THE FOOD OF THE BAIRDIELLA

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INTRODUCTION

Because of the large bairdiella population after their successful hatching in 1952 and the relatively small sizes of the individuals, it was anticipated that they would be important as forage for any larger sport species subsequently established. This assumption was justified upon the later spawning success and multiplication of the orange-mouth corvina. As part of the program to obtain information basic to managing a sportfishery, a food study was begun on bairdiella in 1954. The study was conducted on a part-time basis and terminated in the summer of 1956.

METHODS

Gut contents of approximately 1,000 bairdiella were examined over a two-year period. Gill nets and seines were employed for sampling, on a monthly basis during the first year, and bi-monthly thereafter. Each monthly sample consisted of at least four subsamples taken at equal intervals over a 24-hour period.

Intensive sampling with gill nets started in July 1954, following a few earlier trials that spring and the previous year. Variable-mesh nylon nets were usually used; the net dimensions were 8 x 125 feet, and the mesh size ranged from 0.5 to 2.0 inches (squared). Juvenile and adult bairdiella were usually obtained in abundance and it is believed that all ages were adequately represented. Nets were laid on the bottom, and two sets were made simultaneously in which one of two alternative arrangements was followed: either one set was made in the shallows (approximately six feet) and the other in deep water (25-30 feet), or both were made at the same depth at different locations. Normally the fish were obtained at different depths near Fish Springs. However, some samples were taken at Salton Sea Beach, and at some localities on the east shore.

The digestive tract of *B. icistius* is short, with a sac-like stomach, a pylorus with appendages, and an intestine with one forward-directed loop. The jaws and pharyngeal bones have cardiform dentition. The gill-rakers are fairly long and slender and are studded with fine calcareous tubercles which give them a roughened appearance under magnification. When examining for food, both stomach and intestine were removed and each checked separately. The items were listed on a food card along with accessory data such as degree of stomach fullness; stage of digestion; size, sex, and condition of fish; and the time and locality of capture.

Early in the study it was found that *Neanthes* weight could be accurately predicted from the lengths of the paired mandibles of its pharynx. Fortunately, mandibles were not affected by fish digestive juices and furnished a reasonably accurate index to the size and quantity of the food eaten by the fish. Mandible length was a far more accurate method of estimating worm weight than either segment counts or worm length—segment count varied widely in worms of the same weight because of damaged or lost tail portions. Both of the latter methods were rendered highly inaccurate by digestion.

In order to obtain a standard for estimating weight from mandible length, live worms were gathered from under the bark and barnacles of submerged brush around the edge of the Sea, fixed in mild formalin, and weighed. Damp weights were utilized and all excess liquid was blotted off. After weighing, each worm was dissected for its mandibles which were measured by means of an ocular micrometer. It was found that worm weight increased by a factor slightly less than the cube of the mandible length, for the sizes of worms that were eaten by the fish (Figure 65). Two such samples were taken, one at Salton Sea Beach in April 1954, and the other at Fish Springs in August 1955; both agreed substantially and the estimates were pooled for construction of a weight vs. mandible-length table. Weights of *Neanthes* eaten by individual fish were then computed from the mandible size frequencies recorded from the fish.

