THE BAIRDIELLA, *Bairdiella icistius* (Jordan and Gilbert)

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INTRODUCTION

The bairdiella is a small, silvery sciaenid, native to the Gulf of California. It rarely exceeds 11 inches and is of only minor importance as a food fish in its native waters (Berdegue, 1956).

Douglas (1953) described the successful introduction of bairdiella into the Salton Sea. Only 67 fish made up the entire plant of this species: 57 in 1950 and 10 in 1951. The first known successful spawning in the Salton Sea occurred in 1952 (Douglas, 1953). Sampling indicated that a sizeable year-class had been produced, and that many abnormal individuals were present in the population.

Subsequent sampling by personnel of the Salton Sea Research Project of the University of California indicated that bairdiella spawned every year up to and including 1957, when the project terminated. No doubt the species is sufficiently well established that it will continue to spawn until conditions in the Salton Sea are no longer favorable.

Clearly, bairdiella was well-adapted to the conditions in the Salton Sea. Other species which were introduced in larger numbers failed to maintain themselves. While only small numbers of bairdiella were planted, they found themselves in a large body of water with an abundant food supply and virtually no competitors or predators. The polychaete worm was well-established and abundant, but was fed upon only in the shallow water near shore by the mosquitofish, pupfish, and goby which were largely restricted to that habitat. The open water was occupied only by schools of striped mullet which fed on detritus and plant material. The croaker was further favored by a high reproductive potential, and within two years the offspring of the original 67 fish undoubtedly numbered in the millions.

REPRODUCTION

Spawning and Development

The spawning of the bairdiella and the development of its eggs are very similar to what has been described for *Bairdiella chrysura* of the Atlantic by Kuntz (1914) and Welsh and Breder (1923).

The eggs and fry of bairdiella were taken throughout the Salton Sea during the spawning season. There was no indication of any localization of spawning grounds. The eggs are small, 0.7 to 0.75 mm in diameter, and are pelagic. They tend to float just under the surface in quiet water, but rough water or disturbances may stir them to considerable depths.

Both *B. icistius* and *B. chrysura* spawn in the evening and apparently over a short period of time. Eggs taken in plankton tows were in uniform stages of development. In our samples, most eggs in the early blastula stage were encountered between 6 and 10 PM (Pacific

Standard Time). The fish normally showed increased activity at this time of the day, regardless of the season. Kuntz felt that *B. chrysura* probably spawns in the evening before 8 PM.

Kuntz mentioned that efforts to artificially fertilize eggs from ripe females of *B. chrysura* did not meet with success. Our efforts with *B. icistius* were also unsuccessful, though several attempts were made when ripe males and females were taken together in gill nets. The time of day probably is a factor in the ripening of the sexual products. Since spawning evidently occurs in the evening, it is possible that fertilization can only be accomplished at that time. All of our attempts at artificial fertilization were made earlier in the day.

Eggs were easily collected from the Salton Sea with Number 0 plankton nets (38 meshes per inch). Large numbers could be collected in a short period during most of the spawning season. This plankton net provided an almost pure sample of eggs and fry, since the mesh was large enough to allow phytoplankton and much of the zooplankton to pass through. Some copepods, *Neanthes* larvae, and barnacle nauplii and cyprids were taken, but not in proportion to their abundance.

The eggs hatched in 24 hours at the water temperatures present during the peak of the spawning season. At 6:30 PM (Pacific Standard Time) on May 9, 1956, numerous eggs in early stages of development were brought into the laboratory and placed in aquariums where mild aeration kept them circulating to the full depths (10 inches) of the aquariums. The eggs hatched during the evening of May 10, apparently about 24 hours after being spawned.

Hatching occurs over a rather short period. A large number of eggs collected at 9 AM on May 9, 1956, and placed in aquariums, hatched during the evening of that day. Newly-hatched fry first appeared at 6 PM; the greatest percentage (73 percent) hatched from 8 to 10 PM with the peak between 8 and 9 (Figure 37). By 10 PM, 95 percent of the eggs had hatched, and by 11, 98 percent. Obviously, these eggs had been spawned at very nearly the same time, and had developed at the same rate. The water temperature in the aquariums was between 72 and 74 degrees F. during the period of development. The peak of spawning activity in the Salton Sea took place when the average water temperature was 73 degrees. Kuntz (1914) stated that the egg of *B. chrysura* requires about 18 hours to hatch at a temperature of 82 degrees.

Eggs of *Bairdiella icistius* taken in plankton tows during the day appeared clear and spherical and each had a yellowish-white embryo stretching across it. A clear, transparent perivitelline-space was always present in normally developing eggs. At mid-day the embryo reached a little more than half way around the egg, with the tail-bud near the oil globule. By 3 PM, a pointed, movable tail was present and the embryo reached two-thirds of the way around the egg. The embryo is dotted with chromatophores which are dense just back of the head and sparse toward the tail. The oil globule is also dotted with chromatophores.

Newly-hatched larvae float upside down, just beneath the surface film in quiet water, The chromatophores are inconspicuous except on the oil globule, and they appear to migrate to the dorsal and ...

