table 3).

The average primary production values represent the total daily net production of a column of water 1 m² to a depth of 30 m. This depth approximates the lowermost depth of the euphotic zone in each of the

TABLE 3

"Production" Estimates at Three Trophic Levels in the Study Reservoirs

	Spaulding	Icehouse	Beardsley
Mean daily net primary production and 95% C.I. (mgC/m²) [a]	119 (94–144)	314 (276–352)	227 (191–263)
Mean standing crop zooplankton (mg/m²) [b]	764.8 [c]	562.1 [d]	950.6 [c]
Mean annual yield game fish (kg/ha) [e]	0.75	3.36	6.71

[a] June through October only, all years combined.
[b] Dry weight, to a depth of 30 m.
[c] August and September 1965.
[d] June through October 1966.
[e] Wet weight (unpublished data).

reservoirs. As was expected, some variation in primary production values occurred within any one month for a given year. Yet, the magnitude of the differences between the reservoirs was large enough to be significant at the 5% level for all months except June (Figure 6).

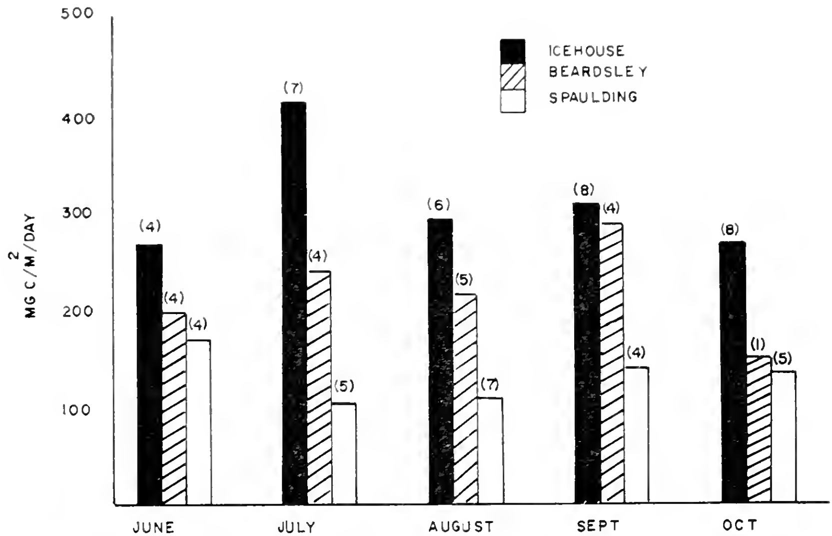

FIGURE 6—Mean daily net primary production in study reservoirs, all years combined (sample size in parentheses).

Mean daily net primary production (June through October combined) varied the most between years in Spaulding, ranging from 92 mgC/m^2 in 1963 to 142 mgC/m^2 in 1964 and 172 mgC/m^2 in 1965. Icehouse varied less between years, averaging 294 mgC/m^2 in 1961 and 326 mgC/m^2 in 1966. Beardsley averaged 227 mgC/m^2 in 1962, 210 mgC/m^2 in 1964, and 247 mgC/m^2 in 1965. The mean values for all years combined (Table 3) were significantly different from one another.

A decline in net production commonly has been associated with aging in other reservoirs. Measurements in the three study reservoirs do not indicate a decline in any of them. However, the data are not extensive enough to form firm conclusions in regard to production and aging. This is especially true of Icehouse Reservoir, since sampling in 1961 did not begin until July 12, when spring phytoplankton blooms may have passed.

The main groups of zooplankters to occur in the samples from each reservoir were Cladocera: *Daphnia* spp., *Bosmina coregoni*, *Holopedium gibberum;* and Copepoda: both cyclopoid and calanoid types, and nauplii (Figure 7). *Polyphemus pediculus* occurred in a small number of samples in Beardsley only and is not included. Actually, rotifers were numerically the most abundant zooplankter in all the samples; however, they did not contribute significantly to the total weight of the samples.

Figure 7 clearly shows that *Daphnia* were the most important zooplankters in Beardsley except in early September, when calanoids were slightly more abundant. Icehouse samples were dominated by cyclopoids and Spaulding samples by *Bosmina*, with *Daphnia* occurring in small numbers in each.

The figures indicated in Table 3 for zooplankton standing crops were derived from limited sampling in but one year and must be regarded as rough estimates at best. For this reason no attempt was

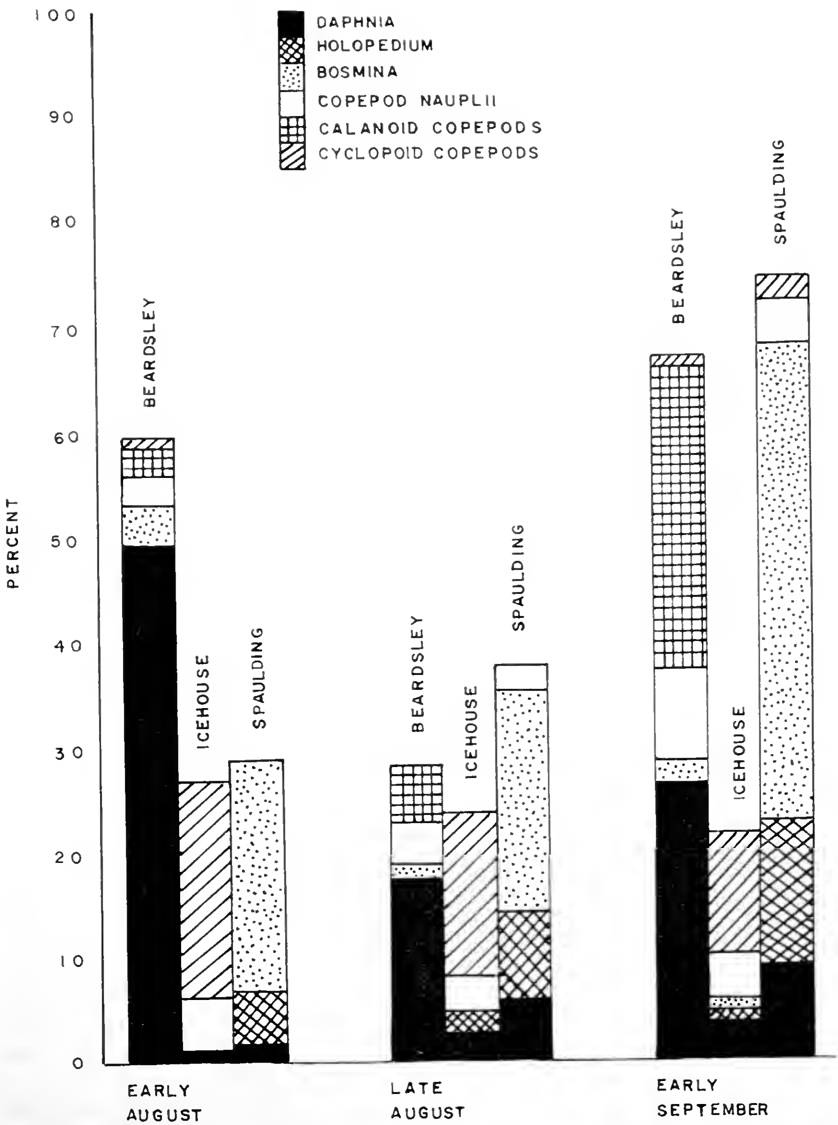

FIGURE 7—Mean percentages of the most abundant groups of zooplankton (rotifers excluded) from replicate vertical hauls at offshore sampling stations.

made to fix their reliability with confidence intervals. Nevertheless, we believe that they provide a good relative measure of the magnitude of "production" for the months involved. There appeared to be no significant difference in the numbers of each of the different organisms per m^3 between the offshore and nearshore sampling stations in either Beardsley or Spaulding Reservoirs. Strong differences between reservoirs did occur, however, in the numbers of *Daphnia*, *Bosmina*, cyclopoids, and rotifers per m^3 at the offshore sampling station. It was observed that there was an inverse correlation in the numbers of *Daphnia* and *Bosmina* between Beardsley and Spaulding: Beardsley contained large numbers of *Daphnia* and small numbers of *Bosmina*, while in Spaulding the situation was reversed. In these reservoirs rotifers comprised about 50% of the samples by number. Icehouse, on the other hand, had very few of both *Daphnia* and *Bosmina*, but rotifers comprised about 75% of the samples by number.

Creel census data showed that the annual game fish yield was highest in Beardsley Reservoir (Table 3). The principal kinds of game fish harvested in the three waters included wild and hatchery-reared rainbow and brown trout. In Icehouse, kokanee salmon were also important. Yield estimates for planted trout were not adjusted to account for the weight at time of planting, since this weight was negligible.

The yield of game fish varied from 0.69 to 0.87 kg/ha in Spaulding and from 2.99 to 9.84 kg/ha in Beardsley. The estimated 3.36 kg/ha for Icehouse is based on 1962 data only. In Beardsley, the average annual catch composition by weight was 95.2% rainbow trout and 4.8% brown trout, while for Spaulding the percentages were 75.2 and 24.8, respectively. In 1961, before the introduction of kokanee, the percentage harvest by number of rainbow trout and brown trout in Icehouse was 90.9 and 9.1, respectively. In 1962, following the introduction of kokanee, the percentages were 76.5 rainbow, 17.8 kokanee, and 5.8 brown trout. Apparently the kokanee predominated in subsequent years, for in 1963 the catch percentages had shifted to 77.4 kokanee, 13.6 rainbow, and 9.1 brown trout. Presently, however, wild trout production in Icehouse is not sufficient to satisfy fishing demands and "catchable" rainbow and brown trout are planted throughout the fishing season, while fishing for kokanee, supported mainly by plants of fingerlings, occurs principally during May and June.

Diet

In both Beardsley and Spaulding it was found that cladocerans, principally *Daphnia*, were the only zooplankton eaten by rainbow trout (Figure 8). The diet of the rainbow trout in the two reservoirs was strikingly different. In Beardsley, zooplankton comprised almost the total volume of food for all sizes of rainbow to 432 mm (17.0 inches), with terrestrial organisms composing the second largest food group. In Spaulding, on the other hand, zooplankton rarely entered the diet of rainbow of any size. Terrestrial organisms and aquatic invertebrates (other than zooplankton) were predominant in the diet of trout to 356 mm (14.0 inches), while fish (primarily *Hypomesus*) assumed greater importance for rainbow larger than 356 mm. On a monthly basis, the rainbow trout food pattern in Beardsley differed little from the situation indicated by Figure 8. Terrestrial organisms comprised a greater part of the rainbow diet in June for fish larger than 279 mm (11.0 inches) than in any other month. The situation was somewhat more variable in Spaulding, with aquatic invertebrates and fish predominant

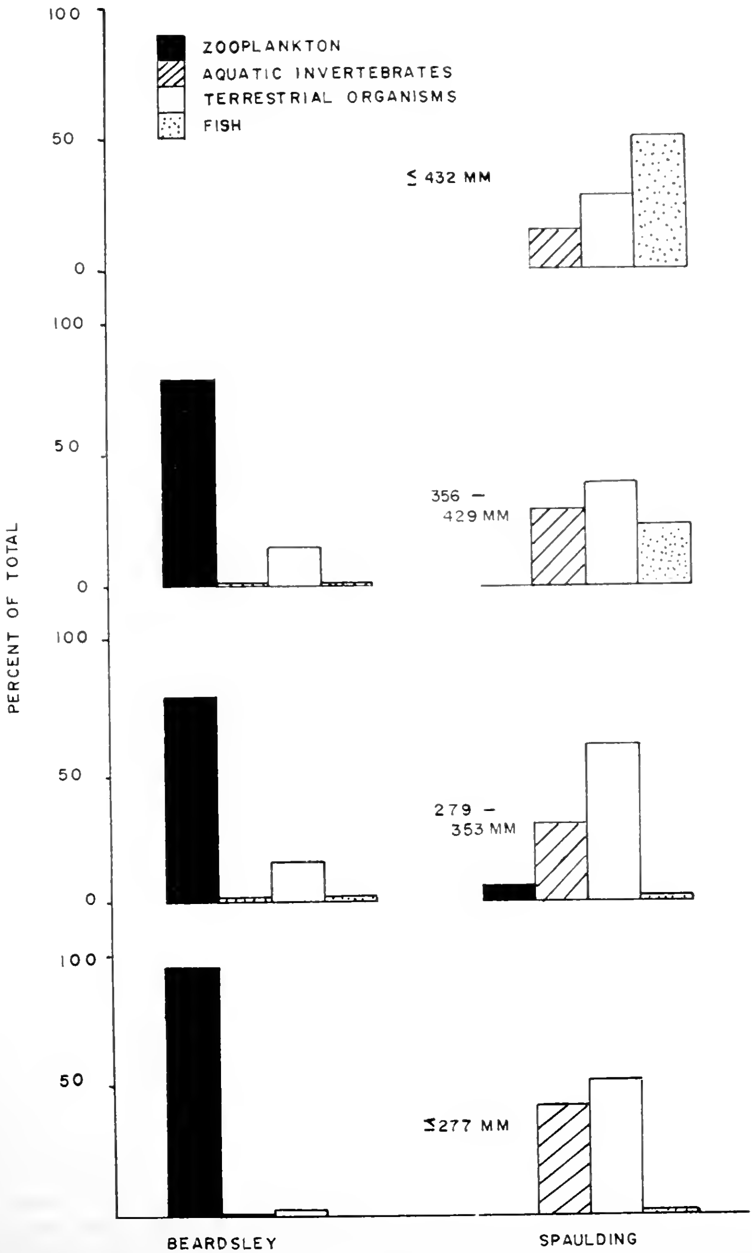

FIGURE 8—Relative abundance of food items of four size groups of angler-caught rainbow trout from study reservoirs, 1962–64.

in May and August and terrestrial organisms predominant in June and July.

In Spaulding, brown trout larger than 279 mm fed almost exclusively on *Hypomesus*. Brown trout smaller than this were not sampled. Since brown trout were only occasionally taken in Beardsley, few stomach samples were obtained, but these indicated a piscivorous diet. The piscivorous diet of brown trout in lakes is well known.

Although no food consumption data are available from Icehouse Reservoir, it is reasonable to assume that kokanee fed almost exclusively on zooplankton, as they do in most lakes (Seeley and McCammon, 1966).

Too few stomach samples of nongame fish from Beardsley and Spaulding were taken to permit a quantitative analysis of their food habits. Some qualitative observations of stomach contents were possible, however. In Beardsley, *Catostomus* fed mostly on benthic invertebrates, mainly aquatic insect larvae and nymphs, while *Lavinia* ate not only benthic invertebrates but cladocerans as well. In Spaulding, *Ptychocheilus* fed on a variety of aquatic invertebrates as well as zooplankton. *Hypomesus* was not sampled but it is believed to feed primarily on zooplankton (Wales, 1962).

DISCUSSION

Using the terminology developed for natural lakes (Hutchinson, 1957), it appears that all three reservoirs are most nearly like second-class dimictic lakes, with Spaulding possibly approaching one of the third-class type. The oxygen profiles in Spaulding and Beardsley resemble orthograde curves, while Icehouse oxygen profiles are of the positive heterograde type. All three reservoirs may be considered oligotrophic or nutrient-poor.

On the basis of the data presented in Table 3, it appears there is no direct relationship between primary production, standing crops of zooplankton, and annual yield of game fish. Given the type of data collected and the complexity of interrelationships among the organisms of the different trophic levels, this is not surprising. Obviously, it would be a great advantage to fisheries managers if the relationship between the reservoir's basic productivity and game fish production could be clearly defined. Although our data are not complete enough to define these relationships precisely, we can make some reasonable evaluations of the factors that affect game fish yield in coldwater reservoirs.

The ultimate factor which determines the potential yield of game fish in a reservoir is the capacity of the primary producers to manufacture food materials that can be used by heterotrophic organisms (i.e., net primary production). The actual yield of game fish, assuming a stable fishery, is dependent on a host of factors that fall into two categories: (i) factors that affect primary production, and (ii) factors that affect the transfer of food material after it is produced. The former includes the supply of nutrients, temperature, light penetration, other chemical and physical variables, the flushing rate, and the abundance and composition of the phytoplankton. The latter includes the number of trophic pathways between phytoplankton and game fish, and the direction and efficiency of energy transfer within and between trophic levels.

Murphy (1962) states that for a reservoir to have good productivity an epilimnion must be present, the turbidity must be low, and there must be some degree of mixing with the nutrient-rich hypolimnion. In Spaulding, with the lowest net primary production, an epilimnion failed to form from June through October, at least to the depth where primary production occurred. Furthermore, the average temperature to a depth of 10 m from July through September was somewhat lower than in Beardsley or Icehouse. Efford (1967) found a close relationship between primary production and temperature in Marion Lake, British Columbia, and Sparrow (1966) noted a direct relationship between mean epilimnion temperature and zooplankton abundance. Thus, temperature appears to correlate directly with the observed primary production. However, more than temperature is involved. In October the temperature of both Icehouse and Spaulding is nearly identical (Figures 2 and 3), yet primary production in Icehouse is about twice as great as in Spaulding (Figure 6).

Another factor which correlates directly with the observed net primary production is the flushing rate (the number of times a volume of water equal to the storage capacity of the reservoir passes through the reservoir each year). The effect of a high flushing rate is to retard the rate of nutrient accumulation (eutrophication) in the reservoir. Flushing, of course, occurs in natural coldwater lakes but usually at a much slower rate than in most reservoirs. Efford (1967) believed that it was not as important as temperature in limiting productivity in Marion Lake. It would also tend to flush out phytoplankton populations if the outflow occurred at or near the surface. The effect of nutrient removal would be most critical in reservoirs with outlet structures that draw water from the nutrient-rich hypolimnion (Murphy, 1962; Johnson and Berst, 1965). This situation exists for each of the three study reservoirs. The flushing rate for Spaulding (Table 1) is considerably higher than for either Icehouse or Beardsley and may be a significant factor affecting primary production.

Alkalinity failed to correlate directly with the observed primary production for each of the reservoirs. However, Carlander (1955) and Moyle (1956) found positive correlations between standing crops of fish and alkalinity concentrations in lakes which they examined. The available nutrients were not measured nor were limiting factor (trace element) bioassays (Goldman, 1962) conducted, so it is not possible to say to what degree nutrients were limiting the primary production.

It is possible that the species composition and abundance of the phytoplankton populations in the three reservoirs was distinctly different and could have led to the difference observed in net primary production and zooplankton standing crop. Wright (1960) showed that the relationship between photosynthesis and phytoplankton standing crop is not linear. Rather, he found that net photosynthesis was maximal at intermediate levels of standing crop and less at concentrations above the intermediate range. Unfortunately, however, these variables were not evaluated in the present study.

The lack of correlation between phytoplankton production and zooplankton standing crop and game fish yield may be explained by examining some of the factors which affect the transfer of energy through the trophic levels. Few game fish are adapted to feeding directly on such tiny organisms as phytoplankton and the game fish in these reservoirs are no exception. The rainbow trout rely heavily on zooplankton in Beardsley, which has a much greater zooplankton standing crop than Icehouse. A likely explanation for the observed differences in primary production and zooplankton standing crop between Icehouse and Beardsley is that the kokanee, predominant in Icehouse, are very efficient plankton feeders. The lack of larger forms of zooplankters in Icehouse suggests that kokanee grazed upon these organisms quite heavily. A depressed population of zooplankters, in turn, would lead to a reduced rate of grazing on the phytoplankters, which could result in a larger population of phytoplankton and possibly a higher rate of primary production. In Beardsley, grazing by the rainbow trout on zooplankton was less severe than grazing by the kokanee on zooplankton in Icehouse. The resultant rate of grazing by the zooplankton on the phytoplankton was then much greater, contributing to a depression of the expected rate of primary production.

The difference in annual yield of game fish between Icehouse and Beardsley may be due to the fact that rainbow trout in Beardsley are more efficiently harvested than the kokanee in Icehouse. Kokanee are quite restricted in their distribution for most of the fishing season, and most anglers lack the knowledge of how to fish for them (Seeley and McCammon, 1966). If they were more readily available to fishermen, it is probable that the yield of game fish in Icehouse would have been greater.

