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ASPECTS OF THE ECOLOGY OF THE HITCH, *LAVINIA EXILICAUDA* (CYPRINIDAE), A PERSISTENT NATIVE CYPRINID IN CLEAR LAKE, CALIFORNIA

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ABSTRACT. Growth, diet, and fecundity of Clear Lake hitch (*Lavinia exilicauda chi*) were investigated to see if any changes had taken place following the establishment of a large population of Mississippi silversides (*Menidia audens*) in the lake. No changes were found. Hitch seem to avoid competing with silversides for zooplankton by being limnetic in all except the early life history stages. Fecundity was found to be higher than that of Beardsley Reservoir hitch, but considerably lower than a previous estimate had indicated.

The Clear Lake hitch (*L. e. chi* Hopkirk 1973) is one of only four (out of 12) native species that has managed to persist in large numbers in Clear Lake, Lake Co., California, following various environmental perturbations and the establishment of 16 exotic species (Moyle 1976). The hitch is a large (to 35 cm standard length), plankton-feeding cyprinid that spawns in the intermittent streams that enter the lake and is taken in small numbers by a commercial fishery. Although brief studies of its feeding habits were undertaken by Lindquist, Deonier, and Hanley (1943), and of its growth and reproduction by Murphy (1948), no studies have been undertaken since the establishment in the lake of the Mississippi silversides (*Menidia audens*) in 1967 (Cook and Moore 1967). The silversides is a small planktivore that now dominates the inshore areas. It has been introduced into reservoirs in Oklahoma and California and appears to be extending its range rapidly (Moyle 1976). An additional aspect of hitch biology needing to be examined was the extremely high fecundity (112,000 eggs/female) reported by Murphy (1948), which was in contrast to the much lower fecundities (about 3,000 to 26,000 eggs/female) reported by Nicola (1974) for *L. e. exilicauda* from Beardsley Reservoir, California. The purpose of this study, therefore, was to examine the feeding habits and growth rates of Clear Lake hitch, for comparison with pre-silversides studies, and to reexamine their fecundity.

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STUDY AREA. Clear Lake is a large (16,194 ha), warm, eutrophic lake located in the Coast Range of central California, at an elevation of 404 m. It has three distinct arms; this study was conducted primarily in the upper arm (Upper Lake), into which most hitch spawning streams flow. A detailed description of the lake and its limnology can be found in Goldman and Wetzel (1963).

METHODS. Collections were made monthly from April through September 1976. These collections were made using a 10.9 x 1.2 m seine with 0.3 cm bar mesh (primarily effective in collecting young of the year), a 91.4 x 2.4 m seine with 2.5 cm bar mesh, a 24.4 x 1.8 m seine with 1.27 cm bar mesh, and a four-seam otter trawl fitted with an 0.3 cm mesh bag. Additional collections were made with the trawl in 1977. For adult fish, weight was measured to the nearest gram, using a 300 g Pesola spring balance; fork length and standard length were measured to the nearest millimeter and scale samples were taken from most fish. Samples of young of the year hitch were preserved in a 4% buffered formaldehyde solution, as were any adults saved for gut analysis and fecundity counts.

For age and growth analysis, about six to 10 non-regenerated scales were mounted between two glass microscope slides and serially labeled. The scales were read in a modified microfilm reader, with a magnification of 28.5 x. Scale radii for the sample were measured, the median radius calculated, and, for two to four scales of near median radius, the distance from the scale focus to each annulus and the scale edge at the left lateral margin was measured. These measurements were averaged for each fish. Criteria used to determine the presence of an annulus were crossing over, crowding of circuli, and starts and stops of lateral rays. When there was a question of age, the scales were read by a second party. If no agreement could be reached, the scales were discarded. Since the calculations for this study were done using standard length (SL) and the previous work on hitch life history used fork length (FL), a conversion factor was calculated to allow comparison: $FL = 2.60 + 1.1 \times SL$ ($r = 0.99$). Comparison of the 1976 data with those of Murphy (1948) was made graphically because the older data were available only in that form.

