CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 55 APRIL 1969 NUMBER 2

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VOLUME 55 APRIL 1969 NUMBER 2

Published Quarterly by
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

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ERRATA

Chadwick, Harold K. Mortality rates in the California striped bass population. 54 (4) : 228–246. 1968.

In equation 8 on page 233 the superscript in the first term of the denominator should range from 0 to (i − 2) instead of to (i − 1).

In equation 9 on page 233 the factor after the first = sign should be:

$$\frac{\hat{M}_{(i-1)}^{(0+\ldots+(i-2))}}{(\hat{M}_{(i-1)}^{(0+\ldots+(i-2))} + M_{(i-1)})}$$

Calif. Fish and Game, 55 (2): 100–120. 1969.

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

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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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[1] Accepted for publication May 1968. This work was performed as part of Dingell-Johnson Projects California F-21-R and Nevada F-15-R, "Lake Tahoe Fisheries Study", supported by Federal Aid to Fish Restoration funds.

[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	4.15	3.04
Gastropoda	4.22	5.77	3.47	3.73	0.02	9.33
Pelecypoda (*Pisidium* 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	8.14	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	1.04	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).

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	1.51	2.82	13.07	13.12	1.67	1.10	2.24	2.36	1.20	0.79	1.65	7.32
Gastropoda	8.27	7.42	1.13	2.67	7.00	2.09	1.33	1.00	27.52	1.17		0.11
Pelecypoda (*Pisidium* sp.)	0.75	1.06	0.57	1.70	1.00	1.00	1.00	1.67	0.05	0.02		0.04
Cladocera	30.07	25.11	18.18	11.41	3.16	2.97	3.00	3.33	0.29	1.26	0.12	0.12
Ostracoda (*Candona tahoensis*)	46.62	55.12	50.57	36.71	1.67	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.	1.51	3.81	39.21	78.52	12.06	5.56	5.77	11.85	1.82	1.34	1.88	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.)	11.30	35.69	19.43	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	38.61	37.58	6.23	2.02	3.73	2.67	1.23	1.51	2.24	1.86
Chironomid pupae	9.77	12.01	9.66	1.52	1.72	2.94	2.33	1.14	0.28	0.72	0.13	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	0.015
Empty (% of total)	10.73	5.67	2.76	2.62								
No. stomachs examined	140	286	179	155								

* In stomachs containing them.

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	4.09
Gastropoda	5.43	4.76	5.68	6.53	6.29	1.11	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	0.19	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		1.11	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	1.05	2.75	2.25	13.96	2.60	3.43	1.98	3.11
Diptera												
Chironomid larvae	76.74	20.25	56.03	22.61	3.27	1.56	1.52	5.17	2.53	1.20	0.61	4.65
Chironomid pupae	39.54	3.68	7.04	1.51	2.60	1.80	1.33	2.27	0.13	0.83		0.14
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	7.71	0.71		3.16	3.92	1.92	3.60	4.66	5.02	1.41	0.53
Charophyceae (*Chara* sp.)	0.79	0.61	0.71	2.02						0.03	0.17	
Chlorophyceae	14.54	50.31	53.19	35.17					17.39	20.12	7.85	8.31
Detritus									38.19	17.13	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	1.78								
No. stomachs examined	163	281	198	144								

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	10–40	41–61	62–81	82–127
Oligochaeta	1.96	6.61	10.41	7.14	1.00	1.35	2.51	2.00	0.65	4.61	5.11	[illegible]
Gastropoda	1.96	1.72	6.84	12.86	1.00	6.00	2.28	7.56		0.30	1.06	21.00
Pelecypoda (*Pisidium* sp.)		1.15	0.60	2.86		1.25	1.50	1.00		0.12	0.03	[illegible]
Cladocera	25.49	23.57	19.91	25.11	3.00	3.42	2.90	3.78	0.97	0.5.	[illegible]	0.18
Ostracoda (*Candona tahoensis*)	58.82	57.47	11.94	32.89	9.51	6.61	3.78	3.87	20.00	2.78	0.50	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	[illegible]
Hyallela sp.	3.92	2.01	1.19		1.50	1.86	2.00		0.65	0.13	0.05	
Acari		0.58	1.19	2.86		1.00	1.00	1.00				
Plecoptera (*Capnia* sp.)	27.45	31.19	32.72	25.11	4.71	2.83	3.62	3.00	20.00	1.74	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	3.81	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				1.28				1.33				21.20
Musci (moss capsules)		6.61	13.99	7.14	--	3.70	3.26	1.60		3.53	3.60	2.27
Charophyceae (*Chara* sp.)		--	0.99	2.86							0.02	0.13
Chlorophyceae	3.92	11.82	51.76	59.14	--					9.33	21.80	1.93
Detritus					--				15.75	59.00	51.45	31.50
Mean volume of food (ml)									0.061	0.025	0.052	0.118
Empty (% of total)	12.07	3.06	6.11	6.67								
No. stomachs examined	58	359	359	7								

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.

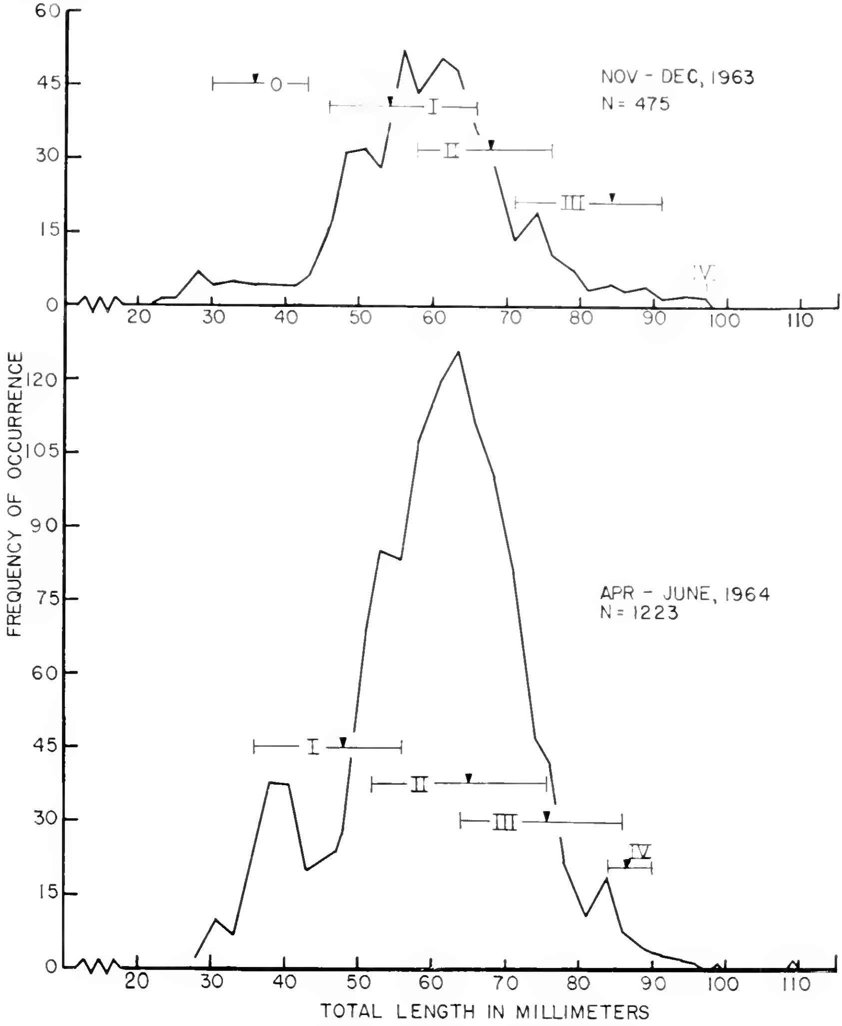

FIGURE 1—Length-frequency analysis of two collections of Lake Tahoe Piute sculpins compared with the range in length of age groups determined by counting annuli on otoliths. Wedges represent mean lengths of the age groups.

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

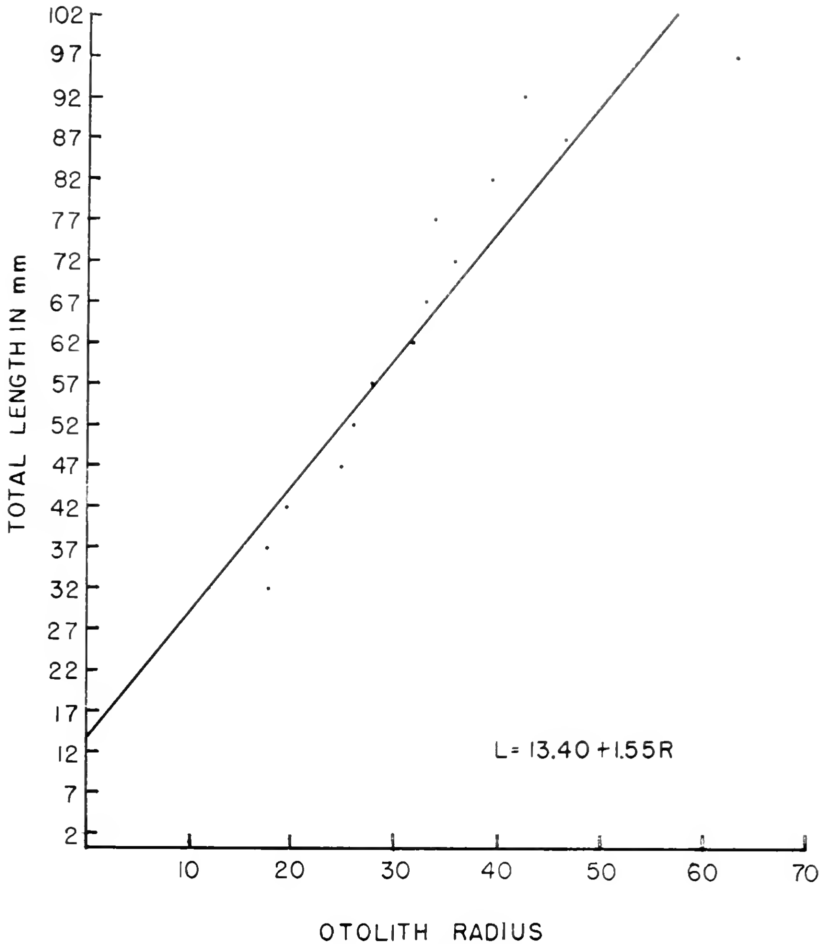

FIGURE 2—Linear regression of the total length-otolith radius relationship for 168 Lake Tahoe Piute sculpins. Dots represent the means of the otolith radius lengths for each of the midpoints of the length classes.

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)
0	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

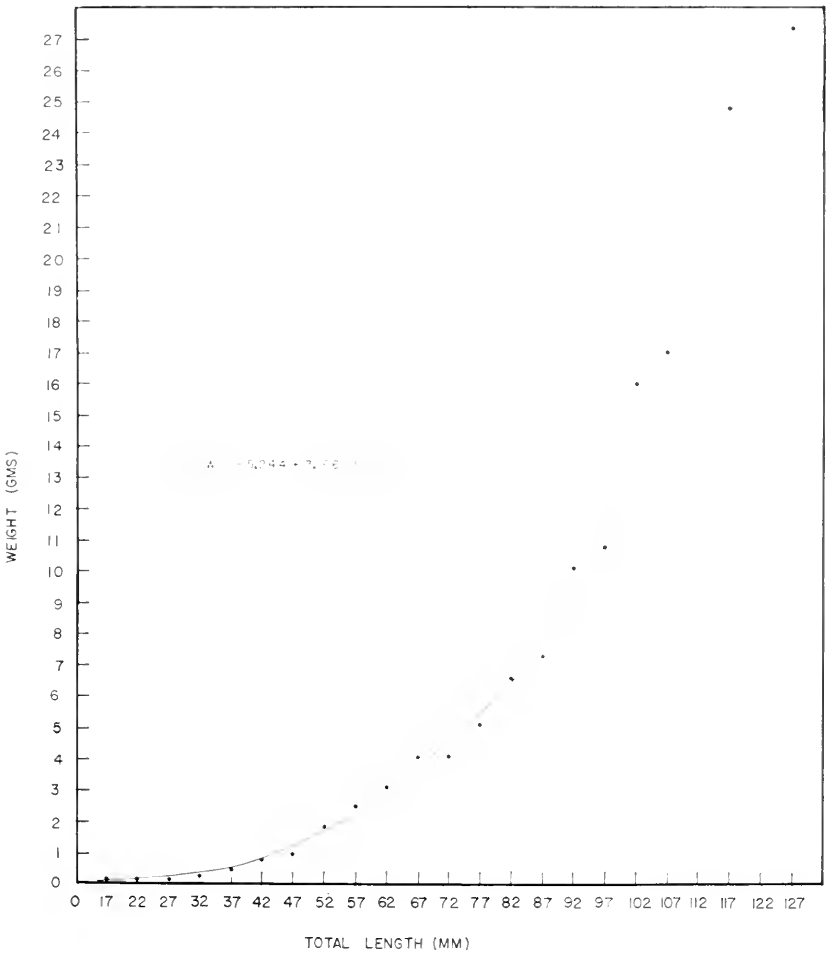

FIGURE 3—Length-weight relationship of the Lake Tahoe Piute sculpin (851 specimens). The line was drawn from the calculated length-weight relationship. Dots represent the mean weight for midpoints of the length classes.