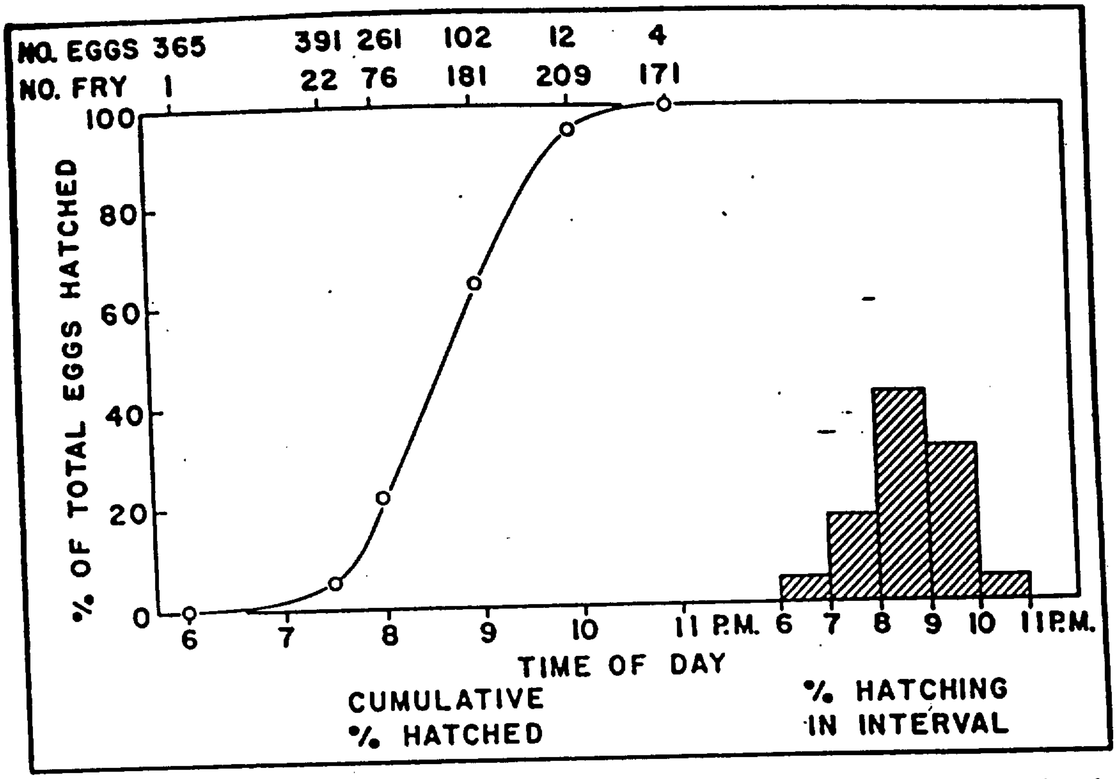

FIGURE 37. Time (Pacific Standard) of day that bairdiella eggs hatched in the Salton Sea.

ing, the chromatophores were clustered in regions along the dorsal and ventral lines of the body and gave an impression of banding. The mouth began to form around noon of the first day after hatching, and by 2 PM, there was a large opening with a well-formed lower jaw.

The larvae died during the second day after hatching. At the time of death, the chromatophores had become more conspicuous and enlarged. They were arranged in a continuous dark line along the dorsal and ventral portions of the body, and there was a cluster just back of the head. The body cavity was also sprinkled with melanophores and there was a cluster along its dorsal wall.

Larval fish up to 5 mm long were taken in plankton tows. Schools of somewhat larger fish were observed near shore. These were sampled with dip nets and individuals measuring 7 to 25 mm standard length were taken.

Number of Eggs

The number of eggs in the ovaries was estimated for three ripe female bairdiella taken in May 1953. The volume of each was determined by the amount of water it displaced, then the volume of a small portion was measured, and the eggs in this portion counted. This count was multiplied by the ratio of the total volume of the ovary to the sample volume. Counting only the enlarged ripe eggs, the estimated number was 38,000 for a 125 mm fish, 35,000 for a 123 mm fish, and 72,000 for one 127 mm long. These estimates are in the order of their reliability. Three subsamples, each about one-tenth the volume of the ovary, were counted and averaged in the first estimate, two in the second, and only one in the third. If these are weighted accordingly, and averaged, the that egg production will vary rather widely, and vary also with size of females.

Spawning Season and Distribution of Eggs and Fry

The duration of the spawning season and the distribution of eggs and fry were ascertained by sampling with "standard" five-minute plankton tows. Number 0 plankton nets were used. The net was towed at a speed which put the top of it just under the surface of the water without splashing. A four-ounce jar at the end of the net collected the eggs and fry and a small quantity of formalin was added as a preservative. The number of eggs and fry was then determined in the laboratory, by direct count in most cases. Samples containing unusually large numbers were estimated with counting-blocks. Each counting-block was 50 by 100 mm, and was marked off into 50 squares. The total was estimated by pouring a reasonable number into a block, and counting a random sample of 5 or 10 squares (depending on the apparent total number of blocks which would be required to contain the sample). This procedure was repeated until the entire sample had been treated, and an estimate for the total sample could be made by summing the series.

To check the variability in the number of eggs and fry which might be expected at the same location, buoys were dropped at the beginning and end of various five-minute tows, and duplicate tows were made over the same course. The numbers of eggs and fry taken in these duplicate tows were in the same order of magnitude (Table 28). Tows made at different locations however, varied considerably.

