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CONTRIBUTIONS TO THE LIFE HISTORY OF THE PIUTE SCULPIN, *COTTUS BELDINGII* EIGENMANN AND EIGENMANN, IN LAKE TAHOE[1]

VERLYN W. EBERT[2] and ROBERT C. SUMMERFELT[3]
Department of Zoology, Kansas State University
Manhattan, Kansas

Certain facets of the life history of the Piute sculpin in Lake Tahoe were studied. Data on diet, age and growth, reproduction, and parasites are presented. The most common foods of the sculpin were ostracods, green filamentous algae, chironomids, plecopterans, amphipods, cladocerans, moss capsules, and oligochaetes. Diet varied with size of fish, season, depth of capture, and collection sites. Examination of annuli on otoliths from 92 sculpins collected in November and December 1963 revealed five age groups, O, I, II, II, and IV. The calculated mean TL in mm at the end of each year of life were 33.3, 48.9, 64.7, and 69.0 for age groups I through IV, respectively. The mean coefficients of condition were 1.05 for 417 males and 0.99 for 382 females. The length-weight relationship was log W = –5.244 + 3.166 log L. Analyses of gonosomatic ratios and egg diameters, coupled with field observations of nests, indicate that most sculpins spawn in May and June. The mean number of eggs per female was 123. Sculpins do not spawn until their second year of life. Three kinds of parasites were found: a large plerocercoid larva of the genus *Ligula* (Cestoidea: Diphyllobothridae) in the abdominal cavity, metacercaria of a strigeoid trematode in the liver, and a microsporidian of the genus *Plistophora* (Cnidosporidia: Microsporida) in the body wall.

INTRODUCTION

The objective of this report is to describe certain aspects of the life history of the Piute sculpin in Lake Tahoe, with emphasis on diet, age and growth, reproduction, and parasites. It is the first published report on the life history of this fish. However, three unpublished theses (Dietsch, 1950; Miller, 1951; Jones, 1954) have contributed to our knowledge of the life history of the species. Also, in a yet unpublished manuscript, Phillip H. Baker describes its distribution, size composition, and relative abundance.

Descriptions of physical-chemical features of Lake Tahoe can be found in Kemmerer. Bovard. and Boorman (1923), Juday (1907), and McGauhey et al. (1963). Weidlein, Cordone, and Frantz (1965), and Cordone and Frantz (1966) present maps of Tahoe and information on the sport fishery. A check list of Tahoe invertebrates was presented by Frantz and Cordone (1966).

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[2] Present address: Kansas Forestry, Fish and Game Commission, Hays, Kansas 67601. Part of this paper was presented at the 96th Annual Meeting of the American Fisheries Society, September 12–14, 1966, Kansas City, Missouri. Mr. Ebert shared the Society award for the best paper delivered by a student at the meeting.

[3] Present address: Oklahoma Cooperative Fishery Unit, Oklahoma State University. Stillwater, Oklahoma 74074.

METHODS

From September 1963 through September 1964, 6,424 sculpins were collected with otter and sled trawls and from shoreline rotenone treatments. Most were collected with the otter trawl. Baker (1967, and MS) describes the collection methods. All specimens were fixed in 10% formalin soon after collection and later preserved in 40% isopropyl alcohol.

From the total collection of preserved sculpins, 851 were randomly selected for study. Total lengths were measured to the nearest mm and body weights and gonad weights were determined to the nearest 0.001 g. Stomachs and otoliths were removed and stored in separate vials of 40% isopropyl alcohol. Each fish was examined externally and internally for parasites. These were preserved in vials of 40% isopropyl alcohol.

LIFE HISTORY

Diet

The contents of all 851 stomachs were analyzed. The results best represent the diet of sculpins in relatively deep water, since about 89% of the specimens were taken in bottom trawls at 100, 200, 300, and 400 ft. Most of the remainder were collected from rubble areas in the littoral zone. The objectives were to determine the kinds of organisms utilized and differences related to collection site, depth of capture, season, and size of fish.

The volume of each taxa was determined by alcoholic displacement to the nearest 0.001 ml in a graduated centrifuge tube. The category "detritus" includes sand, diatoms, desmids, mud, and unrecognizable, partially digested organisms.

In terms of frequency of occurrence, ostracods were the most popular food item, with about 50% of the stomachs containing them.[4] Other popular foods, occurring in about 20 to 40% of the stomachs, were filamentous green algae, chironomid larvae, plecopterans, amphipods, and cladocerans. Virtually all of the amphipods were the deep-water scud, *Stygobromus*. The plecopterans were apterous forms of the genus *Capnia*. Of lesser importance and in decreasing order were moss capsules, oligochaetes, gastropods, pelecypods, water mites, copepods, *Chara*, and sculpins. No fish eggs were found in the stomachs, and the only fish remains consisted of an occasional sculpin.

Nearly 50% of the total volume of sculpin stomach contents was considered detritus. Most of it probably represents partially digested food, and bottom material accidentally taken while ingesting prey organisms. Next in importance were green filamentous algae, which may also be consumed accidentally (this may be true for all types of aquatic plants found in sculpin stomachs). *Stygobromus* comprised an average of about 7% of the total volume of stomachs examined. In decreasing order, the next most significant food items were sculpins, gastropods, oligochaetes, moss capsules, plecopterans, and chironomid larvae. Al-

[4] Numerous bottom fauna collections taken from widely separated areas and depths ranging from the shallows to the lake floor revealed only a single species of free-living ostracod (Frantz and Cordone, 1966). It was described by Ferguson (1966) as *Candona tahoensis*.

though ostracods occur most frequently in sculpin stomachs, they supply very little of the total volume because of their small size. The opposite is true for the few sculpins which enter the diet of other sculpins. *Stygobromus*, ostracods, gastropods, and chironomid larvae were numerically the most abundant organisms in stomachs which contained them.

There was strong similarity in the diet of sculpins from the north and south ends of Tahoe (Table 1). Sculpins apparently consumed nearly the same amount of food in each habitat, since the percentages of empty stomachs were similar. However, there was a greater frequency and volume of cladocerans, gastropods, and the amphipod *Hyallela* in the stomachs of sculpins from the south end. Moss capsules and oligochaetes were more important volumetrically and numerically in

TABLE 1

Diet of Piute Sculpins at Two Locations in Lake Tahoe

Food item	Percentage frequency of occurrence		Mean number of organisms*		Percentage of total volume	
	North	South	North	South	North	South
Oligochaeta	10.17	6.38	2.28	1.87	4.45	3.04
Gastropoda	4.22	5.77	3.47	3.73	0.02	9.33
Pelecypoda (*Piscidium* sp.)	0.74	1.52	1.00	1.40	0.01	0.23
Cladocera	16.38	26.14	2.39	3.88	0.02	0.43
Ostracoda (*Candona tahoensis*)	50.62	51.97	5.70	5.51	1.20	1.16
Copepoda	0.99	0.91	1.67	1.00	--	--
Amphipoda *Stygobromus* sp.	27.05	27.96	11.31	7.44	7.39	6.80
Hyallela sp.	--	3.64	--	2.00	--	0.29
Acari	0.99	0.91	1.00	1.00	--	--
Plecoptera (*Capnia* sp.)	31.76	38.30	3.46	3.07	2.65	3.17
Diptera Chironomid larvae	35.73	34.04	3.30	3.46	2.22	2.33
Chironomid pupae	8.44	10.94	2.60	2.12	0.51	0.39
Cottus beldingii	0.25	0.30	1.00	1.00	4.84	5.40
Musci (moss capsules)	13.15	5.47	3.40	2.94	4.04	1.88
Charophyceae (*Chara* sp.)	--	0.91	--	--	0.01	0.01
Chlorophyceae	45.15	43.16	--	--	16.35	11.58
Detritus	--	--	--	--	45.70	53.80
Mean volume of food (ml)	--	--	--	--	0.048	0.042
Empty (% of total)	4.50	6.80				
No. stomachs examined	456	370				

* In stomachs containing them.

samples from the north end. These area differences probably reflect differences in availability of the organisms in the two areas. Miller (1951) found pronounced variations in the diet of sculpins from three widely separated areas in Lake Tahoe.