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 coefficient 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 Males	South shore Females	North shore Males	North shore Females	Both sites combined Males	Both sites combined 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)	0.9[illegible](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	0.9[illegible](7)	0.8[illegible](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(1[illegible])	0.99(2[illegible])	0.99(28)	0.95(51)	1.01(41)	0.96(74)
60–64	62	1.00(28)	1.05(27)	1.0[illegible](31)	1.01(44)	1.01(59)	1.03(71)
65–69	67	1.04(1[illegible])	0.9[illegible](25)	1.09(40)	0.99(34)	1.07(53)	0.97(59)
70–74	72	1.1[illegible](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

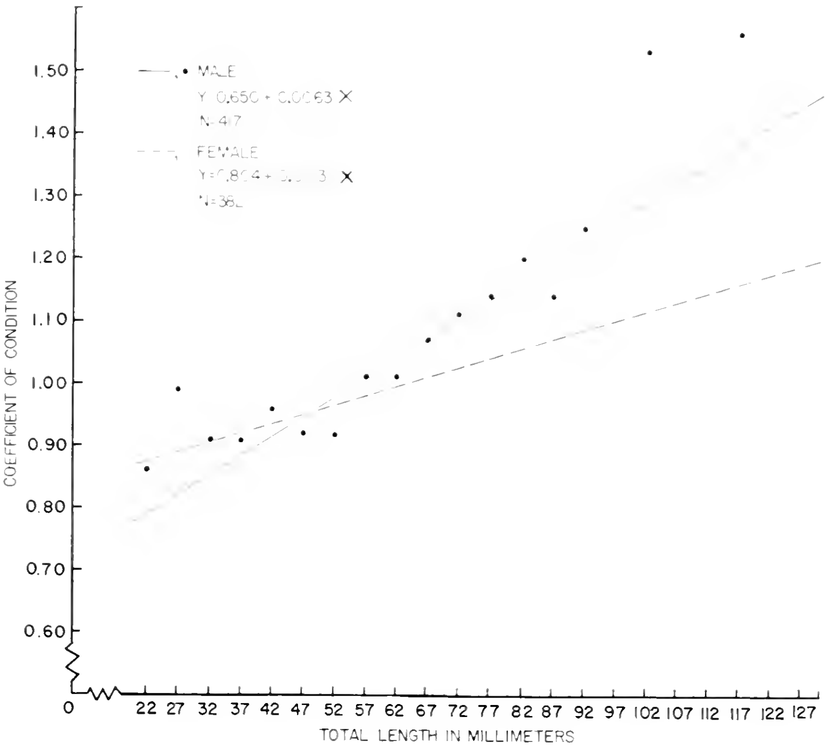

FIGURE 4—Comparison of coefficient of condition-total length regressions of male and female Lake Tahoe Piute sculpins. Regression equation predicts coefficient of condition (Y) from total length (X).

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).

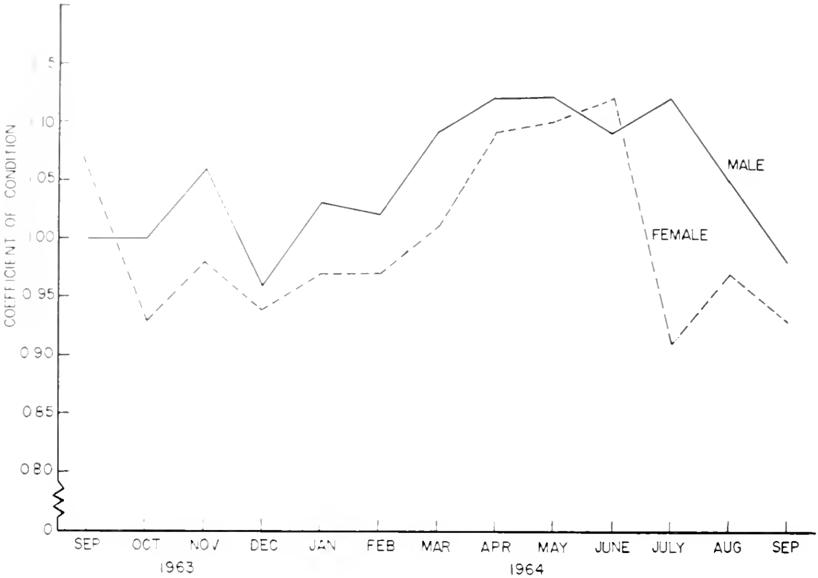

FIGURE 5—Seasonal variation in coefficient of condition of male and female Lake Tahoe Piute sculpins.

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).

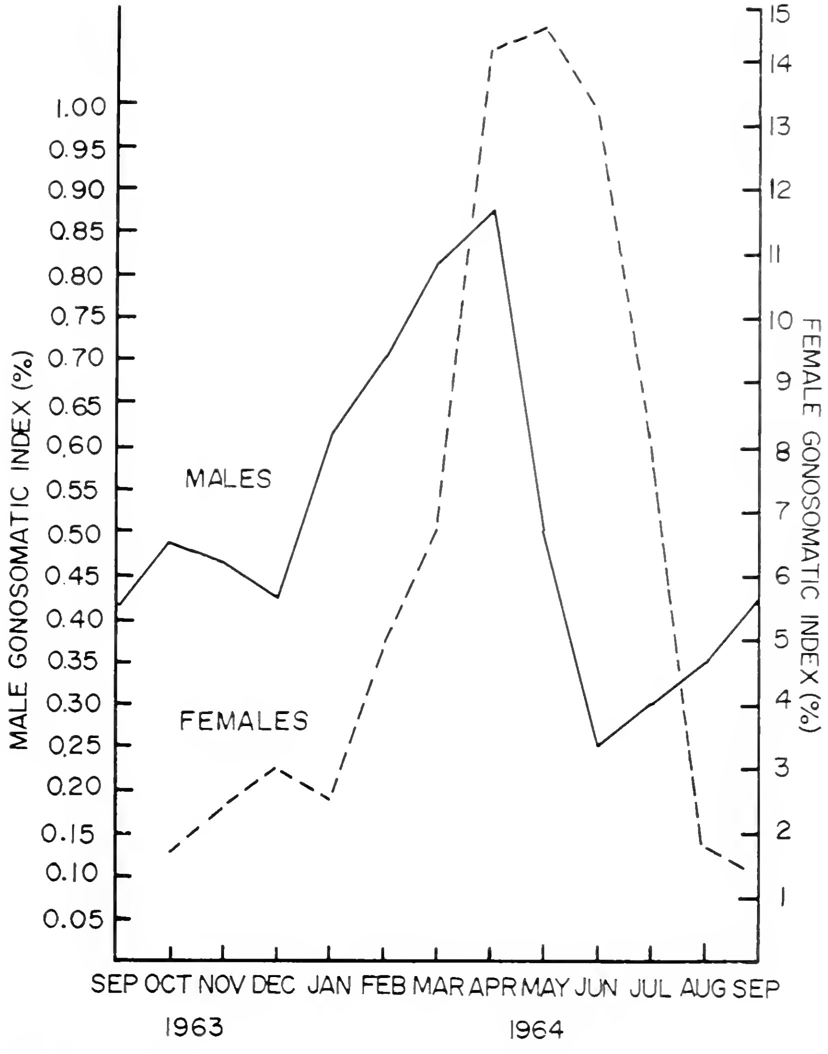

FIGURE 6—Seasonal variation in gonosomatic index (gonad weight ÷ body weight X 100) for male and female Lake Tahoe Piute sculpins.

[illegible] Lake Tahoe. Eggs were [illegible] a cave-like aperture [illegible] from the substrate, and [illegible] sand. All nests were [illegible] rather limited area of [illegible] Trout Creek at the south [illegible] in a wave-swept [illegible] of the Coast Guard [illegible] spawning areas [illegible] Roy Calhoun (unpublished [illegible]) reports sculpins also [illegible] north of Tunnel [illegible] of Crystal Bay. [illegible]. The highest monthly [illegible] was 70 in September. [illegible] and the maxi- [illegible] the fecundity [illegible] Bailey (1952) [illegible] *punctulatus*.

[illegible] sufficient to be clas- [illegible] maximum egg size of [illegible]. With one exception, all females [illegible] small to ripen at [illegible].

[illegible]. The ratio for the north [illegible] 130 males to 180 [illegible] was 417 males [illegible] analysis and [illegible].

Parasites

[illegible] species of internal [illegible] if the degree of [illegible] by three areas: [illegible] and Emerald Bay. Sculpins [illegible] deep water (100 [illegible] were taken in [illegible].

TABLE 9

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

[illegible]	[illegible]	[illegible]	Cestode *Ligula* sp.
[illegible]	[illegible]	[illegible]	0.7[illegible]
[illegible]	[illegible]	24.[illegible]	1.1[illegible]
[illegible]	[illegible]	0.[illegible]	12.0[illegible]
[illegible]	[illegible]	20.[illegible]	1.2[illegible]

[illegible] in parentheses.

White spindles [illegible] of all fish examined. [illegible] long were present between [illegible] infected fish. [illegible] Order Microsporida [illegible] mately the same intensity [illegible] Factors related to [illegible] of infection of fish from Emerald Bay [illegible]

A large [illegible] Order Pseudophyllidea [illegible] quency of 12[illegible] in relation [illegible] Usually [illegible] length of [illegible] of infection [illegible] Emerald Bay [illegible] about [illegible] areas. [illegible] the presence of [illegible]

The [illegible] These appeared [illegible] curred in 24[illegible] of the specimens [illegible] ence between [illegible] Higher incidence [illegible] the [illegible] infection of fish from Emerald Bay [illegible] lated to [illegible]

DISCUSSION

Sculpins are an important [illegible] fishes of Lake Tahoe [illegible] They occurred in [illegible] contained food. This [illegible] none was found in lake trout [illegible] In terms of percentage of total volume [illegible] small lake trout [illegible] size group contained 50[illegible] sculpins by volume; 10[illegible] to 14.9-inch fish 42.5[illegible]; 15.0- to 19.9-inch fish 22.1[illegible] and 20.0-inch and larger fish only 4.8[illegible]. They were relatively unimportant in the diet of rainbow trout (*Salmo gairdneri*), occurring in only 1[illegible] of the 7[illegible]2 stomachs containing food. However, they were very common in the diet of the brown trout (*Salmo trutta*) stomachs with food, occurring in 37[illegible] 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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OBSERVATIONS ON THE BIOLOGY AND BEHAVIOR OF THE CALIFORNIA SPINY LOBSTER, *PANULIRUS INTERRUPTUS* (RANDALL)[1]

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Employing scuba diving techniques, California spiny lobsters, *Panulirus interruptus* (Randall), were collected at monthly intervals off San Clemente Island, California (intertidal to depths of 100 ft). A total of 1,553 lobsters was taken from August 1964 to January 1967. Examination of shell and reproductive condition showed that ecdysis occurred in late summer to fall, immediately after completion of the reproductive cycle. Frequency distribution plots of the carapace lengths of 897 male lobsters and 656 females showed modes indicative of year classes. Analysis of these modes yielded annual carapace growth increments of 3.7 mm for males and 4.4 mm for females. Based on collected data, the time required for a California spiny lobster to reach to legal size of 3¼ inches (83 mm) carapace length is approximately 10 and 11 years for females and males respectively. An inshore movement of the population during spring and summer and an offshore movement in fall and winter correlate with seasonal variations in water temperature; however, availability of forage, reproductive condition, suitable habitats, and the degree of subsurface wave action (surge) may be factors in this movement.

INTRODUCTION

Although California's spiny lobster fishery is quite valuable, valid biological data on the species are sorely lacking. Research on the life history and behavior of *P. interruptus* has been sporadic and largely inconclusive. Information on the fishery, other than that obtained by monitoring the commercial catch, is lacking and the single description of the commercial fishery in 1947 (Wilson, 1948) is no longer applicable because of recent changes in gear and fishing techniques. The sport catch is at present still undetermined. If the fishery is to attain a maximum sustainable yield we must have information about the size of the population and its reproductive capacity, the annual recruitment and its availability to the fishery, the catch per unit of effort (both sport and commercial), and the animal's life history and behavior.

The data presented in this paper should clarify and add to existing information concerning this species and point out areas of paucity in biological information to guide future workers.

Section 8252 of the California Fish and Game Code specifies that lobsters may not be taken if their carapace is less than 3¼ inches (83 mm) in length. This paper is an outgrowth of an effort to supply

[1] Accepted for publication May 1968. This work was performed in supplement to Dingell-Johnson Project California F-22-R, "Environmental and Behavioral Studies of Coastal Sport Fishes".

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the Department's Wildlife Protection Branch, Marine Patrol, with information that would enable them to determine the length of a lobster's carapace when only its tail was available for measurement. The biological and behavioral data, while gathered extralimitally, were of major interest to our project work.

METHODS

Employing scuba diving techniques, we collected spiny lobster samples off San Clemente Island, California (intertidal to 100-ft depths) at monthly intervals from August 1964 to January 1967. The animals were kept alive until their return to the California State Fisheries Laboratory, where they were frozen for later detailed examination. After thawing and segregation by sex, the carapace length was recorded for each individual (Figure 1). Shell and reproductive conditions were designated as follows: 1) old hard shell, (a) ready to be plastered (portion of ventral thorax soft, ready to receive sperm "packet"), (b) plastered (sperm "packet" in place), (c) berried (eggs attached to pleopods); 2) old soft shell (ready to be shed); 3) new soft shell (just shed); 4) new hard shell. Shell condition was determined by inspecting it for encrusting organisms and testing its rigidity. At this point, an identifying number tag was attached to each tail. The tails were then separated from the thorax with the same quick wringing-pulling motion used in fresh fish markets. After tail length and weight had been recorded, the entire sample was cooked in boiling water for approximately 8 to 15 min. The tails were then cooled and their respective weights were recorded.

Data concerning the physical habitat were limited to water temperature, type substrate, and depths of capture.

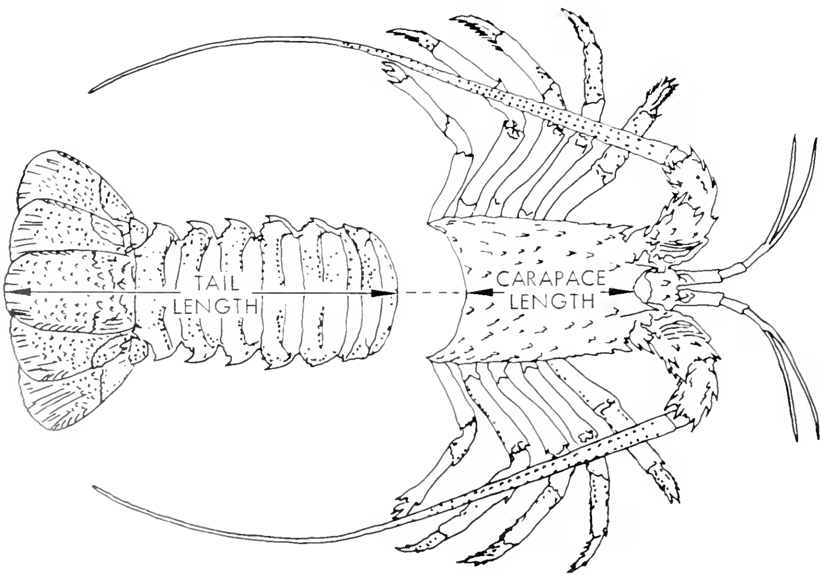

FIGURE 1—Dorsal view of a California spiny lobster, with tail separated, showing measurements taken.

LIFE HISTORY

Molting and Reproductive Cycle

A total of 1,553 lobsters was categorized by sex, shell, and reproductive state. Shell conditions were tabulated by sex and expressed as a percentage of the total number of individuals exhibiting that particular phenomenon that month. Since all females in any reproductive state possess old hard shells, our data concerning these conditions are presented as percentage of the total number of females possessing an old hard shell.