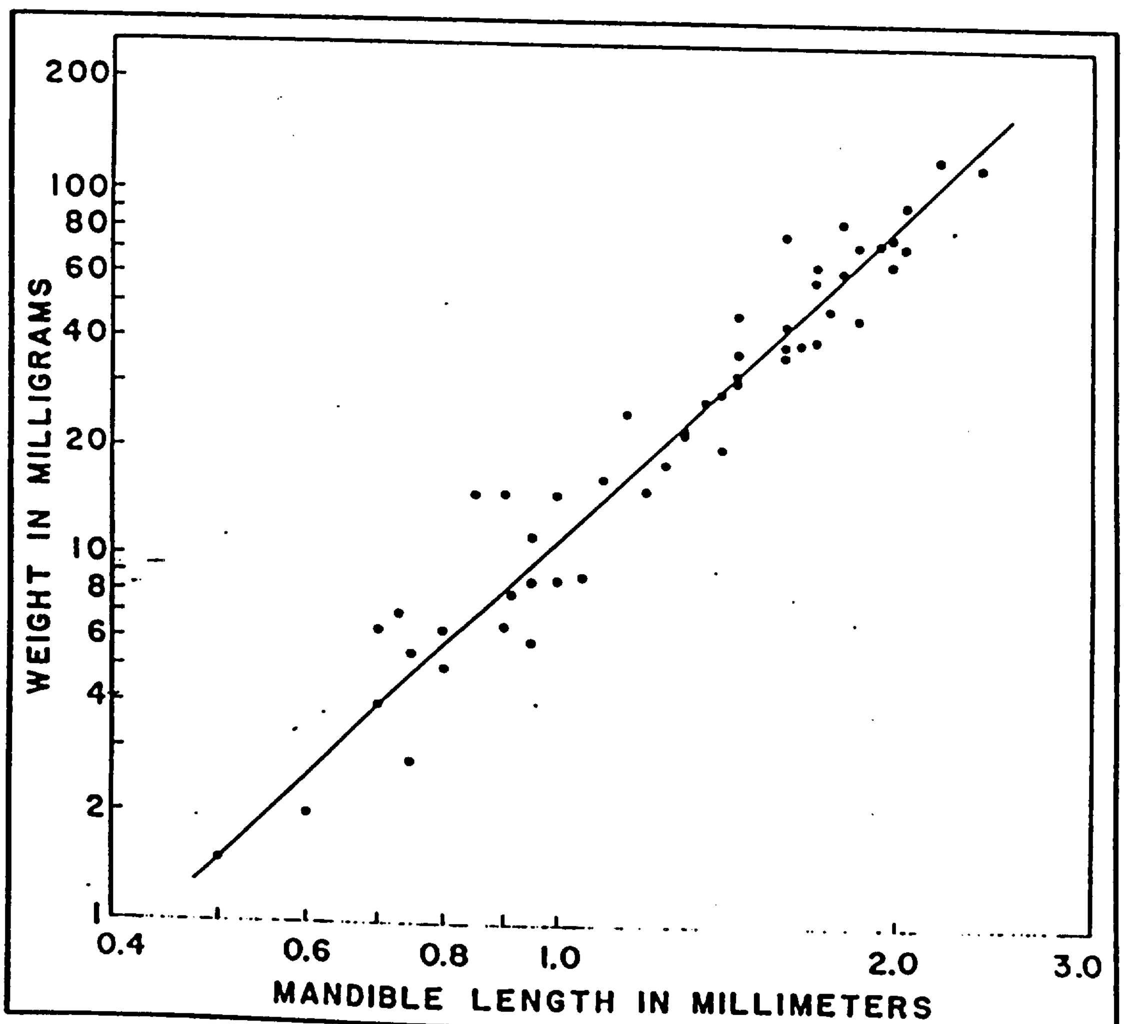

FIGURE 65. Relationship between body weight and mandible length in *Neanthes succinea*. Regression line (log weight = 2.890, log length = 1.844) fitted by least squares. Samples were mainly immature forms, however, some individuals near maturity were included, the sizes of worms nearly duplicating the sizes taken by adult fish.