Some obvious changes in diet with depth were noted, suggesting qualitative and quantitative zonation of the food organisms (Table 2). The percentage of empty stomachs varied inversely with depth, whereas the total volume of food in stomachs containing food varied randomly. There was a well-defined decrease in the percentage occurrence of cladocerans with increasing depth. However, the mean number and percentage of total volume of cladocerans in sculpin stomachs varied randomly with depth. Gastropods tended to decrease with depth, except for a slight increase at 400 ft. A few sculpins from depths of 100 and 200 ft contained *Hyallela*, but these were absent from fish collected at 300 and 400 ft. Both *Stygobromus* and oligochaetes tended to increase with depth. A single sculpin taken from 700 ft contained 15 *Stygobromus*. The frequency of copepods and chironomid larvae and pupae in sculpin stomachs varied randomly with depth of capture. Ostracods, plecopterans, moss capsules, and filamentous algae tended to be more frequent in sculpins taken at the intermediate depths of 200 and 300 ft than at 100 or 400 ft. This pattern is very likely directly related to the depth distribution of aquatic plants. Frantz and Cordone (1967) describe these extensive beds of deepwater plants (*Chara*, mosses, and filamentous algae) in Lake Tahoe. The plants attain their greatest densities at depths from 200 to 350 ft and rapidly diminish at greater and lesser depths.

Sculpin food habits also varied seasonally (Table 3). As indicated by the mean volume of stomach contents, sculpins consumed the least amount in the fall and winter and greatest amount in the spring and summer. This same pattern generally held true for the frequency of occurrence of cladocerans, but the average number and the percentage of total volume of cladocerans varied randomly. The percentages of empty stomachs were relatively similar for the four seasons, however. Occurring much more frequently in the summer than in other seasons were ostracods, chironomid larvae and pupae, plecopterans, amphipods, cladocerans, oligochaetes, and moss capsules. No marked seasonal changes could be detected for frequency of occurrence of gastropods and green filamentous algae. Mean numbers of plecopterans and *Stygobromus* present in sculpin stomachs exhibited pronounced peaks in the spring, whereas mean numbers of most other food items varied randomly or showed seasonal maxima in the summer. On a year-round basis, the largest percentage of total volume of sculpin food was filamentous green algae, which were particularly important in the summer and fall. Volumetrically, gastropods were an important food item in the summer, with *Stygobromus* the most important in the spring. Sculpins were significant items in the diet of other sculpins during all but the spring season, although they occurred with low frequency throughout the study. Variations in seasonal utilization of food by sculpins were also reported by Miller (1951).

TABLE 2
Diet of Piute Sculpins at Four Depths in Lake Tahoe

Food item	Percentage frequency of occurrence				Mean number of organisms*				Percentage of total volume			
	100′	200′	300′	400′	100′	200′	300′	400′	100′	200′	300′	400′
Oligochaeta	4.51	2.82	13.07	13.42	1.67	1.10	2.24	2.36	4.20	0.79	4.65	7.32
Gastropoda	8.27	7.42	1.13	2.67	7.00	2.09	1.33	1.00	27.52	4.17	--	0.14
Pelecypoda (*Piscidium* sp.)	0.75	1.06	0.57	4.70	1.00	1.00	1.00	1.67	0.05	0.02	--	0.04
Cladocera	30.07	25.44	18.18	11.41	3.46	2.97	3.00	3.33	0.29	1.26	0.12	0.12
Ostracoda (*Candona tahoensis*)	46.62	55.12	50.57	36.74	4.67	6.47	6.64	3.51	0.69	2.12	1.35	0.36
Copepoda	0.75	1.06	0.57	0.66	1.00	2.00	1.00	1.00	--	--	--	--
Amphipoda												
Stygobromus sp.	4.51	3.81	39.21	78.52	12.06	5.56	5.77	11.85	1.82	1.34	4.88	24.51
Hyallela sp.	7.52	0.35	--	--	2.10	1.00	--	--	0.27	0.01	--	--
Acari	1.50	1.06	0.57	0.66	1.00	1.00	1.00	1.00	--	--	--	--
Plecoptera (*Capnia* sp.)	14.30	35.69	49.43	24.83	3.43	2.87	3.82	3.25	1.37	3.38	3.82	2.30
Diptera												
Chironomid larvae	33.08	28.98	38.64	37.58	6.23	2.02	3.73	2.67	4.23	1.51	2.24	1.86
Chironomid pupae	9.77	12.01	9.66	4.52	1.72	2.94	2.33	1.14	0.28	0.72	0.43	0.04
Cottus beldingii	0.75	--	--	0.66	1.00	--	--	1.00	15.57	--	--	10.77
Musci (moss capsules)	6.76	12.01	13.07	0.66	2.67	3.68	2.62	5.00	3.61	4.54	3.31	1.26
Charophyceae (*Chara* sp.)	2.26	0.35	--	2.02	--	--	--	--	0.20	--	--	0.01
Chlorophyceae	36.09	40.99	72.73	40.45	--	--	--	--	2.44	22.80	20.75	6.63
Detritus	--	--	--	--	--	--	--	--	37.01	57.10	56.93	45.40
Mean volume of food (ml)	--	--	--	--	--	--	--	--	0.046	0.034	0.056	0.045
Empty (% of total)	10.73	5.67	2.76	2.62								
No. stomachs examined	140	286	179	155								

* In stomachs containing them.