TABLE 28
Numbers of Bairdiella Eggs and Fry in Duplicate Plankton Tows at 13 Locations in the Salton Sea

Eggs	Fry	Eggs	Fry
15 July 1955		**5 June 1956**	
1504	0	230	0
2001	0	241	65
1015	0	86	7
810	1	51	20
5	0	532	2
1	0	878	3
1	1	350	1308
2	0	160	2802
1	0		
0	0		
1 August 1955		**7 June 1957**	
0	1	1028	5
0	1	1386	13
26	0	1596	53
1	1		
1	0		
1	0		

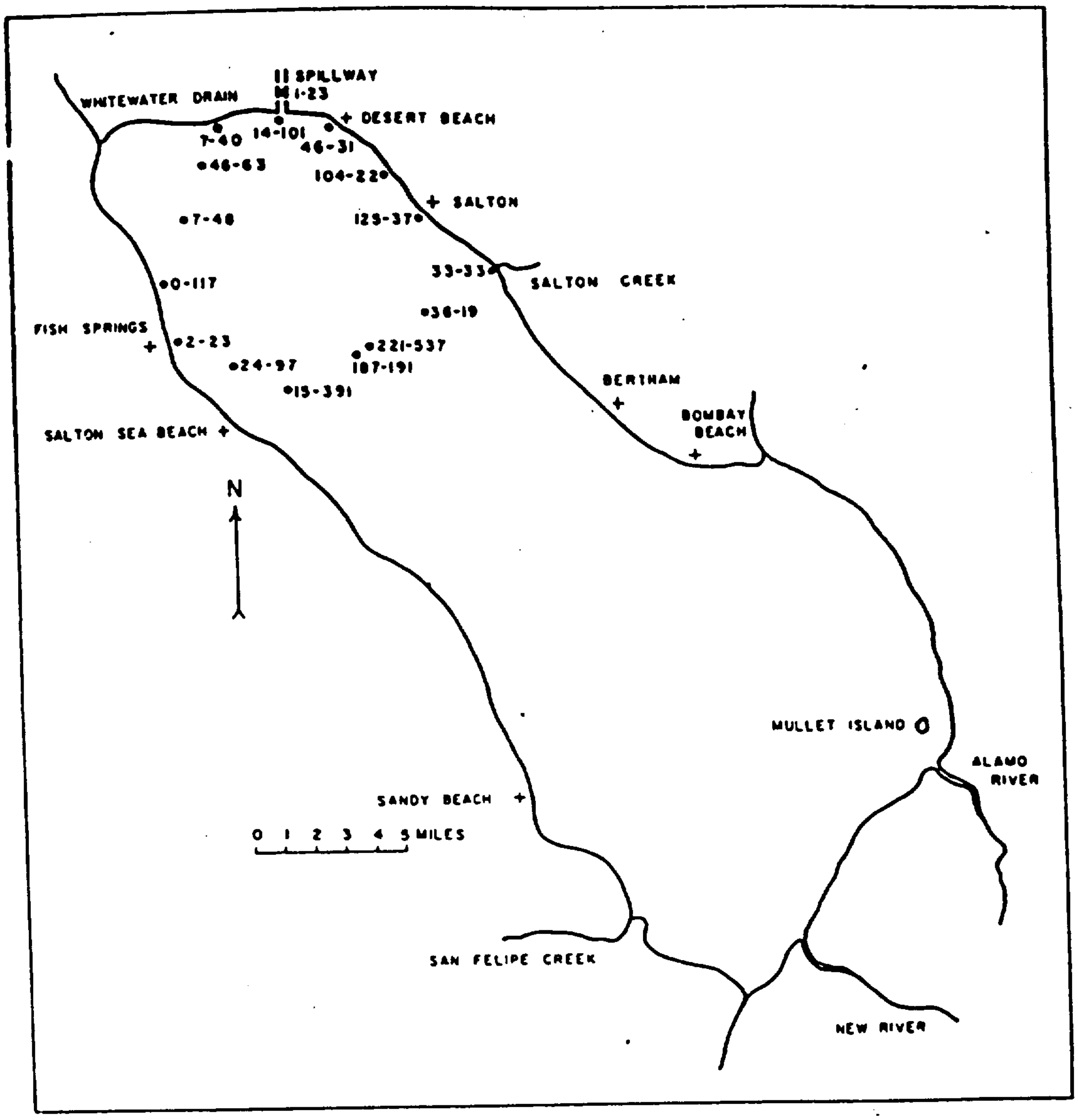

FIGURE 38. Locations of plankton tows and numbers of eggs and fry taken on April 28, 1955, Salton Sea. The eggs are indicated by the first number, and the fry by the second.