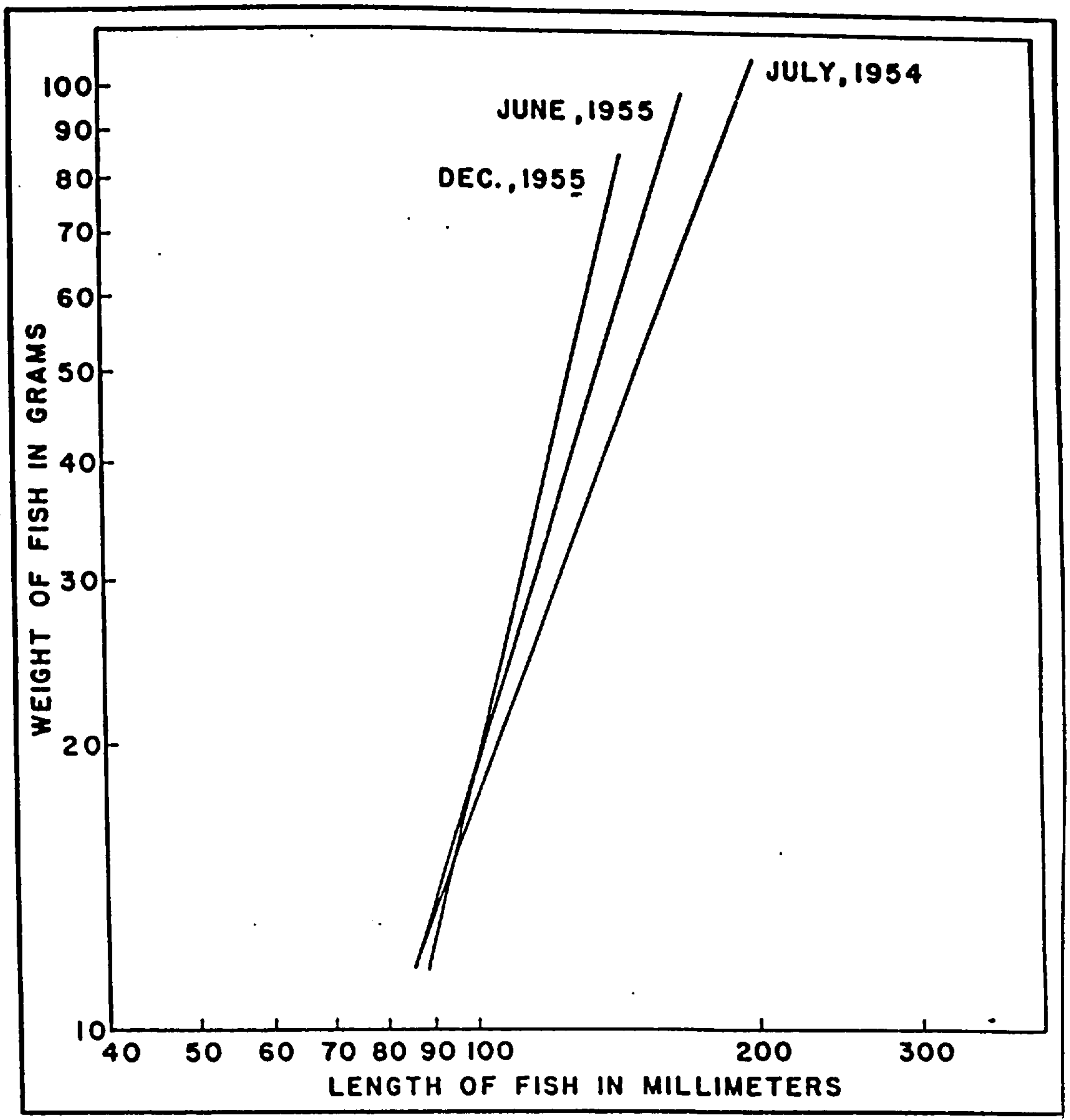

FIGURE 66. Weight-length regressions of bairdiella in three samples from the Saltc Sea. Each sample is based on a minimum of 30 specimens. Data fitted by least square

A small percentage of the worms in stomach samples collected a night probably had spawned and the calculated weights in these case would be too high. This may be especially true for the periods i March when the stomach totals seemed unusually high. However, comparison of these amounts with quantities obtained in feeding exper ments showed that the March figures were high but not unreasonab so. For the remainder of the year, the fraction of weight lost to spaw ing was probably small and reasonably constant.

Individual weighing of all fish was expensive in time and effort, : most fish weights were estimated from a regression based upon the standard lengths. Weight-length relationships were calculated f normal specimens taken at three separate dates (Figure 66). Sin the data for each sample seemed distinct from the others (fish we lightest per-unit-length in the first sample and heaviest in the last weight-length tables were constructed for each of the regressions. assigning weights to measured fish, the table closest chronologically the fish sample was used. Individual fish condition was also evaluated and one of three categories (normal, thin, very thin) was noted on the food cards.

RESULTS

Food Items of Bairdiella in the Gulf of California

B. icistius are common in the shallow surf zone of the beaches near San Felipe, Mexico, at the head of the Gulf of California. Two samples of fish (averaging approximately seven inches total length) were taken there in March (1954 and 1955). Small crustacea (shrimp, amphipods, and isopods) were important in their diets and fish remains and small bivalves were also noted.

Food Items of Bairdiella in the Salton Sea

In the Salton Sea, nauplius larvae of copepods and barnacles, barnacle cypris larvae, larval and small adult *Neanthes*, and *Bairdiella* eggs and larvae made up the total food types found in the stomachs of the 0-30 mm fish (Table 48). The percentage of occurrence of these items differed sharply from the food of adult fish over the same period. Although rotifers were abundant in the plankton throughout the summer none was found in the fish stomachs. Nauplii of barnacles and copepods were the first food of the fish but were not utilized after they reached 30 mm. In addition, some of the smaller fish, when captured near solid objects upon which they appeared to be "grazing", contained an abundance of barnacle cypris larvae. Adult patterns of feeding appeared early and the young fish began to feed on the larger bottom-dwelling *Neanthes* during the first month of their existence. Although copepods were consistent in diets of both young and adult fish, they probably were of major importance only to the smaller fish. *Bairdiella* eggs and larvae were extensively preyed upon by larger postlarval fish of the same species during June and July of 1953, 1954, and 1955 (Table 48).

Neanthes was the staple food item for all but the very young fish (Table 49). The worms were probably taken from the mud or silt bottom during the daytime and from near the bottom or free in the water at night. Fish netted during the day commonly had sand mixed with

TABLE 48

Food of Young and Adult Bairdiella From the Salton Sea, 1953-1955

Sample Period Size of Fish in mm	Percent of Fish Showing Food Item						Number of Fish Examined
	Nauplii	Cypris	Copepods	Fish Eggs	*Neanthes*	Fish	
May-July							
0-30	46	22	36	25	4	13	69
>70	--	--	12	1	66	1	220
Aug-Nov							
30-70	--	--	45	--	72	--	29
>70	--	--	8	--	68	--	412

TABLE 49

Food of Adult Bairdiella by Month From the Salton Sea

Month	Percent of Fish (over 70 mm in Standard Length) Showing Food Item							Number of Fish Examined
	Copepods	Bairdiella		Insects	Barnacles	*Neanthes*	Debris	
		Eggs	Larvae					
Jan.	--	--	--	--	--	79	--	48
Feb.	--	--	--	--	2	81	--	58
Mar.	8	--	--	--	--	100	--	12
April	1	--	--	1	1	88	--	64
May	12	3	--	3	--	66	--	74
June	6	3	--	--	--	75	1	72
July	19	..	3		.	57	15	73
Aug.	7	--	--	2	1	43	11	152
Sept.	5	--	--	1	--	85	--	80
Oct.	16	--	--	1	2	83	4	90
Nov.	3	--	--	2	9	81	1	90
Dec.	16	--	--	--	3	77	1	88