TABLE 3

Seasonal Variations in the Diet of the Lake Tahoe Piute Sculpin *

Food item	Percentage frequency of occurrence				Mean number of organisms†				Percentage of total volume			
	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring
Oligochaeta	16.29	7.14	11.35	6.53	2.34	2.00	1.65	2.35	3.29	4.52	2.75	4.00
Gastropoda	5.43	4.76	5.68	6.53	6.29	4.11	1.73	4.25	13.82	5.11	1.84	2.45
Pelecypoda (*Piscidium* sp.)	1.55	--	0.71	2.51	1.00	--	1.40	1.00	0.03	--	0.06	0.01
Cladocera	51.94	19.32	12.77	22.61	3.98	2.93	2.02	2.29	0.52	0.19	0.16	0.12
Ostracoda (*Candona tahoensis*)	88.37	49.69	55.31	51.25	6.14	5.52	5.14	6.38	0.49	1.63	0.99	1.72
Copepoda	1.55	0.61	1.41	1.01	1.00	--	1.00	2.00	--	--	--	--
Amphipoda												
Stygobromus sp.	51.94	27.39	31.20	22.61	8.71	5.58	3.41	20.74	6.34	3.79	2.36	15.80
Hyallela sp.	5.43	--	1.41	1.51	2.14	--	2.00	1.00	0.14	--	0.07	0.01
Acari	2.33	--	--	6.53	1.00	--	--	1.00	--	--	--	--
Plecoptera (*Capnia* sp.)	75.97	26.99	41.86	26.63	4.05	2.75	2.26	33.96	2.60	3.43	1.98	3.14
Diptera												
Chironomid larvae	76.74	20.25	56.03	22.61	3.27	1.56	1.52	5.17	2.53	1.20	0.64	4.65
Chironomid pupae	39.54	3.68	7.09	1.51	2.60	1.80	1.33	2.27	0.43	0.83	--	0.44
Cottus beldingii	1.00	0.61	0.50	--	1.00	1.00	1.00	--	7.50	10.00	13.30	--
Musci (moss capsule)	31.00	7.74	0.71	--	3.49	3.92	1.92	3.60	4.66	5.02	1.44	0.53
Charophyceae (*Chara* sp.)	0.79	0.61	0.71	2.02	--	--	--	--	--	0.03	0.17	--
Chlorophyceae	44.54	50.31	53.19	35.17	--	--	--	--	17.39	20.12	7.85	8.31
Detritus	--	--	--	--	--	--	--	--	38.19	47.13	65.50	57.00
Mean volume of food (ml)	--	--	--	--	--	--	--	--	0.062	0.036	0.028	0.058
Empty (% of total)	8.51	6.15	6.62	4.78								
No. stomachs examined	163	281	198	141								

* Summer—July, August, and September; Fall—October, November, and December; Winter—January, February, and March; Spring—April, May, and June.
† In stomachs containing them.

TABLE 4

Diet of the Lake Tahoe Piute Sculpin, Ranked According to Four Size Classes (TL in mm)

Food item	Percentage frequency of occurrence				Mean number of organisms*				Percentage of total volume			
	10–40	41–61	62–81	82–127	10–40	41–61	62–81	82–127	10–41	41–61	62–81	82–127
Oligochaeta	1.96	6.61	10.41	7.14	1.00	1.35	2.54	2.00	0.65	4.61	5.11	0.68
Gastropoda	1.96	1.72	6.84	12.86	1.00	6.00	2.28	7.56	--	0.39	0.96	24.30
Pelecypoda (*Piscidium* sp.)	--	1.15	0.60	2.86	--	1.25	1.50	1.00	--	0.03	0.02	0.13
Cladocera	25.49	23.57	19.91	25.11	3.00	3.42	2.90	3.38	0.97	0.53	0.21	0.08
Ostracoda (*Candona tahoensis*)	58.82	57.47	44.94	32.89	9.51	6.61	3.78	3.87	20.00	2.78	0.59	0.15
Copepoda	--	0.86	1.19	1.43	--	1.67	1.25	1.00	--	--	--	--
Amphipoda												
Stygobromus sp.	7.84	26.15	29.76	27.14	5.40	7.19	10.73	7.10	7.74	8.39	8.79	2.90
Hyallela sp.	3.92	2.01	1.19	--	1.50	1.86	2.00	--	0.65	0.13	0.05	--
Acari	--	0.58	1.49	2.86	--	1.00	1.00	1.00	--	--	--	--
Plecoptera (*Capnia* sp.)	27.45	34.19	32.72	25.11	4.71	2.83	3.62	3.00	20.00	4.74	2.94	0.86
Diptera												
Chironomid larvae	31.37	36.21	36.61	32.89	2.60	3.21	3.15	2.70	11.97	3.84	2.17	0.61
Chironomid pupae	7.84	9.91	7.14	14.28	1.80	2.58	1.96	3.33	2.26	0.82	0.39	0.35
Cottus beldingii	--	--	--	4.28	--	--	--	1.33	--	--	--	21.20
Musci (moss capsules)	--	6.61	13.99	7.14	--	3.70	3.26	4.60	--	3.53	3.60	2.27
Charophyceae (*Chara* sp.)	--	--	0.99	2.86	--	--	--	--	--	--	0.02	0.13
Chlorophyceae	3.92	44.82	54.76	59.14	--	--	--	--	--	9.33	21.80	4.93
Detritus	--	--	--	--	--	--	--	--	45.75	59.00	54.45	31.50
Mean volume of food (ml)	--	--	--	--	--	--	--	--	0.061	0.025	0.052	0.118
Empty (% of total)	12.07	3.06	6.41	6.67	--	--	--	--	--	--	--	--
No. stomachs examined	58	359	359	75								

* In stomachs containing them.

Sculpin food habits were also analyzed according to four length classes: 10–40 mm, 41–61 mm, 62–81 mm, and 82–127 mm (Table 4). The mean volume of food in stomachs of the largest size category was considerably greater than the others, but amounts in the other categories varied randomly. Sculpins less than 40 mm had a higher frequency of empty stomachs than the other size groups. Larger fish consumed a greater variety of food: 12 to 14 items were found in fish greater than 41 mm, compared with only 8 items in fish less than 40 mm. The frequency of occurrence of plant remains, gastropods, and oligochaetes varied directly with sculpin size. Ostracods and *Hyallela* occurred more frequently in the smaller sculpins. Ostracods were more numerous and contributed more to the total volume consumed than any other food item in the smallest size class, whereas the larger food items, like *Stygobromus* and gastropods, were more numerous in the larger fish. Chironomid larvae and pupae, cladocerans, and plecopterans were consumed at relatively the same frequency by sculpins of all sizes. However, the percentage of the total volume of these same items varied inversely with the size of the sculpin. Sculpin remains were found only in the stomachs of the largest sculpins. Miller (1951) found a positive correlation between the size of sculpins and the size of their prey.

Detritus consistently made up a high percentage of the total volume of food found in sculpin stomachs of all size classes, ranging from 31.5% in the 82–127-mm group to 59.0% in the 41–61-mm group (Table 4). Also, detritus made up 45.7 and 53.8% of the total volume for the north and south shore sites, and 37.0, 57.1, 56.9, and 45.4% for the 100-, 200-, 300-, and 400-ft depths, respectively (Tables 1 and 2). The large volume of detritus consumed by sculpins suggests that this feeding activity plays an important role in energy transfer by converting the organic component of the bottom detritus into a form available to the large piscivorous fishes which prey on the sculpin. However, plant material in the detritus may not contribute much energy. Miller (1951) observed that the extremely short digestive tract of the sculpin suggests dependence on high protein food.

The diet of the Piute sculpin from Lake Tahoe differs markedly from that of the same species from Sagehen Creek. Immature insects were more frequent in Sagehen Creek sculpin stomachs (Dietsch, 1950). The differences are no doubt attributable to the difference between the environments. Comparison of the food habits of sculpins from the two environments suggests that the species is an opportunistic feeder, whose diet varies with the availability and vulnerability of the food items.

Our observations on the food habits of Piute sculpins also differ from those reported for the same species from Lake Tahoe by Miller (1951). We found a greater frequency of plant remains, ostracods, gastropods, and amphipods; a greater diversity of food items; the presence of plecopterans, oligochaetes, pelecypods, sculpins, and copepods; and fewer empty stomachs. Moreover, Miller reported trichopterans, fish eggs, and branchipods (phyllopods), whereas these items were not encountered in the present study. These differences are likely related to depth of capture. The majority of Miller's specimens were taken from shallow, rubble areas of the littoral zone, while most of ours were collected from the vegetated flats of depths from 100 to 400 ft.