From December to July, male lobsters with old hard shells comprised 82.8 to 100% of each sample (Figure 2). This level of occurrence decreased rapidly through August and September to a low (11.0%) in October. Calcium resorption and subsequent shell softening (old soft shell) was observed from July to October and reached its maximum 19.3%, in the August samples. New soft-shell males were present from June to November, with September and October being the peak months. In those two months, 23.4 and 24.7% of each sample was soft. Individuals with new hard shells were first recorded in June. Their occurrence increased monthly to a maximum of 53.4% in October, then decreased abruptly. None was recorded after January.

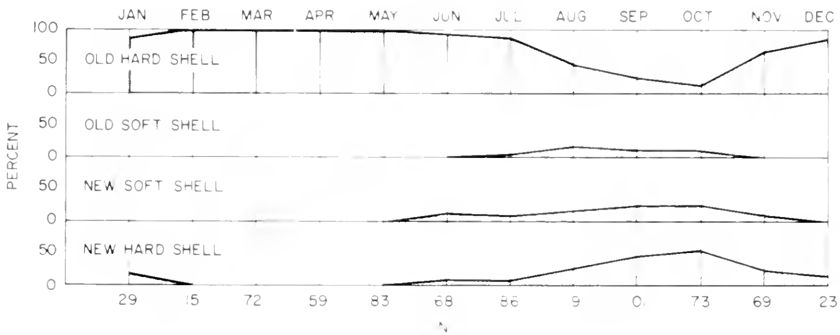

FIGURE 2—Shell conditions of male lobsters, by months, expressed as percentage of the total number of individuals sampled.

Old hard-shell female lobsters were also dominant from December to July, accounting for 97.1% of each sample (Figure 3). As with the males, this rate of occurrence decreased rapidly through August and September, and reached a low of 12.7% in October, then increased in November. Individuals ready to be plastered appeared abruptly in January, encompassing 39.4% of the old hard-shell females, then declined in abundance, accounting for only 8.7% of the May sample.

Plastered females, observed initially in January in relatively large numbers (54.6% of the sample), became more common each month through April (90%), then decreased steadily to only 2.3% of the August sample. The first berried lobsters were observed in May. In June they comprised 77.8% of the sample, but decreased markedly through July and accounted for only 6.8% of the August sample. Old soft-shell females were most abundant in August (20.3%), decreasing

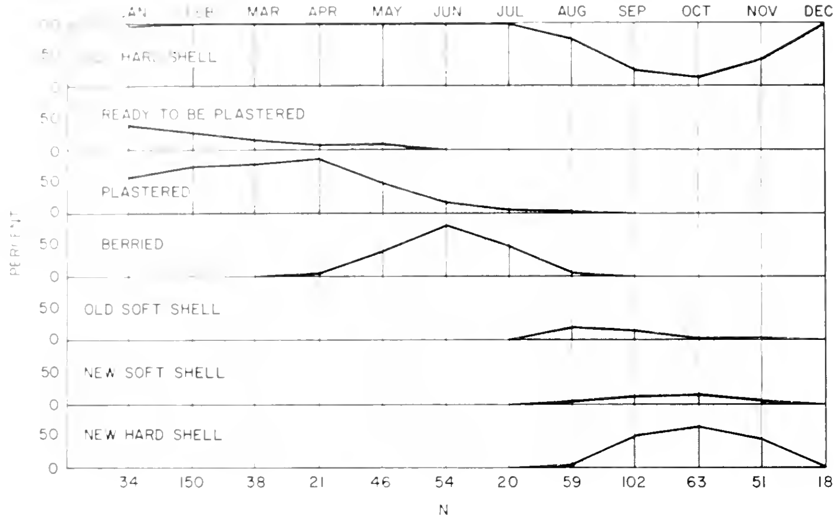

FIGURE 3—Shell and reproductive conditions of female lobsters, by months. Shell conditions are expressed as percentage of the total number of individuals sampled. Reproductive states are expressed as percentage of the total number of individuals possessing old hard shells.

to 3.9% occurrence in November. New soft-shell females were observed during these same months but reached their maximum occurrence (17.5%) in October. New hard shells were observed primarily from August through November. In October, 65.1% of the sample was in this condition.

Various members of the family Palinuridae, *Panulirus argus* (Smith, 1948 and 1951; Travis, 1954), *P. guttatus* and *P. laevicauda* (Smith, 1954), *P. longipes* (Sheard, 1949), and *Jasus lalandii* (Von Bonde and Marchand, 1935) are reported as molting twice yearly. Semiannual molting is also reported for *P. interruptus* by Lindberg (1955). However, our data and the reports of Allen (1916) and Backus (1960) indicate that adult California spiny lobsters (larger than 41 mm carapace length) molt once yearly immediately after completing the reproductive cycle. Maximum occurrence and termination of ecdysis for both sexes is simultaneous, although males begin molting nearly 2 months earlier than females.

Growth

Carapace lengths were determined for 897 male and 656 female California spiny lobsters. These ranged from 41 to 123 mm. Monthly median carapace lengths for females were significantly greater than for males, indicating more rapid growth or greater age in the females sampled (Table 1).

Carapace length frequencies plotted for both sexes yielded peaks which occurred with some regularity and were assumed to represent year classes (Figure 4). If these peaks are truly annual increments of growth, we may make several statements about the lobsters sampled: carapace lengths of males increased from 51 to 88 mm in 10 molts, an

TABLE 1

Median Carapace Lengths (mm) of California Spiny Lobsters, by Months

	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Male	69.0	70.0	67.5	67.0	73.0	72.0	72.0	68.5	64.0	61.0	66.5	69.5
Female	74.5	72.0	72.0	72.0	72.0	75.5	77.0	75.5	69.0	69.0	68.5	69.0

annual increment of 3.7 mm; carapace lengths of females increased from 56 to 91 mm in 8 molts, an annual increase of 4.4 mm. Using the value 0.31, given by Backus (1960) for the average ratio of carapace length to total length, the annual total length increment would be 11.5 mm for males and 13.6 mm for females, slightly lower than the increments reported by Lindberg (1955) and Backus for this species. Oshima (1948), working with *P. japonicus*, indicated that individuals 52 mm in carapace length are in their third year. Masuda (1954), using the antennule flagella to determine ages for the same species, found that by age 3 these lobsters have passed through 18 molts and are 148 to 191 mm TL. Assuming that Masuda measured "total length" in the same manner as Backus, we can adjust these figures (using Backus's 0.31 value) to a mean carapace length of 52.5 mm. This puts Masuda's animals within the lower size limits sampled in our study. Assuming that our smaller individuals are in their third year, female California spiny lobsters attain legal size (83 mm carapace length) in approximately 10 years, the males in 11. This is appreciably older than the 7 or 8 years suggested by Lindberg.

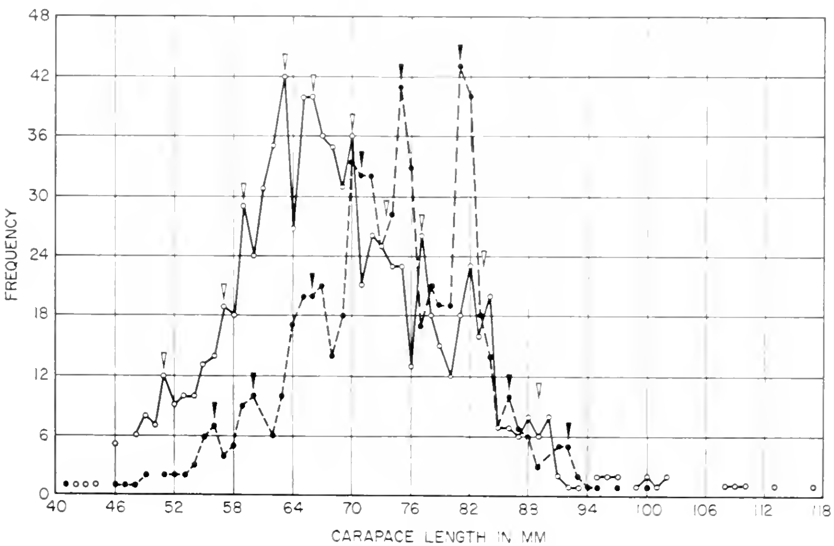

FIGURE 4—Carapace length frequencies for male (solid line) and female (broken line) lobsters. Arrows indicate assumed year classes.

Migrations

The inshore-offshore migration of these animals correlates in part with seasonal variations in water temperature (Allen, 1916; Lindberg, 1955). From June 1965 to October 1966, we made a continuous recording of water temperatures on the northeast side of San Clemente Island. A Ryan Model D-30 recording thermometer was placed in 80 ft of water just inside a large cave from which many of our monthly lobster samples were taken.

Summer temperatures at this depth showed a wide daily variation, as much as 10 to 12 F, apparently due to fluctuations in thermocline depth, which presumably was influenced by the amount of "piling up" of warm surface water against the island by strong prevailing afternoon northwesterly winds. Stratification of the water column broke down and temperatures were more or less uniform during winter months.

During late March and early April, when the thermocline began to form, female lobsters which may have been plastered in deeper water migrated into the shallows (less than 30 ft). By the end of April, when the thermocline was well formed, the shallow-water lobster population consisted largely of berried females and juvenile males. Although larger males were distributed throughout the entire depth range studied, a general inshore movement began about May. Both sexes were observed in the warmer inshore water until hatching was completed in late August to September. As thermal stratification decayed in October, both male and female lobsters were found farther offshore in deeper waters; this coincided with the maximum occurrence of ecdysis. By December most of the observed population was offshore (50- to 100-ft depths, the limit of our study), and water temperatures had resumed a uniformity that is characteristic of the winter months off southern California.

We believe that there are many reasons for this migration, and most would be advantageous to the animal. Juvenile lobsters are most likely to be found in the shallows, where the warmer water and lush growths assure an abundant food supply for maximum growth. Small crevices and other hiding places are usually abundant in shallow rocky areas, offering more protection from predation.

Movement of berried females into the shallow warmer water presumably assures a more rapid development of the eggs. Further, females appear less prone to forage about during this period because of difficulty in locomotion caused by the large abdominal egg masses. In the shallows their caloric needs are more likely to be met, in part, by surge-carried food drifting into their areas of concealment. A possible explanation for the delayed movement into shallow water by males (almost a month after the females) is the decrease in competition for food and protective cover after the females have moved inshore.

Migration into deeper water and the seeking out of dark holes and caves before ecdysis doubtlessly is related to the newly molted lobster's increased sensitivity to light (Hess 1938 and 1940). This also removes the lobsters from the zones of heavy wave surge, where bodily damage could occur during this soft-bodied condition. It may also reduce the probability of predation by such animals as the California sheephead, *Pimelometopon pulchrum*, and the California horn shark, *Heterodontus francisci*, which are usually more abundant in depths of 15 to 60 ft.

These observations are based only on a limited segment of the San Clemente Island lobster population. Spiny lobsters inhabiting the coastal areas of the mainland and even those found at the other Channel Islands may exhibit slightly modified migration patterns. Additional biological and behavioral data, as well as an analysis of the fishery, are sorely needed.

Morphometrics

The following morphometric data, although of interest biologically, have been included primarily for use by members of the Department's Wildlife Protection Branch, Marine Patrol. Unscrupulous individuals are sometimes apprehended by enforcement personnel with quantities of lobster tails which, from their small size, appear to have been from lobsters below the legal minimum size of 3¼ inches carapace length. In such cases, it is desirable for the enforcing officers to have available information that would enable them to determine carapace lengths quickly, within statistically valid parameters.

Tail lengths of 1,364 sublegal lobsters (less than 83 mm (3¼ inches) in carapace length, ranged from 84 to 192 mm, while tail lengths of 187 legal-sized lobsters ranged from 157 to 267 mm. We calculated that 99.7% of all the barely legal spiny lobsters in southern California (carapace length 83 mm) have tails equal to or longer than 166 mm but equal to or shorter than 186 mm (Figure 5).

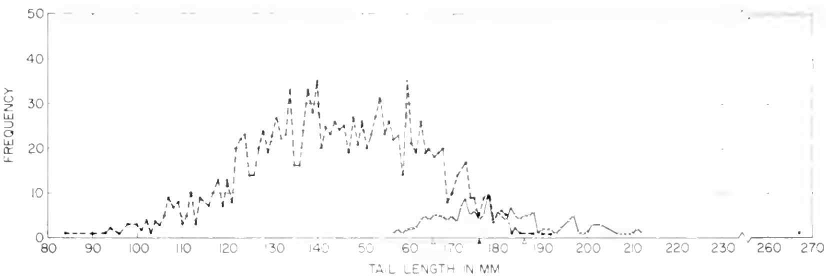

FIGURE 5—Tail length frequencies of 187 lobsters 83 mm or greater in carapace length (solid line) and 1,364 individuals less than 83 mm in carapace length (broken line). Solid triangle represents the calculated tail length for a barely legal lobster. Open triangles enclose 99.7 of all California spiny lobsters 83 mm in carapace length.

Weights of freshly removed tails of 1,310 sublegals ranged from 32 to 288 g. Tail weights of 171 legal-sized animals ranged from 165 to 543 g. Weights of female lobsters with eggs were not included in these data.

The range of tail weights after cooking did not differ significantly from the range of raw tail weights; however, weights of individual tails were highly variable because of water uptake and losses of portions of flesh during cooking.

Regression data for carapace length on tail length (Figure 6) yielded a coefficient of correlation (r) of 0.94 and a standard error of estimate ($Sx.y$) of 3.44. Data for carapace length on raw tail weight (Figure 7) produced an r of 0.88 and an $Sx.y$ of 4.96. Carapace length on cooked tail weight (Figure 8) yielded an r of 0.86 and an $Sx.y$ of 5.43. Regression data for cooked tail weight on raw tail weight (Figure 9) produced an r of 0.97 and an $Sx.y$ of 15.51. This high standard error of estimate reflects the extreme variability in the cooked tail weights mentioned previously.