Neanthes in their stomachs while samples taken at night rarely contained material other than the worms. Because they were small, it is doubtful that copepods made any significant contribution despite the fact that they occurred in fish digestive tracts during almost all parts of the year. Several adult fish contained copepods in very large numbers (estimates of up to 1,000) but only 13 such individuals were encountered during the entire study. The majority of feeding on copepods involved greatly lessened numbers (5-100) which probably contributed little to the total nutrition of the fish. The occurrence of copepods offered evidence that food had been selected, however. In those fish which had eaten large amounts of copepods, these were usually the only food items while other fish taken at the same time and place had only *Neanthes* in their digestive tracts.

During the months of May and June a small percentage of adult fish contained *Bairdiella* eggs in their stomachs (Table 49). During July, a similar percentage of larval and postlarval fish occurred as a food item in the adult fish. It appeared that the eggs and larvae from the late spring spawnings underwent considerable predation during the summer. After July, however, young *Bairdiella* seemed unavailable to the larger fish. Several desert pupfish were noted in the larger fish. At the time, the pupfish was common in the fresh and brackish ponds near the Sea but was rarely encountered away from shore.

Insects made up a small proportion of the food and were noted only from April through November. Because of their small size and their rarity in the diets, they were probably insignificant as a food. Insect items were usually small dipterans or hymenopterans, but occasionally a larger corixid or yellowjacket was encountered. One group of *Bairdiella* that was land-locked in a shore pond had fed heavily on corixids that abounded in the pools.

Debris (twigs, barks, blue-green algae) appeared most commonly in [the stomachs during July and August and seemed to be a result of th] age of fish stomachs contained inedible material in October 1954 during a period of exceptionally low food intake after the peak of a severe "kill." Barnacle shells occurred in a low percentage of fish, especially