Although Lake Spaulding had the lowest primary production and game fish yield, it was intermediate in zooplankton standing crop. Generally, it is usually the larger macroscopic cladocerans which contribute the bulk of the total volume and weight to a sample of zooplankton. Thus, in Beardsley, where the larger *Daphnia* were dominant, the greatest standing crop occurred, while Spaulding, where the smaller *Bosmina* were most abundant, had the second highest standing crop. In Icehouse, however, cladocerans of any kind were relatively scarce, and its zooplankton standing crop was lowest.

It is obvious that the data pose more questions than they can answer about the production relationships in these reservoirs. It appears, however, that Spaulding Reservoir, with the lowest game fish yield, also has the lowest overall productivity of the three reservoirs studied, with Icehouse and Beardsley substantially higher and more nearly equal in overall productivity. The primary reasons for these differences are that Lake Spaulding (i) lacks a shallow epilimnion with only a weak, deep thermocline, if any exists at all, (ii) has substantially lower average temperatures in the euphotic zone, and (iii) has a very high flushing rate. Conditions in Icehouse and Beardsley are quite the opposite and are more conducive to higher productivity.

Productivity Indices

For a number of years biologists have attempted to correlate various physical, chemical, and/or biological characteristics of lakes with fish production. In addition, some have used these characteristics to derive indices of general "productivity" (Moyle, 1946; Rounsefell, 1946; Carlander, 1955; Hayes and Anthony, 1964; Ryder, 1965). Hayes and Anthony, using data from lakes of the midwestern and eastern U. S., incorporated methyl orange alkalinity, area, and depth into a multiple regression equation which was used to derive a "productivity index". They believed that their equation accounted for an estimated 67% of the variability in the index in which 20% was due to area, 29% to depth, and 18% to alkalinity.

When our data were fitted to their equation we obtained predicted productivity indices of 1.9, 3.5, and 2.2 for Spaulding, Icehouse, and Beardsley, respectively. These were compared to the observed productivity indices of 0.2, 0.7, and 1.3 derived by dividing the actual annual yield of fish by the expected annual yields (Hayes and Anthony, 1964, p. 53, 54, Tables 1 and 2). The ratios of the observed productivity index to the predicted productivity index for Spaulding, Icehouse, and Beardsley were 0.08, 0.21, and 0.59, respectively. Assuming that their equation is valid, the fact that these ratios are less than 1.0 suggests that the yield of game fish from the study reservoirs is not commensurate with that expected from their predicted productivity indices. This would seem especially true in Icehouse and Spaulding, where the deviations are large. These results indicate that there is room for improvement in managing these waters for optimum harvest of game fish. Spaulding, it appears, could benefit the most from proper management activities, with Icehouse next. Beardsley, theoretically, has the least room for improvement, being closer to the predicted value than the others.

Primary Production

As we observed, there was no direct correlation between net primary production and game fish yield. In light of the complexity of factors affecting game fish production, as discussed above, this is not unexpected. Rupp and DeRoche (1965) also failed to correlate net primary production with standing crops of fishes in three Maine trout lakes. It is highly unlikely that, in any but the simplest of situations, net primary production will ever correlate directly with game fish production. It may, however, be a valid means of assessing a reservoir's "potential" for producing game fish. Securing accurate estimates of net primary production by the complex C-14 method, however, would require more time and effort than would be practical in a routine management program.

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FOOD OF LAKE TROUT IN LAKE TAHOE[1]

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Stomachs of 1,389 lake trout *(Salvelinus namaycush)* from Lake Tahoe were examined. Of these, 1,097 contained food and were used in food habit determinations. Lake trout were separated into five size groups (inches FL): under 5.0, 5.0 to 9.9, 10.0 to 14.9, 15.0 to 19.9, and over 19.9. The food habits of these groups were evaluated on an annual and seasonal basis. Lake trout less than 5.0 inches preyed heavily on cladocerans and copepods, which occurred in over 90% of the stomachs. No fish remains were found in this size group. Fish (all Piute sculpins, *Cottus beldingii)*, occurred in 28.9% of the stomachs of the 5.0- to 9.9-inch lake trout and provided the highest fraction (56.0%) of the weight. However, cladocerans appeared most frequently (52.6%) in the stomachs. In the 10.0- to 14.9-inch group, 66% of the stomachs contained cladocerans and 43% contained fish, with fish contributing the greater weight. Cladocerans were again important by frequency in the diet of the 15.0- to 19.9-inch lake trout, but were of little consequence by weight. Fish, primarily sculpins, occurred in 65.1% of the stomachs and comprised 84.7% of the weight. Only in stomachs of lake trout over 19.9 inches did fish exceed a frequency of 90%. Tahoe suckers *(Catostomus tahoensis)* were the major food item. The greatest seasonal variation in diet involved the occurrence of fish, which was highest in spring and lowest in summer. In previous Tahoe studies, sculpins were the most important food item for lake trout over 14.9 inches. The data indicated that trout less than 15.0 inches lack suitable forage organisms.

INTRODUCTION

The first confirmed introduction of lake trout (known locally as "mackinaw") into Lake Tahoe was made in 1889 by the former Nevada Fish Commission (Miller and Alcorn, 1945). Earlier plants may have been made beginning in 1886, and subsequent plants were also made. As early as 1903, occasional lake trout to 10 lb were caught (Juday, 1907). By 1923 they were considered plentiful (Kemmerer, Bovard, and Boorman, 1923). Today, the Tahoe sport fishery is dominated by the lake trout (Cordone and Frantz, 1966).

In 1960, California and Nevada initiated a cooperative Lake Tahoe Fisheries Study to evaluate the status of the game fish populations and find ways to improve fishing. An assessment of the food habits of lake trout was one phase of the life history investigation of this species. The purpose was to determine if a need existed for new forage organisms to supplement the lake trout's diet.

Results of earlier life history investigations of Lake Tahoe lake trout, including some food habits data, were described by Miller (1951) and Corlett and Wood (1958). The physical and chemical characteristics

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of Lake Tahoe are described by McGauhey et al. (1963) and Weidlein, Cordone, and Frantz (1965).

METHODS AND MATERIALS

Lake trout stomachs were collected from from January 1962 through September 1964. The greatest number (52%) came from angler-caught fish sampled during both a lakewide creel census by boat and a creel census at the Cave Rock Public Boat Landing (Cordone and Frantz, 1966). Bottom gill nets set at depths from 25 to 900 ft at widely scattered locations around the lake captured many lake trout. This source comprised 14% of the stomachs analyzed. The remaining 4% were from lake trout captured during bottom trawling operations.

All lake trout were measured to the nearest 0.1 inch FL. Stomachs were removed, labeled, and preserved in 10% formalin. The stomachs of 1,389 fish were examined and of these 292 were empty. Food items were identified and counted, and then damp-dried before weighing on a triple-beam balance to the nearest 0.01 g. Length measurements were taken from all ingested fish and crayfish in suitable condition. Crayfish were measured in inches from the tip of the acumen to the end of the telson, and fish were measured in inches FL, except sculpins, which were measured in inches TL.

The number of unidentified fish in stomachs was reduced by identification of vertebrae. Surplus tissue was removed from vertebrae of the unidentified fish with potassium hydroxide and then the vertebrae were stained with Alizarin Red. These were compared with stained vertebrae of known origin for final identification.

The lake trout ranged from 1.5 to 33.2 inches FL. They were separated into five size classes to permit determination of changes in diet with changes in length: under 5.0 inches, 5.0 to 9.9, 10.0 to 14.9, 15.0 to 19.9, and over 19.9. Seasonal variation in food habits was analyzed as follows: winter (January, February, March), spring (April, May, June), summer (July, August, September), and autumn (October, November, December). Comparisons between years were not attempted; rather, samples from different years were combined.

RESULTS

Food of Lake Trout

The number of stomachs examined varied by size group, with the fewest in the two smallest size groups, and the greatest number in the 15.0- to 19.9-inch size group (Table 1). The percentage of empty stomachs increased directly with length, ranging from 6.7% in fish under 5.0 inches to 30.0% in fish over 19.9 inches.

Lake Trout Under 5.0 Inches

Only four groups of foods were found in these small lake trout (Table 2). Cladocerans and copepods were clearly the most important, supplying over 90% of the stomach contents by weight and frequency of occurrence. Cladocerans were found in 61% of the stomachs and copepods in 21%; 14% contained both cladocerans and copepods. Tendipedid larvae and pupae ranked second in utilization, while amphipods and oligochaetes were of lesser importance. The latter are numerous

TABLE 1

Number and Percentage of Lake Trout Stomachs With and Without Food, by Size Groups and Seasons

Size group (inches FL)	Under 5.0				5.0 to 9.9				10.0 to 14.9				15.0 to 19.9				Over 19.9				All fish			
	With food		Empty		With food		Empty		With food		Empty		With food		Empty		With food		Empty		With food		Empty	
Season	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Winter	9	100.0	0	0.0	7	70.0	3	30.0	11	91.7	1	8.3	83	76.1	26	23.9	26	57.8	19	42.2	136	73.5	49	26.5
Spring	2	100.0	0	0.0	14	93.3	1	6.7	53	89.8	6	10.2	237	84.6	43	15.4	79	79.8	20	20.2	385	84.6	70	15.4
Summer	11	91.7	1	8.3	6	85.7	1	14.3	35	83.3	7	16.7	136	84.5	25	15.5	40	65.6	21	34.4	228	80.6	55	19.4
Autumn	6	85.7	1	14.3	11	100.0	0	0.0	51	80.9	12	19.1	203	74.4	70	25.6	77	68.7	35	31.3	318	71.7	118	25.3
All year	28	93.3	2	6.7	38	88.4	5	11.6	150	85.2	26	14.8	659	80.1	164	19.9	222	70.0	95	30.0	1,097	79.0	292	21.0

TABLE 2

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Tahoe Lake Trout, by Five Size Groups

Size group (inches FL)	Under 5.0		5.0–9.9		10.0–11.9		15.0–19.9		Over 19.9	
Number of stomachs with food	28		38		150		659		222	
Item	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Fish (total)			28.9	56.0	13.3	63.3	65.1	81.7	90.1	91.2
Piute sculpin (*Cottus beldingii*)			28.9	56.0	30.0	12.5	38.1	22.1	27.9	4.8
Tahoe sucker (*Catostomus tahoensis*)					2.7	7.1	7.1	18.2	32.1	11.5
Tui chub (*Gila bicolor*)					2.0	2.1	9.9	11.3	13.5	7.0
Lahonton redside (*Richardsonius egregius*)					2.0	1.2	2.1	2.0	1.3	0.2
Lahontan speckled dace (*Rhinichthys osculus robustus*)							0.3	0.0		
Lake trout (*Salvelinus namaycush*)					3.3	6.8	1.8	1.9	1.0	1.3
Other trout[1]							2.3	9.0	6.3	16.6
Kokanee salmon (*Oncorhynchus nerka*)							1.8	3.1	7.7	1.9
Mountain whitefish (*Coregonus williamsoni*)					0.7	2.1	6.1	12.7	10.8	11.3
Unidentified fish					6.0	0.6	10.2	1.3	11.9	0.6
Fish eggs[2]			2.6	0.1	2.0	5.6	1.1	1.5	1.3	0.0
Crustacea										
Cladocera[3]	96.1	90.8	52.6	32.8	66.0	26.3	38.2	1.9	0.9	0.0
Ostracoda (*Candona tahoensis*)			2.6	0.0			0.1	0.0		--
Amphipoda (*Stygobromus* sp.)	7.1	2.2	13.2	1.0	0.7	0.1	0.3	0.0		
Crayfish (*Pacifastacus leniusculus*)					3.3	2.0	12.6	11.7	17.1	8.8
Tendipedidae	14.3	3.8	21.0	1.3	12.7	0.1	10.6	0.1	0.9	0.0
Larvae	7.1	2.6	18.1	1.3	9.3	0.1	5.8	0.0	0.9	0.0
Pupae	7.1	1.2	5.3	0.0	5.3	0.0	7.1	0.1		
Plecoptera (*Capnia* sp.)[4]			7.9	5.4			0.8	0.0	0.1	0.0
Terrestrial insects[5]					0.7	1.1	0.8	0.0		
Oligochaeta	3.6	3.2			0.7	1.1				

[1] Composed primarily of planted Lahontan cutthroat (*Salmo clarkii henshawi*) and Yellowstone cutthroat trout (*Salmo clarkii lewisi*), and planted and wild rainbow trout (*Salmo gairdnerii*), and possibly wild brown trout (*Salmo trutta*).
[2] Because of their size and the time of year they were eaten, these are most likely lake trout eggs.
[3] Primarily *Daphnia pulex*. Copepods (mostly *Epischura nevadensis*) were rare except in fish under 5.0 inches long.
[4] All were apterous stoneflies, either *C. lacustra* or *C. tahoensis*.
[5] Hymenoptera, Hemiptera, Diptera, and Coleoptera.

in Tahoe (Frantz and Cordone, 1966), but were rarely encountered in lake trout stomachs. No fish were found in stomachs of this group.

Lake Trout 5.0 to 9.9 Inches

Cladocerans and fish were the most important items in the diet of lake trout in this size group (Table 2). The only species of fish ingested was the sculpin. The highest number in any one stomach was four, with a total weight of 1.46 g. Other foods contributed much less to the diet, comprising approximately 11% of the total weight. Tendipedid larvae and pupae were present in 21% of the stomachs, but contributed only 1.3% by weight. A maximum of 66 tendipedids occurred in one trout, whereas a record 426 plecopterans occurred in another stomach. Amphipods were much more important to lake trout in this size range than to those in other size categories. The number of amphipods per stomach ranged from 2 to 195. Ostracods and fish eggs were insignificant.

Lake Trout 10.0 to 14.9 Inches

Fish and cladocerans remained the major food types within this group (Table 2). One 13.8-inch lake trout had ingested over 3,500 cladocerans with a weight of 2.8 g. A greater variety of food types was found in these lake trout, particularly the different species of fishes.

Sculpins far exceeded other species of fishes in the diet of lake trout in this group. Single stomachs contained as many as nine sculpins. Lake trout and suckers were utilized to a moderate degree, while chubs, redsides, and whitefish were of lesser importance. Tendipedid larvae and pupae were found in 12.7% of the stomachs, but contributed little to the overall weight. Crayfish appeared for the first time in the stomachs of these fish and occurred as frequently as lake trout. Fish eggs, amphipods, oligochaetes, and terrestrial insects were taken only occasionally.

Lake Trout 15.0 to 19.9 Inches

The consumption of fish overshadowed all other food items of lake trout in this size range (Table 2). Cladocerans, which were very important in the smaller size groups, occurred frequently in stomachs of trout in this group, but contributed little to the weight of stomach contents. Sculpins were the most important food in this group. Large numbers were occasionally present, with one stomach containing 40 sculpins. The average number in stomachs containing them, however, was 2.9.

Other fish species were also important, with suckers and chubs comprising a large proportion of the stomach contents. The number of suckers or chubs found in any one stomach did not exceed four. Whitefish were fourth in importance and trout, other than lake trout, were next. Most of the trout were planted rainbow and cutthroat trout. Lake trout, kokanee, redsides, and dace were only a minor component of the diet.

Crayfish were the third most important food. Forage items of minor consequence were fish eggs and invertebrates other than cladocerans and crayfish.

Lake Trout Over 19.9 Inches

Lake trout in this size group relied almost entirely on fish for their sustenance (Table 2). Suckers comprised the greatest proportion of the food items. The greatest number of suckers found in any one stomach was six.

Sculpins were second in frequency of occurrence but represented a minor proportion of stomach contents by weight. In several instances, however, large numbers were eaten by individual trout: one 23.7-inch trout had consumed 31 sculpins. The average number of sculpins per stomach was 2.9.

All fish species, except dace and redsides, were important in the diet of these large lake trout. Whitefish, chubs, and kokanee salmon contributed significantly to the diet of trout in this size group. Lake trout were eaten occasionally, with nine stomachs each containing one fish.

Trout, other than lake trout, were important also. These consisted of planted and wild rainbow, Lahontan cutthroat, Yellowstone cutthroat, and unidentified *Salmo* which may have included brown trout. Virtually all trout stocked in the lake were marked and when digestion was only moderate such fish could be identified (Cordone and Frantz, 1968). Lake trout appeared to feed heavily on these planted trout. Gill nets were not generally set close to the area where trout were stocked, except for one set in June 1962 off Tahoe City in 40 ft of water two days after a release of Lahontan cutthroat. Stomachs of 8 lake trout that were caught contained 74 cutthroat. In another area, close to where Yellowstone cutthroat were released, three stomachs of angler-caught lake trout each contained from four to nine cutthroat. Crayfish were the only invertebrate of consequence to appear in the diet of the largest lake trout. They were the third most important food, occurring in 17.1% of the stomachs. Fish eggs occurred infrequently.

Seasonal Variation

The percentage of lake trout stomachs with food was highest in spring and summer and lowest in winter and autumn (Table 1). Similarly, the mean weight of food per stomach for all size groups was generally highest in spring and summer and lowest in winter and autumn.

Because of few samples, the two smallest lake trout size groups were combined for the seasonal food habits analysis (Table 3). Lake trout under 10.0 inches utilized sculpins most avidly in the spring. Cladocerans were important during all seasons but particularly in winter, and to a lesser degree in summer. Amphipods and stoneflies were significant only in summer. Tendipedid larvae were consumed primarily in spring and to some extent in winter. Their pupae were most common in summer.

Sculpins also were most important for 10.0- to 14.9-inch lake trout in the spring months (Table 4). The greatest variety of fish was eaten in autumn, with spring second. Cladocerans were an important component of the diet during all four seasons, but especially in winter and summer. Crayfish were found in less than 6% of the stomachs from spring through autumn. Tendipedid larvae were consumed throughout the four seasons but most frequently in winter and summer. Their pupae were most common in summer and somewhat less common in

TABLE 3

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Trout Under 10.0 Inches, by Seasons

Season	Winter		Spring		Summer		Autumn	
Number of stomachs with food	16		16		17		17	
Items	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Piute sculpin	6.2	58.7	31.2	61.1	5.9	37.7	11.8	50.5
Fish eggs	--	--	--	--	--	--	5.9	2.4
Crustacea								
Cladocera[1]	93.7	34.8	56.2	38.0	70.6	21.1	64.7	16.5
Ostracoda		--	6.2	0.0			--	--
Amphipoda	6.2	0.3	--	--	23.5	17.2	11.8	0.5
Tendipedidae	12.5	5.4	37.5	0.9	17.6	0.3	5.9	0.1
Larvae	12.5	5.4	37.5	0.8	5.9	0.1	--	--
Pupae	--	--	6.2	0.0	11.8	0.2	5.9	0.1
Plecoptera			--	--	17.6	23.1	--	--
Oligochaeta	6.2	0.8	--	--	--	--	--	--
Mean weight (g) per stomach	0.2		0.6		0.3		0.2	

[1] Includes copepods.

TABLE 4

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Trout 10.0 to 14.9 Inches, by Seasons

Season	Winter		Spring		Summer		Autumn	
Number of stomachs with food	11		53		35		51	
Items	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Fish (total)	27.3	52.3	54.7	70.0	37.1	34.2	39.2	65.7
Piute sculpin	18.2	48.8	43.4	53.6	25.7	21.1	21.6	35.5
Tahoe sucker	--	--	--	--	--	--	7.8	19.0
Tui chub	--	--	1.9	2.4	2.9	9.9	2.0	0.3
Lahontan redside	9.1	3.1	3.8	2.4	--	--	--	--
Lake trout	--	--	5.7	11.6	--	--	3.9	4.1
Mountain whitefish	--	--	--	--	--	--	2.0	6.2
Unidentified fish	9.1	0.3	3.8	0.0	8.6	3.1	5.9	0.6
Fish eggs	--	--	--	--	--	--	5.9	14.4
Crustacea								
Cladocera	81.8	46.7	56.6	24.1	74.3	54.4	66.7	17.8
Amphipoda	--	--	--	--	2.9	0.8	--	--
Crayfish	--	--	5.7	2.6	2.9	0.4	2.0	2.1
Tendipedidae	27.3	0.9	13.2	0.1	22.9	0.5	2.0	0.0
Larvae	27.3	0.9	7.5	0.0	17.1	0.4	2.0	0.0
Pupae	--	--	7.5	0.0	11.4	0.2	--	--
Terrestrial insects	--	--	1.9	3.1	--	--	--	--
Oligochaeta	--	--	--	--	2.9	9.6	--	--
Mean weight (g) per stomach	0.8		1.6		0.6		1.4	

spring. Other invertebrates were taken seasonally: amphipods and oligochaetes in summer and terrestrial insects in spring.