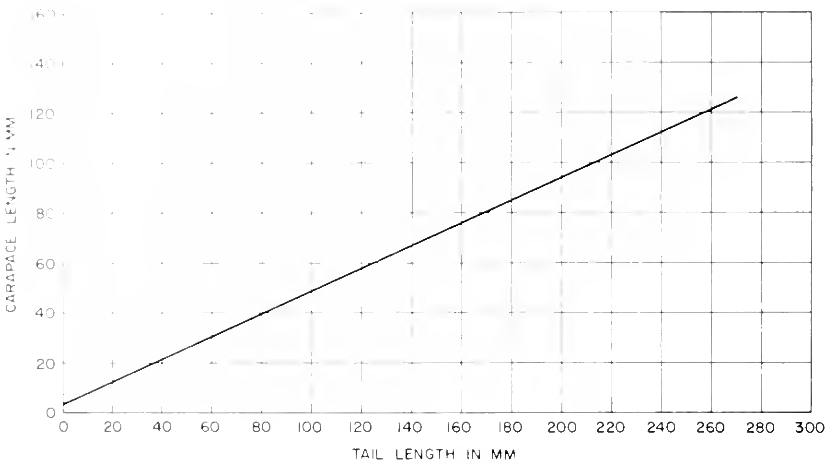

FIGURE 6—Carapace length on tail length relationship for 1,549 California spiny lobsters ($Y = 3.84 + .45X$).

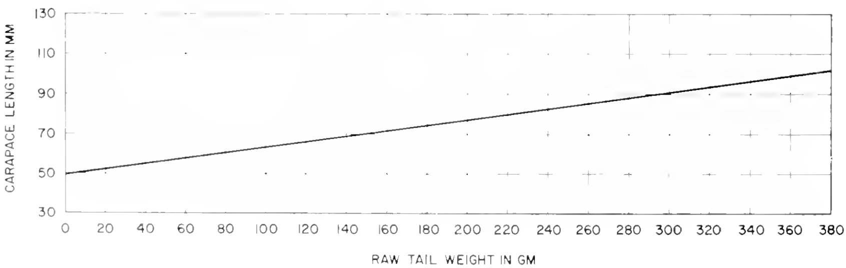

FIGURE 7—Carapace length on raw tail weight relationship for 1,549 California spiny lobsters ($Y = 49.68 + .14X$).

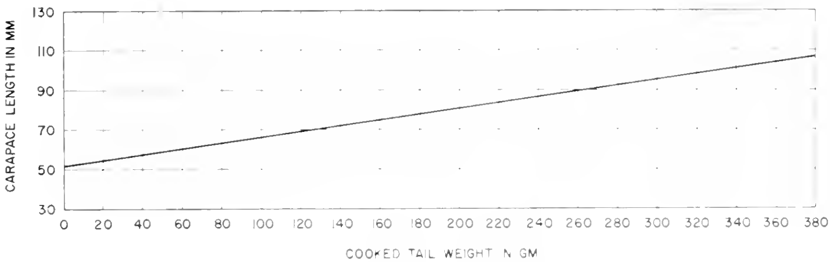

FIGURE 8—Carapace length on cooked tail weight relationship for 1,549 California spiny lobsters ($Y = 51.74 + .14X$).

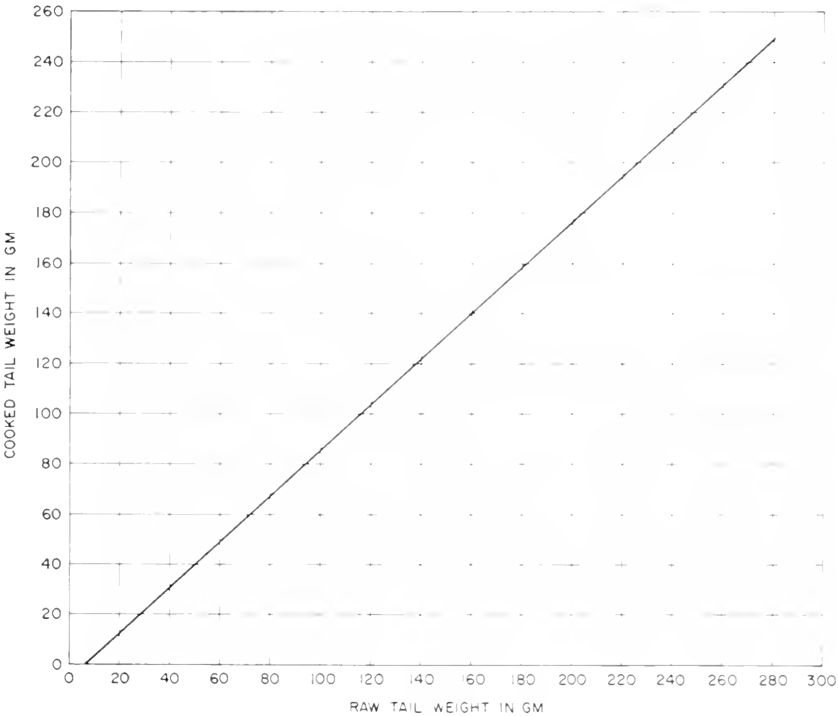

FIGURE 9—Cooked tail weight on raw tail weight relationship for 1,549 California spiny lobsters ($Y = 15.74 + .14X$).

SUMMARY

1. Employing scuba at monthly intervals, 1,553 California spiny lobsters were collected off San Clemente Island, California (intertidal to depths of 100 ft) from August 1964 to January 1967. In the laboratory these were first segregated by sex, then carapace length, shell and reproductive condition, and tail length and weight (before and after cooking) were recorded.

2. Male lobsters were observed with old hard shells throughout the year, but over 80% of the population was in this condition from December to July; old soft shells occurred from July to October, new soft shells from June to November, and new hard shells from January to October.
3. Female lobsters with old hard shells were observed throughout the year, but over 90% of the population was in this condition from December to July. All females in reproductive condition possessed old hard shells. Individuals ready to be plastered occurred from January to May, plastered individuals from January to August, and berried females from May to August. Females with old soft shells and those with new soft shells occurred from August to November, and individuals with new hard shells were observed from August to January.
4. The California spiny lobster molts but once a year, immediately after completing its reproductive cycle.
5. Monthly median carapace lengths for females were significantly greater than for males, indicating more rapid growth or greater age for the females sampled.
6. Frequency distribution plots of carapace lengths of 897 males and 656 females showed modes indicative of year classes. Analysis of modal spacings shows an annual carapace growth increment of 3.7 mm for male lobsters and 4.4 mm for females.
7. Based on our data, the time required for a California spiny lobster to reach the legal size of 3¼ inches (83 mm) carapace length is approximately 10 years for females and 11 for males.
8. Inshore-offshore migrations correlate with seasonal variation in water temperature; however, availability of forage, suitable habitat, and the degree of subsurface wave action (surge) also may be causative agents.
9. The range of tail lengths for sublegal lobsters (84 to 192 mm) overlapped that for legal lobsters (157 to 267 mm). Similar overlapping was present in weights of freshly removed tails (32 to 288 g and 165 to 543 g). Cooking did not affect the range in tail weight significantly but did increase the amount of variability. Regression data for carapace length on tail length, raw tail weight, and cooked tail weight showed high coefficients of correlation (0.86 to 0.94). Similar treatment of cooked tail weight on raw tail weight yielded a coefficient of correlation of 0.97.
10. Additional biological and behavioral data, as well as an analysis of the fishery, are sorely needed.

ACKNOWLEDGMENTS

We are indebted to the California Department of Fish and Game Marine Patrol for the use of its vessels and assistance in collecting the lobster samples. Particular thanks are due the skippers and crews of the patrol boats *Bluefin*, *Broadbill*, and *Marlin*.

Our appreciation is extended to Wayne Dearden, Dearden Fish Company, Long Beach, California, who freely gave of his time and equipment in cooking the larger samples for us; to Robert R. Given, Allan Hancock Foundation, and Earl E. Ebert, California Department of

Fish and Game, who assisted in the collecting and examining of many of the earlier lobster samples; to John E. Fitch, California Department of Fish and Game, who reviewed the manuscript; and to the numerous others who assisted in the study.

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BLUEFIN TUNA MIGRATE ACROSS THE PACIFIC OCEAN[1]

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Eight bluefin tuna tagged and released in the California fishery migrated westward across the Pacific Ocean and were recaptured several years later near Japan. Tagged bluefin also have migrated eastward across the Pacific. These were released near Japan and recaptured during the following year in the California fishery. Bluefin tuna probably undertake a regular migration across the north Pacific Ocean, and Japanese and American fishermen are most likely harvesting the same bluefin resource.

Eight bluefin tuna, *Thunnus thynnus* (Linnaeus), tagged and released in the California fishery, migrated westward across the Pacific Ocean and were recaptured near Japan (Figure 1). The bluefin were among 2,800 that were tagged with spaghetti darts during a cooperative project involving the U.S. Bureau of Commercial Fisheries—Fishery

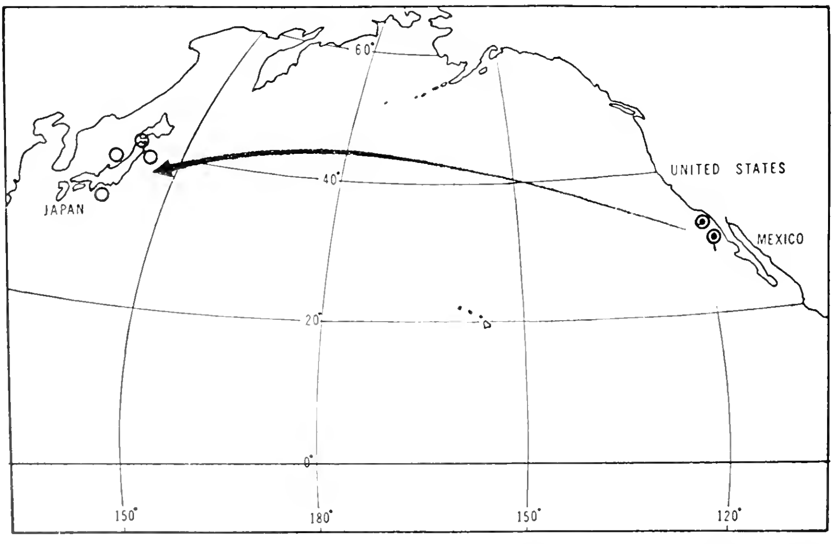

FIGURE 1—Eight tagged bluefin tuna migrated westward across the Pacific Ocean to Japan. The black dots encompass the areas where bluefin were marked and released, while the open circles represent general localities of recapture.

[1] Accepted for publication October 1968.

Oceanography Center, the Oceanic Research Institute, and the Marine Resources Operations of the California Department of Fish and Game (Flittner and Iselin, 1963; Iselin 1963). Since the beginning of the project in August 1962, about 20% of the marked bluefin tuna have been recovered; 550 fish were recaptured in the California fishery during the years 1962–1967, while none was recaptured in 1967.

The first three of the transpacific migrants were tagged and released northeast of Guadalupe Island, Baja California, during the 1962 fishing season. They were at liberty approximately 2 years (Table 1). Bluefin No. 1 was recovered June 18, 1964, in the Sea of Japan. It was caught in a trap net located near the coastal town of Fukaura, Honshu. The second fish was recaptured August 17, 1964, on longline gear fishing south of Cape Esan, Hokkaido, and the third was taken August 29, 1964, by an angler at Mutsu Bay, Honshu. Each bluefin tuna had traveled more than 4,700 miles, as estimated by the great circle route.

The next two bluefin (Nos. 4 and 5, Table 1) also were marked in 1962; however, they remained at liberty for almost 3 years. The first of these bluefin was released August 14, 1962, northeast of Guadalupe Island, Baja California, and recaptured in a Japanese set net near Nakiri, Honshu, about 5,100 miles from the point of tagging. The second fish was released August 21, 1962, west of San Clemente Island, California; it was recaptured by Japanese fishermen trolling near the Hiura lighthouse, Hokkaido, about 4,520 miles distant.

The last three of our transpacific bluefin tuna (Nos. 6, 7, and 8; Table 1) were marked and released in 1964. Bluefin No. 6 was recovered July 1, 1966, about 4,750 miles from the point of release. It had been tagged August 20, 1964, near San Diego, California, and recaptured almost 2 years later in a set net fishing near Awa Island, in the Sea of Japan. The remaining two bluefin were recaptured off Japan, in two-boat purse seines, nearly 4 years after being released. Bluefin No. 7 was recovered July 4, 1968, about 4,740 miles from the release area. It had been tagged August 13, 1964, west of San Martin Island, Baja California, and recaptured east of Osaki Zaki, Honshu. Bluefin No. 8 was recaptured July 14, 1968, approximately 4,550 miles from the release location. It had been tagged August 20, 1964, near San Diego, California, and was caught again off Todo Saki, Honshu.

Mather (1960) reported that a bluefin tuna marked near the Bahama Islands, in the western Atlantic Ocean, was recaptured in the Bay of Biscay, and Orange and Fink (1963) reported that a bluefin tagged near Guadalupe Island, Baja California, was caught again south of Tokyo. Both of these fish were at liberty for about 5 years.

Japanese scientists studying tuna migrations marked and released several hundred bluefin tuna in 1965. Two of these were caught during the following year after swimming eastward across the Pacific Ocean and into the California fishery (Figure 2). Both were tagged August 27, 1965, near Inubo, Saki, Honshu. The first bluefin (No. 9, Table 1) was recaptured July 15, 1966, in a purse seine near San Pablo Bay, Baja California, and the second fish (No. 10) was netted August 9, 1966, by a seiner southwest of San Martin Island, Baja California.

Our investigations show that bluefin tuna probably undertake a regular migration across the Pacific Ocean—some even enter the Tsugaru

TABLE I

Statistics of Tagged Bluefin Tuna That Migrated Across the Pacific Ocean

Specimen no.	Release data						Recovery data							
			Fork length*		Weight†				Fork length†		Weight‡			
	Date	Locality	cm	inches	kg	lb	Date	Locality	cm	inches	kg	lb	Days	Miles
1	Aug. 15, 1962	29°43′N, 117°20′W	76	29.9	9.9	21.9	June 18, 1964	40°44′N, 140°00′E	101	40.9	24.4	53.6	674	4,740
2	Aug. 15, 1962	29°43′N, 117°20′W	76	29.9	9.9	21.9	Aug. 17, 1964	41°39′N, 141°09′E	111	44.9	32.0	70.5	734	4,750
3	Aug. 16, 1962	29°43′N, 117°20′W	78	30.7	10.7	23.6	Aug. 29, 1964	41°15′N, 140°43′E	---	---	----	---	745	4,740
4	Aug. 14, 1962	30°10′N, 117°05′W	78	30.7	10.7	23.6	June 23, 1965	34°16′N, 136°53′E	137	53.9	55.9	123.0	1,045	5,100
5	Aug. 21, 1962	33°02′N, 119°01′W	61	24.0	5.3	11.6	Aug. 10, 1965	41°42′N, 141°01′E	118	46.5	36.1	79.1	1,086	4,520
6	Aug. 20, 1964	32°41′N, 117°55′W	62	24.4	5.4	12.0	July 1, 1966	38°25′N, 139°15′E	103	40.6	23.0	50.7	681	4,750
7	Aug. 13, 1964	30°31′N, 116°45′W	84	33.1	13.2	29.0	July 4, 1968	38°49′N, 142°28′E	155	61.0	77.7	170.9	1,421	4,740
8	Aug. 20, 1964	32°41′N, 117°55′W	65	25.6	6.2	13.7	July 14, 1968	39°37′N, 143°16′E	158	62.2	83.6	183.9	1,425	4,550
9	Aug. 27, 1965	35°31′N, 140°46′E	36	14.2	1.2	2.7	July 15, 1966	27°00′N, 114°34′W	68	26.8	7.3	16.0	323	5,220
10	Aug. 27, 1965	35°30′N, 140°53′E	36	14.2	1.2	2.7	Aug. 9, 1966	30°01′N, 116°39′W	71	28.0	8.3	18.3	349	4,920

* Estimated from length frequency sampling at time of tagging.
† Obtained from weight-length tables for the appropriate year.
‡ Reported by the fishermen.