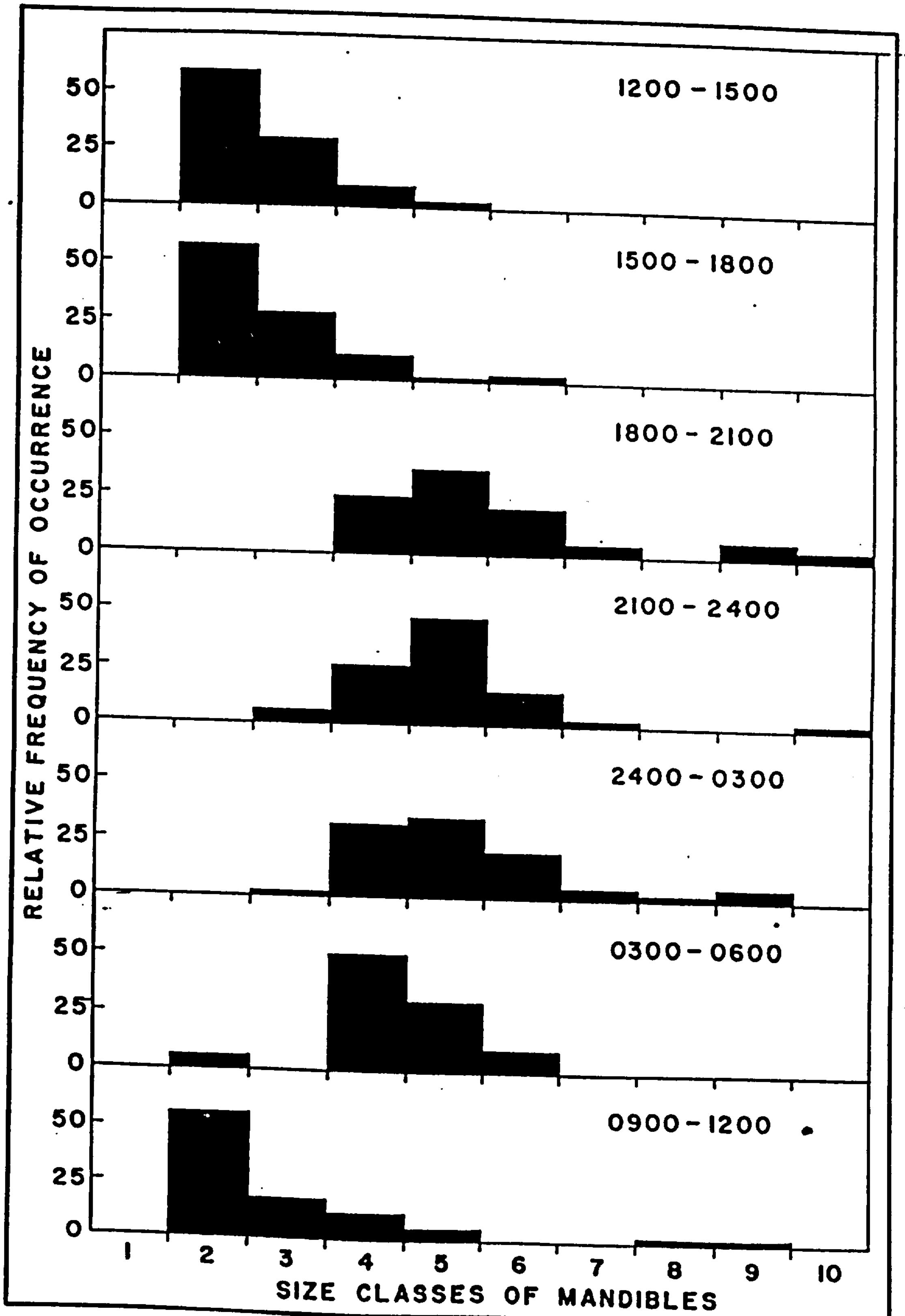

FIGURE 67. Diurnal variation in sizes of worms eaten by bairdiella in the Salton Sea. Frequency of each size-class is presented as a percentage of the total

in the fall months. Whether these were entire animals the fish had managed to remove from the substrate, or merely loose plates, is not known.

Diurnal Variation in Food Intake

A comparison of size classes of worms taken by fish at various times of day usually demonstrated that those taken at night were considerably larger (Figure 67). Usually the break between fish feeding on large or small worms coincided with night and day. This was evident for nearly every month and whenever worms of two modal frequencies were noted the larger ones had been taken at night. In general, the greatest differences between the day and night modes corresponded to periods of good feeding (Figure 68); however, the fish fed more heavily at night than during the day even during periods of poorer feeding.

Spring increase in worm size coincided with rising temperatures which were lowest in January and reached a peak during July and August. Modal size of night-swimming worms was lowest during January which was also the month of the lowest total intake during the winter and spring. After January, both the day and night size-frequency peaks of worms moved to larger classes and reached their