For fecundity determinations, ovaries were removed from 18 preserved females in the laboratory, air dried overnight, and weighed to the nearest 0.01 gram. Four samples were taken arbitrarily from both ovaries, pooled, and weighed to the nearest 0.01 g, and the number of eggs in the sample was counted. The number of eggs per gram was then calculated, and used to estimate the number of eggs in the ovary. Pooled sample weights ranged from 5 to 17% of the total ovary weight.

For diet determination, the contents of the "stomachs" of 168 fish were examined. The "stomach" was taken as the initial portion of the intestine down to the first bend. The point-volume method (Hynes 1951) was used to estimate the percent contribution of each food item to the diet.

RESULTS. *Age and Growth.*—The body length-scale radius relationship was plotted for all the fish examined and found to be linear ($r = 0.80$), but directly proportional, so the modified direct proportionality formula described by Tesch (1971) was used for back-calculation. The size at scale formation used was 22 mm, which was also the average size of the smallest scaled hitch collected. Comparison of back calculated lengths using a *t-test* shows that female hitch are significantly larger than male hitch ($\alpha < 0.001$) at all ages except age V, where the difference is non-sigificant, presumably due to the small sample size.

Comparison of results of the age and growth analysis from this study with the results of Murphy (1948) shows that the growth rate of Clear Lake hitch has remained about the same since 1947. The female hitch from the 1976 sam-

TABLE 1. *Back-calculated lengths in mm at each annulus for male and female hitch from Clear Lake.*

Year Class	N	I	II	III	IV	V
			FEMALES			
			Annulus			
1974	27	119	193			
1973	48	107	176	219		
1972	30	106	162	203	234	
1971	1	122	166	216	246	264
Combined	106	110	176	213	234	264
			MALES			
			Annulus			
1975	7	105				
1974	43	100	163			
1973	37	106	165	203		
1972	8	89	139	177	209	
1971	2	92	120	151	179	200
Combined	97	102	161	196	203	200

ple have a slightly smaller average size than those from the 1947 sample, while the male hitch in 1976 were slightly larger than those of 1947. In both cases, the differences are minor, and probably due to natural variation. Although males and females grew at different rates, the length-weight relationships for both sexes were similar. Comparison of the regression lines for the log-transformed data, using analysis of covariance, showed no significant difference in their slopes ($P > 0.01$). The data for both sexes were then pooled, to give the equation: $W = 2.17\ SL^3$ ($r = 0.98$, where W = weight).

Because 18 samples (most with $n = 20$) of young of year hitch were taken during the 80 days following hatching in early April, growth was examined during this period. Growth was linear ($r = 0.94$) for length vs days since hatching, with a growth rate of approximately 0.45 mm/day, and an average size of 40 mm at the end of 80 days.

Fecundity.—Fecundity was plotted against weight, standard length, and fork length, with all three showing a large spread about the line. The average fecundity of the 18 fish examined was about 36,000, ranging from about 9,000 (in a 212 mm SL fish) to 63,000 (in 312 mm SL fish). Curves were fitted to the data by computer and the best fitting curve was the linear equation for the weight-fecundity relationship, $F = 7154 + 106\ W$ ($r = 0.65$). The best fitting curve for fork length was the linear equation $F = 52299 + 353\ L$ ($r = 0.57$), while the best fitting curve for standard length was $F = -30384 + 504\ L$ ($r = 0.57$). The fork length-fecundity relationship will be the only one referred to in comparison with the data of Nicola (1974) and Murphy (1948), since it is the only relationship they used.