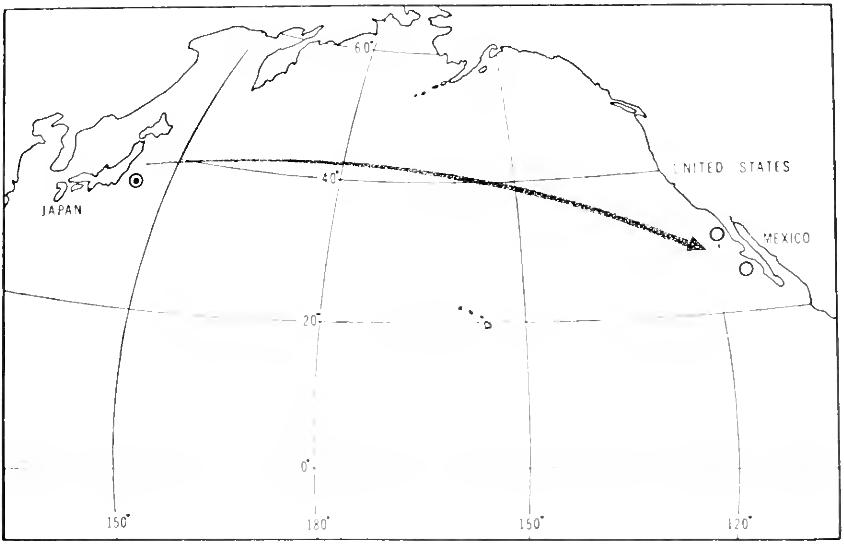

FIGURE 2—Two tagged bluefin tuna migrated eastward across the Pacific Ocean to America. The black dot encompasses the area where bluefin were marked and released, while the open circles represent general localities of recapture.

Channel and the Sea of Japan. These data also reveal that Japanese and American fishermen are most likely harvesting the same bluefin resource.

Data concerning the recovery of tagged bluefin tuna were sent to us through the courtesy of scientific personnel of the Tohoku Regional Fisheries Research Laboratory, the Nankai Regional Fisheries Research Laboratory, and the Japanese Fisheries Agency.

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TUNA SCHOOLING TERMINOLOGY[1]

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The terms used by California tuna fishermen to describe 18 school types are listed, synonyms are identified, and a brief description of each school type given. The school types are divided into categories on the basis of depth, time of day or night, and association with other animals or floating objects.

INTRODUCTION

Fishermen of the California tuna fleet use a variety of terms to identify different types of tuna schools (McNeely, 1961). The many terms and wide variations in their usage complicate any attempt by the agencies who study tuna (Inter-American Tropical Tuna Commission, Bureau of Commercial Fisheries, and California Department of Fish and Game) to evaluate tuna catchability with respect to types of tuna schools. This paper records, defines, and categorizes the terms used by California fishermen.

Tuna are found in schools ranging in size from several hundred pounds to several hundred tons, and in various environmental conditions. These conditions, combined with the behavior of the fish, result in different school types which are described in fishing logs by a word or a short phrase.

The distinction between school types is not often exact; for example, a school may exhibit several types of behavior in sequence or, less often, simultaneously. The name assigned to a school may vary, depending upon whether the observer is viewing it from the bridge or from the mast of the vessel. Often only one name is assigned and other observed conditions are ignored; for example, a "breezer" may have "jumpers" out in front and an occasional "shiner" down deep. The dominant behavior, "breezer", is noted in the logbook. When tuna schools are found with porpoises, whales, sharks, or floating objects, it is the association that is logged, regardless of other environmental or behavioral conditions. Schools which are similar in appearance and behavior are distinguished subjectively.

I have grouped the terms for the various school types into major categories on the basis of depth of school, time of day or night, and association with other animals or floating objects (Table 1). Descriptions and terms are based on personal observations, interviews with captains and mastmen of the San Diego based purse seiner fleet, and analysis of the observers' logs of the Bureau of Commercial Fisheries and the logbooks of the Inter-American Tropical Tuna Commission.

[1] Accepted for publication July 1968.

TABLE 1

Terms Used by Southern California Purse Seine Tuna Fishermen to Describe Various Types of Tuna Schools and Associations

School fish	Associated schools*
Surface schools*	Fish and mammal association*
Breezer	Porpoise schools
Finner	Spotters
Jumper	Spinners
Boiler, foamer, smoker, or meat ball	Spotters and spinners
	Whitebelly
Subsurface schools*	Whale schools
Black spot, dark spot, brown spot, green spot, or black ball	Shark schools
Shiner	
	Inanimate object association*
Night schools*	Log schools
Fireball, ardura, glow, white spot, or flare	Bait boat
Popper	

* These terms are used for organization of the table and are not used by the fishermen.

SCHOOL FISH

I define school fish as those tuna which are not associated with logs, porpoises, whales, or sharks. Such schools are often detected by the presence of large flocks of birds (gannets, boobies, terns, gulls, or frigate birds) which are attracted by bait the tuna have driven to the surface.

Surface Schools

Surface schools are those which are located by the physical disturbance they create at the surface of the water. These are classified into six types.

1) Breezer—A school of fish which is located by a light to heavy rippling of the water surface, similar to that caused by local wind disturbance or a rip current. No part of a fish's body appears above the surface of the water, and the school is generally moving in one direction.
2) Finner—Any school or group of fish in which the dorsal and sometimes the caudal fin of individual fish can be seen above the water surface. These groups are generally less active than the boiler or foamer schools.
3) Jumper—A school or group of fish which is characterized by the jumping of individual fish. The activity of the fish is controlled so that those jumping fish often return to the water head first.
4) Boiler or foamer—A very active, feeding school which can be detected by the "boiling" white water caused by jumping fish in pursuit of their prey. The activity is more frantic and less controlled than in the jumping schools.
5) Smoker—This term is sometimes considered to be synonymous with boiler or foamer. Most fishermen, however, say that the "boiling" is greater and covers a wider area than in either the boiler or foamer schools.

6) Meat ball—A school of fish which is feeding actively on a "ball" of bait fish. The tuna are generally boiling and foaming at the surface of the water and the term may be considered synonymous with boiler.

Subsurface Schools

Subsurface schools are those which swim deeper and do not disturb the water surface. They are detected by their color difference from the surrounding water.

1) Black spot, dark spot, brown spot, green spot, or black ball—A tuna school which appears as a spot much darker than the surrounding water. The character of the water seems to be the determining factor in the choice of the term used. The color, however, may vary between species.
2) Shiner—A school of fish, deep in the water, in which individual fish twist and turn longitudinally, exposing their silvery ventral and lateral surfaces to the sun and reflecting a flash of color. This school type is often observed with black spot schools.

Night Schools

It is possible to sight school fish at night because they disturb luminescent planktonic organisms, which are very abundant at times in certain waters. The activity of fish and other moving objects causes these organisms to emit flashes of light, making the fish school visible to observers aboard a purse seiner.

A mast light is often flashed to stimulate activity of the school. This facilitates identification of the species and permits an estimate of school size before the net is set.

1) Fireball, ardura, glow, white spot, or flare—A light spot caused by the activity of a tuna school in waters with luminescent plankters. The glow is generally uniform throughout.
2) Popper—A fireball school in which brilliant bursts of light are seen. These bursts are caused by the activity of individual fish, causing a greater display of luminance.

ASSOCIATED SCHOOLS

Associated schools are those found with porpoises, whales, sharks, or floating objects. These schools may be divided into two groups: those affiliated with animals and those associated with inanimate objects.

Associations with Fish and Mammals

1) Porpoise schools—Yellowfin and skipjack tuna are often found associated with porpoises in the eastern tropical Pacific (Godsil, 1938; McNeely, 1961). Four types of schools are recognized.
   a) Spotter schools—the schools of tuna associated with the eastern Pacific spotted dolphin, *Stenella graffmani*. The common name is derived from the numerous white spots distributed over the gray body of this species of porpoise.
   b) Spinner schools—schools of tuna associated with the spinner porpoise, *Stenella longirostris*. This porpoise gets the name

Schools Associated with Floating Objects

[illegible]

ACKNOWLEDGMENTS

I thank R[illegible] [illegible] Hester and R[illegible] [illegible] San Diego [illegible]

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FIRST REPORT OF ANCHOVY TAGGING IN CALIFORNIA[1]

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California Department of Fish and Game biologists began a tagging study of the northern anchovy, *Engraulis mordax*, in March 1966. Fish were tagged and released in areas of the California Current Region as far north as San Francisco Bay and as far south as Cape Colnett, Baja California. In all, 100,114 anchovies were tagged with internal tags made from a magnetic stainless steel alloy between March 14 and November 22, 1966. Recoveries were made from the meal product, using both plate and rotating-grate permanent magnets at reduction plants.

INTRODUCTION

The decline of the Pacific sardine, *Sardinops caerulea*, fishery, the expanding population of the northern anchovy reported by California Cooperative Oceanic Fisheries Investigations scientists (Ahlstrom et al., 1967), and numerous requests by the fishing industry resulted in the authorization by the California Fish and Game Commission of an experimental anchovy fishery for reduction. The fishery began with the issuance of permits on November 1, 1965, and in conjunction with this experimental fishery the Department of Fish and Game began a tagging study. From March 14 to November 22, 1966, Department biologists successfully tagged and released 100,114 anchovies in California and Baja California waters. Release of tagged fish and the subsequent recovery of tags during the reduction process was intended to provide information on north-south and inshore-offshore migrations, population estimates, and mortality rates. Anchovies were tagged and released as far north as San Francisco Bay, as far south as Cape Colnett, Baja California, and in southern California inshore and offshore waters.

Between March 14 and April 30, 1966 (the close of the 1965–66 anchovy reduction season), approximately 23,000 fish were tagged and released in southern California waters, and 150 tags were recovered from reduction plants near San Pedro and Port Hueneme. As expected, all returns came from southern California fishing areas because the short time tagged fish were available for capture by the fishery precluded extensive migration. About 77,000 additional anchovies were tagged and released between the close of the 1965–66 season and the opening of the 1966–67 season (October 1).

OBTAINING AND HOLDING ANCHOVIES FOR TAGGING

Two tagging and release conditions were essential to insure maximum survival: (1) a minimum of damage to the fish during capture, tagging,

[1] Accepted for publication October 1968.
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and release; and (ii) the release of the tagged fish as a group to minimize losses to predation.

Four methods were used to obtain fish:

1. netting fish from department research vessels;
2. taking fish from commercial fishermen's nets prior to brailing the catch into the hold of the vessel;
3. purchasing fish from shoreside receivers of live-bait dealers;
4. contracting with live-bait fishermen to catch and hold anchovies.

For the majority of tagging trips the fourth method was used because live-bait fishermen have the necessary equipment and knowledge to handle live anchovies.

Typically, fish were caught in lampara nets (Scofield, 1951) early the same morning that they were tagged. As a result, the fish were in holding tanks a minimum of time before tagging. Anchovies were generally caught at sea and transported to sheltered waters where the taggers could work comfortably and efficiently. Under these conditions, the fish suffered a minimum of damage.

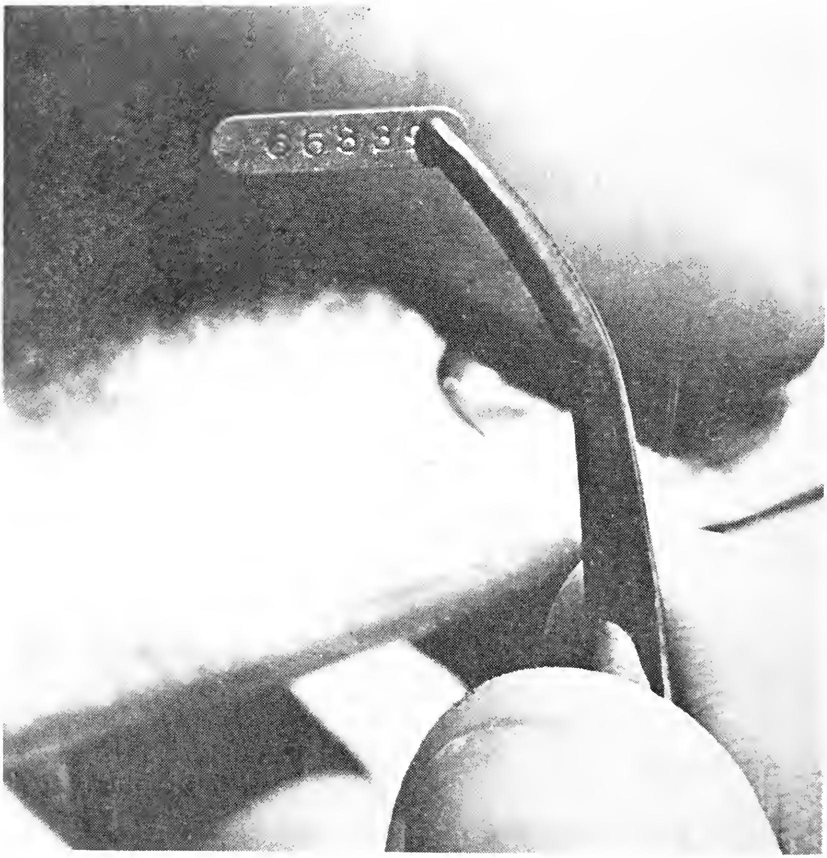

FIGURE 1—Internal stainless steel anchovy tag ready to be inserted. *Photograph by Bill Beebe.*

THE TAG

Anchovy tags are similar in shape to those used by department biologists to tag Pacific sardines (Janssen and Aplin, 1945). The flat tags are made from type 430 stainless steel, an alloy with magnetic properties, and are 13 mm long, 3 mm wide, and 0.5 mm thick, with a number stamped on one side (Figure 1). The tags were received from the factory in numbered bags of 500. They were then sterilized, coated with an antibiotic paste (tetracycline in alba), and packed in aluminum foil in packs of 50. Each pack was numbered with the series number, and all 500 banded together (Figure 2).