The area of capture may also be responsible for the virtual absence of fish and fish eggs in sculpin stomachs during the current study. Probably only the lake trout (*Salvelinus namaycush*) spawns in this depth range, but most likely over steep, rocky shelves which provide shelter for eggs and fry. The only other bottom-dwelling species common at depths over 100 ft are the tui chub (*Gila bicolor*) and Tahoe sucker (*Catostomus tahoensis*). These species spawn in shallow water (the latter also spawns extensively in tributary streams) and by the time their young-of-the-year penetrate into deep water they may be too large to be eaten by sculpins. Although none was found in the present study, Miller (1951) found nine sculpin eggs in one sculpin and four in another. Both fish were collected in May.

The Piute sculpin of Lake Tahoe is closely associated with the substrate throughout its life cycle (Phillip H. Baker, MS). Therefore, the cladocerans that contribute signficantly to its diet are probably the common pelagic forms which come in contact with the substrate, as well as those forms associated solely with the bottom. Twelve species of cladocerans found associated with the substrate have been described from Lake Tahoe (Frantz and Cordone, 1966).

Age and Growth

Because sculpins lack scales, their age is determined either by length-frequency analysis or by counting annuli in otoliths or vetebrae (Bailey, 1952; Zarbock, 1952). Both length-frequencies and otoliths were used to age Lake Tahoe Piute sculpins.

The otoliths are located in the chambers of the labyrinth, which are exposed by removing the lower jaw and the roof of the mouth. When exposed, the chambers appear as bulbous structures below each eye. Before examination, otoliths were cleared in oil of wintergreen (methyl salicylate) for about 1 week. However, oil of cloves was used on otoliths which did not clear sufficiently in oil of wintergreen and actually proved to be a much more effective clearing agent. The otoliths were examined under a dissecting microscope with reflected light against a black background. The annuli appear as dark, translucent bands alternating with light or opaque zones. The distance from the focus to each annulus and to the edge of the otolith was measured with an ocular micrometer at a magnification of 20×.

Ages were determined by counting annuli for 92 fish collected in November and December 1963 and 61 fish collected from April through June 1964. Five age groups were established and designated as 0, I, II, III, and IV. These indicate the number of annuli, and in all cases there was growth beyond the last annulus. The large amount of growth beyond the last annulus in April–June otoliths suggests that annulus formation occurs early in the spring.

Length-frequency distributions were prepared for 1,223 sculpins from the April–June collection and 475 sculpins from the November–December collection. Comparisons of these distributions with the range in lengths of fish aged by the otolith method illustrate the difficulties involved in identification of the year classes from multimodal distributions (Figure 1). The April–June collection shows modes at 38, 53, 64, and 84 mm, which would indicate age groups I through IV, respectively. The modes at 53, 64, and 84 mm correspond most closely to mean lengths at capture for age groups I, II, and IV (Table 5). There is no mode corresponding with the mean for age group III, but the distinct mode at 38 would appear to best represent age group I. Comparisons of length-frequency modes with mean length at capture for November–December samples (Table 6) adequately reflect age group 0. However, modes at 51, 56, 61, and 73 mm do not correlate well with mean lengths of the remaining age groups. Because of the wide length range for fish of the same age group, the length-frequency method appears very inaccurate for assigning ages to individual specimens, except possibly the age group 0 fish.

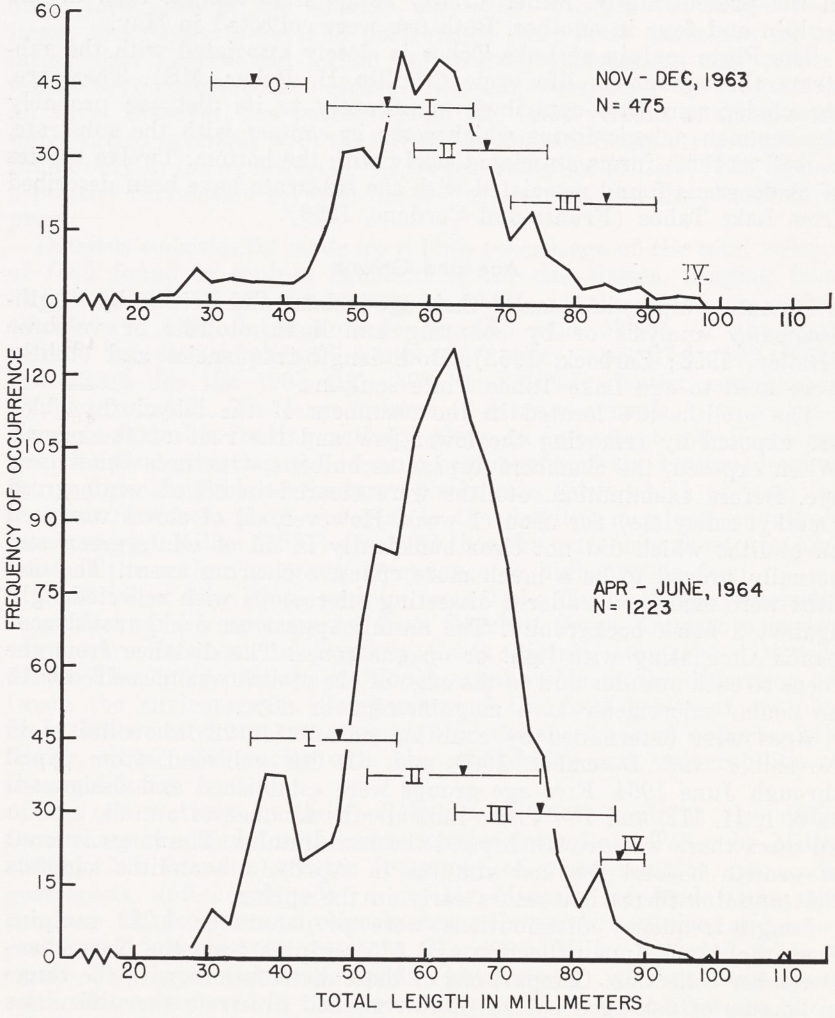

FIGURE 1—Length-frequency analysis of two collections of Lake Tahoe Piute sculpins compared with the range in length of age groups determined by counting annuli on otoliths. Wedges represent mean lengths of the age groups.

TABLE 5

Lengths at Capture, Calculated Lengths, and Increments of Growth of Lake Tahoe Piute Sculpins Collected in April–June 1964

Age group	Number of fish	Mean total length at capture* (mm)	Mean calculated total length at end of year of life (mm)			
			1	2	3	4
O						
I	12	48.4 (36–56)	35.6	--	--	--
II	36	65.1 (53–76)	32.5	49.0	--	--
III	11	75.5 (64–86)	27.1	46.6	57.7	--
IV	2	86.5	25.5	41.0	57.0	70.5
Total number	61					
Weighted mean total length (mm)			31.5	47.6	57.6	70.5
Mean annual increment (mm)			31.5	16.1	10.0	12.9
Number of fish			61	49	13	2

* Range in parentheses.

TABLE 6

Lengths at Capture, Calculated Lengths, and Increments of Growth of Lake Tahoe Piute Sculpins Collected in November–December 1963

Age group	Number of fish	Mean total length at capture* (mm)	Mean calculated total length at end of year of life (mm)			
			1	2	3	4
O	4	35.5 (30–43)	--	--	--	--
I	44	53.7 (46–66)	34.7	--	--	--
II	33	67.6 (58–76)	31.7	49.1	--	--
III	10	83.8 (71–91)	33.2	49.9	66.0	--
IV	1	97.0	23.0	35.0	52.0	69.0
Total number	92					
Weighted mean total length (mm)			33.3	48.9	64.7	69.0
Mean annual increment (mm)			33.3	15.6	15.8	4.3
Number of fish			88	44	11	1

* Range in parentheses.