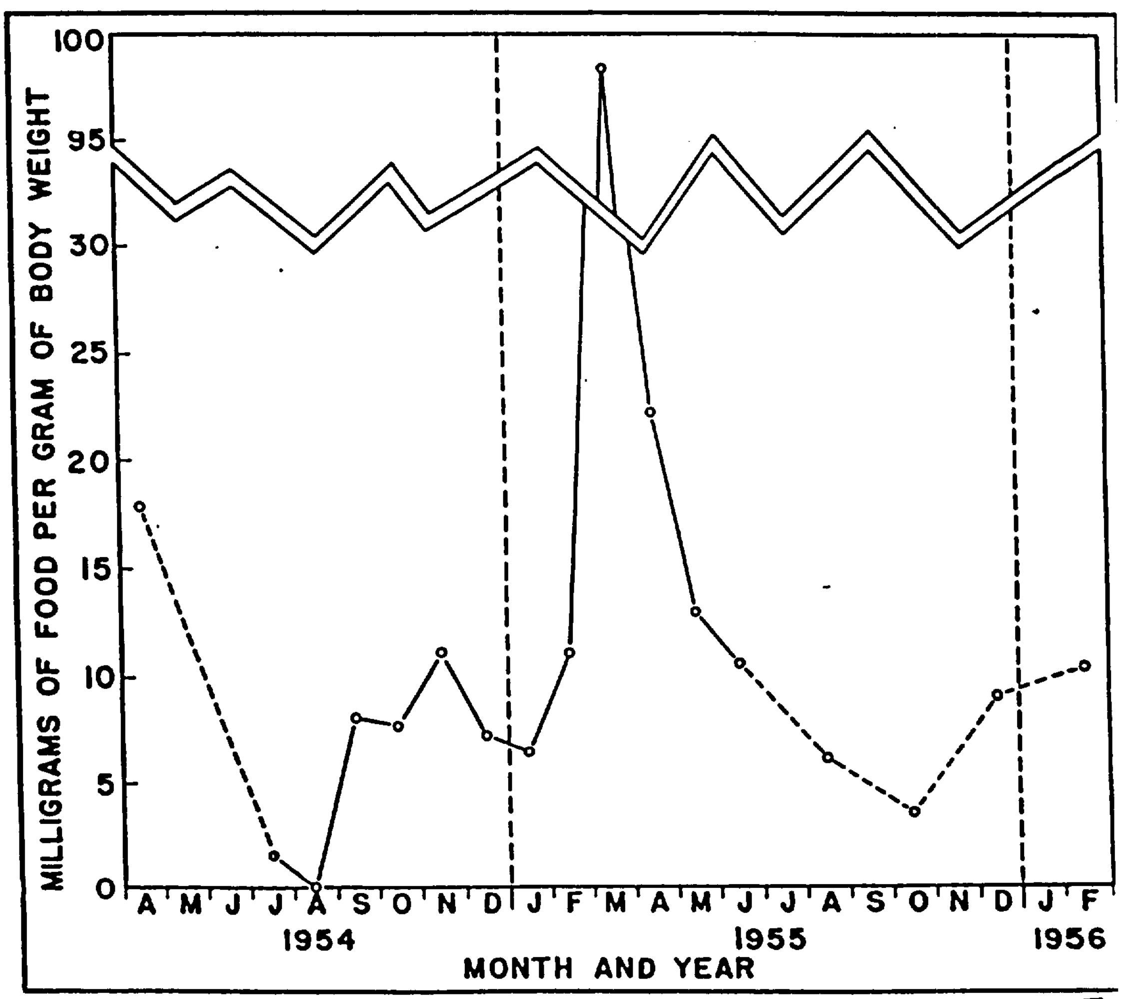

FIGURE 68. Averaged food intakes of bairdiella in the Salton Sea for monthly sampling periods. Because of considerable size differences between the fish age-classes

maxima in March. After March, size peaks of ingested worms declined in both day and night samples.

Seasonal Variation in Food Intake

Food intake varied considerably through the seasons and two peaks of high feeding were noted each year. The spring peak, however, dwarfed that of the fall (Figure 68). During the seasonal peaks all size classes of worms became more available to the fish, indicating a probable overall increase in productivity in the worm population (if maturation of adults was the sole factor governing the increased food intake it would be expected that the large mature or nearly mature worms would be the chief size classes that became more available). Despite severe fluctuations in the worm population, spawning worms were eaten by the fish at all times of year. Peaks in the numbers of spawning worms ingested occurred during the spring and fall, the spring peak being much the larger.

At numerous times, extensive fish mortalities occurred and thousands of *B. icistius* washed ashore. Frequently these were very thin fish, literally made of "skin and bones." These catastrophies were apparently due to several factors, but food shortages during late summer seemed to be a principal cause. The relationship between fish condition and the kills is particularly clear when the incidence of thin and very thin fish in the samples is compared with the relative intensity of the kills (Figure 69). In both 1954 and 1955, thin fish and large numbers of dead fish occurred in the fall, the frequencies of each category rising and falling together.

The evidence is quite conclusive that the autumnal die-offs were due to severe food shortages during the summer. Pooled percentages for the two years show that the lowest percentages of *Neanthes* occurred in the fish stomachs during July and August (Table 49)—an important fact when it is considered that *Bairdiella* was nearly completely dependent upon the worm for food. The high incidence of inedible debris (sticks, mud, sand) in the fish stomachs at this time and the low volumes of food intake during the summer months corroborated these findings (Figure 68). Summer food shortages seemed largely due to the anoxic conditions in the deeper waters during the warmer months.

Despite improved feeding conditions from September through the fall of 1954, large numbers of thin and dead fish continued to appear on and near the beaches. Gill nets set in shallow locations caught some extremely thin individuals and others that were in excellent condition. This paradoxical situation continued into the winter, apparently because very thin fish were too weak to obtain their food, which normally consisted of actively-swimming worms. This was shown by comparing the diets of thin and normal fish over this period (Table 50). Feeding conditions were not as restricted in the fall of 1955 as in the same season of the previous year. Thin fish appeared in samples taken during the fall of the second year but they were not as emaciated, and the associated die-off was less intense. The factors responsible for the improved conditions in the second year are not known. These could have included increased productivity of worms, shorter periods of worm absence in deep water or a smaller population of fish utilizing the