Most species of fishes encountered in the stomachs of 15.0- to 19.9-inch lake trout were present each season (Table 5). Spring continued to be the period when sculpins contributed the most, occurring in 53.6% of the stomachs. Whitefish were equally important in winter and autumn, occurring in about 10.8%. The number of stomachs containing suckers increased from winter to autumn, whereas by weight the percentage was greatest in winter and summer. Chubs occurred in the diet most frequently in spring and autumn.

TABLE 5

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Tahoe Lake Trout 15.0 to 19.9 Inches, by Seasons

Season	Winter		Spring		Summer		Autumn	
Number of stomachs with food	83		237		136		203	
Items	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Fish (total)	63.9	90.2	73.8	91.3	58.8	76.4	59.6	81.3
Piute sculpin	32.5	14.3	53.6	35.4	41.2	17.9	21.2	10.3
Tahoe sucker	3.6	24.9	5.1	14.0	6.6	23.0	11.3	17.6
Tui chub	8.4	16.6	10.5	9.4	6.6	12.0	11.8	22.1
Lahontan redside	2.4	0.1	2.5	3.7	1.5	0.6	2.0	1.5
Lahontan speckled dace	--	--	0.8	0.0	--	--	--	--
Lake trout	2.4	1.1	2.1	2.0	2.2	2.3	1.0	1.6
Other trout	1.2	0.0	2.9	15.9	3.7	11.4	1.0	0.4
Kokanee salmon	3.6	7.2	2.5	3.6	0.7	0.3	1.0	3.8
Mountain whitefish	10.8	24.2	3.4	6.0	2.2	8.2	10.8	22.2
Unidentified fish	12.0	1.6	9.3	1.3	7.3	0.7	12.3	1.7
Fish eggs	--	--	--	--	--	--	3.4	5.2
Crustacea								
Cladocera	47.0	2.0	34.2	2.2	10.4	1.6	37.9	1.7
Ostracoda	--	--	--	--	0.7	0.0	--	--
Amphipoda	--	--	--	--	0.7	0.0	0.5	0.0
Crayfish	7.2	7.5	9.7	6.1	21.3	21.8	12.3	11.7
Tendipedidae	12.0	0.3	13.5	0.2	16.2	0.1	3.0	0.0
Larvae	12.0	0.3	3.4	0.0	10.3	0.1	3.0	0.0
Pupae	1.2	0.0	11.4	0.2	13.2	0.1	0.5	0.0
Plecoptera	4.8	0.0	--	--	0.7	0.0	--	--
Terrestrial insects	--	--	1.3	0.1	0.7	0.0	0.5	0.0
Mean weight (g) per stomach	**3.7**		**5.9**		**6.6**		**5.1**	

Cladocerans occurred in 34 to 47% of the stomachs during all seasons, but constituted only about 2% of the stomach contents by weight. Occurrence of crayfish increased from a low of 7.2% in winter and 9.7% in spring to a substantial 21.3% in summer, followed by a decrease to 12.3% during autumn. Tendipedids contributed little weight to the lake trout diet; however, larvae were taken frequently in winter and summer, and pupae in spring and summer. Other organisms were of minor importance, with ostracods occasionally taken in summer, amphipods in summer and autumn, stoneflies in winter and summer, and terrestrial insects from spring through autumn.

Seasonal food habits of lake trout over 19.9 inches consisted primarily of fish, with crayfish of secondary importance (Table 6). Suckers

TABLE 6

Percentage Frequency of Occurrence and Percentage of Total Weight of Food in Stomachs of Lake Tahoe Lake Trout Over 19.9 Inches, by Seasons

Season	Winter		Spring		Summer		Autumn	
Number of stomachs with food	26		79		40		77	
Items	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Fish (total)	96.1	96.7	93.7	96.9	85.0	80.3	87.0	87.6
Piute sculpin	34.6	5.9	44.3	8.4	22.5	1.0	11.7	0.6
Tahoe sucker	38.5	59.8	32.9	38.0	12.5	65.9	24.7	38.4
Tui chub	11.5	2.4	8.9	7.7	12.5	6.5	19.5	6.9
Lahontan redside			3.8	0.5				-
Lake trout	3.8	0.6	7.6	2.1	2.5	0.8	1.3	0.2
Other trout	7.7	0.6	13.9	33.7			1.3	0.4
Kokanee salmon	11.5	15.7	7.6	3.7	7.5	5.2	6.5	4.8
Mountain whitefish	23.1	10.8	5.1	2.4			18.2	35.5
Unidentified fish	23.1	0.7	5.1	0.4	17.5	0.8	20.8	0.8
Fish eggs	-					-	3.9	0.0
Crustacea								
Cladocera	--		1.3	0.0			2.6	0.0
Crayfish	11.5	3.3	15.2	3.1	30.0	19.8	11.3	12.3
Tendipedidae larvae	--	--	--		5.0	0.0		--
Plecoptera	3.8	0.0	--		-		-	--
Mean weight (g) per stomach		**14.9**		**48.5**		**37.1**		**27.4**

were the most common food item in all seasons except spring, when more sculpins appeared. The weight of suckers, however, clearly exceeded that of any other species in all seasons. Occurrence of suckers was highest in summer and lowest in autumn. Sculpins occurred most frequently in spring and winter, and less frequently in summer and autumn. Whitefish were important in winter and autumn, but were unimportant in spring and absent in summer. The percentage of stomachs with chubs was highest in autumn. Kokanee salmon were found in 11.5% of the stomachs in winter, and gradually decreased from spring through autumn. Lake trout and "other" trout were more prevalent in lake trout stomachs during spring. The occurrence of "other" trout during this period is largely due to predation on planted Lahontan and Yellowstone cutthroat in May and June of 1962. Spring was the only period when a few stomachs contained redsides. As in the diet of smaller lake trout, fish eggs occurred only in a few stomachs and only in autumn. Because of their size and their appearance in autumn only, it seems likely that these were lake trout eggs. Whitefish eggs are much smaller, and beach spawning of kokanee salmon was extremely limited when the study was made.

Consumption of crayfish during the summer was second to that of suckers. Other invertebrates were unimportant.

Size of Fish Eaten

As anticipated, the larger lake trout consumed larger prey (Table 7). Suckers and whitefish 9 to 11 inches long were not uncommon in the stomachs of 20- to 25-inch lake trout. Although not part of this study, a 34-inch (19.2 lb) lake trout caught in 1961 contained a 16.5-inch lake trout. Corlett and Wood (1958) describe a 36-inch lake trout which had eaten three fish, one of which was at least 19 inches long. The smallest lake trout with fish was a 5.2-inch specimen which had eaten a 1.3-inch sculpin.

TABLE 7

Mean and Maximum Lengths of Fish and Crayfish Ingested by Lake Tahoe Lake Trout, by Size Groups

Size group (inches FL)	5.0-9.9			10.0-14.9			15.0-19.9			Over 19.9		
Item	No.	Mean length	Max. length	No.	Mean length	Max. length	No.	Mean length	Max. length	No.	Mean length	Max. length
Piute sculpin	9	1.9	2.3	57	1.9	3.1	154	2.0	4.2	116	2.4	4.1
Tahoe sucker	--	--	--	4	3.1	3.8	27	4.4	7.8	38	6.4	11.5
Tui chub	--	--	--	2	1.9	2.9	38	3.5	5.8	15	4.3	9.5
Lahontan redside	--	--	--	--	--	--	8	3.1	3.8	2	3.4	3.4
Lake trout	--	--	--	5	2.8	3.0	7	4.3	6.4	4	5.0	7.5
Other trout	--	--	--	--	--	--	13	5.0	6.0	15	4.8	7.1
Kokanee salmon	--	--	--	--	--	--	3	3.9	4.5	6	5.6	7.3
Mountain whitefish	--	--	--	1	3.7	3.7	23	4.7	7.1	9	8.6	11.9
Crayfish		--	--	2	1.6	1.8	44	2.3	4.2	46	2.9	4.3

DISCUSSION

Comparisons with Previous Tahoe Studies

The two previous studies on food of lake trout in Tahoe by Miller (1951) and Corlett and Wood (1958) were compared with the present study. Miller obtained 191 stomachs from May through September in 1948 and 1949. They were taken from fish 9 to 32 inches FL, but most were from fish over 15 inches. During their study from 1954 through 1958, Corlett and Wood collected 386 stomachs from lake trout ranging from 14 to 36 inches FL. Of these, 255 contained food and the contents were evaluated only by percentage frequency of occurrence. For comparative purposes, results of these two studies were compared with food habits of lake trout over 14.9 inches from the present study.

In all studies, fish were by far the most significant food, with the sculpin the most common of the fishes (Table 8). Miller lists the chub as the second most common food and the sucker as the third in frequency of occurrence. The occurrence of bottom food was fourth. Miller stated, "Among the bottom foods the only form of note is the crayfish. . . .". Those of lesser importance and in decreasing order were redsides, plankton, surface food, whitefish, and lake trout. Miller found that the suckers contributed the greatest percentage by volume, followed closely by chubs and sculpins.

TABLE 8

Comparisons of Lake Tahoe Food Habit Studies for Lake Trout

	Present study 1962–64		Corlett and Wood (1958) 1954–58	Miller (1951) 1948–49	
Size (inches FL)	15 to 33		14 to 36	9 to 32	
	Frequency (%)	Weight (%)	Frequency (%)	Frequency (%)	Volume[1] (%)
Fish (total)	71.4	89.1	89.9	80.8	95.7
Piute sculpin	35.7	10.3	45.5	50.2	23.9
Tahoe sucker	13.5	36.1	4.7	14.0	33.6
Tui chub	10.8	9.3	3.9	23.2[2]	23.8[2]
Lahontan redside	1.9	0.8	11.9	4.9	2.6
Lahontan speckled dace	0.2	0.0	--		--
Lake trout	2.4	1.4	--	0.7	0.7
Rainbow trout	--	--	1.2	--	--
Other trout	3.3	14.2	--	--	--
Trout, unidentified	--	--	2.7	--	--
Kokanee salmon	3.3	4.3	1.6	--	--
Mountain whitefish	7.5	11.8	3.1	1.4	1.7
Unidentified fish	11.3	0.8	46.3	19.6	2.7
Fish eggs	1.1	0.5	0.8	--	--
Cladocera	28.8	0.6	--	--	--
Ostracoda	0.1	0.0	--	--	--
Amphipoda	0.2	0.0	--	--	--
Plankton	--	--	5.9	2.8	0.1
Crayfish	13.7	9.7	5.5	--	--
Bottom food	--	--	--	18.9	3.07
Tendipedidae					
Larvae	4.5	0.0	1.2	--	--
Pupae	5.3	0.0	--	--	--
Plecoptera	0.7	0.0	--	--	--
Aquatic insects	--	--	0.8	--	--
Terrestrial insects	0.6	0.0	--	--	--
Surface food	--	--	--	2.1	0.0

[1] Volume was measured in cc and was generally comparable with weight.
[2] Miller lists two subspecies: *G.b. obesus* (included here) and *G.b. pectinifer*, which had 9.8% by frequency of occurrence and 6.5% by volume.

Corlett and Wood found that redsides were the second most important food item in frequency of occurrence, followed by plankton, crayfish, suckers, chubs, whitefish, trout, kokanee salmon, and midge larvae, in that order. Fish eggs, assumed to be lake trout eggs, and aquatic insects were of minor importance.

The present study indicates that cladocera are the second major food in frequency of occurrence but unimportant by percentage weight. Crayfish, suckers, and chubs ranked third, fourth, and fifth in occurrence and the whitefish ranked sixth. Other food items of decreasing importance in occurrence were immature tendipedids, trout, kokanee salmon, redsides, and fish eggs. In percentage weight, suckers were first by a large margin, followed by trout, whitefish, sculpins, crayfish, chubs, and kokanee salmon.

Several obvious differences exist among the three studies, but it was not possible to determine the reasons for them. Sampling may be involved, since the two earlier studies were restricted in sample size, seasonal representation, and the area and depth from which lake trout were collected. Certain differences in methods of stomach analysis may also be involved. It is also possible, however, that annual variations in prey abundance and availability were responsible.

Need for Additional Forage Supply

The literature suggests that lake trout are opportunistic feeders, with a strong predilection for relatively large prey organisms. In Lake Superior, young-of-the-year (1.1 to 3.7 inches TL) and age I and II (3.6 to 8.9 inches TL) lake trout subsisted almost entirely on *Mysis relicta* (Eschmeyer, 1956). For both groups, fish occurred in 9% of the stomachs and contributed about 12% by weight. A 1.5-inch lake trout contained fish larvae. Numerous other studies describe the heavy utilization by juvenile lake trout of relatively large invertebrates, such as *Mysis* and *Pontoporeia*, and of small fish as well (e.g., Larkin, 1948; Cuerrier and Schultz, 1957; Webster, Bentley, and Galligan, 1959; Rawson, 1961; Hacker, 1962; Dryer, Erkkila, and Tetzloff, 1965). Several authors have commented on the significance of such a diet. In one Wisconsin lake, in a year when *M. relicta* was especially abundant, survival of young stocked lake trout increased threefold (Threinen, 1962). Investigations at Waterton Lakes in Canada led Cuerrier and Schultz (1957) to state, "The availability of small fish for young lake trout seems to be a very important factor in the successful development of the population". Results at another Canadian water, Lake Minnewanka, indicated that a scarcity of forage fish for lake trout under 15 inches was responsible for poor growth and survival of the population (Cuerrier, 1954).

McCaig and Mullan (1960) noted a marked increase in lake trout growth rates subsequent to establishment of an abundant population of the American smelt (*Osmerus mordax*) in a Massachusetts reservoir. Perhaps the best testimony of the impact of food habits on lake trout biology came from a long-term study of a series of Canadian lakes in Algonquin Park (Martin, 1966). In lakes where lake trout depended heavily on plankton for summer food, they grew more slowly, did not attain as great a size or age, and matured at a smaller size and younger age in comparison with lake trout in lakes where fish are an abundant summer forage. Annual yield in numbers was higher in planktonivorous than piscivorous populations, but yield in pounds was comparable. We interpreted the Lake Tahoe lake trout population, at least that segment under 15 inches, as more planktonivorous than piscivorous.

During the summer months, most Lake Tahoe lake trout are found in the hypolimnion close to the bottom, whereas most of the potential forage fishes are found in the littoral portion of the epilimnion (Lake Tahoe Fisheries Study, unpubl. data). A number of other workers have described similar distribution patterns (e.g., Martin, 1952; Cuerrier, 1954). However, at Lake Tahoe considerable overlap exists, since in summer a few lake trout are taken in shallow water. Also, sculpins are abundant at 200 ft and common at 400 ft.

The summer distribution data, the predominance of plankton in the diet of fish under 15 inches, and the relatively slow growth rate of Lake Tahoe lake trout (Hanson and Cordone, 1967) indicated a need to augment the summer supply of forage organisms in the deep, cold waters occupied by the lake trout. This led to the introduction of the opossum shrimp, *Mysis relicta*, and the Bonneville cisco, *Prosopium gemmiferum* (Frantz and Cordone, 1965; Linn and Frantz, 1965). The shrimp is now established in Lake Tahoe, but its utilization by lake trout has not yet been measured. The status of the cisco is unknown.

CONCLUSIONS

The diet of lake trout in Lake Tahoe shows several obvious patterns that vary with size of fish and time of year. As trout increase in length they change from an invertebrate to a fish diet. Cladocerans dominate the intake of lake trout under 5.0 inches, and remain significant until trout attain a length of about 15 inches. Other invertebrates, such as immature tendipedids and amphipods, tend to be fairly important in the diet of small trout but also decline substantially in importance when the fish reach a length of about 15 inches. The crayfish is the one exception to this trend. It is significant in the diet of lake trout under 15 inches and is of moderate importance in the diet of larger fish.

Fish are not found in the stomachs of lake trout under 5.0 inches. They become a progressively significant component in the diet of larger trout. Fish between 5.0 and 9.9 inches consume Piute sculpins only, and these remain the most prevalent fish in lake trout stomachs until the trout attain a length of about 20 inches. After this, more Tahoe suckers than sculpins are eaten and, because they are much larger, suckers make up an even greater portion of the total weight consumed. A wider variety of fishes is taken by lake trout over 15 inches, with tui chubs and mountain whitefish assuming prominent roles also.

Lake trout feed more avidly on fish during the spring months than during any other time of year. Not only are there fewer empty stomachs in spring, but the actual weight consumed is generally higher at this time of the year. The fewest fish in lake trout stomachs occur in summer. The percentage contribution of sculpins by both frequency and weight is highest during spring for all sizes of lake trout. Because of the dominance of sculpins in the diet of lake trout, the values for all fish combined generally show the same spring peak. However, other species of fishes do not follow the same pattern as the sculpin. Mountain whitefish are much more prevalent in lake trout stomachs in autumn and winter. Since whitefish spawn in November and December, this may be a function of greater availability, related to their pre- and post-spawning behavior. Suckers and chubs occur most frequently in summer and autumn, kokanee salmon in winter, and lake trout and redsides in spring and winter. Definite trends are observed for the major invertebrates in the lake trout diet. Cladocerans are most common in stomachs of 10- to 20-inch fish in winter, followed by summer, autumn, and finally spring. Crayfish contribute most in the summer to lake trout over 15 inches.

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FOOD HABITS OF THE WESTERN GRAY SQUIRREL[1]

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Fungi were the staple food item of 310 western gray squirrels *(Sciurus griseus)* collected in Trinity, Tehama, and Monterey Counties, California. Hypogeous (subterranean) fungi were the most important, with the orders Gasteromycetes and Tuberales occurring in the diet every month of the year. In Trinity and Tehama Counties, pine nuts and acorns also were important items, eaten mainly in the summer and fall. In Monterey County, fruit of the California bay *(Umbellularia californica)* was second in importance. Forb leafage and stems, utilized principally in the spring, made up most of the green vegetation eaten.

Although hypogeous fungi are the staple food, acorn and pine mast may be the more critical. These high-energy foods prepare the squirrels for overwintering.

Supplemental data are included from a collection of 59 gray squirrels from four counties on the western slope of the central Sierra and 31 from Humboldt County in northwestern California.

INTRODUCTION

The western gray squirrel ranges widely in California, occurring principally in the oak and conifer-oak forests of the Upper Sonoran and Transition life zones. It is absent from the dense coastal redwood forests, most of the low valley areas, the higher mountains, the typical sagelands of the Great Basin, and the southeastern deserts.

Considerable work on the life history and management of the eastern gray squirrel (*Sciurus carolinensis*) has been published. However, little information about the western species in California is available and virtually nothing has been written about its food habits.

A food habits study is a basic step toward game management. The present study was designed to form the basis for further investigation of the life history of the western gray squirrel and to generate ideas about its management.

The main collections of gray squirrel stomachs were made in Trinity and Tehama Counties, in the northwestern and north central parts of the State, respectively, and in Monterey County, along the Pacific Coast south of Monterey. Supplemental collections were made in the central Sierra and in Humboldt County (Figure 1).