The sculpin body length-otolith radius relationship was determined for 168 sculpins from the combined November–December and April–June collections. The scattergram of these data approximates a linear relationship between total body length and otolith radius (Figure 2). The straight line fitted by least squares to these data is represented by the equation $L = 13.40 + 1.55R$, where L is the length in mm and R is the enlarged anterior otolith radius in ocular micrometer units measured at a magnification of 20×.

Growth was back-calculated by the nomographic method of Carlander and Smith (1944). Back-calculated lengths for a given age group approximated lengths at capture for corresponding age groups, and back-calculated lengths for the two collections were very similar (Tables 5 and 6). This tended to corroborate the reliability of the

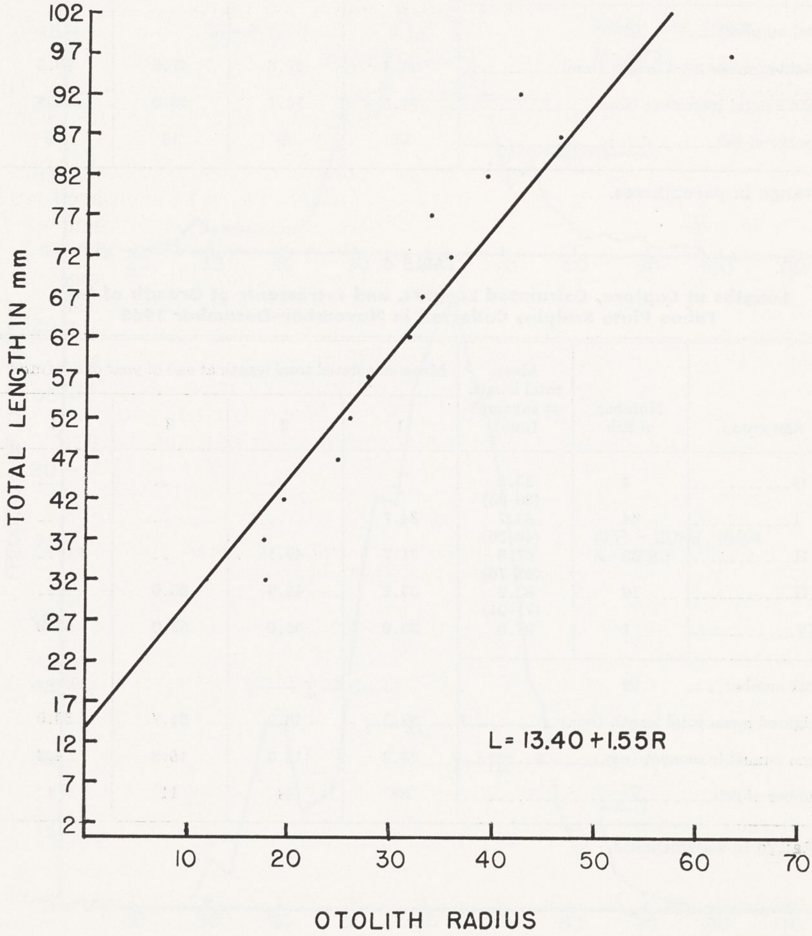

FIGURE 2—Linear regression of the total length-otolith radius relationship for 168 Lake Tahoe Piute sculpins. Dots represent the means of the otolith radius lengths for each of the midpoints of the length classes.

age assessments. However, Lee's phenomenon was shown by the progressive decrease in calculated lengths in successively older fish. Lee's phenomenon appeared in every year class for both the November–December and April–June collections. This made the back-calculated lengths from older fish smaller than back-calculated lengths from younger fish for corresponding age groups.

In the November–December collection (Table 6), the length at capture for age group 0 was closely approximated by the mean calculated length of the age group I fish for the end of the first year of life. Where sample sizes were adequate, this same general agreement was found for the remaining age groups and for fish from the April–June collection (Table 5). The difference in mean total lengths at capture for fish of a given age group between the two periods represents the approximate length increment between November–December and April–June (Tables 5 and 6). Thus, the 0 age group fish grew from about 35.5 mm in November–December to 48.4 in April–June; age group I fish grew from 53.7 to 65.1; and age group II fish grew from 67.6 to 75.5. Except for differences due to sample variation, the difference in size between fall and spring collections suggests that most of the annual growth occurs in the spring and early summer.

Age and growth data presented by Jones (1954) and Dietsch (1950) for Piute sculpins from Sagehen Creek, California, were compared with data for Tahoe sculpins (Table 7). There was very close agreement in mean lengths for all but age group 0 in the November–December collection and age group I in the April–June collection. Tahoe specimens appeared significantly larger than Sagehen specimens at these ages. The small number of fish used in the Tahoe sample could account for these differences, however. Although differences for the older age groups are small, Tahoe sculpins were generally larger at a given age than fish of the same age from Sagehen Creek. No 5-year-old fish were aged but some of the largest fish shown in the length-frequency distribution may have been 5-year-olds (Figure 1).

TABLE 7

Lengths at Capture of Lake Tahoe Piute Sculpins Compared with Sculpins from Sagehen Creek (TL in mm) *

Age group	Lake Tahoe (Nov.–Dec.)	Sagehen Creek Jones, 1954 (Oct.–Dec.)	Sagehen Creek Dietsch, 1950 (Oct.–Nov.)	Lake Tahoe (Apr.–June)	Sagehen Creek Jones, 1954 (May–June)
O	35.5	26.3	26–30	--	--
I	53.7	53.8	46–50	48.4	28.3
II	67.6	--	71–75	65.1	65.3
III	83.8	82.5	--	75.5	72.1
IV	97.0	93.0	--	86.5	85.1
V	--	--	--	--	97.0

* Ages for Lake Tahoe fish were determined by examination of otoliths, whereas ages for Sagehen Creek fish were from length-frequency analysis.

Length-Weight Relationship

The relationship between length and weight was derived from all 851 specimens, males and females combined. The collection was condensed into 23 size groups of 5 mm each. The midpoint of each group was used as the mean length of that group and the mean weight for each group was derived. These values were used to determine the length-weight relationship according to the equation $W = aL^n$, where W = weight in g, L = TL in mm, and n and a are constants.