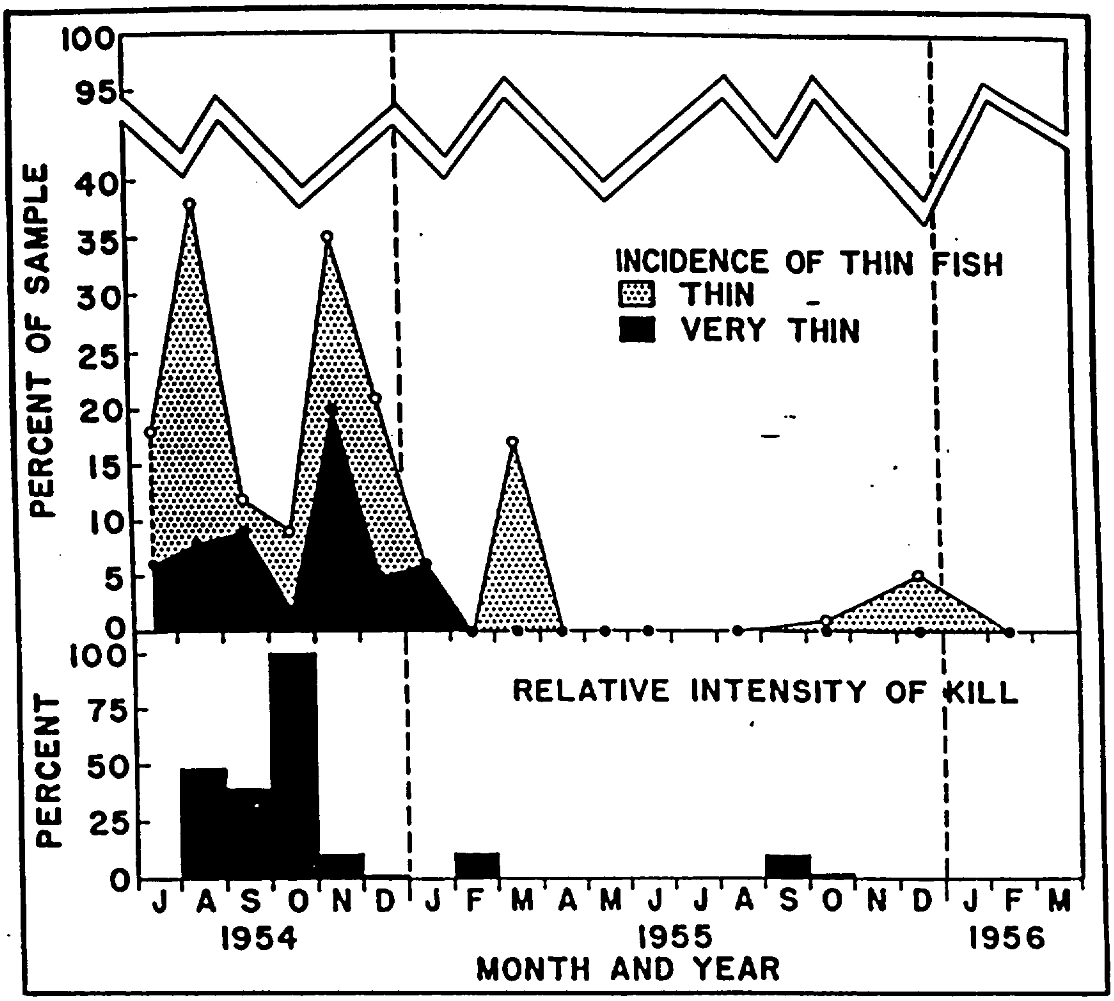

FIGURE 69. Incidence of malnourished bairdiella compared with numbers of dead fish on the shoreline, Salton Sea.

A comparison of amounts of food eaten by fish from deep water (25-30 feet) and shallow water (approximately six feet) during January through June 1955, indicated that the fish from both regions probably fed equally well. Although considerable differences were noted in the amount of food eaten by the fish at the two depths at any one time of day, neither position seemed superior during the spring. Unfortunately,

TABLE 50

Comparison of Amount of Food in Stomachs of Normal and Thin Bairdiella From the Salton Sea After Two Periods of Summer Food Shortage

Sample Period	Normal Fish		Thin Fish		Very Thin Fish	
	No. of Fish	Mg of Food Per gm of Fish	No. of Fish	Mg of Food Per gm of Fish	No. of Fish	Mg of Food Per gm of Fish
August 1954	63	.07	25	.10	6	.00
Sept 1954-January 1955	224	9.00	25	5.59	37	3.75

shallow and deep sets were not run during the periods of severe bottom anoxia. The role of bottom conditions in the economy of the Sea was not sufficiently understood at that time.

Feeding and Digestion Rates

Feeding and digestion rates were sought from two sources: consecutive fish samples taken during 24-hour periods in the same locality, and experiments in which the fish were fed whole worms and then sacrificed at various periods after feeding. Although the results of both approaches were inconclusive, some general information was obtained.

A food ratio of 150 mg of worms per gram of fish is probably near the upper limit for bairdiella gastric capacity. In only three instances was this value exceeded, and these included calculations for the entire digestive tract (excesses of 2 to 56 mg). Far more common were quantities ranging from 60-90 mg/g for the fullest fish of the night-time samples. Average values were much lower (Figures 68 and 70).

Feeding experiments with captive fish in aquaria disclosed tremendous variation in digestive rates, apparently depending upon the quantity of food eaten. Although fish that had eaten small amounts were able to empty their stomachs sooner, fish ingesting 500-2,000 mg of food usually retained it after 16 hours of digestion at 30 degrees C. In the latter group, fish weights varied from 12-28 g and food ratios for their stomachs from 44-78 mg/g.