DESCRIPTION OF AREAS

Trinity Collection Area

Trinity County is situated in the southern part of the Klamath Mountains, a rugged, though not particularly high, region west of the Cascade Range and east of the Coast Ranges. The Klamath Mountains

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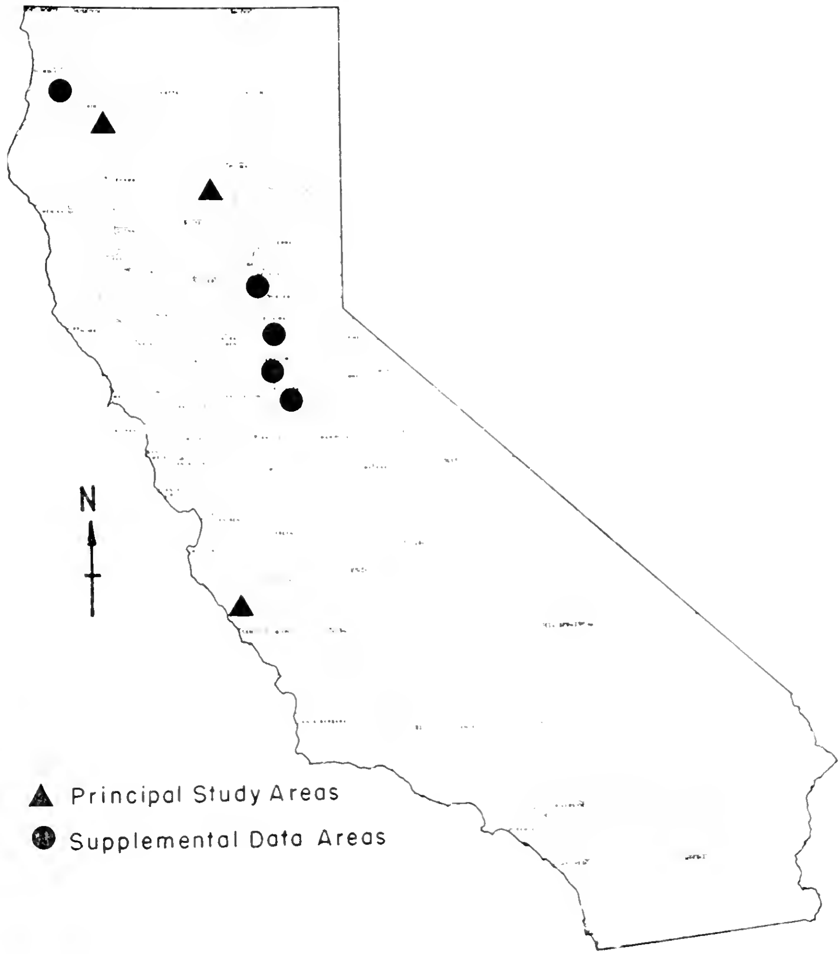

FIGURE 1—Location map, showing gray squirrel collecting areas. Drawing by Cliffa Corson.

extend into western Siskiyou and western Shasta Counties, part of Del Norte County, and southwestern Oregon.

Yellow pine (*Pinus ponderosa*)—Douglas fir (*Pseudotsuga menziesii*) forests form the dominant vegetation of the Klamath Mountains. These forests are interspersed with chaparral, oak-hardwood, some coastal forests of Douglas fir and coast redwood (*Sequoia sempervirens*), and woodland-grass and grassland areas. Broadleaf maple (*Acer macrophyllum*), hazelnut (*Corylus cornuta*), and dogwood (*Cornus* sp.) grow on the north-facing slopes and in the moist canyons, and willows (*Salix* spp.), California bay, and wild berries (*Rubus* spp.) are found along the canyon bottoms.

The area is within the influence of moisture-laden winds which sweep eastward from the Pacific Ocean. The annual rainfall generally varies from 25 to 50 inches, with 8 to 10 inches falling from April through September and providing water for many permanent streams. Temperatures range from below freezing to over 100 F, with 80 F the more common summer maximum.

There were five collecting areas in the county. Sampling represented a wide variety of habitats and choice of food. Elevations ranged from 1,800 to 2,800 ft. The habitat ranged from canyon bottoms to ridge tops. The vegetation varied from thick conifer forests to oak stands to more open woodland-grass areas.

Tehama Collection Area

The part of the Tehama Winter Deer Range in which the squirrels were collected lies in the western Sierra foothills in Tehama County, at elevations from approximately 800 to 3,500 ft. The area is of volcanic origin, having been created by a series of lava mud flows from activity in the Mt. Lassen region to the northeast. Watercourses have cut steep-sided canyons, with prominent rim rocks and lava outcroppings, through the once continuous volcanic breccia.

The squirrels were collected in the upper margin of the winter deer range, where thickets of California black oak (*Q. kelloggii*) and Brewer oak (*Q. breweri*) occur, and stands of yellow pine grow on the ridges. Western chokecherry (*Prunus demissa*), creek dogwood (*Cornus californica*), willow, alder (*Alnus* sp.), and California wild grape (*Vitis californica*) grow along the watercourses.

The climate is characteristic of much of the central Sierra foothills region of California. Generally, winter temperatures are mild and summer temperatures high. Normally the winters are rainy, while the summers are virtually rainless. Snow occurs occasionally at the lower elevations but usually melts off rapidly, while at the higher elevations it may remain longer. The rainy season is sometimes accompanied by fog, which can last for a considerable time.

Monterey Collection Area

The study area is in southern Monterey County, in the Santa Lucia Range, a unit of the Coast Ranges. The area is almost 6 square miles in extent and is situated about 3 miles from the coast, in Los Padres National Forest. Elevations range from 1,600 to 2,800 ft on Plaskett Ridge and up to 3,000 ft on Prewitt Ridge.

The area consists of approximately 80% forest and 20% grass and chaparral vegetation types. Conifers consist of yellow pine, Coulter pine (*Pinus coulteri*), and coast redwood. Broadleaf trees include interior live oak (*Quercus wislizenii*) on the higher and drier sites and canyon live oak (*Q. chrysolepis*) and tanbark oak (*Lithocarpus densiflora*) in draws and canyon bottoms. California bay and madrone (*Arbutus menziesii*) are scattered throughout the area. The remaining trees consist of broadleaf maple, red alder (*Alnus oregona*), valley oak (*Q. lobata*), and coast live oak (*Q. agrifolia*). Two species of wild lilac (*Ceanothus* spp.), coffeeberry (*Rhamnus californica*), silk tassel (*Garrya fremontii*), chamise (*Adenostoma fasciculatum*), poison oak (*Rhus diversiloba*), and manzanita (*Arctostaphylos* sp.) are the common shrubs.

Temperatures are tempered by summer fogs. Precipitation varies from about 16 to 30 inches per year, with approximately 80% of the rain (and occasional snow at the higher elevations) falling from December to March.

METHODS

In the major study, 310 western gray squirrels were collected by shooting over a 5-year period, from June 1963 to December 1968. Counties represented and animals collected in each were Trinity, 112; Tehama, 117; and Monterey, 81. A supplemental collection of 58 squirrels was made in four central Sierra counties and another 31 were taken in Humboldt County.

Part of the contents of each stomach was washed in a fine sieve, to ease identification of individual items. The remainder was used to make gross precentage estimates. Most items were identified with a dissecting microscope with 10x oculars and 0.7x to 3x objectives. Fungus spores and cell structures of acorns and pine and bay nuts were identified with a compound microscope with 10x oculars and 10x and 43x objectives. Spore and peridium characters were used to identify different fungi. Nut and acorn fragments were identified by cell structure, texture, starch reaction to iodine, and the presence of shell and pericarp fragments.

The quantity of each food item was determined by visual estimate. The volumes were converted to percentages, which were then summarized by the aggregate percentage method (Martin, Gensch, and Brown, 1946). The frequency of occurrence of each item was tallied.

RESULTS

Hypogeous fungi, pine nuts, acorns, fruit of the California bay, and green leafage (mostly forbs) were the major foods eaten. These five foods supplied 96% of the diet in the three main study areas (Tables 1, 2, 3). Supplemental data from the central Sierra counties (El Dorado, Amador, Calaveras, and Nevada) and Humboldt County revealed no other major food items.

Fungi

In the three major study areas hypogeous fungi were the staple food, utilized throughout the year (Tables 1, 2, 3). Peak utilization occurred in June in Trinity County (86%) and Tehama County (82%), and in May in Monterey County (74%). Seasonal consumption of fungi varied least in Trinity County (56 to 60%), more in Tehama County (39 to 73%), and most in Monterey County (14 to 58%).

Rhizopogon was the most important genus of fungi eaten. It appeared in the stomachs every month of the year. *Rhizopogon* belongs to the Class Basidiomycetes, whose spores are borne on small basidia, and to the Order Gasteromycetes. This genus is one of the largest and most diverse groups of the hypogeous fungi, with 137 recognized species in North America (Smith and Zeller, 1966).

Some of the rhizopogons are relatively firm textured, but a number become distinctly gelatinous at maturity. Many squirrel stomachs contained this gelatinous form.

The majority of the squirrels were collected in conifer stands or conifer-oak associations. Most species of *Rhizopogon* in the western states are associated with conifers (Smith and Zeller, 1966).

TABLE 1

Food Habits of 112 Western Gray Squirrels
Trinity County
1963, 1964, 1965

	(5) Jan.		(4) Feb.		(14) Mar.		(10) April		(7) May		(18) June		(17) July		(16) Aug.		6 Sept.		5 Oct.		5 Nov.		Dec.		Total	
	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F
Fungi (hypogeus)	53.0	5	61.3	4	61.5	13	38.0	8	26.1	6	85.6	17	67.9	17	19.7	15	11.6	5	50.0	4	62.0	5	55.0	5	58.2	104
Pine nuts (*Pinus* spp.)	5.0	1	27.5	3	11.4	4	18.5	3	33.6	5	2.2	2	20.3	9	16.6	11	16.7	4	tr	1	10.0	1	20.0	1	20.3	45
Acorns (*Quercus* spp.)	12.0	3	3.7	1	25.0	6	38.0	6	31.3	5	11.1	4			3.1	1	6.7	1	16.0	4	28.0	2	20.0	1	17.5	34
Green vegetation	*tr	1	7.5	1	tr	4	5.5	4	5.7	1	0.1	4	5.9	3	0.6	2	5.0	1	3.0	1					2.5	25
Unidentified fruit fragments													1.4	1											0.7	1
Mistletoe (*Phoradendron villosum*)					2.1	1																			0.3	1
Unidentified nut fragments													1.5	1											0.2	1
Needle fragments (*Pseudotsuga menziesii*)											tr	1											5.0	1	0.2	2
California bay fruit (*Umbellularia californica*)											0.8	1													0.1	1
Insect larvae	tr	1			tr	3	tr	2	tr	2	0.2	3	tr	2											tr	13
Woody fragments	tr	1			tr	2					tr	2	tr	1	tr	1									tr	7
Club moss (Lycopodineae)											tr	1			tr	1									tr	5
Oak leaf fragments (*Quercus* sp.)											tr	1							tr	1					tr	2
Needle fragments (*Pinus* sp.)	tr	1			tr	1																			tr	2
Unidentified material													tr	2											tr	2
Unidentified pod fragments																			1.0	1					tr	1
Thistle leaf and spine fragments (*Cirsium* sp.)															tr	1									tr	1
Pollen, catkin fragments (*Pinus* spp.)											tr	1													tr	1

* tr = trace, less than 0.1%.

TABLE 2

Food Habits of 117 Western Gray Squirrels
Tehama County
1963, 1964, 1965

	(5) Jan.		(5) Feb.		(17) Mar.		(14) April		(10) May		(1[illegible]) June		(14) July		(10) Aug.		(14) Sept		(5) Oct.		(7) Nov.		(3) Dec.		(117) Totals	
	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F
Fungi (hypogeous)	27.0	3	30.0	4	11.5	17	62.3	14	75.7	10	81.6	12	71.3	13	48.5	8	63.2	11	60.0	4	32.1	1	66.7	2	58.8	105
Pine nuts (*Pinus* spp.)	40.0	2	16.0	3	23.2	11	13.4	6	2.2	4	5.0	4	13.9	3	12.0	8	27.5	10	40.0	3	17.2	6	33.3	1	22.1	61
Acorns (*Quercus* spp.)	25.0	4	37.0	4	25.0	13	18.9	6	6.0	4	6.9	5	0.4	1			tr	1			20.7	5			11.1	43
Green vegetation	8.0	2	3.0	2	3.8	6	5.4	6	7.5	6	tr	2	11.4	2	0.5	3	2.1	5			tr	2	tr	1	1.0	37
Unidentified nut fragments									8.5	1							1.8	1							0.9	2
Bark, woody fragments			tr	1	0.8	5	tr	1	tr	1	tr	2	tr	1	1.5	2	1.8	1							0.7	16
Unidentified fruit fragments											6.5	1													0.7	1
Fungi (epigeous)	tr	1	11.0	1	0.3	1																			0.6	3
Insect larvae, eggs	tr	1			2.1	5	tr	3	0.1	2					0.5	2	tr	1	tr	2					0.4	16
California bay fruit (*Umbellularia californica*)																	3.6	1							0.4	1
Unidentified matter															2.5	1									0.2	1
Needle fragments (*Pinus* spp.)					tr	1			tr	1	tr	1	tr	2	1.0	2									0.1	7
Fescue seeds (*Festuca* spp.)															tr	1									tr	1
Oat seeds (*Avena* spp.)					tr	1																			tr	1
Squaw carpet dry leafage (*Ceanothus prostratus*)															0.5	1									tr	1
Mistletoe (*Phoradendron villosum*)					tr	1																			tr	1
Club moss (Lycopodineae)																	tr	1							tr	1
Needle fragments (*Abies* spp.)							tr	1																	tr	1

TABLE 3

Food Habits of 81 Western Gray Squirrels
Monterey County
1965, 1966, 1968

	(5) Jan.		(5) Feb.		(5) Mar.		(5) April		(12) May		(10) June		(5) July		(5) Aug.		(5) Sept.		(5) Oct.		Nov. [illegible]		Dec. [illegible]		[illegible]	
	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F
Fungi (hypogeous)	26.0	1	36.0	3	13.0	1	29.0	1	71.2	12	53.1	10	28.0	3	57.8	1	39.1	3	21.0	3	20.0	1	2.2	1	67.5	55
California bay fruit (*Umbellularia californica*)	61.0	1	19.0	3	13.0	4	49.0	5	6.7	1	26.5	6	9.0	1					58.0	3	49.1	9	79.5	8	15.8	17
Unidentified vegetative material									5.4	1	9.0	2	28.0	1	28.0	2	60.0	3					11.1	1	10.3	13
Acorns (*Quercus* spp.)									1.7	6	9.5	2	2.0	2	13.2	3	0.6	2	20.0	1	10.0	1			1.9	17
Fungi (epigeous)					13.0	1	11.0	1	tr	1	tr	1									10.5	2	7.2	2	3.8	8
Pine nuts (*Pinus* spp.)			15.0	2					2.5	5	1.0	1	33.0	3	1.0	2			tr	1					3.5	14
Green vegetation	13.0	2	tr	1	1.0	2	5.0	2	tr	1	0.6	2			tr	1			1.0	3	10.1	3			2.5	17
Insect fragments			tr	1					6.6	5	tr	1	tr	1					tr	1					1.0	12
Forb leafage (*Cirsium* spp.)									2.5	1															0.1	1
Pollen grains (*Pinus* spp.)							3.0	2																	0.2	2
Insect larvae			tr	1	tr	1	tr	1	0.1	5			tr	1							tr	1	tr	1	0.1	11
Bark fragments, grit	tr	1													tr	1			tr	1	tr	1			tr	1
Rootlet fragments									tr	1	tr	1													tr	2
Club moss (Lycopodineae)											tr	1													tr	1
Conifer needle fragments									tr	1															tr	1
Dry grass (Gramineae)									tr	1															tr	1
Unidentified seed													tr	1											tr	1

Other Basidiomycetes fungi identified in the stomachs were *Gautiera*, *Hysterangium*, and probably *Melanogaster*.

Another important group of hypogeous fungi used by squirrels belong to the Class Ascomycetes, Order Tuberales. Members of this class bear spores in asci, or sacs, rather than on basidia. These fungi are also eaten every month of the year.

The epigeous (above-ground) mushrooms, including the gill mushrooms, occurred in the diet, but composed less than 1% of the yearly food in each of the three counties. The highest monthly utilization was 14% both in February in Tehama County and April in Monterey County. No consumption in Trinity County was recorded.

The identification and assignment of materials from the stomachs to the major groups of fungi can be done with certainty when both spores and associated structures are present. When spores alone are present (this happened in a few cases), there is possibility of misidentification.

Pine Nuts

Pine nuts were a significant food item, but the amount eaten fluctuated more than in the case of fungi. In Trinity County, pine nuts comprised 20% of the yearly total, with the peak (47%) occurring in both August and September. In Tehama County, pine nuts comprised 22% of the yearly food. The peak months were November (47%), August (42%), and October and January (40%). In the Monterey County study area, pine nuts formed only 4% of the year's food. Consumption reached a high of 33% in July.

In the two northern counties, some of the pine nut fragments were from digger pine (*Pinus sabiniana*). The large seeds eaten in Monterey County were from Coulter pine. These fragments could be identified by the relatively large pericarp tip. Other such tips were found and probably came from yellow pine and sugar pine (*P. lambertiana*).

Acorns

Acorns are another important food. In both Trinity and Tehama Counties, acorns were significant during a large part of the year. In Trinity County, the seasonal range was from 2% in summer (July–September) to 31% in fall (October–December). In Tehama County, acorn use peaked in February (37%) and comprised 11% of the yearly total. In Monterey County, acorns were less important, with highest consumption in October and a yearly total of 8%.

California Bay

In Monterey County, the second most important food was the fruit of the California bay, with a yearly utilization of 36%. On a seasonal basis, bay use varied from 3% during the summer to 63% during the fall. Fowells (1965) stated that seed crops of the California bay are abundant in most years and that gray squirrels feed on them extensively. Because the California bay produces abundant seed crops almost every year, its fruit is an important food item, even though the tree does not make up a large portion of the forest in the Monterey County study area.

In Tehama and Trinity Counties, only a small amount of bay fruit was eaten. Although the bay grows in these counties, it is not usually associated with the conifer-oak habitat from which the squirrels were collected.

Green Vegetation

Gray squirrels ate some green vegetation throughout the year. On a yearly basis, vegetation comprised less than 5% of the food eaten in the three major study areas. Highest use in Monterey County occurred in January (13%). In Tehama County it was highest in July (11%) and in Trinity County highest in February (about 8%).

Supplemental Data

Fifty-eight gray squirrels were collected from April to December 1968 from several areas on the west slope of the central Sierra, in El Dorado, Nevada, Calaveras, and Amador Counties. The three principal food items, hypogeous fungi, pine nuts, and acorns, were the same in order of importance as in the main study areas (Table 4). Hypogeous fungi made up 50% of the yearly food consumed, pine nuts 19%, and acorns 10%. Animal matter comprised under 4%, green vegetation 3%, and California bay less than 2%.

Another collection of 31 specimens was made in Humboldt County during May, June, July, September, and October 1968. Again there are similarities in the food consumption pattern (Table 5). Peak fungus use occurred in June (71%) and May (67%). However, fungus use dropped to 8% and 9% in September and October, respectively. The average fungus use over the 5-month period was 37%. Pine nuts were the most important item in Humboldt County (48%). The high use of pine seeds extended over a longer period of time. There was a marked rise from 1% in June to 57% in July, 74% in September, and 85% in October. Acorns comprised about 6% of the total diet, and 14% of the food in September.

Other Foods

Other items eaten by western gray squirrels, but always in small or trace amounts, were pine and fir needles, fragments of oak, *Ceanothus* and thistle leafage, pine pollen grains, fescue (*Festuca* spp.) seeds, and club moss fragments (Lycopodineae). Animal foods, consisting of fragments of insect adults and larvae, occurred mostly in trace amounts. The latter were probably obtained when the squirrels were eating fungi. Ants (Formicidae) were the insects most frequently eaten.