The numbers of eggs and fry taken at different localities varied from day to day. For example, on April 28, 1955 all of the tows made on the west side of the Sea contained more fry than eggs, while those on the east side contained more eggs than fry (Figure 38). The differences might have been caused by wind transporting the eggs to the east side. A series of tows made at some of the west shore stations on April 27, 1955, the evening before the above series was taken, contained more eggs than fry (Table 29). The vast majority of the eggs taken in this evening series were in late stages of development. Very few were in early stages, though spawning should have been taking place during the sampling. Possibly, cooler water temperatures inhibited spawning that particular evening. A longer period of development would be expected at the temperatures normally present during this early part of the spawning season, and would allow more time for transport. The sampling stations were visited in a clockwise direction beginning at Fish Springs (Figure 38), so the differences were not due to changes

TABLE 29

Number of Bairdiella Eggs and Fry Taken per Five-minute Tow With a 12-inch Plankton Net * on April 27, 1955, Salton Sea

Pacific Standard Time	Number of Eggs	Number of Newly Hatched Fry	Number of Advanced Fry	Location
6:30 PM	432	2	26	First Canal N. of Fish Springs
7:00 PM	295	0	28	First Canal
7:30 PM	198	52	48	1 mi off First Canal
8:00 PM	165	9	34	North of First Canal
8:30 PM	608	13	6	1 mi offshore
9:00 PM	244	27	6	2-3 mi offshore
9:30 PM	150	1	338	3 mi off Fish Springs

* Number 0 mesh.

in wind or water conditions which might have taken place during the sampling.

Peak spawning activity was in mid-May (Figure 39). The fry were available to plankton nets much longer than the eggs so the curve for fry reflects a cumulative effect of adding hatching fry.

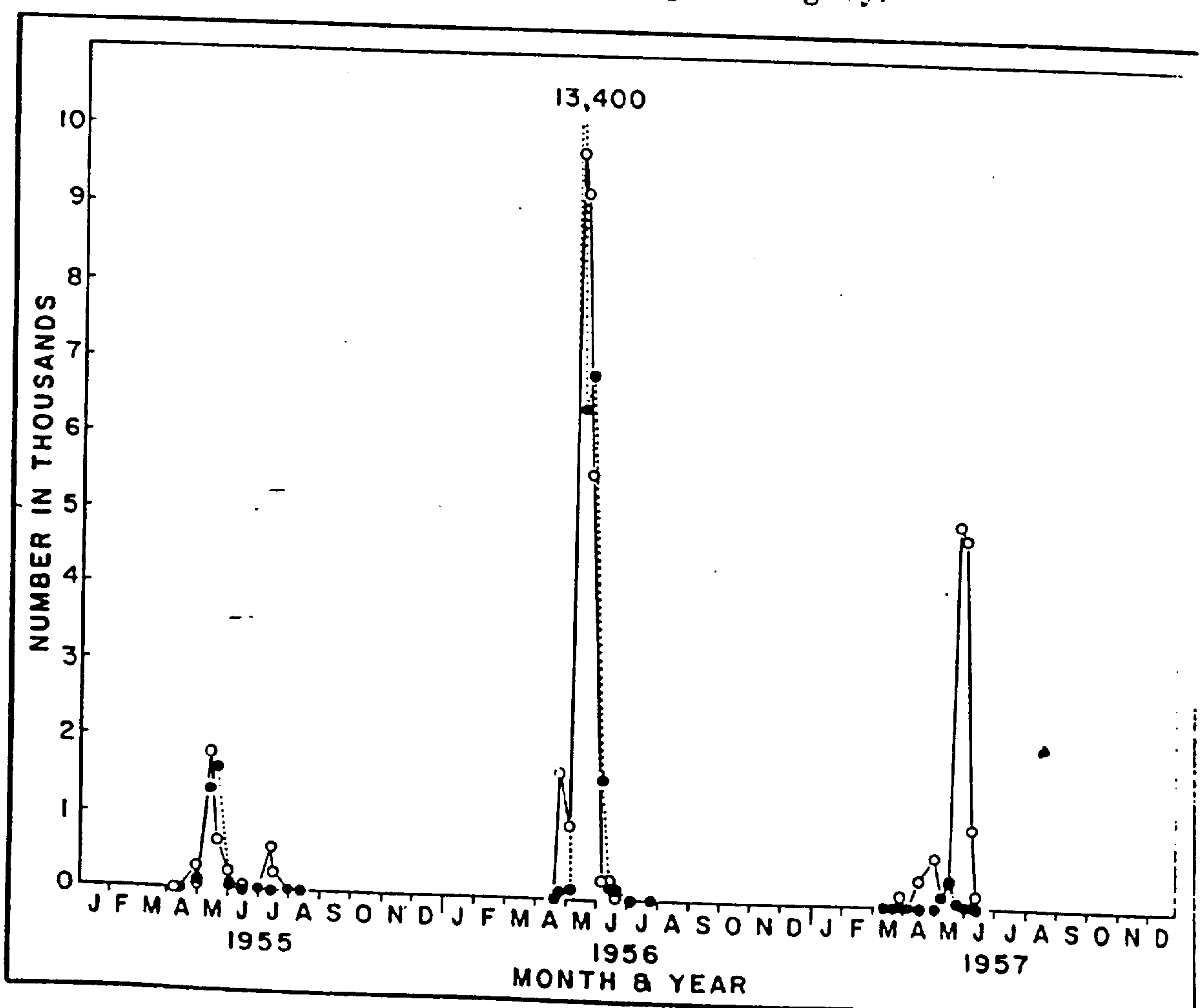

FIGURE 39. Number of eggs and fry of bairdiella in the plankton in 1955, 1956 and

The increase in egg production in July 1955, occurred in local areas and was not followed by any increase in the number of fry. Eggs were found in the plankton from April 13 to August 1, 1955; the greatest number being taken on May 12, 1955. Very few fry appear to have been produced after about June 19. Surface water temperatures varied from 65 degrees F. on April 15 to 96 degrees F. on August 1, 1955 and during the peak period, May 11 to 20, 1955, averaged 73 degrees F. Prior to June 19, 1955 the maximum surface water temperature was 90 degrees F., while night surface water temperatures remained cool, reaching 75 degrees F. or lower.