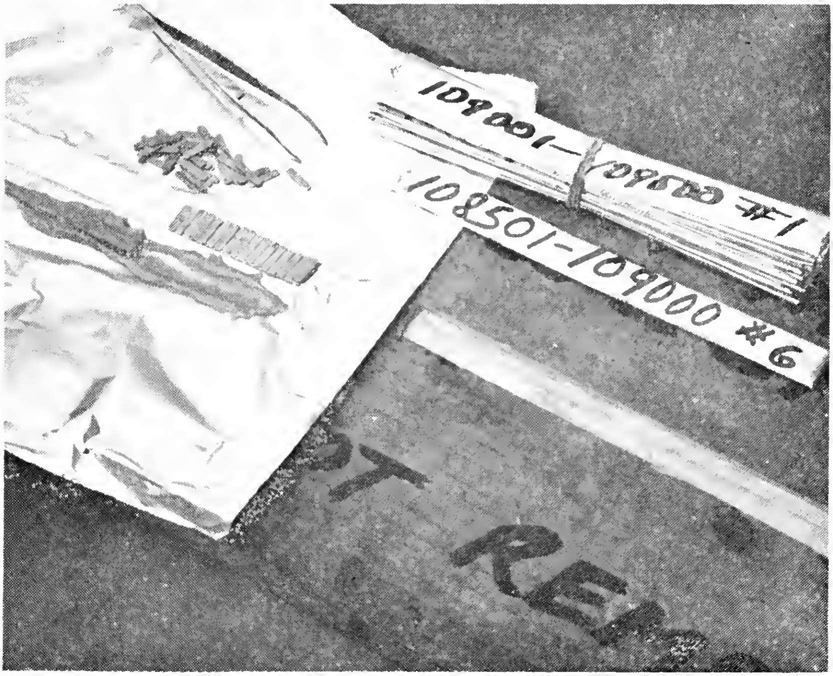

FIGURE 2—Fifty tags are packed in a single layer in aluminum foil with tetracycline antibiotic paste. Ten packages are bound together in a 500-tag lot. *Photograph by Jack W. Schott.*

TAGGING PROCEDURES

Two tanks were used aboard the tagging vessel, one to hold untagged fish and one to receive tagged fish. The anchovies were dipped from the holding tank and placed in a shallow plastic tray supplied with flowing seawater. They were then caught by hand, tagged, and released into the receiving tank. On several tagging trips, only one tank was available and it had to be used concurrently as the holding and the receiving tank. Fish mortalities were generally higher under this latter condition.

Tagging methods, based on tagging and mortality experiments conducted by Vrooman, Paloma, and Jordán (1966), were as follows. A pack of 50 tags was opened and placed in a slot cut into a block of wood so the tags stood upright (Figure 3). An anchovy was caught from the tray, held firmly, and an incision was made through the body wall just posterior to the tip of the pectoral fin. A tag was taken from the block, using forceps, and inserted posteriorly through the incision into the body cavity. Care was taken to insert the tag parallel to the body wall in order to avoid damage to internal organs (Figures 4 and 5). The anchovy was then dropped into the receiving tank to be held until release of the entire group.

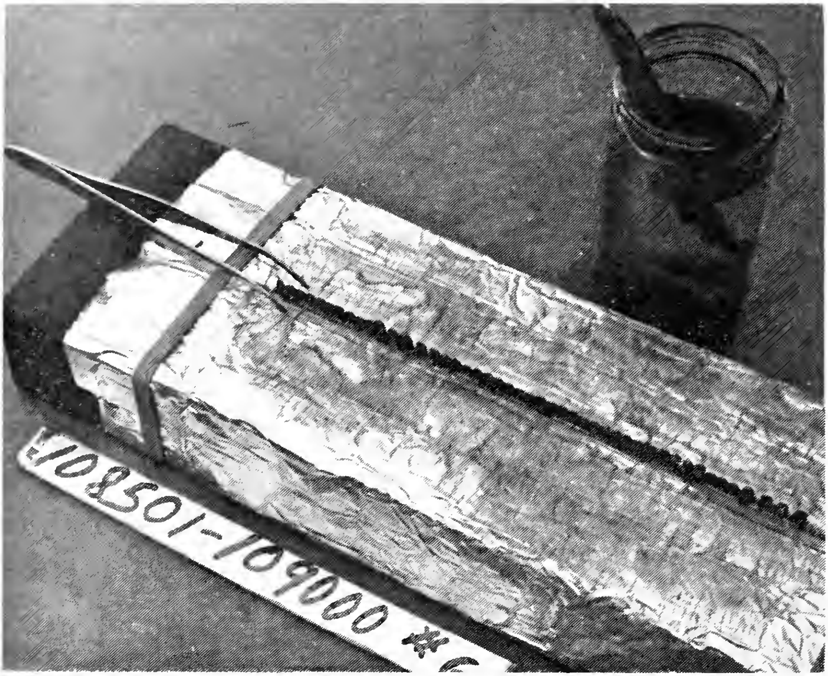

FIGURE 3—The tags are held vertically in the groove of the tagging board, ready for use. *Photograph by Jack W. Schott.*

At the end of each tagging day, tagged fish along with the remaining untagged fish were transported offshore and released in the general area where they were caught. Normally they were released into or near anchovy schools to provide protection from predators and prevent "chumming" of predator fish (Janssen, 1938). When released, the fish moved without hesitation toward the school. When a school was not present, the fish milled about near the surface for a short period of time, formed a school, and then moved away from the vessel.

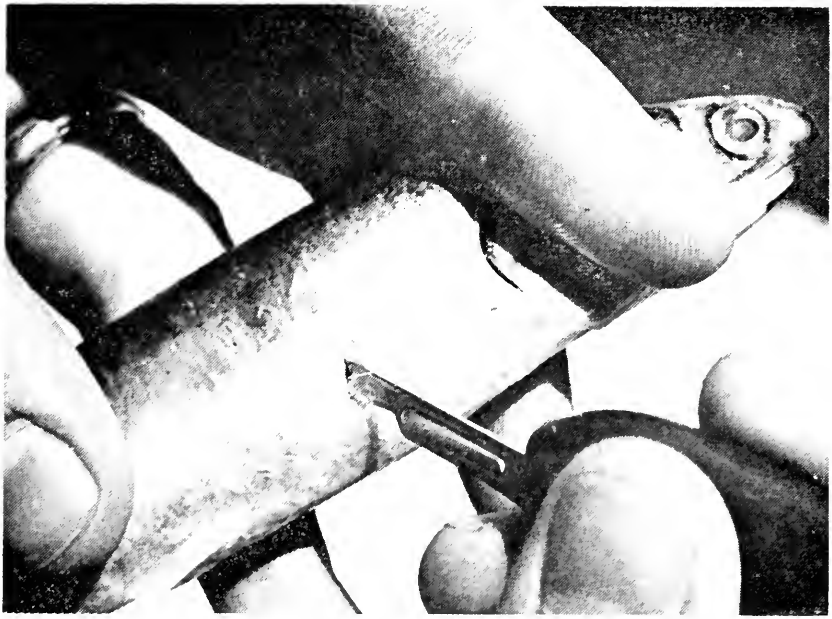

FIGURE 4—The incision is made with a quick stab of a scalpel blade normally the fish is held much more firmly than is shown here. *Photograph by Bill Beebe.*

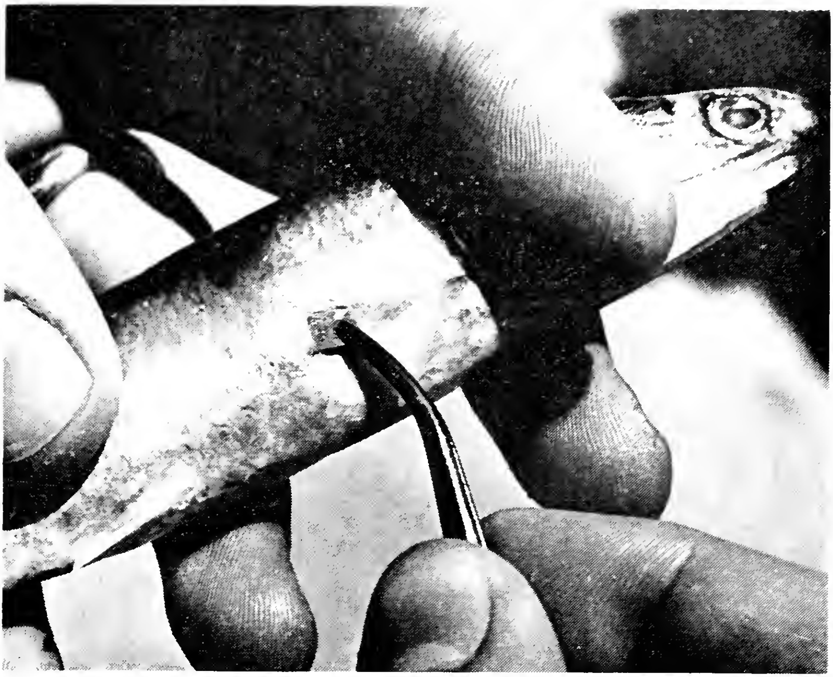

FIGURE 5—The tags are inserted posteriorly, parallel to the body wall. *Photograph by Bill Beebe.*

RELEASE LOCATIONS

Release locations were chosen to test the hypothesis that anchovies migrate between major fishing areas as well as offshore and inshore. Tagging was generally restricted to areas near ports where anchovies were caught for live bait. One tagging trip was made into Baja California waters aboard the Department's research vessel *Alaska*. Offshore tagging was also done near Santa Catalina and San Clemente Islands aboard the Oceanic Research Institute's research vessel *Five Bells*.

Tagging began at San Pedro in March 1966 and continued that same month at Port Hueneme. In April and early May, we tagged fish around Santa Catalina and San Clemente Islands. Releases were made in late May off northern Baja California as well as at San Diego. Santa Cruz and San Francisco Bay releases followed in July. The taggers returned to Port Hueneme for additional tagging in October, and tagged at San Pedro in November (Table 1 and Figure 6). During 1966, we tagged and released 100,114 viable fish.

TABLE 1

Summary of Anchovy Tagging During 1966

Tagging area	Release locality	Date tagged	Number tagged	Total number for area
San Francisco	San Francisco Bay between Tiburon and Sausalito	July 23	1,990	1,990
Santa Cruz	½–1 mile W of Aptos	July 21, 25–27	5,390	5,390
Port Hueneme	½–1 mile SW of Port Hueneme	March 22, 25 and April 5–6	6,914	
		October 18–28	24,360	31,274
San Pedro	1 mile S Pt. Fermin	March 14–17	7,962	
	½ mile S Cabrillo Beach in Los Angeles Harbor	November 21–23	12,450	20,412
Santa Catalina Is.	½ mile SE East End	April 26, 27	7,977	
	3 miles SSW China Pt.	October 2	4,973	
	15 miles SE China Pt.	October 3	4,871	17,821
San Clemente Is.	½–2 miles E Pyramid Pt.	May 2	1,448	
	3 miles S Wilson Cove	September 30	8,655	
	5 miles S Pyramid Pt.	October 1	5,451	15,554
San Diego	8–10 miles W Pt. Loma	May 24, 25	3,914	3,914
Baja California	Ensenada	May 19	1,952	
	Cape Colnett	May 22	900	
		May 23	907	3,759
Totals			100,114	100,114

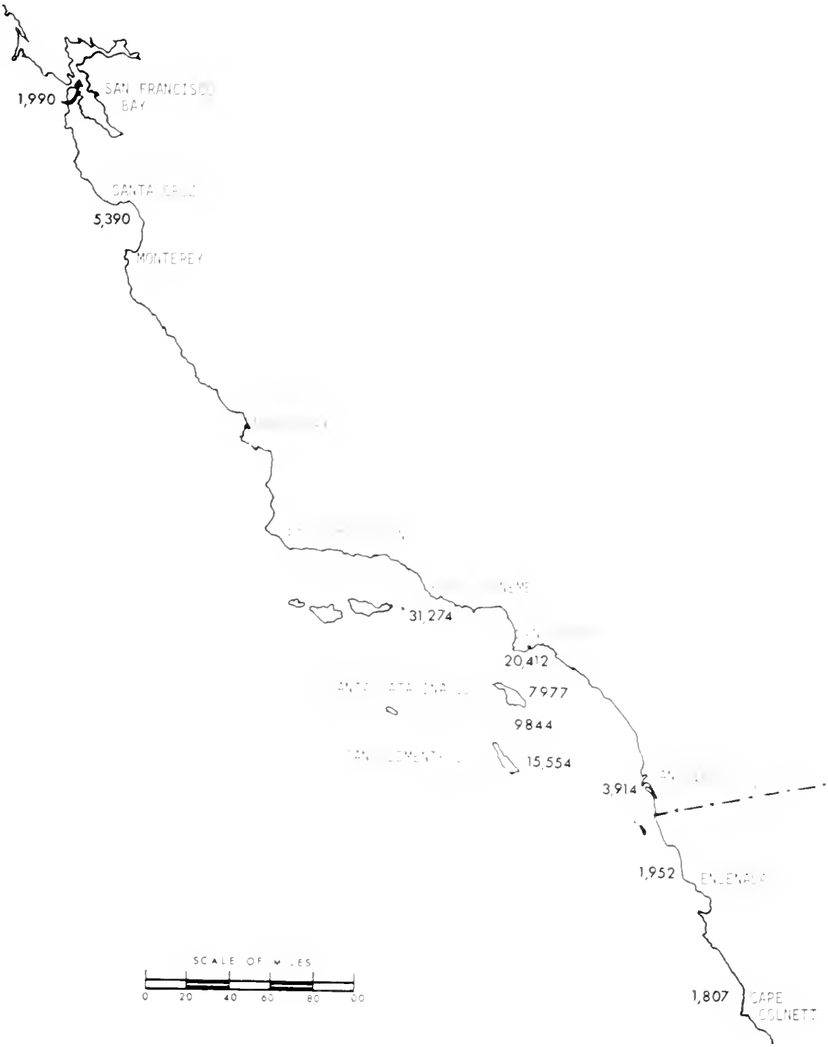

FIGURE 6—Areas and numbers of tagged anchovies released during 1966.