Ingles (1947), conducting a study in a park-like area of Sacramento Valley, listed the following foods which he had observed gray squirrels eating:

Valley oak	*Quercus lobata* (acorns, catkins)
California black oak	*Quercus kelloggii* (acorns)
California black walnut	*Juglans hindsii* (nuts)
Pecan	*Carya pecan* (nuts)
Almond	*Amygdalus communis* (nuts)
Yellow pine	*Pinus ponderosa* (nuts)
Jeffrey pine	*Pinus ponderosa jeffreyi* (nuts)
Digger pine	*Pinus sabiniana* (nuts)
Monterey cypress	*Cupressus macrocarpa* (nuts)
Red mulberry	*Morus rubra* (berries)
Silver maple	*Acer saccharinum* (samaras)
American elm	*Ulmus americana* (samaras)
Mistletoe	*Phoradendron flavescens* (berries)

TABLE 4

Food Habits of 58 Western Gray Squirrels
Central Sierra
(Amador, Nevada, Calaveras, El Dorado Counties)
1965, 1966, 1968

	(9) Apr., May		(6) June		(5) July		(17) Aug.		(8) Sept.		(6) Oct.		(7) Nov., Dec.		(58) Totals	
	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F
Fungi (hypogeous)	28.9	7	41.1	5	47.2	5	60.5	16	41.5	6	25.7	5	86.5	7	50.0	51
Pine nuts (*Pinus* spp.)	0.1	1	20.0	3	28.1	1	28.8	13	22.2	2	30.8	3	tr	1	19.2	27
Acorns (*Quercus* spp.)	18.2	2	4.2	1	24.0	1	7.6	5	[illegible]	[illegible]	15.8	3			9.8	18
Walnut fragments (*Juglans* spp.)	11.1	1					0.6	1	[illegible]	1	12.5	1			4.1	4
Insect larvae	20.5	6	tr	2	tr	[illegible]	tr	4	tr	[illegible]			2.9	6	3.5	21
Green vegetation	6.2	6	9.2	1			2.5	1	tr	2	tr	2	3.5	2	3.1	20
Fungi (epigeous)			7.5	2					15.4	2					2.9	4
Unidentified fruit	13.3	2							[illegible]	2			3.6	2	2.6	6
California bay fruit (*Umbellularia californica*)			11.2	1											1.5	1
Thistle seeds (*Cirsium* spp.)											[illegible]	1			1.1	1
Poison oak seeds (*Rhus diversiloba*)									[illegible]	2	0.2	1			0.9	3
Bark, woody and dirt fragments	1.7	[illegible]			tr	1	tr	2	tr	4			2.1	5	0.5	14
Grass leafage and seed (Gramineae)			0.8	1	0.1	2	tr	[illegible]			tr	1	1.1	1	0.3	6
Thistle leafage (*Cirsium* spp.)									tr	1	1.7	1			0.2	2
Needle fragments (*Pinus* spp.)			tr	1	tr	2	tr	[illegible]	tr	1			tr	1	tr	6
Hair (*Sciurus*)							tr	2			tr	1			tr	3
Ant fragments (Formicidae)	tr	1											tr	1	tr	2
Incense cedar leafage (*Libocedrus decurrens*)							tr	1	tr	1					tr	2
Barley seeds (*Hordeum* spp.)	tr	1													tr	1
Manzanita fruit (*Arctostaphylos* spp.)							tr	1							tr	1
Club moss (Lycopodineae)							tr	1							tr	1
Ditch grass seeds (*Ruppia maritima*)									tr	1					tr	1
Pollen grain (*Pinus* spp.)									tr	1					tr	1
Feather fragments									tr	1					tr	1
Unidentified material													tr	1	tr	1

TABLE 5

Food Habits of 31 Western Gray Squirrels
Humboldt County
1968

	(5) May		(7) June		(6) July		(9) Sept.		(4) Oct.		(31) Total	
	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F
Pine nuts (*Pinus* spp.)	27.0	2	0.7	1	56.6	5	73.9	8	85.0	4	48.1	20
Fungi (hypogeous)	66.6	4	70.7	7	36.2	6	8.2	6	8.8	2	37.2	25
Unidentified matter	6.0	1	20.0	3							5.5	4
Acorns (*Quercus* spp.)	0.1	2					11.0	3	6.2	2	4.9	7
Fungi (epigeous)			8.6	2							1.9	2
Unidentified nuts					5.8	1	1.1	1			1.4	2
Horsetail stem (*Equisetum* spp.)							1.7	1			0.5	1
Thistle leafage (*Cirsium* spp.)							1.1	1			0.3	1
Insect fragments	tr	1			0.7	1					0.1	2
Insect larvae	tr	1			0.7	1	tr	1			0.1	3
Rootlets	tr	1			tr	2	tr	1			tr	4
Hair (*Sciurus*)							tr	3	tr	1	tr	4
Green vegetation					tr	1	tr	1			tr	2
Club moss (Lycopodineae)							tr	2			tr	2

Miner's lettuce ______________________________ *Montia perfoliata* (leaves)
Common chickweed ________________________ *Stellaria media* (flower buds)
Aphis, causing leaf roll in Oregon ash bone ________________ *Fraxinus oregona*

DEPREDATION

The western gray squirrel is known to do damage to nut crops in northern California, especially in orchards planted in cleared areas within the natural habitat. Walnuts (*Juglans* spp.) seem to be hit the hardest by the squirrels and reports of damage have come from Napa, Sonoma, Tuolumne, Lake, Glenn, Butte, and Trinity Counties. Almonds (*Prunus amygdalus*) and filberts (*Corylus* spp.) are also eaten by the gray squirrel.

Cambium fibers were not found in stomachs examined in this study, although there are reports from both southern and northern California that gray squirrels occasionally girdle the top branches of conifer trees.

DISCUSSION

Utilization of fungi is not restricted to the western gray squirrel. It may be that all sciurids inhabiting western coniferous forests are dependent upon hypogeous fungi. McKeever (1964) reported that 56% of the food of 207 Douglas squirrels (*Tamiasciurus douglasi*), collected over a year in the Susanville area of Lassen County, consisted of subterranean fungi. Tevis (1952, 1953) has documented fungi as an important food of chipmunks (*Eutamias* spp.), golden-mantled ground squirrels (*Citellus lateralis*), flying squirrels (*Glaucomys sabrinus*), and Beechey ground squirrels (*Spermophilus beecheyi*). Kaibab squirrels (*Sciurus kaibabensis*) (Hall, 1967) and Abert squirrels (*S. aberti*) (Keith, 1965) rely heavily upon hypogeous fungi during certain seasons of the year.

Even though fungi are the staple food during much of the year, little is known about their nutritional value. The literature gives the impression that the food value of terrestrial mushrooms is rather low. With respect to the hypogeous fungi, however, Singer (1961) states, "The nutritional value of truffles is higher [than of mushrooms]. Their water content is lower than that of mushrooms. They are high in proteinic substances, salts, and phosphorus." Although the role of hypogeous fungi in the diet of the gray squirrel is not well understood, it appears that the common subterranean fungi play an important part in its ecology.

Mast probably is the critical gray squirrel food. Pine nuts are eaten extensively during the summer and fall periods, starting when the pine nuts reach the milk stage. Pine seeds are very high in oil and moderately high in carbohydrates, making them a nutritious food which starts the process of laying on body fat in preparation for overwintering.

During the fall and winter months, acorns provide the squirrels with a good source of carbohydrates to help condition them to survive the rigors of the winter and the breeding season.

Another mast producer along the Pacific Coast is the California bay and the squirrels in Monterey County eat much of its fruit. Very little is known about the food value of bay.

The influence of food on the annual populations of squirrels is recognized. Allen (1943) stressed the close relationship between populations and food supplies. Christensen and Korschgen (1955), studying the annual mast survey data in Missouri, state that "there is an indication of a direct relationship of the annual squirrel harvest to the abundance of the acorn crop". It is probable that mast crops are a key factor governing California gray squirrel populations as well.

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A DESCRIPTION OF THE NORTHERN ANCHOVY LIVE BAIT FISHERY, AND THE AGE AND LENGTH COMPOSITION OF THE CATCH DURING THE SEASONS 1957–58 THROUGH 1964–65[1]

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California's live bait fishery began in 1910, when Japanese albacore fishermen used small forage fish to increase their catch. The fishery is now a rather complicated industry exploiting several different techniques to catch, transport, and hold small marine fish alive until they are sold to sport or commercial fishermen.

Voluntary catch records and sampling are used to determine the size of the landings and age composition of the catch for each port of landing. Throughout all seasons reported, there is little variation in the total poundage of northern anchovies (*Engraulis mordax*) landed for live bait use. Fish of age group I were dominant in most samples taken, closely followed by age group II. One exceptionally large year class, 1959, was noted in the southern California fishery in conjunction with above average sea-surface temperatures.

INTRODUCTION

The anchovy live bait industry includes the harvest, maintenance, and sale of small, live, marine fish to anglers for use as bait and or chum. Live bait fishing was introduced to southern California in 1910 by Japanese albacore fishermen, who used small forage fish in their fishing operations.

To catch these forage fish, they employed a blanket net and chummed over the net to attract the bait fish. When the bait school was over the net, the net was raised and the fish captured (Young, 1949; Radovich and Gibbs, 1954).

Boats carrying sportsmen to the offshore fishing grounds began using lampara nets for capturing bait in 1912. This kind of net, a special type of round-haul net, is in use today. As the sport fishing industry grew, the demand for live bait also increased, causing a greater degree of specialization in boats and nets, and in the methods of locating and distributing the live bait. Shortly after World War II, the demands for live bait became sufficient to support a fleet engaged solely to supply bait. This fishery is important today because the most prized sport fishes usually prefer live bait to any other offering.

The live bait fishery is located principally in southern California, with smaller fisheries at Morro Bay, Monterey, and San Francisco (Figure 1). During the 1963–64 season, over 20 vessels were engaged in the California fishery. During the 1964–65 season, 13 bait vessels operated in the San Pedro area.

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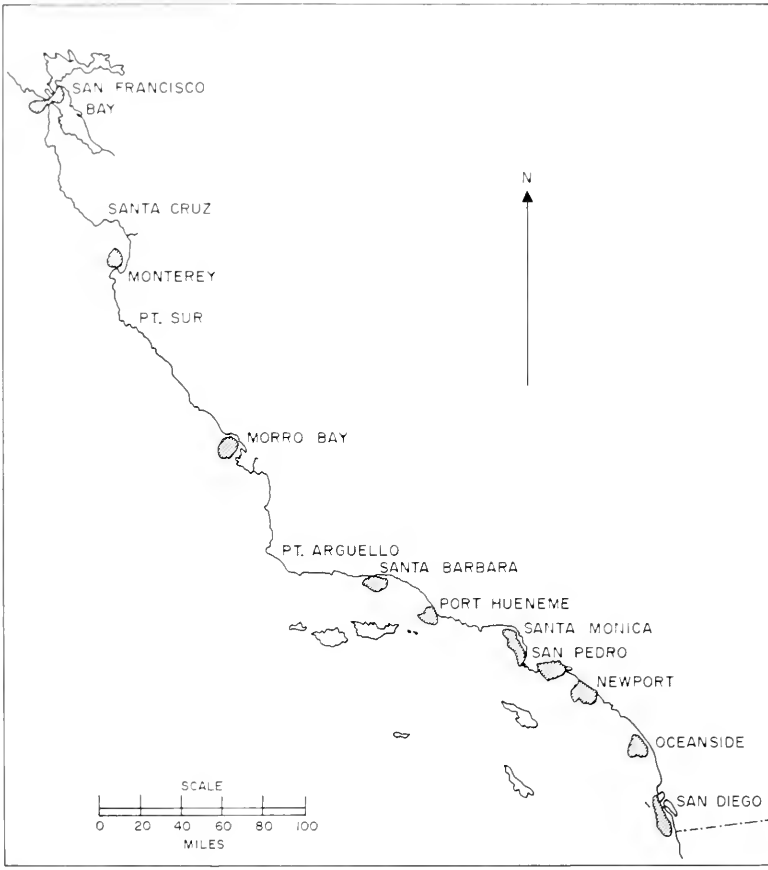

FIGURE 1—California northern anchovy live bait catch areas, 1957–65. The shaded areas indicate locations where the fish were actually caught.

The mainstay of the industry is the northern anchovy, which comprises about 98% of the total live bait sold. Pacific sardine, *Sardinops caeruleus*, white croaker, *Genyonemus lineatus*, queenfish, *Seriphus politus*, Pacific mackerel, *Scomber japonicus*, jack mackerel, *Trachurus symmetricus*, Pacific herring, *Clupea pallasii*, and squid, *Loligo opalescens*, comprise the remaining 2%. In the San Francisco area, Pacific herring ranks second to the northern anchovy in importance.

The principal methods of locating bait fish are: (i) flashing light or paper recording fathometer, (ii) observation of birds feeding on the surface of the water, (iii) observation of color of a fish school in the water, (iv) nighttime phosphorescent glow or "fireball", and (v) use of lights on small skiffs or fishing boats to attract fish at night.

The "fireball" method is used only at night when luminescense caused by the action of the schooling fish can be seen. Using this method, the fishermen are attracted to the bait fish by a "light." In a reverse situation, bait fish may be attracted or brought to the fishermen by a light. In the Los Angeles-Long Beach Harbor area, "light plants" consisting of a small skiff with a gasoline-powered electric generator providing electricity to light bulbs ranging from 500 to 1,000 watts are used to attract and hold schools of fish so they can be netted (Young, 1950).

After locating a school, an experienced skipper can often determine the species by noting the characteristic "color" or shadow in the water from the schooling fish below the surface. The amount and size of air bubbles released by the fish also are a clue to the size of fish and species.

A lampara net costs from $1,600 to $6,000, depending on size and type of material. It is usually constructed entirely of nylon; however, some nets have cotton wings. Mesh sizes vary from 6 to 8 inches in the wings to ½ inch in the "bag" or "sack", stretch mesh. The net usually has a depth range of 20 to 30 fathoms and a cork-line length of 120 to 240 fathoms.

When making a set, a marker buoy (lighted at night) attached to one end of the net is thrown into the water, pulling the net off the moving vessel. When the vessel has circled the school of fish, the crew picks up the marker buoy, both ends of the net are placed on a mechanical net puller, and the net wings are brought aboard and stacked on deck until the first part of the bag appears. Then the fishermen pull the bottom of the net aboard, trapping the fish in a section of the bag which remains in the water. Live bait is now ready for sale or transfer to various holding facilities (Turner, 1958).

Bait may be transferred from the lampara net to a 200- to 1,000-scoop bait tank aboard a hauler in 4- to 20-lb scoops, or in wet brailers with capacities of 35 to 40 scoops. Since 1959, an average weight of 12.5 lb per scoop has been used by the Department to calculate catch tonnages.

Bait also may be transferred directly from the lampara net to a carrier vessel by "swimming" it through an opening in the boat's side. With this method, all but a few inches of water is removed from the carrier's bait tank by discharging it into ballast tanks. The cork line on the bait net is pushed down and a sideboard on the carrier is pulled up. This manipulation causes both water and fish to flow quickly or "swim" into the carrier's bait tanks. A bait operator in San Diego is the only one using this specialized "swimming" method.

Bait is transferred from either the hauler's or the carrier's bait tank to sport fishing boats, private boats, piers, commercial fishing boats, other bait carriers, or live bait receivers. Transfers are usually made with a hand scoop; however, a few bait boats use a wooden trough to sluice the bait into receivers. This sluicing process is called "rolling" bait. A crowder is used to direct the fish into the flume. The receiver is a submerged box made of wooden slats or nylon net strung on a suitable frame. The top is covered with a screen to keep sea gulls and seals from stealing the bait.

AGE AND LENGTH COMPOSITION

This report on the age and length composition of the northern anchovy in the live bait fishery off the coast of California for the 1957–58 through 1964–65 seasons is a continuation of data published on the commercial catch for the 1952–53 and 1953–54 seasons (Miller et al., 1955); and for the commercial and live bait catch for the 1954–55 through 1956–57 seasons (Miller and Wolf, 1958). The data are presented as seasonal summaries for each of nine ports where catches were sampled. The methods of sampling and age determination are essentially those described by Miller and Wolf.

There is no law requiring that fish sold as "live bait" be reported to the Department and fishermen report their catches voluntarily. Approximately 75% of the live bait operators cooperate by submitting monthly logs with a daily record of the area fished, number of hauls completed, and the number of scoops of bait sold. Some fail to do so through oversight or lack of time, while a few simply refuse to release the requested catch information. Frequently those few do not understand why this information is wanted. An explanation of the live bait study and need for this catch information generally clears up any misunderstanding. The reported seasonal catch varied little in total poundage throughout the period covered by this report.

We have used only those port months for which both samples and landing data are available in computing age composition (Table 1). We have not attempted to estimate missing catch information; therefore, the poundages and numbers of fish reported are minimal.

Boat operators who release all unsold bait at the end of the work day report that portion of their catch which they have marketed as "scoops sold". How much of the released bait gets back into the fishery is not known, but at times the amount released is considerable. Live bait operators who store their bait in receivers until it is sold report their landings as "scoops caught". This bait is held alive until picked up by the sport fishermen. Some of the fish used on sport boats "escape" either off the sportsman's hook, when used as chum, or when released from the boat's bait tank at the end of the fishing day. We have observed these releases many times and believe that few fish survive.

Our estimates of age and length composition of the catch are based on random samples of 50 fish each. The samples were obtained from bait dealers' nets, bait tanks, and shoreside receivers. Each anchovy was measured to the nearest even mm SL. Scale samples were taken from a male and female in each cm group when possible. The smallest and largest cm groups in which anchovies were measured were 72–80 and 142–150 mm, respectively. The age composition equation used to obtain the numbers of fish landed at each port is discussed fully by Messersmith and Hyatt (1965).

With few exceptions, fish of age group I were dominant, closely followed by age group II. These two groups usually comprised more than 75% of the landings (Tables 2 through 9)[3]. No fish older than 5 years was found; the oldest anchovy ever recorded was 7 years (Roedel, 1953).

An exceptional season occurred in 1959–60, when there was a very large influx of small fish-of-the-year into the southern California bait fishery. At San Pedro, 86.7% of all fish sampled were of age group 0 (Table 6). This 1959 year class was very strong and provided a very large proportion of the catch in subsequent years. Even in 1964–65, when these fish were 5 years old, they were still being landed at a majority of ports.

[3] Raw data for the age-length composition by season and port are recorded in Marine Resources Operations Reference No. 69-3.

TABLE 1

Summary of Reported Landings and Age Composition Sampling by Port and Season, 1957–58 Through 1964–65

Season	Months: Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Reported landings sampled (1,000 lb)	Reported landings (1,000 lb)
Morro Bay														
1957–58													a	a
1958–59	S	S	–	–	S	S	S	S	S	–	S	–	122.6	122.6
1959–60	S	S	S	S	S	S	S	–	–	–	–	–	84.9	84.9
1960–63													a	a
1963–64	–	S	L	S	S	S	S	L	L	S	L	L	314.8	450.6
1964–65	–	S	L	L		L	–		–	–	–		47.5	225.4
Santa Barbara														
1957–58	S	S	S	S	S	S	–					–	147.8	147.8
1958–59	–		S	S	S	S	S	S	L	L	–	–	122.0	129.8
1959–60	S	S	S	S	S	L	–	–	–	–	–		81.5	89.0
1960–61	S	S	L	S	L	L	L			–			79.9	162.4
1961–64													a	a
1964–65	L	L	L	S	S	S	L	S	L	–		–	37.9	65.8
Port Hueneme														
1957–58	L	S	S	S	S	L	S	L	L	–	–		25.0	30.6
1958–59	S	S	S	S	–	–		–	–	–	–	L	134.0	136.4
1959–61														
1961–62	–	L	S	S	–	S	–	S		S		S	212.5	220.5
1962–63	S	S	S	S	S	L	S	L	L	L		L	578.5	776.1
1963–64	L	S	S	S	S	S	L	L	L	S	S	S	497.8	600.8
1964–65	S	S	S	S	S	L	L	S	L	S	S	S	514.6	701.4
Santa Monica														
1957–58	S	S	S	S	S	S	S	–	–	–	–	S	702.7	702.7
1958–59	S	S	S	S	S	S	S	–	–	–		S	881.5	881.5
1959–60	S	S	S	S	–	–	–	–		–	–	–	391.0	391.0
1960–61													a	a
1961–62	–	S	S	S	S	S	S	S	S	–		L	672.1	705.0
1962–63	L	S	S	S	S	S		L	L	L	L	S	663.8	845.8
1963–64	S	S	S	S	S	S	S	S	S			–	605.8	605.8
1964–65		S	S	S	S	L	S	S	L	–		–	636.4	824.1
San Pedro														
1957–58	S	S	S	S	S	S	L	L	L	L	L	S	3,751.7	4,664.3
1958–59	S	S	S	S	S	S	S	S	S	S	S	S	4,950.8	4,950.8
1959–60	S	S	S	S	S	S	S	S	S	S	S	S	5,074.8	5,074.8
1960–61	S	S	S	S	S	S	S	S	S	S	S	S	2,311.2	2,311.2
1961–62	S	S	S	S	S	S	S	S	S	L	L	S	4,275.9	4,603.4
1962–63	S	S	S	S	S	S	S	L	L	L	S	S	5,227.9	5,668.2
1963–64	S	S	S	S	S	S	L	L	–	L	S	L	2,925.1	3,271.0
1964–65	S	L	S	S	S	S	S	S	–	S	S	S	4,739.0	5,390.6
Newport Beach														
1957–58	S	S	S	S	S	S	L	L	L	–	–	L	765.3	825.4
1958–59	L	S	S	S	S	S	S	S	S	S	S	S	534.6	988.2
1959–61													a	a
1961–62	L	S	S	S	S	S	S	S	S	S	S	S	1,655.4	1,794.4
1962–63	S	S	S	S	L	S	S	–	–	–	–	S	1,100.0	1,419.6
1963–64	S	S	S	S	L	L	L	L	S	S	S	S	805.0	827.2
1964–65	S	S	S	S	L	S	S	S	–	–	–	–	850.1	864.4
Oceanside														
1957–58	–	S	S	L	S	S	S	–	–	–	–	–	221.0	318.2
1958–64													a	a
1964–65	–	–	–	–	L	S	S	L	L	–	–	–	109.2	234.4
San Diego														
1957–58	S	S	S	S	S	S	S	L	L	L	L	S	2,497.1	2,606.0
1958–59	S	S	S	S	S	S	S	L	L	L	L	L	2,291.7	2,318.6
1959–60	S	S	S	S	S	L	L	L	L	L	L	S	1,673.1	1,800.4
1960–61	S	S	S	S	S	S	L	–	L	L	L	–	1,361.3	1,463.6
1961–63													a	a
1963–64	L	L	L	S	S	S	L	L	S	S	S	S	414.9	1,121.6
1964–65	L	L	L	L	L	S	S	L	L	S	S	S	484.6	2,183.6

S = Reported landings and sample taken to estimate age and number composition.
L = Reported landings, sample not taken.
[a] No reported landings.