Welsh and Breder (1923) found the peak of spawning for *B. chrysura* was May in North Carolina waters, and June in New Jersey waters. Kuntz (1914) found the peak was in June in North Carolina waters, perhaps because of unusual water temperatures that year.

It is apparent that there were many more eggs and fry in the plankton in 1956 than in 1955. Tows made during May 1956 caught consistently high numbers. The average catch-per-tow in 1956 during peak activity was over 9,000 eggs and 12,000 fry; whereas, in 1955 during the same period, the average catch was under 2,000 eggs and 2,000 fry. In order to smooth somewhat the variation between tows, the 1956 counts were grouped by weekly intervals and averaged.

Spawning appears to have occurred slightly later and on a somewhat more limited scale in 1957 than in 1956, but probably exceeded that of 1955. Of particular interest, was the surprising failure in fry production in 1957. The largest number taken in a tow was 1,184 on May 17, 1957, while in both previous years there had been over 40,000 in a tow.

Each year an apparent false spawning start was made in April. Part of this false peak might have been due to eggs remaining unhatched for more than 24 hours during the early part of the season. Water temperatures reached about 70 degrees F. by the first of May in 1955 and 1956 so that the eggs would be in the plankton for only 24 hours after that time.

Relative Abundance of Year-Classes

Beach seines 50 feet long with ⅜-inch stretched mesh were used to sample the fish populations at monthly intervals from May 1953 to the end of 1956. This same type of seine was used by Douglas in 1952. A general idea of the relative abundance of the year-classes was obtained from the catch with this seine. Identification of the year-classes was generally simple because of differences in their rates of growth. The 1952 and 1953 year-classes could be separated by the Petersen size-frequency method until 1955. The same method provided separation of subsequent year-classes from the 1953 year-class until late in their first summer when they approached the size of the 1953 year-class. By this time, the numbers of fish in these later year-classes were so reduced they were inconsequential. Scale samples were read to verify these conclusions.

The 1952 year-class was produced by the first known successful spawning of bairdiella in the Salton Sea. These fish matured at the end of their first year, and produced a huge 1953 year-class. As an example of their unusual abundance, two hauls made in July 1953 with a 50-