METHOD OF RECOVERY

Tags are recovered with permanent magnets used in the reduction plants to remove metallic scraps from the meal. In the reduction process, the fish are first cooked and pressed to remove the oils, and then pulverized before being dried. After drying, the meal is fine ground and bulk stored or sacked. The process is practically unchanged since first described by Hatton and Smalley (1938). The magnets are generally placed between the dryer and the fine grinder. Metal scrap adhering to the magnets at each plant is collected daily by a department employee, screened to remove excess fish meal, and sorted for tags. Recoveries of tags have largely come from fish at liberty only a day to a few weeks.

and show little movement. Several, however, were at liberty an extended period, and showed movement from southern California to Monterey Bay (Messersmith, 1967).

Tag recoveries up to August 1968 can be assigned only to the major areas of fishing: central California (Monterey), southern California, and Baja California. Recovered tags cannot be assigned to individual vessels, since several unload daily at each plant. Studies on tag recovery rates at each plant show a large variation (0 to 80%) in recovery efficiency. Additional magnet installations have been made to improve tag recoveries and permit us to assign the tag recovery to individual vessels. While the efficiency of these magnets has not been tested due to lack of landings since their installation, we believe that we will be able to determine the area of catch by checking the appropriate vessel's fishing log.

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NOTES

FIRST CALIFORNIA RECORD OF THE GUADALUPE CARDINALFISH, *APOGON GUADALUPENSIS* (OSBURN AND NICHOLS)

While diving off the southeastern tip of San Clemente Island, California (lat 32° 50′ N, long 118° 22′ W), on November 12, 1967, I observed six small fish, all approximately 50 mm long, hovering in loose association beneath a ledge at a depth of 50 ft. Since these fish appeared to be members of the tropical cardinalfish genus *Apogon*, no species of which was known to inhabit California waters, I took two color photographs. Carl L. Hubbs, Scripps Institution of Oceanography, compared these photographs with specimens in the Scripps collection and identified the San Clemente Island fish as *Apogon guadalupensis* (Osburn and Nichols) (Figure 1).

FIGURE 1—A Guadalupe cardinalfish, *Apogon guadalupensis* (Osburn and Nichols), at San Clemente Island, California.

This identification was confirmed after Lloyd D. Richards and I, using an ichthyocide, took 11 specimens (34–44 mm SL) at the same location on February 22, 1968. These fish were collected along a precipitous rock face, where water depths drop abruptly from about 15 ft to over 90 ft. The cardinalfish were in rocky crevices at depths of 40 to 50 ft, usually with one to six fish in a crevice. We saw many cardinalfish that we did not take, and all were within approximately the same size range as those collected. The specimens were deposited in the Scripps Institution of Oceanography fish collection (SIO 68–135).

Since it was first described by Osburn and Nichols (1916), *A. guadalupensis* has been regarded as endemic to Guadalupe Island (lat. 29° N, long. 118° 15′ W.), which lies approximately 140 miles off the western coast of Baja California, Mexico, and 214 miles south of San Clemente Island. The original description was based on a single specimen, but many of these fish have subsequently been taken in Guadalupe Island waters, and 248 specimens (48–96 mm SL) from 18 collections are now in the fish collection at Scripps.

Apogon guadalupensis is very similar to *Apogon atricaudus* Jordan and McGregor, which was once thought to be endemic to the Revillagigedo Islands, Mexico, but was taken recently at Cape San Lucas, B. C. Sur, Mexico, by Richard H. Rosenblatt, Scripps Institution of Oceanography. The lone specimen of *A. guadalupensis* listed by Breder (1936) from Cape San Lucas probably was *A. atricaudus*.

The similar body colors of the two species distinguish them from other eastern Pacific species of *Apogon*. Under natural light at a depth of 50 ft, the San Clemente Island *A. guadalupensis* is bluish-grey dorsally and posteriorly, with the head and ventral portion of the body mostly pale orange. In freshly collected specimens out of water, the bluish-grey areas are purplish-grey, and the pale orange is deep orange-red. Richard H. Rosenblatt (pers. comm.) found similar hues in fresh specimens of *A. atricaudus* at the Revillagigedo Islands. Small individuals of both species have a prominent dark blotch on their first dorsal, but this becomes less apparent in larger specimens. Other characteristics distinguishing both *A. atricaudus* and *A. guadalupensis* from other eastern Pacific cardinalfishes are their relatively slender bodies and the pale posterior margins of their caudal fins. *A. guadalupensis* can be distinguished from *A. atricaudus* by its even more slender body and by the wider pale posterior margin of its caudal fin.

On February 13, 1968, Charles H. Turner and Alec R. Strachan, California Department of Fish and Game, collected 16 Guadalupe cardinalfish (36–48 mm SL) at San Clemente Island. These, too, were taken along the southeastern shore, all from rocky crevices in water 30 to 60 ft deep (Charles H. Turner, pers. comm.). John E. Fitch, California Department of Fish and Game (pers. comm.), after studying otoliths from the specimens collected by Turner and Strachan, believes that these fish were in their second winter.

Since this readily observable species previously has not been reported from California and all observations and captures were made in the southern part of the southernmost of California's Channel Islands, probably *A. guadalupensis* does not occur elsewhere in California waters. Yet, it was numerous in the collection locality when these observations were made. In view of the small, rather uniform size of all individuals seen or taken at San Clemente Island, compared with the size range of the species, these California representatives probably are recent immigrants, having arrived together as pelagic larvae.

Surface waters surrounding Guadalupe Island generally flow southward as part of the California Current system. Thus, it becomes noteworthy that this fish was apparently transported northward to San

Clemente Island. A surface countercurrent flows north along the coast of Baja California during late fall and winter (Reid, Roden, and Wyllie, 1958), but this generally lies well to the east of Guadalupe Island. Nevertheless, vagaries in the California Current system (Wyllie, 1966) readily permit exceptions to the general pattern.

I thank John E. Fitch for his estimate of age based on study of the otoliths, Carl L. Hubbs for making the initial identification from the photographs, Richard H. Rosenblatt for information regarding *Apogon atricaudus*, and Charles H. Turner for providing data on specimens collected by him and Alec R. Strachan.

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MIGRATIONS OF STRIPED BASS OCCURRING IN TOMALES BAY

The objective of this study was to learn about the migrations of striped bass, *Roccus saxatilis*, found in Tomales Bay, California. The entrance to Tomales Bay is on the Pacific Coast about 40 miles northwest of San Francisco (Figure 1). The Bay extends 10 miles southwest from the entrance and in most places is less than a mile wide. Striped bass are caught in the shallow waters near Inverness, at the south end of the Bay.

My personal experience indicates that very few striped bass were caught in Tomales Bay from some time before 1952 until after 1958. There is a report that 7 tons of striped bass were accidentally caught by a commercial fisherman in the spring of 1946 (Adams, 1958, p. 136). The presence of striped bass in Tomales Bay before 1952 and after 1958 may be related to the findings of Chadwick (1967) that "migrations into San Francisco Bay and the Pacific Ocean were much greater in the late 1950's and early 1960's than in the early 1950's", and that "a substantial fishery existed in San Francisco Bay from 1938 through 1943".

Between December 1963 and May 1966, 94 striped bass were caught on sport tackle and tagged with disk-dangler tags using methods described by Chadwick (1963). An additional 113 bass were caught in gill nets and tagged in December 1964 and February 1965.

Tag return data from 65 fish were received as of July 1968. Forty-six (70.7%) of these fish were caught in Tomales Bay. Fifteen (23.0%) were recaptured in the Sacramento-San Joaquin River system and San Francisco Bay. Four fish (6.3%) were caught in the ocean near Pacifica.

The times of recapture outside Tomales Bay varied widely, but eight bass, almost half the outside recaptures, were recaptured either in San Pablo Bay or upstream during April and May of different years (Figure 1). Also, four striped bass tagged and released in the Sacramento-San Joaquin River system in the springs of 1958, 1960, 1961, and 1966 were recaptured in Tomales Bay (Figure 1). Thus, at least some of the striped bass occurring in Tomales Bay participate in the Sacramento-San Joaquin Delta spawning migration described by Calhoun (1952).

Of the 46 fish recaptured in Tomales Bay, about 20% were caught before a spring season had passed, 50% between the first and second spring, and 30% between the second and third spring. One fish was recaptured after the third spring. The implication is that these fish were either resident or returned after spawning migrations.

Dates of release, elapsed times between release and capture, and fork lengths were similar for bass recaptured in Tomales Bay and those recaptured elsewhere. However, 47% of the latter group were caught in April, May, and June, while only 16% of the Tomales Bay recaptures were in these months.

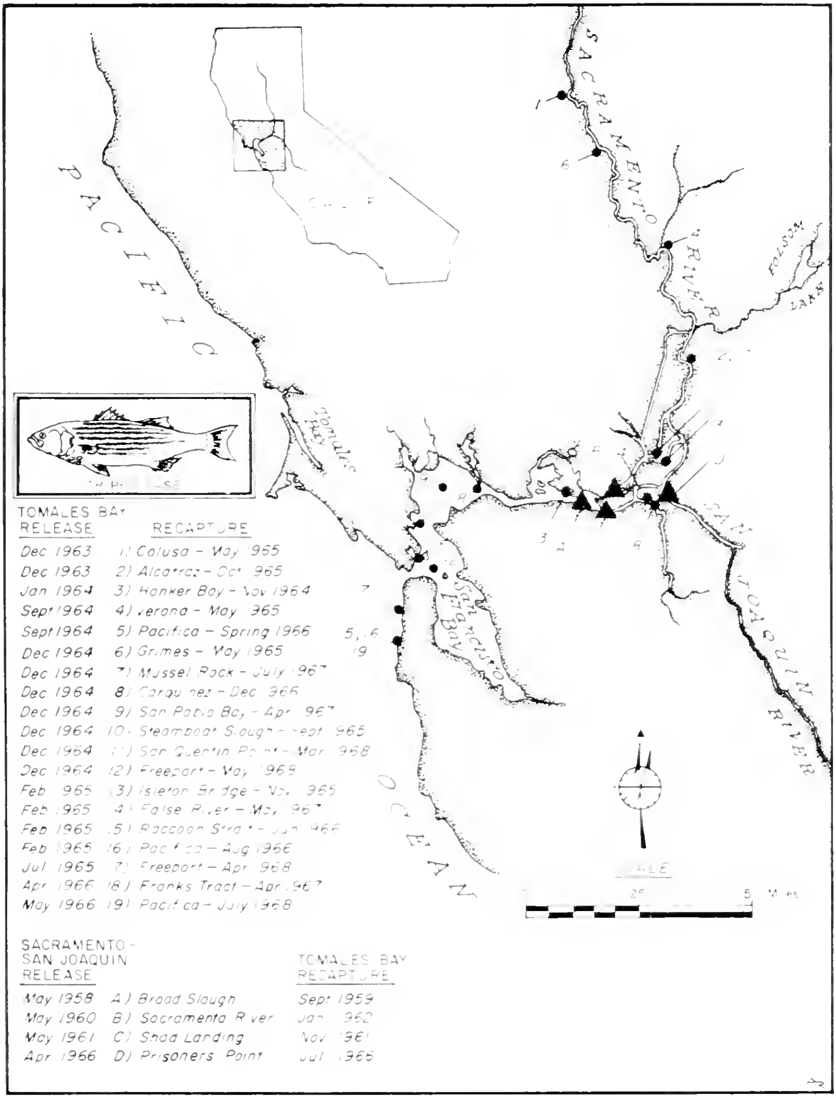

FIGURE 1—Recovery localities far striped bass tagged in Tomales Bay and recovered outside Tomales Bay and tagging localities for four bass tagged in the Sacramenta-San Joaquin Delta and recovered in Tomales Bay.

Newspaper reports, game warden field records, and my personal fishing records were compiled from October 1958 to December 1966. These records show a 2-month period in spring or early summer of the years 1960 to 1965 when there is no indication of striped bass having been caught in Tomales Bay. However, this did not hold true in 1966. The compilation indicates that bass were caught every fall and winter of the years 1961 to 1966. This information corresponds closely with the dates of bass migration away from Tomales Bay shown by the tag re-

[illegible] spawning in the Sacramento-San Joaquin Delta. The [illegible] of these fish from Tomales Bay during [illegible] seaward migrations described by [illegible] (1967).

The [illegible] ranged from 10.5 to 41 inches FL. The [illegible] 24 inches. Thus, a majority of these fish were [illegible] smaller ones were males, they might [illegible]. The scarcity of small bass suggests that striped bass [illegible] Tomales Bay, and the predominance of larger [illegible] present are largely of the size most likely [illegible] Sacramento-San Joaquin system to the ocean [illegible] 1967).

My findings demonstrate that at least some Tomales Bay striped bass [illegible] the Sacramento-San Joaquin River system population and suggest that [illegible] of them originate outside Tomales Bay. The chief [illegible] of these findings is that striped bass fishing success in Tomales Bay is probably largely controlled by migrations from other [illegible], with the factors controlling migrations out of the Sacramento-San Joaquin system presumably being the most important factor.

ACKNOWLEDGMENTS

I am grateful to Arnold B. Albrecht (deceased), Lee W. Miller, Thomas R. Doyle, John L. Thomas, and Harold K. Chadwick of the California Department of Fish and Game for their patient assistance and encouragement. Warden Alfred F. Giddings and Bill Thomson, fishing editor of the *Point Reyes Light*, provided much useful information.

This study was partially supported by Dingell-Johnson Project California F-9-R, "A Study of Sturgeon and Striped Bass".

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Richard Plant, Inverness, Calif. 94937. *Accepted September 1968.*

NEW NORTHERN RECORD FOR THE THREADFIN SHAD, *DOROSOMA PETENENSE* (GÜNTHER), IN COASTAL WATERS OF CALIFORNIA

Two mature male threadfin shad (117 mm and 125 mm TL) were collected March 10 and April 2, 1968, in Arcata Bay, the northern portion of Humboldt Bay, California. They were caught in a 16-ft semiballoon trawl. One fish was taken near the outfall of the Arcata sewage oxidation pond; the other was collected in Mad River Slough, a tributary of Arcata Bay.

This is the northernmost record of threadfin shad in coastal waters of California. Isaacson and Poole (1965) reported the capture of one threadfin shad in Drakes Bay in January 1963. Authorized introductions of threadfin shad have been made in the reservoirs of the Sacramento and San Joaquin river systems in 1959 and subsequent years, but none has been made in coastal waters north of these systems. Correspondence with Robert Loeffel, Oregon Fish Commission, and Donald Kauffman, Washington Department of Fisheries, revealed that the threadfin shad has not been reported from the coastal waters of those states. Consequently, its occurrence in Arcata Bay must be the result of either a northward coastal migration (from the San Francisco Bay area) or an unauthorized stocking.