TABLE 2

Estimated Anchovy Landings in the Live Bait Fishery by Port and Season, 1957–58 Through 1964–65 *

Morro Bay

Season	Reported landings during sampling months (1,000 lb)	Age composition during months of sampling (Numbers of fish are given in thousands)							
		Number of annuli	0	1	2	3	4	5	Total
		Year class	1958	1957	1956	1955	1954	1953	
		Number	35	2,451	1,500	102	--	--	4,088
1958–59	122.6	Percentage	0.88	59.96	36.69	2.49	--	--	100.02
		Year class	1959	1958	1957	1956	1955	1954	
		Number	160	2,326	729	53	--	--	3,268
1959–60	81.9	Percentage	4.90	71.18	22.31	1.61	--	--	100.00
		Year class	1963	1962	1961	1960	1959	1958	
		Number	507	2,233	3,220	1,291	426	--	7,677
1963–64	314.8	Percentage	6.61	29.09	41.94	16.81	5.55	--	100.00
		Year class	1964	1963	1962	1961	1960	1959	
		Number	--	123	394	261	74	12	864
1964–65	47.5	Percentage	--	14.25	45.61	30.21	8.56	1.35	100.01

* Seasons with no reported landings are omitted.

TABLE 3

Estimated Anchovy Landings in the Live Bait Fishery by Port and Season, 1957–58 Through 1964–65 *

Santa Barbara

Season	Reported landings during sampling months (1,000 lb)	Age composition during months of sampling (Numbers of fish are given in thousands)							
		Number of annuli	0	1	2	3	4	5	Total
		Year class	1957	1956	1955	1954	1953	1952	
		Number	106	1,353	1,559	803	70	--	3,891
1957–58	147.8	Percentage	2.73	34.78	40.03	20.65	1.81	--	100.00
		Year class	1958	1957	1956	1955	1954	1953	
		Number	304	2,322	3,124	620	51	--	6,421
1958–59	122.0	Percentage	4.74	36.16	48.65	9.66	0.79	--	100.00
		Year class	1959	1958	1957	1956	1955	1954	
		Number	--	1,861	1,318	84	--	--	3,263
1959–60	81.5	Percentage	--	57.02	40.42	2.56	--	--	100.00
		Year class	1960	1959	1958	1957	1956	1955	
		Number	145	1,932	959	36	--	--	3,072
1960–61	79.9	Percentage	4.72	62.88	31.22	1.18	--	--	100.00
		Year class	1964	1963	1962	1961	1960	1959	
		Number	--	255	654	199	--	6	1,114
1964–65	37.9	Percentage	--	22.92	58.72	17.83	--	0.53	100.00

* Seasons with no reported landings are omitted.

TABLE 4

Estimated Anchovy Landings in the Live Bait Fishery by Port and Season, 1957–58 Through 1964–65 *

Port Hueneme

Season	Reported landings during sampling months (1,000 lb)	Age composition during months of sampling (Numbers of fish are given in thousands) Number of annuli	0	1	2	3	4	5	Total
		Year class	1957	1956	1955	1954	1953	1952	
		Number	11	162	219	81	8	--	481
1957–58	25.0	Percentage	2.37	33.61	45.52	16.89	1.61		100.00
		Year class	1958	1957	1956	1955	1954	1953	
		Number		3,481	885	170			4,536
1958–59	134.0	Percentage		76.74	19.50	3.76	--		100.00
		Year class	1961	1960	1959	1958	1957	1956	
		Number	754	3,330	2,369	341	60		6,854
1961–62	212.5	Percentage	11.00	48.59	34.57	4.96	0.88		100.00
		Year class	1962	1961	1960	1959	1958	1957	
		Number	1,026	10,111	4,854	1,136	403		17,530
1962–63	578.5	Percentage	5.85	57.68	27.69	6.48	2.30		100.00
		Year class	1963	1962	1961	1960	1959	1958	
		Number	1,503	6,343	3,845	1,745	326	66	13,828
1963–64	497.8	Percentage	10.87	45.87	27.80	12.62	2.36	0.48	100.00
		Year class	1964	1963	1962	1961	1960	1959	
		Number	434	6,619	5,036	1,941	573	99	14,702
1964–65	511.6	Percentage	2.95	45.02	34.25	13.20	3.90	0.67	99.99

* Seasons with no reported landings are omitted.

TABLE 5

Estimated Anchovy Landings in the Live Bait Fishery by Port and Season, 1957–58 Through 1964–65 *

Santa Monica

Season	Reported landings during sampling months (1,000 lb)	Age composition during months of sampling (Numbers of fish are given in thousands) Number of annuli	0	1	2	3	4	5	Total
		Year class	1957	1956	1955	1954	1953	1952	
		Number	101	4,797	5,363	3,521	692	165	14,639
1957–58	702.7	Percentage	0.69	32.76	36.63	24.05	4.73	1.13	99.99
		Year class	1958	1957	1956	1955	1954	1953	
		Number	4,822	41,007	21,985	--	--	--	67,814
1958–59	881.5	Percentage	7.11	60.46	32.42	--	--	--	99.99
		Year class	1959	1958	1957	1956	1955	1954	
		Number	16,179	10,006	1,820	132	--	--	28,137
1959–60	394.0	Percentage	57.50	35.56	6.47	0.47	--	--	100.00
		Year class	1961	1960	1959	1958	1957	1956	
		Number	3,791	13,849	12,574	1,585	221	--	32,020
1961–62	672.4	Percentage	11.84	43.25	39.26	4.95	0.69	--	99.99
		Year class	1962	1961	1960	1959	1958	1957	
		Number	2,556	17,253	6,903	741	205	--	27,658
1962–63	663.8	Percentage	9.24	62.38	24.96	2.68	0.74	--	100.00
		Year class	1963	1962	1961	1960	1959	1958	
		Number	8,847	10,108	4,332	824	119	--	24,230
1963–64	605.8	Percentage	36.51	41.72	17.89	3.40	0.49	--	100.01
		Year class	1964	1963	1962	1961	1960	1959	
		Number	5,134	22,491	7,733	--	--	--	35,358
1964–65	636.4	Percentage	14.52	63.61	21.87	--	--	--	100.00

* Seasons with no reported landings are omitted.

TABLE 6

Estimated Anchovy Landings in the Live Bait Fishery by Port and Season, 1957–58 Through 1964–65 *

San Pedro

Season	Reported landings during [illegible] months 1,000 lb	Number of anchovies	Age composition during months of sampling (Numbers of fish are given in thousands) 0	1	2	3	4	5	Total
		Year class	1957	1956	1955	1954	1953	1952	
		Number	2,401	49,997	58,439	11,905	1,838	463	125,042
1957–58	3,751.7	Percentage	1.92	39.98	46.73	9.52	1.47	0.37	99.99
		Year class	1958	1957	1956	1955	1954	1953	
		Number	29,375	161,149	73,548	7,096	881	--	275,049
1958–59	1,950.8	Percentage	10.68	59.68	26.74	2.58	0.32	--	100.00
		Year class	1959	1958	1957	1956	1955	1951	
		Number	314,242	28,782	19,103	362	--	--	362,489
1959–60	5,074.8	Percentage	86.70	7.94	5.27	0.10	--	--	100.01
		Year class	1960	1959	1958	1957	1956	1955	
		Number	27,677	42,146	39,638	6,102	--	--	115,563
1960–61	2,311.2	Percentage	23.95	36.47	34.30	5.28	--	--	100.00
		Year class	1961	1960	1959	1958	1957	1956	
		Number	17,916	102,707	73,310	19,113	748	--	213,794
1961–62	4,275.9	Percentage	8.38	48.04	34.29	8.94	0.35	--	100.00
		Year class	1962	1961	1960	1959	1958	1957	
		Number	13,401	64,233	66,394	23,229	6,726	279	174,262
1962–63	5,227.9	Percentage	7.69	36.86	38.10	13.33	3.86	0.16	100.00
		Year class	1963	1962	1961	1960	1959	1958	
		Number	5,646	48,078	29,438	3,918	1,560	--	88,640
1963–64	2,925.1	Percentage	6.37	54.24	33.20	4.42	1.76	--	99.99
		Year class	1964	1963	1962	1961	1960	1959	
		Number	58,221	73,850	46,412	15,955	1,797	1,224	197,459
1964–65	4,739.0	Percentage	29.49	37.40	23.51	8.08	0.91	0.62	100.01

* Seasons with no reported landings are omitted.

TABLE 7

Estimated Anchovy Landings in the Live Bait Fishery by Port and Season, 1957–58 Through 1964–65 *

Newport

Season	Reported landings during sampling months (1,000 lb.)	Number of annuli	Age composition during months of sampling Numbers of fish are given in thousands 0	1	2	3	4	5	Total
		Year class	1957	1956	1955	1954	1953	1952	
		Number	225	6,945	5,700	3,27[illegible]	48[illegible]	--	16,639
1957–58	765.3	Percentage	1.35	41.74	34.27	19.71	2.94		100.01
		Year class	1958	1957	1956	1955	1954	1953	
		Number		15,731	13,794	178	--	--	29,703
1958–59	531.6	Percentage		52.96	46.44	0.60			100.00
		Year class	1961	1960	1959	1958	1957	1956	
		Number	12,54[illegible]	32,5[illegible]	25,217	8,25[illegible]	197	56	78,827
1961–62	1,655.4	Percentage	15.[illegible]	41.[illegible]	32.[illegible]	10.47	0.25	0.07	100.00
		Year class	1962	1961	1960	1959	1958	1957	
		Number	[illegible],612	11,[illegible]	11,88[illegible]	[illegible]	2,491	[illegible]	[illegible],286
1962–63	1,100.0	Percentage	16.83	33.56	[illegible]	[illegible]	6.34	0.23	100.01
		Year class	1963	1962	1961	1960	1959	1958	
		Number	7,28[illegible]	1[illegible],822	8,[illegible]	[illegible]56	229		30,[illegible]57
1963–64	805.0	Percentage	23.51	44.65	28.[illegible]	2.12	0.74		[illegible]
		Year class	1964	1963	1962	1961	1960	1959	
		Number	91[illegible]	2[illegible],[illegible]65	[illegible],[illegible]65	2,128	482	[illegible]	40,482
1964–65	850.1	Percentage	2.27	66.[illegible]1	24.[illegible]	5.01	1.19	0.23	100.00

* Seasons with no reported landings are omitted.

TABLE 8

Estimated Anchovy Landings in the Live Bait Fishery by Port and Season, 1957–58 Through 1964–65 *

Oceanside

Season	Reported landings during sampling months (1,000 lb.)	Number of annuli	Age composition during months of sampling Numbers of fish are given in thousands 0	1	2	3	4	5	Total
		Year class..	1957	1956	1955	1954	1953	1952	
		Number....	316	3,074	2,752	823	164	--	7,129
1957–58	221.0	Percentage	4.43	43.12	38.60	11.55	2.30		100.00
		Year class..	1964	1963	1962	1961	1960	1959	
		Number	266	1,369	2,016	--	76	38	3,765
1964–65	109.2	Percentage	7.07	36.36	53.54	--	2.02	1.01	100.00

* Seasons with no reported landings are omitted.

TABLE 9

Estimated Anchovy Landings in the Live Bait Fishery by Port and Season, 1957–58 Through 1964–65 *

San Diego

Season	Reported landings during sampling months (1,000 lb)	Number of annuli	Age composition during months of sampling (Numbers of fish are given in thousands) 0	1	2	3	4	5	Total
		Year class	1957	1956	1955	1951	1953	1952	
		Number	521	40,210	12,575	2,020	166	--	55,492
1957–58	2,497.1	Percentage	0.94	72.46	22.66	3.61	0.30	--	100.00
		Year class	1958	1957	1956	1955	1954	1953	
		Number	20,063	76,472	7,646	--	--	--	104,181
1958–59	2,291.7	Percentage	19.26	73.41	7.34	--	--	--	100.01
		Year class	1959	1958	1957	1956	1955	1954	
		Number	--	58,337	20,811	526	--	--	79,674
1959–60	1,673.1	Percentage	--	73.22	26.12	0.66	--	--	100.00
		Year class	1960	1959	1958	1957	1956	1955	
		Number	--	33,910	21,763	1,049	--	--	56,722
1960–61	1,361.3	Percentage	--	59.79	38.37	1.85	--	--	100.01
		Year class	1963	1962	1961	1960	1959	1958	
		Number	5,112	2,622	5,292	3,051	519	--	16,596
1963–64	414.9	Percentage	30.80	15.80	31.89	18.38	3.13	--	100.00
		Year class	1964	1963	1962	1961	1960	1959	
		Number	2,948	8,622	7,144	912	--	--	19,626
1964–65	484.6	Percentage	15.02	43.93	36.40	4.65	--	--	100.00

* Seasons with no reported landings are omitted.

Water temperatures undoubtedly had much to do with this heavy proportion of small anchovies. Surface water temperatures recorded at Scripps Institution of Oceanography's pier, and at other California locations, were above normal. Some of the biological anomalies occurring during this period of warm water were reported by Radovich (1961).

It is apparent from fishermen's observations, stomach analyses of offshore fish, and our sample data, that the larger anchovies prefer colder waters, and the younger, smaller fish prefer the warmer inshore waters. Bait fishermen have stated that when the sea surface temperature exceeds 62 F schools of anchovies suitable for live bait become increasingly hard to locate. Those large anchovies which remain in the fishing areas become dispersed and do not school. Radovich (1961) states that large anchovies were found in the stomachs of tuna caught offshore over deep waters in 1959. Our samples indicate that fish caught in the bait nets north of Santa Monica Bay, where the waters are cooler, are consistently larger than those caught to the south.

SUMMARY

1. Throughout all seasons reported, there was little variation in the total poundage of anchovies landed for live bait use.
2. Fish of age group I were dominant in most samples taken, closely followed by age group II.
3. An exceptional year class, 1959, occurred in conjunction with higher than normal water temperatures in southern California.

ACKNOWLEDGMENTS

We wish to thank the many people who helped in the preparation of this paper, particularly the fishermen who have been so generous of their time and equipment, and who allowed us to obtain fish samples and gave us their catch information. There have been many sample collectors, all of whom deserve special thanks. Involved in the preparation of this report were the scale readers: John MacGregor, Makoto Kimura, and Robert Wolf of the U.S. Bureau of Commercial Fisheries, Fishery-Oceanography Center, La Jolla, and from the California Department of Fish and Game, Anita E. Daugherty (now retired), Harold Hyatt (now with the California Department of Public Health), Doyle E. Gates, and C. E. Blunt, Jr. Gertrude Cutler, Kathleen O'Rear, and June Thompson have been most helpful in preparation of the manuscript, and J. D. Messersmith gave much valuable advice on the layout and initial editing. The editorial assistance of John L. Baxter is gratefully acknowledged.

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A FIBROMA IN THE ABDOMINAL CAVITY OF A KING SALMON, *ONCORHYNCHUS TSHAWYTSCHA*[1]

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A king (chinook) salmon with a fibroma in its abdominal cavity was caught near San Francisco, California. This fibrous tumor was partially attached by mesenteries to the pyloric ceca and was composed of collagenous fibers. The growth comprised an estimated 20 to 25% of the weight of the fish. The fish appeared normal in all other respects.

INTRODUCTION

Schlumberger and Lucké (1948), Nigrelli (1953), Sindermann (1966), and van Duijn (1967) have presented reviews of tumors and tumorlike growths in fish. Nigrelli states that, with certain exceptions, knowledge concerning neoplastic growths in fishes is extremely limited. He suggests a greater effort in recognizing such abnormal conditions in fishes. With this in mind, we are reporting our observations.

The king salmon bearing the neoplastic growth reported here was caught aboard the sport fishing boat *Marion*, on or about April 13, 1969. The point of capture was off Muir Beach, approximately 5 miles northwest of San Francisco.

METHODS

The salmon was obtained by the authors frozen and partially eviscerated. The fish and tumor were thawed, measured, weighed, and photographed. Sections of the tumor were fixed in Davidson's solution (Shaw and Battle 1957, p. 326), processed using standard histological techniques, and stained with hematoxylin and eosin. Mallory's aniline blue collagen stain was used for the detection of collagen.

RESULTS

The salmon measured 61 cm TL and weighed 1,816 g dressed. The tumor weighed 499 g, an estimated 20 to 25% of the live weight of the fish. This neoplastic growth consisted of five lobes comprising three separate masses (Figure 1). The largest mass (comprising 2 lobes) was 19 cm long, with a maximum diameter of 8 cm. The smallest was 6 cm in diameter and 4 cm thick. The larger lobe of the intermediate mass (comprising 2 lobes) was 9 cm long, 7 cm thick, and 4 cm wide; the smaller lobe was 7 cm long, 4 cm thick, and 2 cm wide.

Grossly, the fibroma was very firm to the touch. The color was glistening white, with localized reddish areas which appear to rep-

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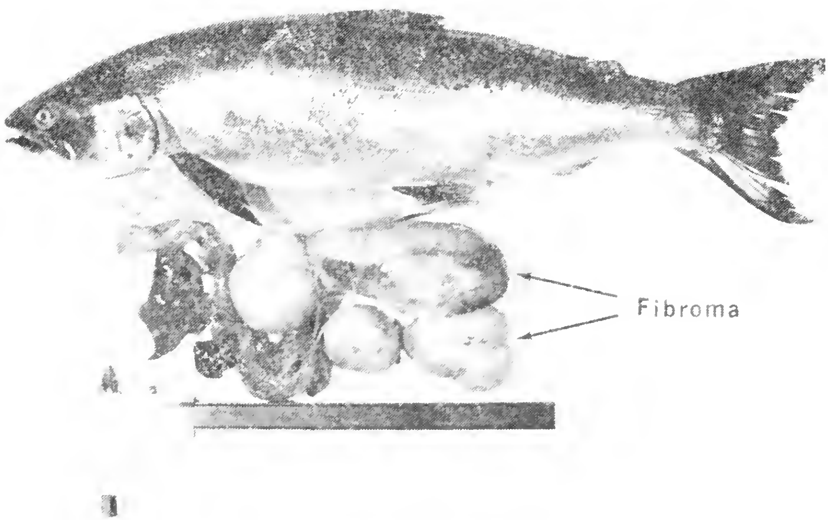

FIGURE 1—A fibroma from the abdominal cavity of a king salmon. The calipers are 25 cm.

resent areas of hemorrhage. The fibroma was partially attached by mesenteries to the pyloric ceca. Histologically, the fibroma was composed of spindle cells and bundles of collagen arranged in straight or wavy ribbons or whorls (Figures 2, 3, and 4). Small blood vessels were noted in the neoplasm and blood cells were observed in some tissue spaces. The outer covering of the fibroma was composed of densely packed collagenous fibers (Figure 5). Microscopic examination revealed no visible organisms associated with this growth.