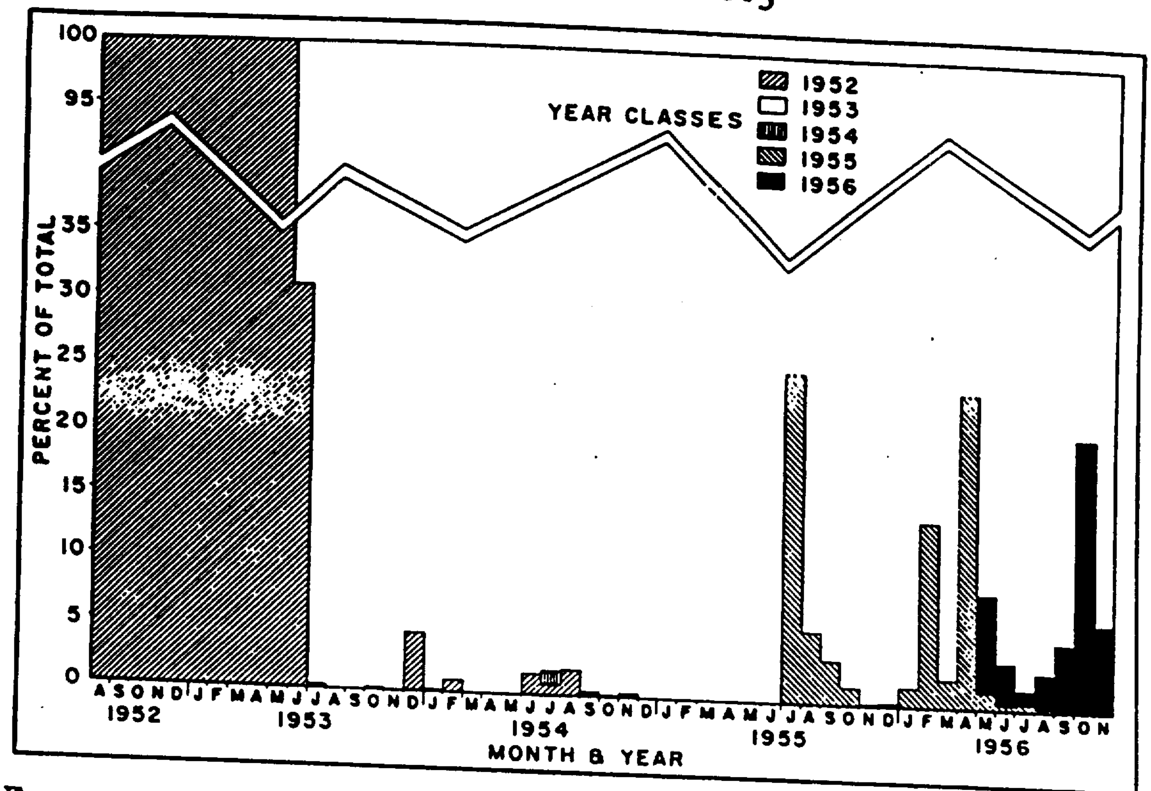

FIGURE 40. Relative abundance of bairdiella year-classes in the Salton Sea as indicated by their percentage in the seine catch.

dominance and maintained it throughout the period of study (Figure 40). The importance of the year-classes after 1953 probably has been overemphasized in Figure 40, because young-of-the-year bairdiella were attracted to shallow water where they were more susceptable to capture in seines than older fish. Furthermore, the older fish moved inshore and offshore seasonally, so that their susceptability to capture in beach seines would vary with the season. In spite of these differences in habits, fish of the 1953 year-class always made up at least 75 percent of the catch by numbers after June 1953.

The 1953 year-class first appeared June 1953. Beginning in July 1953, the 1953 year-class took the role of a typical dominant group. The 1954 year-class did very poorly and it seems obvious that it was suppressed by the 1953 year-class. It is doubtful that any of its members survived more than a few months.

Probably the typical pattern of a new year-class competing with the dominant 1953 group was shown by the 1955 hatch. Initial high catches in July 1955 were followed by sharp declines through the rest of the year. The increase in the percentage of fish from the 1955 year-class, in February 1956, was primarily due to a decrease in the catch of 1953 fish, which had moved to deeper water.

A slight increase in the catch of 1955 fish took place in April 1956, indicating that perhaps some offshore movement had occurred previously and that the fish were then moving back into the sampling range of the seines. The total catch of 1953 fish increased only slightly at the same time, so the 1955 year-class showed a false increase in relative abundance (Figure 41). The total catch of the 1953 year-class then increased while the 1955's decreased during the rest of 1956. The per-