Hydrographic data were recorded once each month in Arcata Bay. Surface temperatures near the sewage pond outfall ranged from 11.6 to 14.4 C and in Mad River Slough from 11.2 to 15.4 C for the months February through April 1968. Gast (1962) recorded temperatures below 8.0 C only once during a 2-year hydrographic study of Humboldt Bay. Parsons and Kimsey (1954) reported high mortalities in threadfin shad at temperatures below 45 F (7.2 C), and almost no survival at 40 F (4.4 C) in fresh waters.

Briggs (1958) described the threadfin as euryhaline. Miller (1963) indicated that threadfin shad less than 100 mm long preferred salinities less than 15‰ and that larger fish occurred more frequently in higher salinities. In Arcata Bay, surface salinities in the Mad River Slough area ranged from 12.4‰ to 30.7‰, and 27.7‰ to 33.3‰ near the oxidation pond during the months February through April 1968. Gast (1962) reported that the tidal prism is large relative to Humboldt Bay's volume; he seldom recorded salinities less than 29‰ at all depths. However, none of his sampling stations was in a tributary of Humboldt Bay.

Kimsey (1958) stated that the exact temperature range for spawning was not known, but that approximately 70 F (21.0 C) was suitable. He also stated that the threadfin shad seek fresh or nearly fresh water for spawning. Rawstron (1964) observed threadfin shad spawning in Pine Flat Lake in Fresno County, California, when surface water temperatures were as low as 58 F (14.4 C).

Although delicate, the threadfin shad will invade favorable waters very rapidly (Burns, 1965). It appears that proliferation in north coastal waters, other than through emigration or stocking, will occur only if the fish finds suitable conditions of salinity and temperature for spawning. Favorable spawning conditions may be extant in the spring and summer months in the lower reaches of many of the north coast streams (U. S. Gelogocial Survey, 1965). These conditions may exist in the freshwater tributaries of Humboldt Bay. Although suitable temperatures are reached within Humboldt Bay proper (unpubl. data, California Department of Fish and Game, Marine Resources Laboratory, Eureka), salinities may be too high.

ACKNOWLEDGMENT

We wish to thank Harold Jones for assistance with field collections.

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C. F. Bryan and T. R. Sopher, California Cooperative Fishery Unit, U. S. Bureau of Sport Fisheries and Wildlife, Humboldt State College, Arcata, California. *Accepted December 1968.*

ADDITIONAL RECORD OF A TROLL-CAUGHT KING SALMON, *ONCORHYNCHUS TSHAWYTSCHA* (WALBAUM), WITH SPAWNING FEATURES

Swartzell (1967) reported king salmon with spawning features taken in the California commercial ocean troll fishery. A similar specimen was taken by Mr. Pete Beltrano of the troller *Florence* on August 10, 1967, off Navarro Head, California (lat 39° 12′ N, long 123° 47′ W), and brought to my attention by California Department of Fish and Game Warden L. H. Redfern. It measured 37 inches (94 cm) FL but weighed only 16 lb dressed, head on, compared with an average 23 lb for troll-caught king salmon of this length dressed, head on (Fry and Hughes, 1951).

According to Beltrano, when this fish was first taken from the ocean it had a noticeable iridescence and a brilliant golden or copper color with dark brown spots. It was dressed and the entrails discarded at sea so that neither sex nor condition of gonads could be determined, but it appeared similar to a spawning male.

This fish had other features characteristic of a spawning king salmon. The upper jaw was elongated and the premaxillary "hooked". Skull radiographs revealed the presence of breeding teeth which had been worn or broken off, leaving imbedded stumps. Scales were difficult to remove. They were recessed deeply into their dermal pockets and gave the fish a scaleless appearance. Margins of the scales were eroded and resorbed. These characteristics were also noted in Swartzell's two specimens. There were several sores on the dorsal and upper caudal fins. There was no evidence of fin wear. Previous hooking injuries were not apparent.

Kidney smears were examined for "fish tuberculosis" by Harold Wolf, California Department of Fish and Game pathologist. No evidence of the disease, which inhibits spawning in king salmon, was found.

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John M. Jackson, Marine Resources Branch, California Department of Fish and Game.

Accepted July 1968.

BOOK REVIEWS

Taxonomy: A Text and Reference Book

By R. E. Blackwelder; John Wiley & Sons, Inc., New York, 1967; xiv + 698 p. $19.95.

According to the author's definition, "taxonomy, as the term is employed in this book, refers to the day-to-day practice of dealing with the kinds of organisms. This includes the handling and identification of specimens, the publication of data, the study of the literature, and the analysis of the variation shown by the specimens." In view of this definition, it is surprising that so many professional biologists are frightened silly by the word, and shy away from being associated with taxonomy as if avoiding the plague. Fortunately, the subject can be self taught, and what better text for the interested individual than the present volume.

The chapters have been laid out in a natural sequence, and Dr. Blackwelder's coverage and style are easy to follow and understand. A 55-page bibliography is arranged so that headings parallel those in the text and are arranged by chapters or groups of chapters. Thus, if one's appetite for specific knowledge is not sated by what he reads in the text he can search out some of the references and pursue the subject as far as he wishes.

The volume is arranged in six parts, and "is planned to be used as a textbook in two courses: a beginning course on the nature and practice of taxonomy and an advanced one on the theory and technicalities of taxonomy." Part VI on "Zoological Nomenclature" contains a strong critique of the latest code of nomenclature, and to be fully understood, one must have in hand a copy of the 1964 *International Code of Zoological Nomenclature*. Details that Dr. Blackwelder presents regarding the history of zoological nomenclature and the Hemming era will not be found in any other publication, to my knowledge. These two short subsections set the stage for his critique of the code, and whether one "goes along" with the author or not, the need for such a critique is clearly evident and few, if any, are better qualified to do the job than Dr. Blackwelder.

This book should be found on every biologist's bookshelf alongside two other necessary (though underutilized) references: a dictionary, and a style manual for biological writing.—*John E. Fitch.*

Caribbean Reef Fishes

By John E. Randall; T.F.H. Publications, Inc., Jersey City, N.J., 1968; 318 p., profusely illustrated in color and black-and-white. $12.50.

I was quite disappointed when I found that not all the Caribbean reef fishes were included in this volume, but the book does serve its stated primary purpose admirably, namely, "to provide for the identification of the 300 most common fishes that one might observe while snorkeling or diving on reefs of the Caribbean Sea or over adjacent sand flat or sea-grass environments." Most of the 139 color photographs are outstanding, to say the least, and the black-and-white photos are also of top quality.

The family discussions usually include some general information regarding distribution, life history, and behavior of some of the family members, whereas the species accounts contain more exacting information on the same subjects, as well as morphometrics. There are no keys, but since each species discussed is also illustrated, identification should be no problem. If its picture isn't in the book, it's either one of those not covered, or it is new to science.

A section on methods of counting and measuring fishes, a glossary of ichthyological terms, and an index to common and scientific names are included and useful. Because the photographs are of such high quality and show family characters to good advantage, the book will be helpful to fishermen, aquarists, ichthyologists, skin divers, and nature lovers regardless of their fields of interest, geographic assignments, or vacation selections.—*John E. Fitch.*

Mushrooms and Other Common Fungi of Southern California

By Robert T. and Dorothy B. Orr; University of California Press, Berkeley and Los Angeles, 1968; 91 p., illustrated with line drawings and color photographs. $1.75 paper.

Fewer than one-fourth of the nearly 125 species discussed in this small booklet are illustrated, and without illustrations it will prove extremely difficult for a beginning mycologist to identify a mushroom he finds. When one considers that some of the wild mushrooms that grow in southern California are the most deadly species of fungi in the world, the warning given on page 9 becomes even more meaningful: "*The only way to avoid danger is to make absolutely certain that the wild fungus is an edible species.*" Since the Orrs do not inform the reader as to the edibility of very many species, it seems prudent that a successful amateur mushroom hunter proceed with extreme caution if he wishes to be around to partake of his finds on more than one occasion.

Mushrooms lend themselves well to photography, and for up-to-date information on times and places to find some of the more elusive (rare) species, as well as a chance to identify some that are found and photographed, the booklet is worth owning. Nature lovers would also derive a great deal of pleasure from this small volume, but if the only purpose in mind is to collect for the table, one should seek enlightment elsewhere.—*John E. Fitch.*

The Preservation of Natural History Specimens. Volume 2

Edited and compiled by Reginald Wagstaffe and J. Havelock Fidler; Philosophical Library, Inc., New York, 1968; xv + 404 p., 150 text figures. $17.50.

The first volume of this series discussed preservation of invertebrates. This book is the second and final volume, which encompasses the preservation of vertebrates (fishes, amphibians, reptiles, birds, and mammals) and various botanical and geological materials. A chapter is devoted to the Walters plastic method for the reproduction of reptiles and amphibians. There are parts of chapters dealing with the modeling of whales and the modeling and casting of relief maps.

The zoological section gives detailed instructions on killing, measuring, preliminary treatment fixing, permanent labeling, permanent preservation and storage, and microscopical preservation. Special techniques for the preservation of large and small adults, as well as ova and larvae, are included.

For the botanist, there are chapters discussing the preservation of schizomycetes, soil microflora, myxomycetes, algae, mycophyta (fungi excluding lichens), lichens, bryophyta, pteridophyta, cycadophyta and coniferophyta, and anthophyta. One whole chapter is devoted to pollen analysis.

A third major section deals with geology, vertebrate palaeozoology, and palaeobotany.

The appendices are extremely comprehensive and cover instruments, apparatus, and miscellaneous materials; preservatives; labels and labeling; storage and storage containers; general maintenance of installed collections; photographic records; microscopy; and first aid measures (for those who might try to add their own appendage to the collection).

Meticulous instructions coupled with excellent line drawings, by Elizabeth Begg and others, make each technique easy to follow. This book's greatest appeal will be to professional scientists, and will have its greatest usefulness as a reference text in libraries, colleges, and universities.—*Alec R. Strachan.*

The Sockeye Salmon

By R. E. Foerster; Fisheries Research Board of Canada, Ottawa, 1968; Bulletin 162; xv + 422 p., illustrated. $8.

Let's hope this remarkable book will encourage others to write similar ones for additional fishes. It summarizes the great bulk of scientific literature dealing with sockeye salmon. Only a professional like Foerster, with an intimate understanding of this fish based on much personal experience, could have sifted and organized this great mass of information with such discernment. He begins with a chapter on systematics, distribution, and general life history. I particularly enjoyed his discussion of the evolution of the Pacific salmonids. Succeeding chapters deal with trends in the commercial fishery, spawning escapement, reproductive success, migrations, and spawning. The lake residence phase of sockeye is covered in great depth, with careful attention to the whole matter of production in lakes. Terminal chapters deal with life in the ocean, identification of stocks, and artificial propagation. The book is beautifully illustrated with three-color plates, some black-and-white, and a host of graphs and charts. It includes massive documentation in the form of summary tables tied in with highly analytical discussions which, along with a long list of references, will save a lot of time for biologists working on this animal in the future. Considering the great wealth of data the book contains, it reads along very pleasantly and the primary facts emerge very clearly. I particularly liked the way Dr. Foerster highlighted the great gaps which still exist in our knowledge of sockeye salmon and suggested how they might be filled in the future.—*Alex Calhoun.*

The Life of the Pond

By William H. Amos; McGraw-Hill Book Company, New York, 1967; 232 p., profusely illustrated. $4.95.

This book deals with the natural history of ponds, which the author defines as those standing bodies of water that are shallow and rather small with a more or less uniform temperature throughout. The author, a consultant in biophotography at the Woods Hole Marine Biological Laboratory, emphasizes the ecology of ponds and the diversity of live forms that are found in them. As might be expected from a biophotographer, the photographs are many, varied, and, above all, superb. The book's 232 pages are packed with 125 color photos, 24 black-and-white and duotone photos, and 72 diagrams and drawings.

With the quantity and quality of the photographs involved, the text is relegated to a somewhat secondary status. At times, in fact, the text seems only to supplement the captions. More disturbing, however, is that many of the photographs are grouped so that as many as five pages of photographs and extensive captions intervene between pages of text. Sentences are often parted in the middle to be completed several pages later. The reader, more than once, finds it necessary to return and pick up the train of thought after looking at several pages of photos with their captions and subcaptions.

The text is of high school level and requires no biological knowledge of the reader, since the book as a whole is slanted toward the general public. It attempts to stimulate an interest in nature study, and the reader finds himself persistently invited and challenged to investigate pond biology.

In line with this philosophy of encouraging the study of ponds, this book contains an appendix with sections entitled "Homemade Ponds", "Keeping Pond Animals in the Home", "Exploring the Microscopic Pond World", and "How to Learn More About a Pond". The latter describes simple collecting equipment and instructions for its manufacture.

The appendix also contains a list of selected National Parks with comments about the ponds found in them, a key to some common pond animals, a brief discussion about the sight of fishes, and a glossary of elementary ecological and anatomical terms.

Despite the book's shortcomings, almost any person with an interest in nature will find that this volume, with its surprisingly low price of $4.95, will enhance his library.—*Franklin G. Hoover.*

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Notice is hereby given that the Fish and Game Commission shall meet on April 2, 1969, at 9 a.m. in Room 1138, New State Building, 107 So. Broadway, Los Angeles, California, to receive recommendations from its own officers and employees, from the Department of Fish and Game and other public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to birds or mammals, or any species or variety thereof, for the 1969 hunting season.

Notice is hereby given that the Fish and Game Commission shall meet at 9 a.m. on April 25, 1969, in the Board of Supervisors' Chambers, Shasta County Courthouse, Redding, California, for public discussion of and presentation of objections to the proposals presented to the Commission on April 2, 1969, and after consideration of such discussion and objections the Commission shall publicly announce the regulations it proposes to make relating to birds or mammals, or any species or variety thereof, for the 1969 hunting season.

Notice is hereby given that the Fish and Game Commission shall meet on May 23, 1969, at 9 a.m. in the Main Auditorium, Resources Building, 1416 Ninth Street, Sacramento, California, to hear and consider any objections to its determinations or proposed orders in relation to birds and mammals for the 1969 hunting season, such determinations resulting from hearing held on April 25, 1969. This notice is published in accordance with the provisions of Section 206 of the Fish and Game Code.

Fish and Game Commission
Leslie F. Edgerton
Executive Secretary

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