The length-weight relationship in logarithmic form is log W = —5.244 + 3.166 log L. The curve plotted from calculated weights derived from the length-weight equation closely parallels the empirical length-weight data for size groups from 5 to 102 mm (Figure 3). For size groups larger than 102 mm there is an obvious difference between

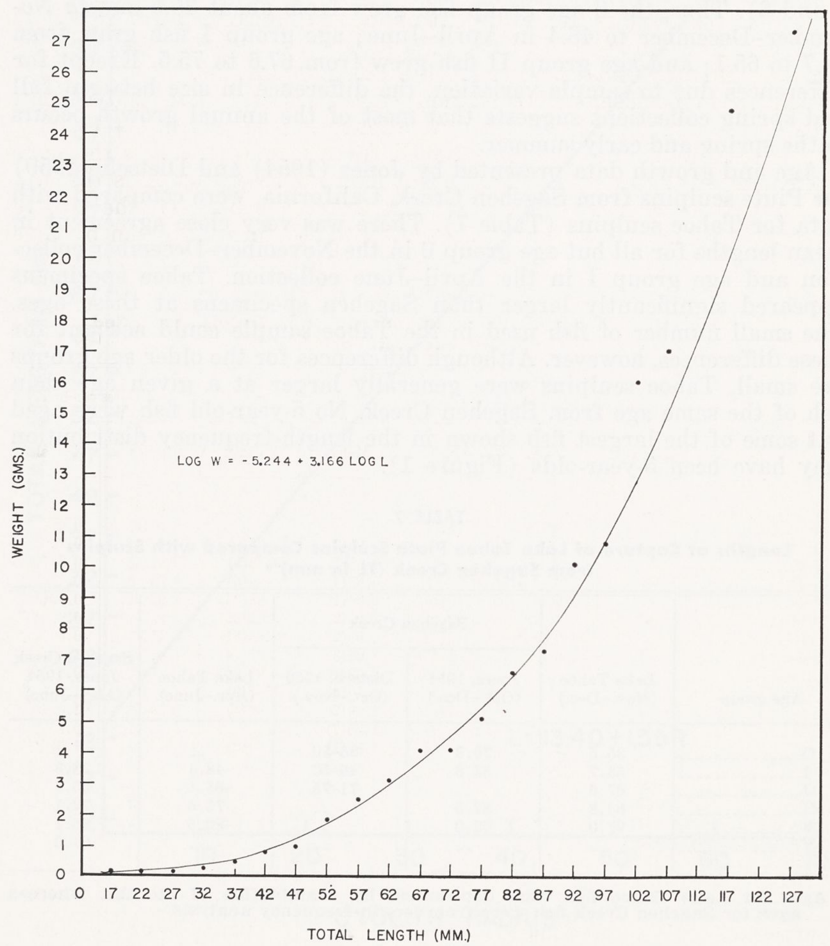

FIGURE 3—Length-weight relationship of the Lake Tahoe Piute sculpin (851 specimens). The line was drawn from the calculated length-weight relationship. Dots represent the mean weight for midpoints of the length classes.

empirical and calculated weights. This may result from a change in body form of larger sculpins or may be due to small sample size. The relationship between body form and length is considered again in the next section.

Coefficient of Condition

The coefficient of condition was computed from the equation: $K = \frac{100,000\ W}{L^3}$, where W = weight in g and L = TL in mm. Because the coefficient of condition can vary with a number of environmental and biological factors, the data were stratified by sex, body length, collection site, and season.

The mean K values for pooled data are 1.05 for 417 males and 0.99 for 382 females. Although the value for males is about 6% greater than the value for females, this difference is not significant (t-test, $P > .05$). The largest K value for males is 1.56 in the 115–119-mm class, and the largest value for females is 1.34 in the 125–129-mm class.

The mean coefficent of condition varies directly with body length (Table 8). The length-condition relationship is $Y = 0.804 + 0.0031X$ for females and $Y = 0.650 + 0.0063X$ for males, where Y is the mean coefficient of condition for the various length classes and X is the midpoint of these classes (Figure 4). The difference between the two regression coefficients was tested according to the formula given by Steel

TABLE 8

Coefficients of Condition (K) of Lake Tahoe Piute Sculpins Stratified by Size, Collection Site, and Sex *

Length class (mm)	Midpoint	South shore		North shore		Both sites combined	
		Males	Females	Males	Females	Males	Females
20–24	22	0.86(3)	--	--	--	0.86(3)	--
25–29	27	0.99(2)	0.95(1)	--	--	0.99(2)	0.95(1)
30–34	32	0.92(9)	--	0.90(2)	0.76(2)	0.91(11)	0.76(2)
35–39	37	0.89(6)	1.00(2)	0.93(7)	0.86(2)	0.91(13)	0.93(4)
40–44	42	1.00(14)	0.96(8)	0.82(4)	0.99(5)	0.96(18)	0.97(13)
45–49	47	0.90(7)	0.89(14)	0.94(13)	0.93(22)	0.92(20)	0.92(36)
50–54	52	0.95(15)	0.98(17)	0.91(27)	0.99(26)	0.92(42)	0.99(43)
55–59	57	1.06(13)	0.99(23)	0.99(28)	0.95(51)	1.01(41)	0.96(74)
60–64	62	1.00(28)	1.05(27)	1.03(31)	1.01(44)	1.01(59)	1.03(71)
65–69	67	1.04(13)	0.90(25)	1.09(40)	0.99(34)	1.07(53)	0.97(59)
70–74	72	1.13(15)	1.04(24)	1.10(47)	1.05(9)	1.11(62)	1.04(33)
75–79	77	1.18(18)	1.07(17)	1.09(20)	1.06(4)	1.14(38)	1.07(21)
80–84	82	1.19(25)	0.95(5)	1.26(7)	--	1.20(32)	0.95(5)
85–89	87	1.15(14)	1.01(11)	1.37(1)	1.01(2)	1.14(15)	1.01(13)
90–94	92	1.25(6)	1.15(6)	--	--	1.25(6)	1.15(6)
95–99	97	--	--	--	--	--	--
100–104	102	1.53(1)	--	--	--	1.53(1)	--
105–109	107	--	--	--	--	--	--
110–114	112	--	--	--	--	--	--
115–119	117	1.56(1)	--	--	--	1.56(1)	--
120–124	122	--	--	--	--	--	--
125–129	127	--	--	--	1.34(1)	--	1.34(1)
Total number		190	180	227	202	417	382
Weighted mean K		1.07	1.02	1.04	0.98	1.05	0.99

* Number of specimens in parentheses.

and Torrie (1960, p. 173). The computed t value ($t_{.01}$, 791 d.f.) is significant at the 1% level, requiring that the relationship between body length and coefficient of condition be presented separately for males and females. The K values are similar for males and females to about 65 mm, but then the values for males increase more rapidly. The difference between the mean K values for males and females larger than 65 mm is statistically significant (t-test, $P < .05$). Two-year-olds have a mean length of about 65 mm, indicating that significant sexual dimorphism occurs at this age. Although it is generally assumed that the basic difference in body shape between the sexes is related to gonadal development, a change in body configuration makes mature males broader and heavier-bodied than the more streamlined mature females. There were no obvious differences in condition between individuals from the north and south ends of the lake.

A seasonal fluctuation in K values was observed in both sexes (Figure 5). For females this is apparently directly related to gonadal development. The K values for females were lowest in July and highest in April, May, and June. However, in the males, the K values were lowest from late summer through early winter and highest from March through July. The K values for males declined well past the spawning season. This suggests that their fluctuations in condition may be related to