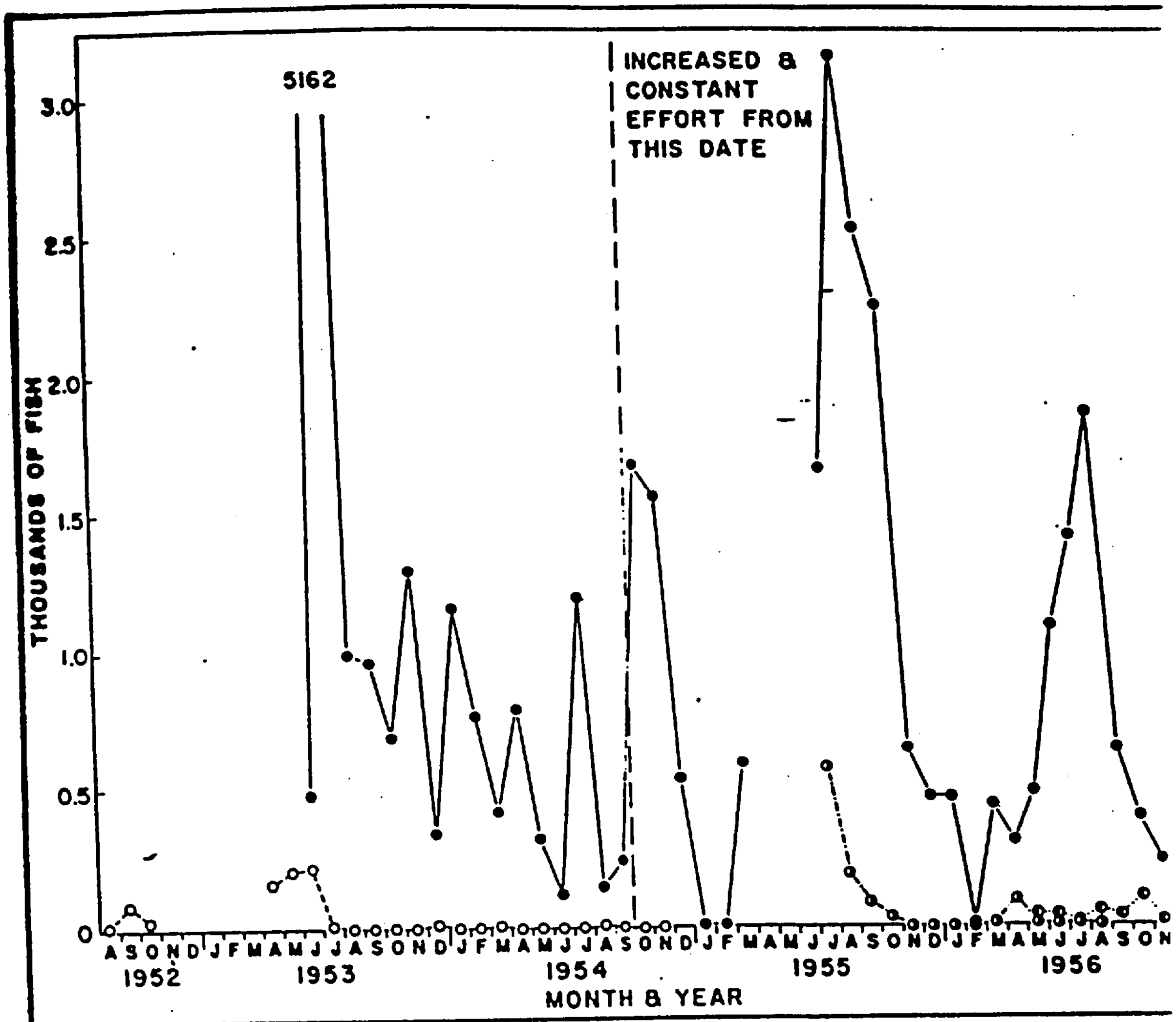

FIGURE 41. Total catch of each year-class of bairdiella taken in beach seines, 1952-1956, in the Salton Sea. The 1954 year-class was not taken in large enough numbers to show in the figure. ○ = 1952 year-class; ● = 1953 year-class; ◑ = 1955 year-class; ◐ = 1956 year-class.

centages shown in Figure 40 are probably correct in implying virtual elimination of the 1955 year-class.

The catch of fish of the 1956 year-class was almost constant from May to September 1956. As a result, when the 1953 fish moved into deeper water in the fall, a false increase in the 1956 year-class is indicated in Figure 40. Probably the August value of 2.7 percent could be considered a maximum estimate for the contribution of this year-class to the population of the Salton Sea.

Each year-class produced after 1954 was slightly more successful than its predecessor. However, none can be said to have contributed important numbers to the population.

The complete dominance of the 1953 year-class is most strikingly illustrated in Figure 41, showing the total catch made by seines. Their excessive abundance evidently drove the fish of the 1952 year-class into water deeper than was sampled by the seines, for very few of them were taken with this gear after June 1953. They apparently never returned to the shore areas. However, when gill nets were used in deeper water, large numbers of the older fish were taken. In April 1954, for example, one set of 200 feet of one-inch-mesh net caught 1,769 fish of the 1952 year-class in 24 hours.

SEASONAL MOVEMENTS INSHORE AND OFFSHORE

The total seine catch from October 1954 to the end of 1956 was indicative of the inshore availability of bairdiella. During that period, a constant number of hauls was made each month at 16 locations around the Salton Sea. The catch after May 1953 consisted almost entirely of 1953 year-class fish, except for a brief period in July and August 1955 when the 1955 year-class first appeared (Figure 41).

Considering only the 1953 year-class after October 1954 a clear pattern of availability was shown by the catches. A maximum catch occurred in August each year and a minimum in January or February. Apparently, they moved to deeper water in the late winter, and to shallower water in late summer. Inshore movement began in March and April, as shown by the increased catches in the beach seines. Perhaps this movement was heightened in late summer by lack of oxygen and the resulting failure of the food supply in certain areas of deep water. In areas near shore the pile worm spawned the year round, but in water over 25 to 30 feet deep it was eliminated from the bottom during the summer due to lack of sufficient oxygen. However, the movement of the bairdiella toward shore was probably not entirely due to these factors, since it began before any oxygen shortages occurred. In September, the croakers began to move away from shore, and by January or February they could not be reached in appreciable numbers by beach seines.

There was great variability in the catch from month to month before October 1954 making interpretation difficult. This variability was undoubtedly caused by the limited sampling during this period. It would seem, however, that no general movement of the 1953 year-class to deeper water took place in the winter of 1953-54. The trend of the catches was downward in 1953 and 1954, probably partly a result of high natural mortality associated with the high population level. It is also probable, however, that a movement toward deep water tended to reduce the catch in late 1954. This movement must have started earlier in 1954 than in 1955, since larger catches were made in October 1955 with the same amount of effort.

Gill nets were also used to sample the 1953 year-class beginning in April 1954. Usually, the gill nets were set in water which would not be reached by the seines. The catch-per-effort of bairdiella in gill nets should therefore provide a check on the information of inshore and offshore movements indicated by the seine catches. It was not practical to make standard sets of gill nets. During the course of the study, nets of various mesh sizes, lengths, depths, and materials (linen and nylon) were used. Furthermore, catches were highly variable even when using the same net at different times.

One factor contributing to the variability stems from the tendency of bairdiella to move more (or at least to be netted more readily) at night (Table 30). This was probably related to their feeding behavior, since *Neanthes* spawned at night and was free-swimming and hence more

TABLE 30

Comparison of Catch-per-Unit-Effort of Day and Night Gill-Net Sets for Bairdiella in the Salton Sea