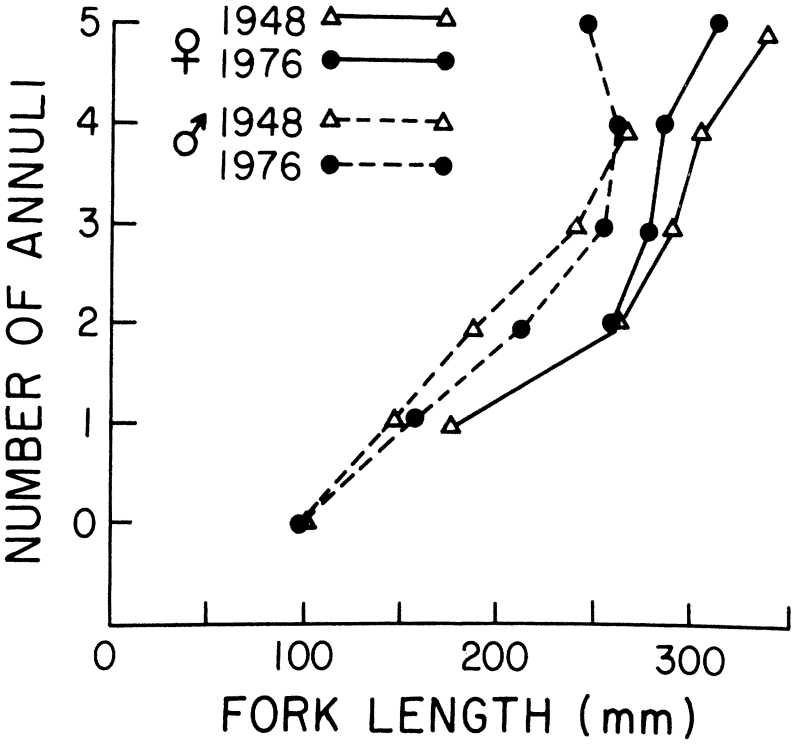

Fig. 1. Fork length and age at capture of male and female hitch from spawning runs in streams tributary to Clear Lake, in 1976 and 1947.

Food Habits.—Of 168 hitch stomachs examined, only 94 contained identifiable food items. The remainder were empty for a variety of reasons, including the time of collection, method of collection, method of preservation, or chance. All stomachs taken from spawning fish were empty, as were stomachs of adult fish taken early in the morning. Typically, hitch caught during the afternoon or evening contained food in at least some portion of the gut.

The smallest hitch examined (19–30 mm SL), all taken inshore in shallow water, fed primarily on adult and larval chironomids. As the fish increased in size, *Daphnia* became more important, making up about half the diet of the 31–50 mm size class. Fish larger than 50 mm were generally unavailable inshore, and they were presumed to become limnetic at about this size. After the fish become limnetic, they feed almost exclusively on *Daphnia*, with other zooplankton and adult midges taken in small numbers.

DISCUSSION. It is evident that neither the diet nor the growth rates of Clear Lake hitch have changed since the 1940's, despite the introduction of the Mississippi silversides, a potential competitor for zooplankton. Hitch seem to be able to avoid competing with silversides by being present in inshore areas mainly in spring and early summer, when silversides populations are

TABLE 2. *Percent composition by volume of stomach contents of different size classes of Clear Lake hitch taken April – July, 1976.*

Size Range (S.L., mm)	N	*Daphnia*	*Bosmina*	*Cyclops*	*Hyalella*	ostracods	Misc. crustaceans	Larval chironomids	Adult Diptera
19–30	27	14	3	–	3	<1	–	18	61
31–50	24	48	6	3	–	2	–	5.8	35
51–200	26	84	5	2	–	1	<1	–	7
201–270	12	98	<1	<1	–	<1	1	–	–

likely to be lowest (H. W. Li, unpubl. data), and by becoming limnetic in habit once they exceed 50 mm SL. These habits of the hitch do not seem to have developed in response to the silversides, but were probably evolved as a way of avoiding competition with the inshore-oriented (and now extinct) Clear Lake splittail (*Pogonichthys ciscoides*) (Moyle 1976). The Clear Lake sculpin (*Cottus asper* subsp.) also maintains large populations in the lake, due in part to the absence of any ecologically similar exotic species (Broadway and Moyle 1968).

Growth in Clear Lake hitch was about twice as fast as that for hitch from Beardsley Reservoir, the only other population that has been studied, for the first 2 years of life (Nicola 1974). This is presumably related to the higher primary productivity of Clear Lake, which is several times that of Beardsley (Nicola 1974). After the second year, when hitch of both populations matured, growth rates (as indicated by annual length increments) of the two populations were about equal. This may reflect the greater effort Clear Lake hitch put into reproduction. Not only was their absolute fecundity higher than Beardsley hitch, but their size-specific fecundity as well. This, a 250 mm FL hitch from Clear Lake would have a fecundity of about 36,000, while a similar fish from Beardsley Reservoir would have a fecundity of about 14,600. Despite the comparatively high fecundities estimated for Clear Lake Hitch, the estimate of 112,000 for a single 250 mm FL female by Murphy (1948) is obviously too high and in error.

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