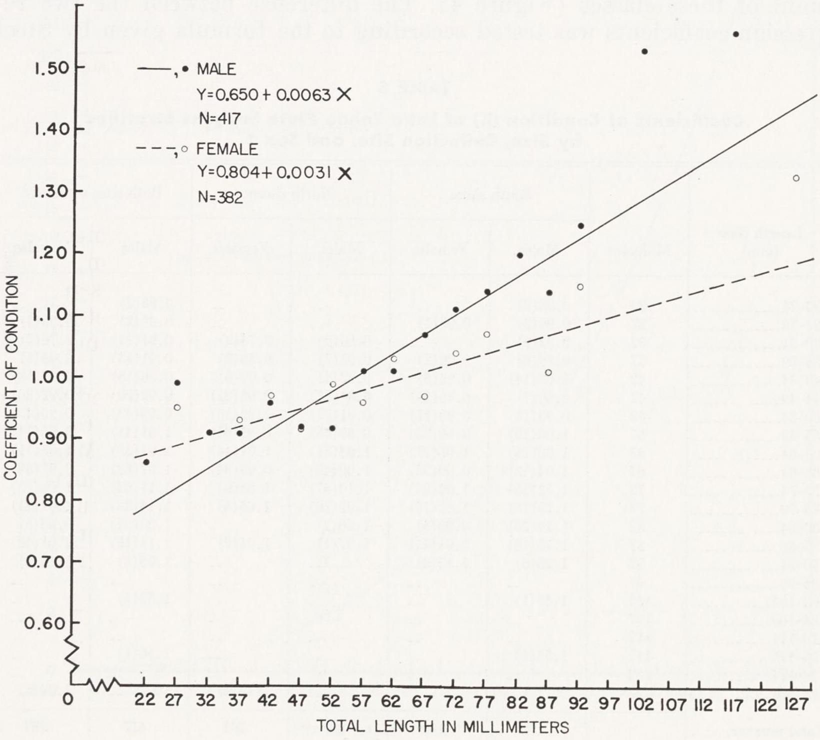

FIGURE 4—Comparison of coefficient of condition-total length regressions of male and female Lake Tahoe Piute sculpins. Regression equation predicts coefficient of condition (Y) from total length (X).

other factors, possibly the vernal increase in food supply, as revealed by the larger volume of food found in the stomachs in spring and summer compared with fall and winter (Table 3).

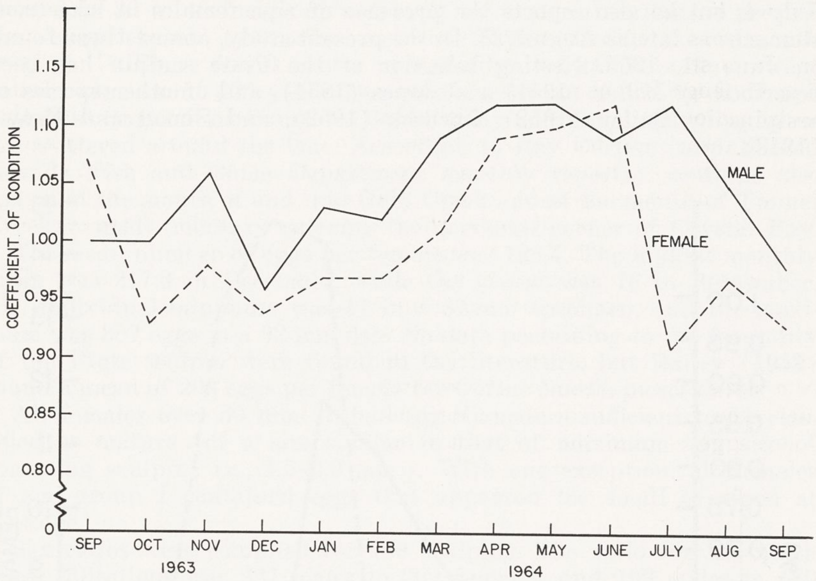

FIGURE 5—Seasonal variation in coefficient of condition of male and female Lake Tahoe Piute sculpins.

Reproduction

The time of spawning of the Piute sculpin was determined from monthly changes in mean egg diameters and computation of the gonadal-body weight ratio, or gonosomatic index. A random sample of 20 eggs was taken from the ovaries of each of 136 fish. Diameters were measured to 0.001 mm. Fecundity was measured by direct count of the total number of eggs from both ovaries.

Low monthly mean gonosomatic indexes for females occurred following spawning and in the fall and winter months (Figure 6). Peak monthly indexes of over 13% for females occurred in April, May, and June. The peak value for males was only 0.86% and it occurred in April. The index for females dropped sharply between June and August, coinciding with a sharp decline in the condition factor during the same interval (Figure 5). Changes in males were of a lower magnitude and preceded similar changes in females by nearly 2 months. Fluctuations in the gonosomatic ratios for males did not correspond with seasonal variations in condition factors. Gonadal development in males apparently exerts little influence on their condition.

Mean diameters of sculpin eggs increased from a low of 0.397 mm in September, corresponding to the lowest monthly gonosomatic index, to a high of 2.104 mm in May and then dropped to 1.503 mm in June. No samples were available for July, but the mean diameter in August was 0.750 mm.

Seasonal changes in gonosomatic ratios, mean egg diameters, and condition factors indicate that the major spawning period of the Piute sculpin in Lake Tahoe during 1964 probably occurred in May and June. Miller (1951) found nests as early as May 7 and as late as July 4, but he also reports the presence of ripe females in lake trout stomachs as late as August 28. In the present study, one nest was found on June 21, 1965. Nesting behavior of the Piute sculpin has been described by Miller (1951) and Jones (1954), and of other species of sculpins by Bailey (1952), Zarbock (1952), and Simon and Brown (1943).

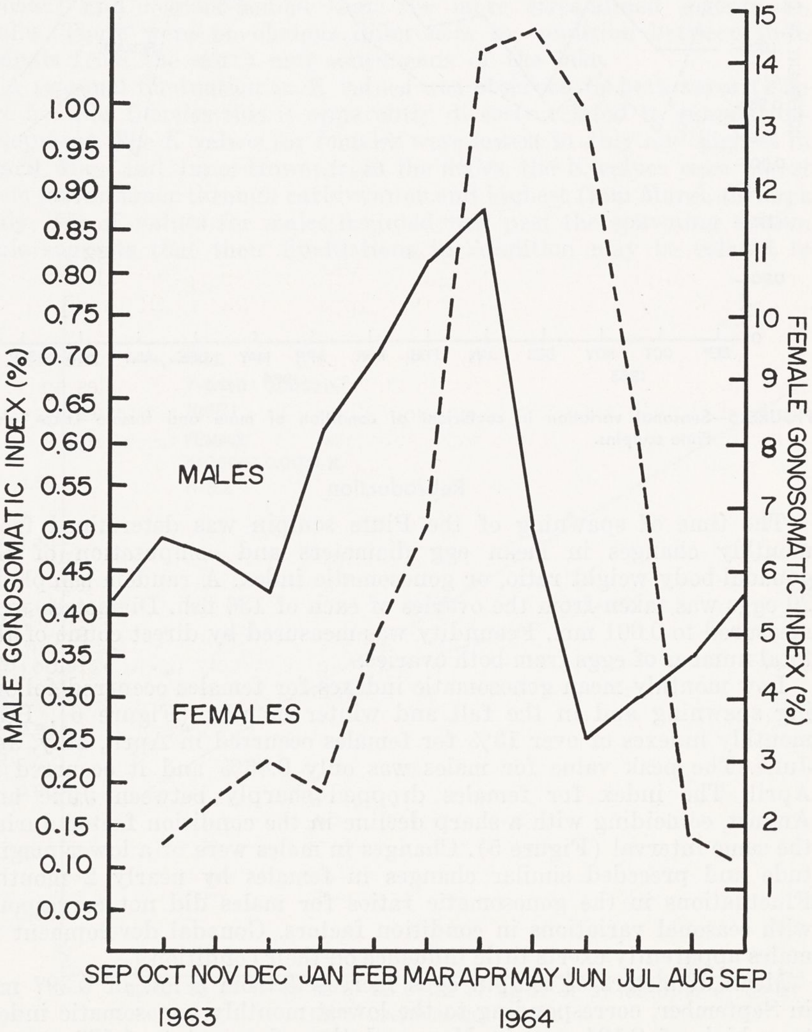

FIGURE 6—Seasonal variation in gonosomatic index (gonad weight ÷ body weight X 100) for male and female Lake Tahoe Piute sculpins.