DISCUSSION

Neoplasms are seldom reported in fish and of those seen few reach qualified observers. Fish possessing such growths are generally improperly cared for and of little value if they do reach qualified personnel. In the case of the specimen under discussion, the gills had been removed and discarded and the viscera partially removed from the body cavity before freezing, so the precise manner in which the fibroma was situated in the abdominal cavity is unknown. Verbal reports given to the authors indicate that the ventral portion of the fish was greatly distended. The loss of a portion of the viscera makes an exact determination of the proportion of the weight of the salmon comprised by the fibroma impossible.

The freezing of tissue before fixation for histological examination is not advised, since ice crystals tend to damage the tisssue at the cellular level. However, sufficient detail was evident in this fibroma for diagnosis.

Examination of this salmon revealed it to be normal in all respects except for the neoplasm. Microscopic examination of the scales indi-

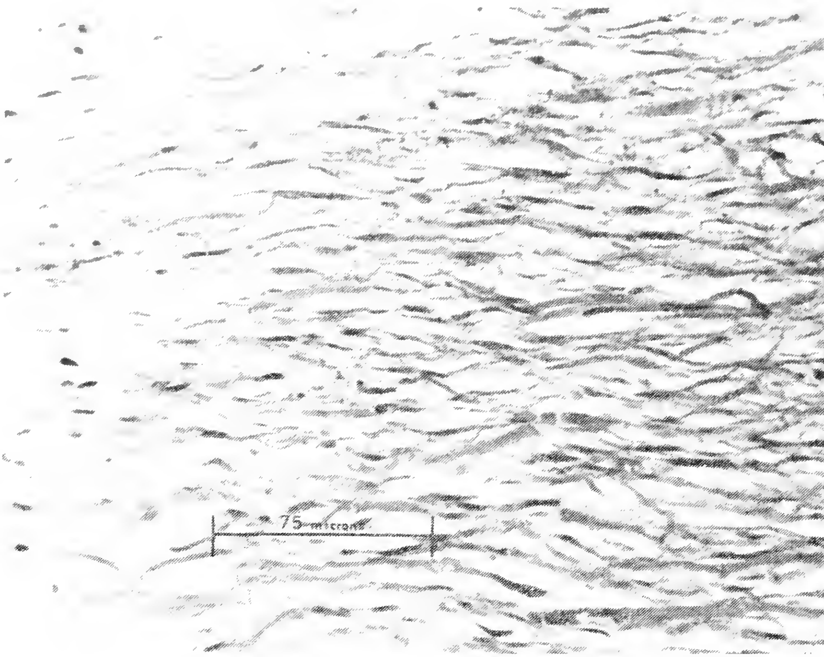

FIGURE 2—Collagenous fibers arranged in straight ribbons.

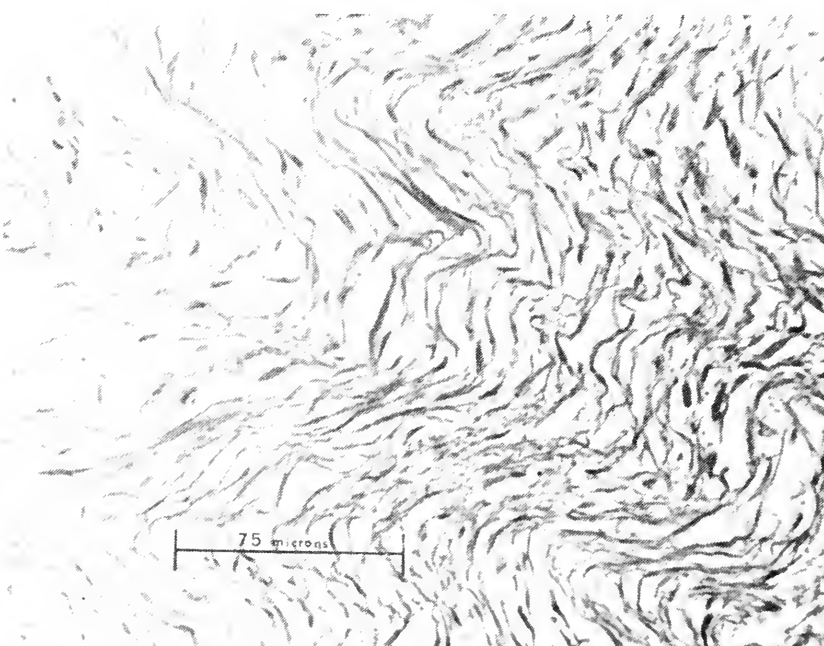

FIGURE 3—Collagenous fibers arranged in wavy ribbons.

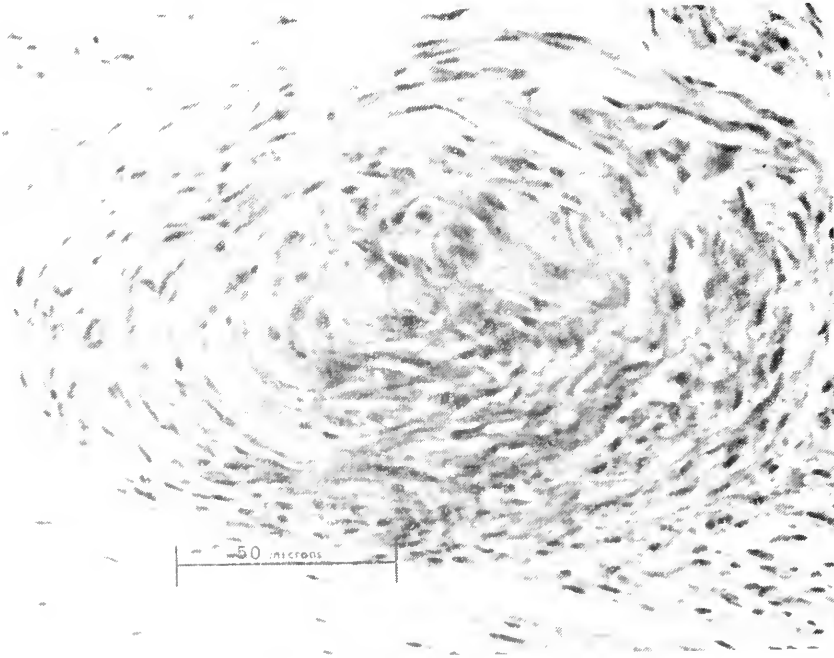

FIGURE 4—Collagenous fibers arranged in a wharl.

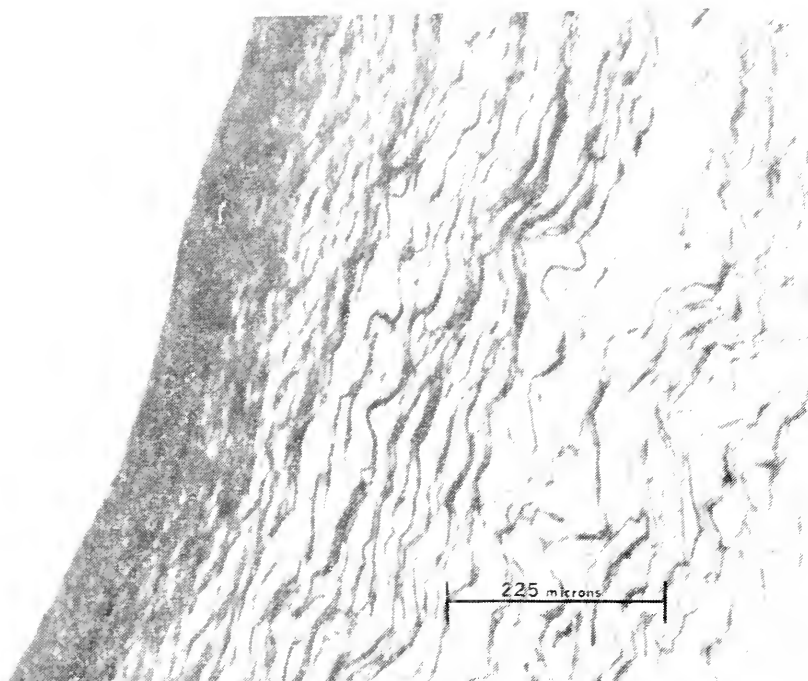

FIGURE 5—Collagenous capsule surrounding the fibroma.

cated that it had spent a year in the ocean. Since this salmon was of average size for its age, the fibroma had not adversely affected its growth to the time of capture.

The causative agent for this neoplasm is not known. Sindermann (1966) and van Duijn (1967) have indicated possible viral etiologies for neoplastic growths in fish, but we were unable to test this possibility.

We consider this neoplasm to have been benign because of its noninvasiveness. It is of interest to note the similarities of this fibroma to those described by Robbins (1962) in human pathology.

ACKNOWLEDGMENTS

The authors express their sincere appreciation to E. W. Engberg, skipper of the sport fishing boat *Marion*, for saving and reporting the specimen discussed here.

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NOTES

A PUNCH TO FACILITATE THE REMOVAL OF SALMONID OTOLITHS[1]

There are three pairs of otoliths in the inner ear of teleosts. Of these, the sagittae have been used for age determination in salmonids (McMurrich, 1910, 1913; Clutter and Whitesel, 1956; Kim and Koo, 1963; Koski, 1964; Bilton and Jenkinson, 1968; and Kim and Roberson, 1968), as well as in other fishes (Hickling, 1931; Einarsson, 1951; Fitch, 1951; Kohler, 1958; Larsen and Skud, 1960; and Watson, 1965).

The location of the sagittae beneath the cranial cavity makes them difficult to remove. Kim and Roberson (1968) collected otoliths by splitting the heads of sockeye salmon, *Oncorhynchus nerka*. Koski (1964) found this method tedious and messy, and developed an "otolith punch" for taking sagittae from sport-caught steelhead trout, *Salmo gairdnerii*, without mutilating the heads so badly. The punch was used to remove a circular plug from the skull of the fish to expose the cranial cavity. The brain was removed and the sagittae were lifted from the exposed pockets. We found Koski's punch cumbersome, and constructed the improved model described herein.

MATERIALS

The materials used to construct our improved punch were two lengths of $\frac{5}{8}$-inch (I. D.) steel conduit, two lengths of $\frac{5}{8}$-inch diameter Plexiglas rod, a 3 x $\frac{1}{2}$-inch spring, and a $2\frac{1}{2}$-inch length of $\frac{1}{8}$-inch diameter steel rod. A $2\frac{1}{2}$-inch length of conduit served as a handle, while a $4\frac{1}{2}$-inch length was used for the barrel. A 3-inch length of Plexiglas rod was used to fill out the contour of the handle, while a $2\frac{1}{2}$-inch length served as a plunger to remove tissue from the barrel. The spring activated the plunger, and the steel rod acted as a trigger.

CONSTRUCTION

The conduit, Plexiglas, and rod were cut to appropriate lengths. Ends of the shorter length of conduit, both lengths of Plexiglas, and the rod were smoothed. One end of the barrel was notched to fit closely the contour of the handle. Next, the handle was silver-soldered to the barrel. With a drill press, a series of six $\frac{3}{16}$-inch holes was bored through the barrel beginning $1\frac{1}{4}$ inches from the open end and progressing toward the handle. At the top of this series, one hole was bored to the side of the last hole. A small round file was used to connect these holes, and the slot between the holes was smoothed with a flat file. The finished slots were hook-shaped, with the openings to the hooks opposed, at the end closest to the handle (Figure 1).

To assemble, the plunger was inserted in the barrel so that one end was flush with the terminus of the barrel, then a $\frac{1}{8}$-inch hole was bored

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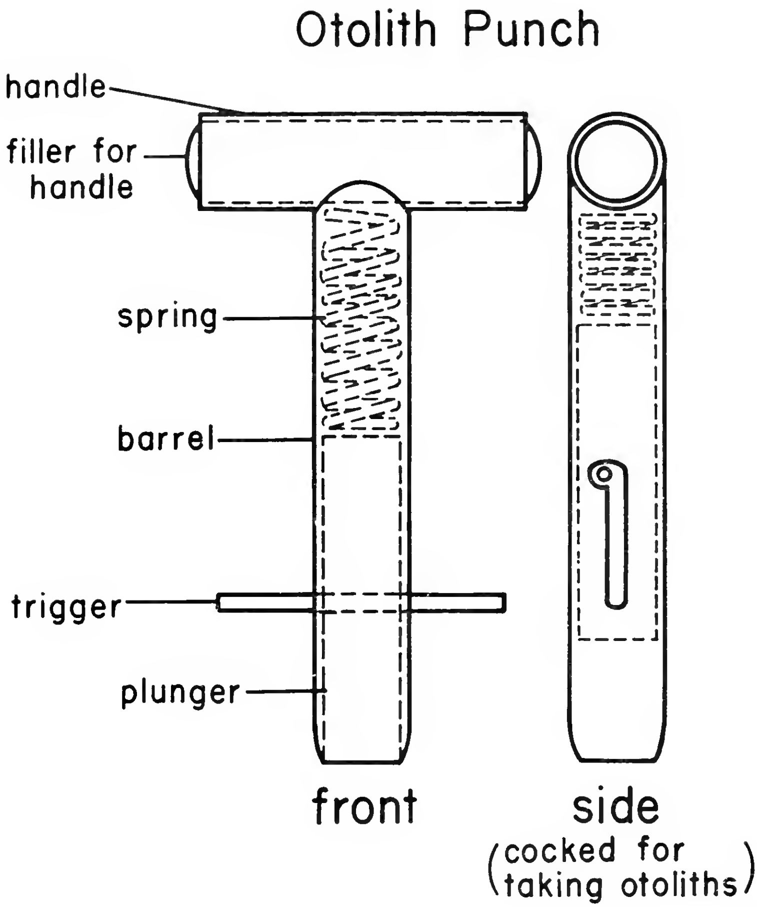

FIGURE 1—Construction details of the punch used to remove otoliths from steelhead trout and other large salmonids.

through the plunger at the bottom of the slot. The plunger was then removed and the cutting end of the barrel sharpened. Finally, the spring was placed in the barrel, followed by the plunger, which was sufficiently depressed to permit the rod to be centered through the hole. The otolith punch was now completed. By compressing the spring and rotating the plunger so the rod caught in the hooked ends of the slots, the punch could be cocked.

USE OF THE OTOLITH PUNCH

Taking otoliths by this technique depended on cutting the core from the appropriate area of the cranium. The scales of salmonids end in a broad "V" shape at the nape (Figure 2). When the core was taken just anterior to the "V," the region of the cranial cavity directly above the sagittae was exposed. The tip of the punch was allowed just to break through the skull so that a core was withdrawn without forcing

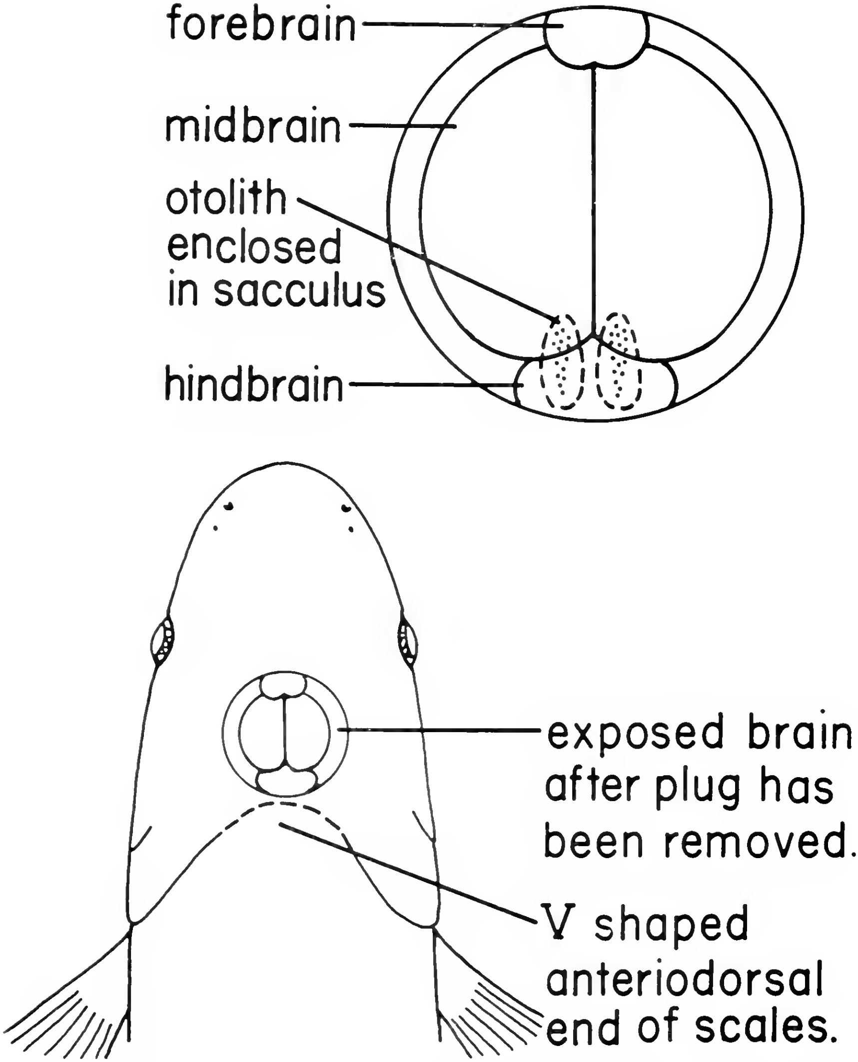

FIGURE 2—Diagram of a salmonid head showing the area from which the circular plug and otoliths were removed. An enlargement of the area exposed by removal of the plug is shown at the top of the figure.

the sagittae out of position. The otoliths were then gently removed with forceps. Once the otoliths were removed, the tip of the punch was placed in the hole and the trigger tripped. In this way, the core was replaced and the appearance of the fish was only slightly damaged. We used this punch to collect otoliths from over 250 steelhead trout and found it to be a convenient and effective tool.

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A NOTE ON THE BEHAVIOR OF THE OCTOPOD *OCYTHOE TUBERCULATA*

On February 4, 1967, while diving from the charter vessel *Maverick* in Emerald Bay, Santa Catalina Island, California, I captured an octopus. With the aid of John E. Fitch (California Department of Fish and Game), I identified it as a male *Ocythoe tuberculata* Rafinesque. I first observed the octopus inside the body cavity of a salp, *Thetys vagina*, which was approximately 6 ft above the bottom in water 30 ft deep. As I approached to investigate, the octopus momentarily left the salp for a maximum distance of about 4 inches before returning to its "hiding place". When I grasped the salp, the octopus abandoned it and swam about 60 ft before I could capture it; at that time it expelled ink which formed a cloud. Close examination showed that the salp was dead, as there was no body pulsation and the diagonal septum was absent. Both the octopus and the salp are now in the possession of S. Stillman Berry of Redlands, California.

Among pelagic octopods of the superfamily Argonautoides (Berry, 1910), one of the third pair of arms (either right or left) is sexually modified into a hectocotylus. In *O. tuberculata* this is the third right arm. The hectocotylus has a sperm reservoir near its base and a filamentous organ at its end. Until the male *Ocythoe* is mature the hectocotylus is contained in a sack. This sack is burst by the movements of the hectocotylus and eventually the hectocotylus breaks from the octopus (Lane, 1960). The hectocotylus on my specimen was extended at the time captured (Figure 1). Berry (1955) indicated that he had not seen the hectocotylus of any *O. tuberculata* taken from California

FIGURE 1—Male *Ocythoe tuberculata* with hectocotylus extended. *Photograph by Jack Schott.*

waters, and that if racial differences occur in this worldwide species they would most likely be detected in the elaborate hectocotylus. Since 1955, John E. Fitch (pers. comm.) has found male *Ocythoe* in several fish stomachs; however, none had an extended hectocotylus in good condition. Berry (1955) noted that "no student of the genus has ever possessed material from outside his own area of investigation sufficient to permit direct comparison of comparable series." Therefore, as Berry did, I have included here some measurements made on this *Ocythoe* (Table 1).