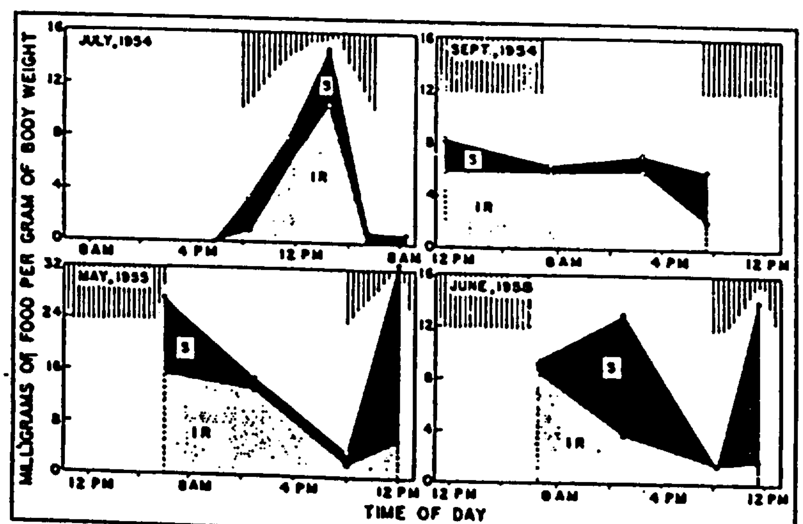

FIGURE 70. Diurnal feeding patterns of bairdiella in the Salton Sea. S = estimated weight of food in stomach; IR = estimated weight of food in lower digestive tract; vertical shading at top indicates hours of darkness. Fish examined per day = 30 to 50.

The variation in diurnal feeding patterns in respect to volume of food was observed by graphing consecutive diurnal samples (Figure 70). On July 13 and 14, 1954, the stomachs were empty during the daytime, contained various quantities of worms during the first half of the night (the stomachs and intestines reached their maximum expansion after midnight), and were nearly empty the following morning. On September 11, 1954, food was found during the entire sampling period, and feeding was apparently quite constant. In May 1955 and removed by the following evening. The June sample showed a daylight peak in feeding, as judged by stomach contents, and also a constant decline in contents of the intestine and rectum during the day. This daylight peak in feeding was exceptional and indicated an abnormally high availability of worms. Such availability, normally seen only after dark, may have been caused by anoxic conditions developing near the Sea bottom.

During the warmer part of the year (April-October), declines were usually discernable in the daily feeding records during the afternoons with peaks occurring at night. This feeding cycle was evidence that the result of the night's feeding normally was digested by the following evening. This was substantiated by the modal sizes of the worms in the digestive tracts: the large mandibles of night-swimming worms normally disappeared completely from the digestive tracts during the 12 to 14 daylight hours that followed a night feeding period.

Reliability of Stomach Fullness Estimates

When fish were opened a visual estimation was made of stomach fullness, in the hope that it might be a rapid yet reasonably accurate method of measuring food intake. Subsequent examination of the data, however, led to the conclusion that such a technique had serious shortcomings as far as bairdiella was concerned. Estimates of weight of food in the stomachs that were made in the summer and fall of 1954 and 1955 were consistently lower than those made in the spring of 1955. The fall estimates for 1954 were also consistently lower than those of the fall of 1955, but the discrepancy was smaller. Although a reasonably reliable regression line, estimating the fullness from actual worm weight, could be drawn within each of the three periods, there was a very great variation in regard to the estimate and the actual weight. The errors among the three periods were probably not due to changing bias on the part of the observer but rather upon actual changes in the stomach dimensions with the seasons. In the poorest feeding period of the study (summer and fall 1954), stomachs one-half or one-quarter full actually contained much less weight of food than those with the same estimated amounts taken in the summer and fall of 1955. The spring of 1955, which was one of glut for the fish, gave the highest actual weights for the estimates of fullness. Evidently during periods of heavy feeding, such as the spring of 1955, the stomach maintained a larger size, which persisted throughout the period of food abundance. This led to higher weights for a given estimated stomach fullness. During the season of heavy feeding, the stomach walls appeared very thin, even when they were not filled to capacity.

DISCUSSION

Reproduction of *Bairdiella icistius* in the Salton Sea resulted in the rather unique situation of having a large population of marine fish dependent upon a single food resource. This food resource effectively limited the size of the fish population by severe fluctuations in standing crop during the year. Although actual data on fish population densities are lacking, a decrease in numbers may be inferred from the large kills ... of starvation and attrition of the fish population occurred during and after summer food scarcities that presumably were caused by anoxia in the deeper waters.

Young-of-the-year bairdiella utilized copepods and their larvae, barnacle larvae, and fertile eggs and smaller larvae of their own species. Many young bairdiella were able to bridge the summer *Neanthes* shortage, and were recruited into the fish population during the fall, when the *Neanthes* again became available in quantity. Survival of the fish population through the annual summer worm shortages was assured because of three factors: the young were able to utilize a different food resource than the adults; they were not completely destroyed by larger fish during the summer food shortage; and large numbers of adults survived despite the shortages. Significant predation on adults did not occur during the period of study because no predator was present in sufficient numbers at that time.

The benefits to fish production as a result of introducing the same or a similar polychaete into the Black and Caspian Seas were described by Zenkevich (1957). In the Sea of Azov, at least, it was the sturgeon that benefited most from the introduction. In both bodies of water, however, elaborate food chains were present before the worm was introduced (Caspers, 1957), in contrast to the limited chains present in the Salton Sea. Establishing a predator in the Sea (successfully accomplished at the time of writing) and introducing other food sources for forage and predator species should smooth out the fluctuations that characterized the relatively simple worm-fish economy.