Miller (1951) located 18 sculpin nests in Lake Tahoe. Eggs were attached in clusters to the ceiling of the nest, "a cave-like aperture under a rock". In all cases, the rocks were free from the substrate, and the floor of the nest was composed of gravel and sand. All nests were located in 30 to 40 inches of water, ". . . in a rather limited area of wave-swept beach two miles east of Taylor Creek at the south end, . . .". Ebert found a nest in a similar habitat in a wave-swept littoral zone about 800 yards long and northwest of the Coast Guard beacon at Sugar Pine Point. No doubt many additional spawning areas are scattered around the lake. According to Ray Corlett (unpublished Nevada Fish and Game Department monthly reports), sculpins also spawn at the mouth of and into Griff Creek and at the mouth of Tunnel Creek, a small tributary entering the northeast corner of Crystal Bay.

The mean number of eggs per female was 123.4. The highest monthly mean was 217.3 in December, while the lowest was 76 in September. The individual minimum was 11 in a 67-mm specimen, and the maximum was 387 eggs in a 92-mm fish. No data pertaining to the fecundity of the Piute sculpin were found in the literature, but Bailey (1952) found a mean of 203 eggs per female for *Cottus bairdii punctulatus*.

All females over 50 mm TL had egg diameters sufficient to be classified as mature (of a size similar to that of maximum egg size of spawning sculpin; i.e., 1.5–2.0 mm.). With one exception, all females of age group I contained eggs that appeared too small to ripen at that age.

Sex ratios were compiled for 799 sculpins. The ratio for the north shore collections was 227 males to 202 females, and 190 males to 180 females for the south shore collections. The overall ratio was 417 males to 382 females. These ratios were subjected to chi-square analysis and the differences from a 1 : 1 ratio were not significant.

Parasites

During gross examination of 851 sculpins, three species of internal parasites were encountered (Table 9). To determine if the degree of infestation varied by lake area, results were analyzed by three areas: north shore, south shore, and the west shore and Emerald Bay. Sculpins caught in the first two areas were taken in relatively deep water (100 to 400 ft), while those caught in the remaining area were taken in shallow water (1 to 5 ft).

TABLE 9

Percentage Infestation of Three Types of Parasites on Piute Sculpins from Three Localities in Lake Tahoe

Locality*	Protozoan *Plistophora* sp.	Trematode metacercaria	Cestode *Ligula* sp.
North shore (456)	7.5%	0.2%	0.7%
South shore (370)	5.7%	24.0%	1.1%
West shore and Emerald Bay (25)	0.0%	0.0%	12.0%
Total collection (851)	6.5%	10.6%	1.2%

* Number of fish examined in parentheses.

White spindle-shaped cysts were found in the abdominal wall of 6.5% of all fish examined. One to several cysts approximately 0.4 to 0.9 mm long were present between the skin and the muscles of the body wall of infected fish. This parasite was a microsporidian (Class Cnidosporidia: Order Microsporida) of the genus *Plistophora*. It occurred at approximately the same intensity at both the north and south ends of the lake. Factors related to depth or small sample size might account for the lack of infection of fish from Emerald Bay and the west shore.

A large plerocercoid larva of the genus *Ligula* (Class Cestoidea, Order Pseudophyllidea) occurred in the abdominal cavity with a frequency of 1.2% for all fish examined. These tapeworms were quite large in relation to their host and were coiled about the digestive tract. Usually the length of the worm was from two-thirds to three-fourths the length of the sculpin. There was an interesting difference in the degree of infection for the three areas. About 12.0% of the sculpins from Emerald Bay and the west shore contained *Ligula*, compared with only about a 1% occurrence in sculpins from the north and south shore areas. The higher infestation of fish from shallow water might be due to the presence of fish-eating birds in such areas.

The third type of parasite occurred as small cysts in the liver. These appeared to be metacercaria of a strigeoid trematode. They occurred in 24.0% of the sculpins from the south shore and only 0.2% of the specimens from the north shore. The most obvious habitat difference between the north and south areas, which might account for the higher incidence of liver cysts, is the presence of large marshy areas at the mouths of the Upper Truckee River and Taylor Creek. Such marshes are much less extensive in the north area. Again, the lack of infection of fish from Emerald Bay and the west shore is probably related to either depth or small sample size.

DISCUSSION

Sculpins are an important link in the food web of the major game fishes of Lake Tahoe (Lake Tahoe Fisheries Study, unpubl. data). They occurred in about 30% of the 1,099 lake trout stomachs which contained food. This was true for all sizes of lake trout, except that none was found in lake trout smaller than 5.0 inches FL. In terms of percentage of total volume, they were relatively more important to small lake trout. Stomachs of lake trout in the 5.0- to 9.9-inch size group contained 56.0% sculpins by volume, 10.0- to 14.9-inch fish 42.5%, 15.0- to 19.9-inch fish 22.1%, and 20.0-inch and larger fish only 4.8%. They were relatively unimportant in the diet of rainbow trout (*Salmo gairdnerii*), occurring in only 1.6% of the 702 stomachs containing food. However, they were very common in the diet of 66 brown trout (*Salmo trutta*) stomachs with food, occurring in 37.9% of them.

Because of their role in the diet of the game fishes, their widespread distribution and abundance (Phillip H. Baker, MS), and their omnivorous food habits, sculpins occupy a key role in the ecology of Lake Tahoe. As a forage fish, they convert a great diversity of bottom-dwelling invertebrates and detritus into a form readily available to piscivorous game fishes, notably the lake trout. Significantly, it is the lake trout that supports the Lake Tahoe sport fishery (Cordone and Frantz, 1966).

ACKNOWLEDGMENTS

The Lake Tahoe Fisheries Study made available the collections on which this study is based, and appreciation is extended to the many men who were involved in that work. Special credit is due Project Leader Almo J. Cordone and Jack A. Hanson and Phillip H. Baker for their assistance and advice. Appreciation is expressed to the Zoology Department of Kansas State University for laboratory space and equipment.

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DIVISION OF NATURAL SCIENCES AND MATHEMATICS

March 28, 1968

Dr. Robert Behnke
Colorado Cooperative Fisheries Unit
Colorado State University
Fort Collins, Colorado 80521

Dear Dr. Behnke:

Enclosed is a copy of some data taken on fish collected in the Uncompagre River north of Montrose. Please check gill raker numbers as it does not agree with the photocopy of one undergraduate's work you sent me. I measured a lot of things which may not be of any value to us just to get the feel of the fish.

We found no "Coarse Scaled Flammelmouths" down there, but on the second Uncompagre collection, there seemed to be a bunch of Blue-heads with odd looking heads. Please look at that data.

I have disposed of the fish which had rotted. It was a shame, but I feel confident that we can collect many more out of Blue Mesa. The river is open now and the reservoir will open very soon, no later than 1½ weeks according to Bill Wiltzius. Bill has also provided us with the use of three more gill nets so we'll be able to do a lot of collecting, and soon.

Concerning admission to your work, are all my credentials in, and is there anything else I need to do? I hope to be able to bring some "Coarse Sclaed Flannelmouths" up in a week or two. I look forward to seeing you then.

Thank you.

Sincerely yours,

Bill Middleton

Bill Middleton
Graduate Assistant
Department of Biology

WHM:nlh

also, the Gunnison paper just came out with a letter something on suckers, thought you might get a kick out of it.