TABLE 1

Measurements of *Ocythoe tuberculata* taken at Santa Catalina Island

Total length	69 mm
Length of body (dorsal)	16 mm
Tip of body to interocular line	18 mm
Tip of body to base of dorsal arms	22.5 mm
Maximum width of body	14 mm
Width of nuchal commissure	12 mm
Width of head at eyes	13 mm
Length of funnel	9.5 mm
Mouth to tip of right dorsal arm	49 mm
Mouth to tip of left dorsal arm	49 mm
Mouth to tip of right second arm	25 mm
Mouth to tip of left second arm	23 mm

TABLE 1—Continued

Measurements of Ocythoe tuberculata taken at Santa Catalina Island

Mouth to tip of hectocotylus arm	51 mm
Mouth to tip of left third arm	21 mm
Mouth to tip of right ventral arm	54 mm
Mouth to tip of left ventral arm	54 mm
Mantle length (ventral)	15.5 mm
Mantle breadth	13.5 mm
Diameter of largest sucker of first left arm	1.8 mm
Diameter of largest sucker of second left arm	1.5 mm
Diameter of largest sucker of third left arm	1.2 mm
Diameter of largest sucker of fourth left arm	1.8 mm
Diameter of largest sucker of hectocotylus	2.1 mm

I found only one publication that reported octopods in salps. Jatta (1896) recorded the occurrence of a male *Ocythoe tuberculata* in *Salpa tilesii* and noted that Schmidtlein had in 1880 (no reference given) recorded finding a male *Argonauta argo* in a salp.

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ESTABLISHMENT OF *TILAPIA MOSSAMBICA* PETERS IN BARD VALLEY, IMPERIAL COUNTY, CALIFORNIA

On July 2, 1968, Franklin Hoover and Marschall Stevens, California Department of Fish and Game, verified the presence of tilapia in two irrigation drains, the Araz Drain and the Reservation Main Drain, near Bard, Imperial County. The only other known free-living tilapia in California exist in a small ditch near the Hot Mineral Spa, Imperial County, approximately 75 miles northwest of Bard (St. Amant, 1966).

Melvin Sheldon, Imperial Irrigation District, first informed us of the presence of tilapia in Bard Valley on June 28, 1968. Ethelwynn Trewavas, British Museum (Natural History) Zoological Department, provided positive identification of the tilapia as *T. mossambica.* Carl L. Hubbs, Scripps Institution of Oceanography, gave valuable assistance in the identification.

Tilapia were collected from the Araz Drain in July 1968, and from the Reservation Main Drain in July 1968 and February, May, and June 1969.

Tilapia are known to exist, from these collections, in approximately 15 miles of these drains.

Water temperatures in most areas of these ditches seldom drop below 60 F (Melvin Sheldon, pers. comm.). This temperature is within the lower temperature limits of *T. mossambica* (Kelly, 1957).

The Arizona Game and Fish Department introduced *T. mossambica* in several drains near Yuma. "The Tilapia that were stocked in the Yuma canal system are *T. mossambica* and have been self-supporting in that area for some six years." (Al Essbach, pers. comm., 1968.) We believe the tilapia now found in the Bard Valley originated from the tilapia introduced near Yuma, and are the result of natural migration or unauthorized introductions.

Due to the popularity of tilapia as a sport fish, we anticipate its further dispersal in southern California as a result of unauthorized introductions by anglers.

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Franklin G. Hoover and James A. St. Amant, Inland Fisheries, Region 5, California Department of Fish and Game. *Accepted August 1969.*

SCRUB JAY POSSIBLY FEEDING ON ECTOPARASITES OF A BLACK-TAILED DEER

A scrub jay (*Aphelocoma coerulescens*) possibly feeding on ectoparasites of a Columbian black-tailed deer (*Odocoileus hemionus columbianus*) was observed on August 31, 1965, about 2 miles northeast of Alpine Lake, Marin County, California. Through 7 x 35 binoculars, we saw the jay land on the back of the foraging deer. As we moved to within appoximately 60 yards of the deer, a three-point buck, it looked directly towards us and stood motionless. The jay quickly flew to the antlers and perched there a few moments. It then hopped onto the head and, pecking at the skin every few seconds, moved from the head down the back of the deer's neck. After remaining on the deer 2 or 3 minutes, the jay flew a short distance away and disappeared into the brush. The deer appeared undisturbed by the bird's activity; it remained motionless, watching us, for at least 5 min.

We believe that the jay was feeding on ectoparasites (ticks or deer keds or both), although we could not see them. Dixon (1944) reported seeing a "California Jay" (scrub jay) presumably picking ticks and deer keds from a mule deer in Sequoia National Forest on March 22, 1944. Local residents told him that this was a common sight.

REFERENCE

Dixon, J. S. 1944. California jay picks ticks from mule deer. Condor, 46 : 204.

—*Terry A. Schulz and Paul D. Budwiser, G. W. Hooper Foundation, University Of California Medical Center, San Francisco.* *Accepted August, 1969.*

BOOK REVIEWS

The Fishes of the British Isles and North-West Europe

By Alwyne Wheeler; Michigan State University Press, East Lansing, 1969; xvii + 613 p., profusely illustrated in color and black-and-white. $25.

Species accounts take up the bulk of this volume and are separated into three natural sections: lampreys and hagfish (12 pages); sharks, rays, and chimaeras (82 pages); and bony fishes (471 pages).

The text starts off with an 8-page list of species (396 entries), which I found more useful than the index. This list is arranged systematically by family and includes the authority for each scientific name as well as the date of publication.

A 9-page "picture key" follows the introduction, and should prove especially helpful to the individual with little or no knowledge of fish families and higher groups. Keys to genera and species appear throughout in appropriate sections, and again sketches have been used to illustrate salient features.

Typical treatment for a given species includes a listing of its common (in the British Isles) and scientific names, and in a few instances an "authorized" or fisherman's vernacular. Rarely a popular synonym is given for the scientific name, but never more than one. French, Dutch, German, Danish, Norwegian, etc., vernaculars are listed, and details are given for distinguishing the species being discussed. This account is followed by a concise report of available biological data including size, diet, depth distribution, spawning habits and behavior, age and growth, and so on. Distribution is depicted by means of a shaded map of the British Isles and northwest Europe but, of course, many species range well beyond the margins of this standardized map.

Almost every species is illustrated with a line drawing and 77 species are included in the 16 color plates.

This volume is indispensable to anyone concerned with the fisheries or fishes of northwest Europe. Since many of the ichthyologists and fishery personnel using this book have only a cursory knowledge of the taxonomy and systematics of the fauna, it is unfortunate that so few synonyms are given for the various scientific names.

The price of the book is bound to limit its sale, particularly among students and struggling fishery workers—people who have the greatest need for the information contained in this work.—*John E. Fitch.*

Deep-water Teleostean Fishes of California

By John E. Fitch and Robert J. Lavenberg; University of California Press, Berkeley and Los Angeles, 1968; 155 p., illustrated. $2.25 paper.

This book is number 25 in the series of *California Natural History Guides*, published by U. C. Press. It covers 71 families of fishes that inhabit the ocean off California. For each family, one "typical" member is illustrated with a coquille-board drawing, and that species is rather thoroughly discussed. The coverage for each illustrated species includes: "distinguishing characters", "natural history notes", "fishery information", a notation of "other family members" and characters for distinguishing them, and the "meaning of [the scientific] name." Much of the information, particularly that concerning life history, is based upon original research by the authors. These notes contain a storehouse of knowledge obtained from the many combined years the authors have devoted to the study of marine fishes.

In several instances, more than one member of a family is illustrated. These "additional" drawings show species that are "oddballs" within the family, or, in the case of the gonostomatids, *Cyclothone* and *Danaphos*, depict two of the several subgroups found in this large family. In all, there are 74 figures and all were drawn from fresh or preserved specimens, or from photographs when exteremely large and unwieldy fishes were involved. These illustrations are both detailed and accurate; hence, they are of tremendous help in identifying deep-sea fishes for those who are not thoroughly familiar with these creatures.

In a brief introductory section, the authors discuss, among other things, such items as "special adaptations of some deep-water fishes", the "history of deep-water ichthyology affecting California", and "California's fossil record of deep-water fishes." Three appendices contain some very useful information, especially the "checklist of deep-water teleostean fishes from off California." Fisheries workers will for the first time have a complete list of known forms inhabiting the deep waters off our coast. Authorities and publication dates are given for the almost 260 species considered. Finally, there is a glossary and an index.

Several minor errors have crept into this edition. On page 42 mid-Chile is listed as 18° S; the date of publication for *Scopelogadus mizolepis bispinosus* (Gilbert) should be changed from 1890 to 1915. In distinguishing the two genera of threadtail snipe-eels (p. 64), the authors separate *Avocettina* "in having only one set of pores along the lateral line compared with five in *Nemichthys*". Lateral line pores in a row (*Avocettina*) vs lateral line pores of three rows (*Nemichthys*) seems less confusing and is more prevalent in previous literature. The omission of *Survey of Pelagic Fishes of the California Current Area* (Berry, F. H., and H. C. Perkins, 1966, U.S. Fish and Wildl. Serv., Fish. Bull., 65(3): 625–682) from the list of "helpful references" is an unfortunate oversight.

The use of superlatives in discussing this volume can not be avoided and its publication must be considered a major contribution to the understanding of California marine fishes and deep-water fishes in general. Ichthyologists, marine biologists, librarians, teachers, and students can only look forward with great anticipation to future volumes by Fitch and Lavenberg on other marine fishes of our coast.—*Robert N. Lea.*

The Behavior and Physiology of Pinnipeds

Edited by R. J. Harrison, Richard C. Hubbard, Richard S. Peterson, Charles E. Rice, and Ronald J. Schusterman; Appleton-Century-Crafts, New York, 1968; xiv + 411 p., illustrated. $12.

This volume is a collection of papers written and edited by five noted experts on pinniped behavior, physiology, and husbandry, with contributions from several other experts from closely related fields.

The book is divided into four parts; the first two deal with behavior, one being primarily ethological, the other dealing with experimental behavioral studies of captive animals and trained animals in the wild. The two remaining sections deal with physiology and husbandry.

The various parts of the book, each under a separate editor, describe recent and ongoing pinniped research along with a comprehensive review of the literature and past research. One facet of pinniped research receiving considerable attention in recent years involves the ability of various pinnipeds, notably the California sea lion, to utilize active sonar or echolocation in much the same way as do porpoises. Chapters written by Poulter, defending the echolocation theory, and by Schusterman, negating the echolocation theory, appear in different parts of this book and provide an interesting dichotomy of views. It is especially interesting since the two researchers, both well-known in their fields, have conducted much of their basic research concurrently at Stanford Research Institute's Bio-Sonar Laboratory in Fremont, California.

Though much of the book is concerned with research conducted on seals and sea lions found in the eastern Pacific, attention is also given to pinniped species from all over the world. The chapters on general physiology and pinniped nutrition provide information on nearly every species of seals, sea lions, and walruses found throughout the world.

The chapter on husbandry is excellent and provides valuable information on feeding, housing, handling, and medical care.

It is obvious that no single volume can adequately cover the more than 20 genera of pinnipeds found throughout the world. This publication does, however, bring together into one volume most of the recent information on the physiology and behavior of pinnipeds and provides an excellent source of information for anyone conducting research in this field.—*Mel Odemar.*

From Sea to Shining Sea, A Report on the American Environment—Our Natural Heritage

Prepared by the President's Council on Recreation and Natural Beauty; U.S. Government Printing Office, Washington, D.C. 20402, 1968; 304 p., profusely illustrated with black-and-white photographs. $2.50 paper.

The stated major objectives of this report are (i) to outline progress in environmental improvement programs since the 1965 White House Conference on Natural

Beauty, (ii) to present proposals and recommendations which will stimulate federal, state, local, and private action to further enhance the quality of our environment and the beauty of our Nation, and (iii) to present a guide for action by local officials, professional men and women, citizen groups of many kinds, and individuals.

The report presents a well-balanced although necessarily somewhat limited cross section of the environmental problems which lower the quality of our everyday lives. By word and picture, the reader is taken through the country's urban, rural, and wild areas; presented with the actions required and being taken to cope with their problems; and given extensive lists of publications, films, and agencies and organizations which can help.

Undoubtedly, this publication will prove useful. To the interested but less initiated, it may be an eye opener. To those already well versed in the problems of our environment, it will serve as a reasonably comprehensive compendium.

Recognition of the environment is not new. In the early years of the Republic Thomas Jefferson wrote, "Communities should be planned with an eye to the effect made upon the human spirit by being continuously surrounded with a maximum of beauty." A century later President Theodore Roosevelt, and later Presidents Franklin D. Roosevelt, John F. Kennedy, and Lyndon B. Johnson, issued strong statements emphasizing the importance of natural beauty and the need to preserve, restore, and enhance the Nation's environmental quality.

Will Americans at last respond to these wise admonitions? Perhaps they will when they finally realize that environmental quality is a necessity rather than a luxury.—*Leo Shapovalov.*

Symposium on Salmon and Trout in Streams

Edited by T. G. Northcote, Institute of Fisheries, The University of British Columbia, Vancouver, 1969; 388 p., illustrated. $3.00 paper. Sold by Institute of Fisheries Library.

The H. R. MacMillan fisheries symposia, held annually at the Institute of Fisheries of The University of British Columbia, merit more attention outside the local area than they seem to get, judging from this report on the 1968 session. It contains 23 contributions on various aspects of trout and salmon biology in streams, including reproduction, egg and alevin ecology, feeding, growth, movement, survival, and production dynamics. The individual papers are generally excellent. They tend to emphasize behavioral and ecological phases of salmonid biology. Some of the papers are general; others report on detailed investigations of species as varied as rainbow trout, sockeye salmon, Atlantic salmon, and ayu. Fisheries professionals interested in salmonid biology will find this symposum a valuable addition to their libraries because it draws so much information and so many literature citations together in one place for convenient reference.—*Alex Calhoun.*

Managing Water Quality: Economics, Technology, Institutions

By Allen V. Kneese and Blair T. Bower; The Johns Hopkins Press, Baltimore, Maryland, 1968; x + 328 p., illustrated. $8.95.

This book represents an up-to-date review of the problems associated with water quality management and pollution control, with emphasis on economic analysis. The first four chapters are devoted to summarization of the basic elements of water quality problems facing this nation. The reader who may be unfamiliar with these elements will profit from the authors' treatment of basic issues, the nature of waste discharges and their effects on receiving waters, the relation of water quality to water uses, and the management of waste loads in relation to waste assimilative capacity of the receiving waters.

Having established a base of understanding of the physical problem, the book then treats the economic concepts and policies for controlling waste discharges. Here under one cover and directly related to water quality is a summary education in the economics of pollution. It explains the terms and concepts which are so often used in water management these days but which are frequently confusing to the water quality biologist or manager untrained in economics. Although fairly easily understood, it is by no means a simplified treatment of economic principles. As is the case with most such treatments, this section tends to reduce all facts of the problem to one of minimizing costs and making dollar comparisons. However, unlike many economic oriented treatments of such problems, the authors recognize the difficulty of assessing and properly weighing the values of intangibles and also conclude that the levels of water quality to be achieved in each of the nation's watercourses cannot be directly established on economic grounds.

The authors go on to detail the cases for and problems associated with economic incentives for reducing waste discharges, including effluent charges, incentive payments, benefits to industrial users, effluent standards, tax breaks, sewer charges, etc.

It is of interest to note that on the basis of certain limited studies and analyses the authors come to the conclusion that ". . . higher water quality must be justified primarily on aesthetic and recreational grounds, if it is to be justified at all". The studies indicate that provision of high quality water for industry or municipal uses is seldom justified economically. The authors conclude from their analysis that, despite some shortcomings and problems, the effluent charges approach is the one most likely to result in efficient and equitable arrangements and they strongly urge reorienting the nation's policies in this direction.

The book discusses several case studies of problem rivers, including the Delaware, the Potomac, and the Ruhr River basin of Germany. Institutional and organizational approaches to water quality control in the Ruhr, England, France, and the Delaware River Basin Commission are discussed and compared.

Finally, the authors set forth their recommendations for a regional water quality management agency, including its objectives, organization, criteria to be met, and financing.

Although the book's treatment of water quality problems in relation to fish and wildlife is somewhat sketchy and at least in one place misleading ("Salinity . . . within limits ordinarily encountered . . . is not destructive of fish life. . . ."), it is of value to the fisheries biologist and particularly to the water quality biologist. It conveys a clear picture of economic, organizational, and institutional problems which so often have a major effect on the control of pollution in relation to fish and wildlife.—*J. C. Fraser.*

Oceanographic Atlas of the Pacific Ocean

By Richard A. Barkley; University of Hawaii Press, Honolulu, 1968; 20 p. + 156 full-page figs. $30.

This atlas summarizes the results of observations made throughout the Pacific Ocean during a period of over 50 years. Data gathered at over 50,000 stations, representing some 3 million individual observations of temperature, salinity, dissolved oxygen, and depth of sampling, provided the basis for the document. As might be expected, these observations were quite unevenly distributed in both time and space, but in many areas they provided adequate data to determine conditions during each of the four quarters of the year. Contours of equal depth, salinity, and dissolved oxygen concentration are indicated on individual charts as continuous lines when adequate data are available, and as dashed lines when data are lacking but continuity reasonably can be inferred.

The most significant feature of the procedures for processing observed data for this atlas is the use of an interpolation technique based upon density rather than depth as the independent variable. Values derived from the density relationships seem to reflect conditions in the upper layers of the sea better than values derived from depth relationships. This feature makes the atlas particularly valuable to marine scientists concerned with the upper 2,000 meters of the Pacific Ocean.

While the atlas is a welcome addition to the library of the marine scientist, it is of limited value to the layman—*Herbert W. Frey.*

The Life of the Marsh

By William A. Niering; McGraw-Hill Book Co., New York, 1967; 232 p., profusely illustrated. $4.95.

The Life of the Marsh explores both the readily visible and minute animals and plants and their niches in the marsh. The beauty and the values of marshland are shown. Although to the casual observer the marsh may appear as an uninviting swamp area, consisting of biting insects and poisonous snakes, those who take a second look, after reading this book, will find that the marsh has much more to offer.

The ecological succession from lake to forest is described, explaining that all lakes are doomed to die and that most marshes result from dying lakes or the natural filling in of coastal waters.

Man's importance in upsetting or maintaining nature's balance is stressed. Establishment of marshland refuges are failing to keep up with the destruction of wildlife habitat resulting from land reclamation. Niering points out that reclamation in many instances has been performed hastily and unwisely. The wetland areas in the National Park system and the nation's wildlife refuges are discussed briefly. Endangered wetland species mentioned include the Venus's-flytrap, the dusky seaside and Cape Sable sparrows, and the alligator and crocodile. The text is suited for both layman and professional although, unfortunately, scientific names were not included.

A glossary is provided, as well as a short bibliography. The photographs and illustrations are excellent. Whether the reader ever visits a marsh or not, the book makes for worthwhile and enjoyable reading. Hopefully those who are involved in land reclamation work will be exposed to *The Life of the Marsh.*—*James A. St. Amant.*

Handy Medical Guide for Seafarers, Fishermen, Trawlermen, Yachtsmen

By R. W. Scott; Fishing News (Books) Ltd., London, 1969; ix + 86 p., illustrated. £1.10.0 cloth, £1.0.0 paper.

This booklet is appropriate for ready reference in many isolated situations, but it is not intended to replace or supersede the knowledge and use of more comprehensive texts on first aid or medicine.

The book's langauge is colloquial and readable. The inclusion of English idioms in various chapters does not detract from the American reader's understanding of each section.—*Charles H. Turner.*

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