Time	Catch (Numbers of Fish) per 100-Foot Gill-Net-Hour Numbers in Parentheses Indicate Number of Net Sets				
	September	October	November	January	Unweighted Average
Daylight	0.1 (6)	0.0 (5)	0.1 (4)	0.1 (1)	0.1
Overnight	0.3 (1)	0.8 (8)	1.8 (10)	0.6 (3)	0.9

during daylight hours were omitted. In comparing the gill-net catch-per-effort with the seine catch, only fish of the 1953 year-class were considered. No attempt was made to separate the catches according to mesh size, except that catches from experimental gill nets were not included since they were excessively high compared to the other nets, and since they were not set as consistently. The catch-per-effort data in Figure 42 were therefore derived from nets of 1.0- to 2.5-inch bar mesh of various twine sizes and materials set overnight. Time in the water averaged about 24 hours, but variations contributed to the error along with that incurred from using different nets. The lowest average catch was in late summer; August and September in 1954 and 1956, and September in 1955 (Figure 42). This corresponded with the time when the seine catches were near their maximum. Increased catches in the gill nets in October of each year followed the expected pattern, and

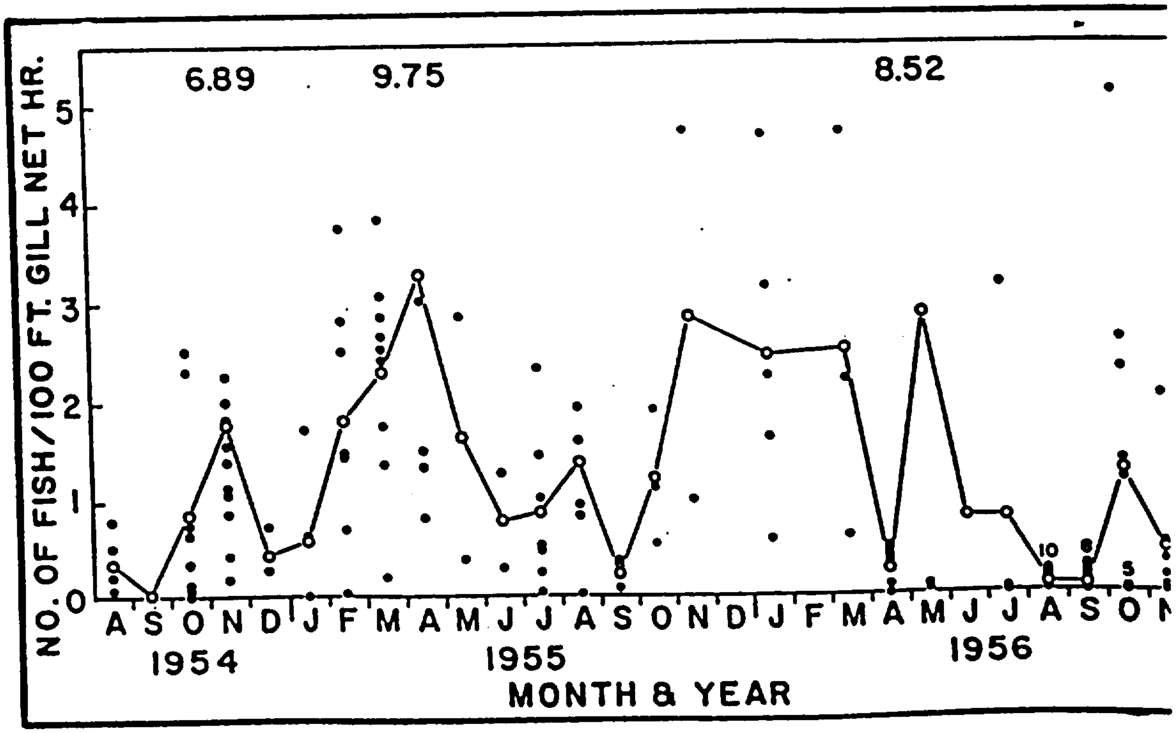

FIGURE 42. Gill net catch of bairdiella per unit-of-effort in the Salton Sea. ● Catch per 100-foot gill-net-hour in a 24-hour set: ○ = Average catch-per-effo

implied movement into deeper water. The high October catches might also have been influenced by the increased activity of the croaker feeding on spawning *Neanthes*. The low gill-net catches in the winters of 1954 and 1956 might have been due to reduced activity of the fish in response to cooler water temperatures, though the catch in the winter of 1955 was rather high.

SURVIVAL ESTIMATES FOR THE 1953 YEAR-CLASS

A decline would be expected in the catch-per-effort for the 1953 year-class from year to year, and this is indicated in Figure 41. A rough estimate of survival can be derived from the data. A discussion of the method used can be found in Ricker (1958). Differences in the degree to which the population moved toward shore each year would distort the estimate. It appears that they did not remain near shore as long in 1956 as in 1955, as indicated by the rapid decline in catch in September and October 1956, compared to the same period in 1955. Perhaps some of this distortion can be reduced by considering only the catches for August of each year: 3,122 in 1955, and 1,860 in 1956. This produces a survival estimate of 60 percent from 1955 to 1956. If the catch from July through November of each year is used to estimate survival (the catch for 1955 was 10,270 and for 1956, 4,519) the survival was 44 percent. Thus, the estimates indicate survival was between 44 and 60 percent, though both might still be subject to error due to differences in the degree of inshore movement in the two years.

RATE OF GROWTH

Materials and Methods

All netted fish were placed in 10 percent formalin, allowed to fix, washed in water and then placed in 50 percent isopropyl alcohol in which they were stored until measured and weighed. Preservation affects lengths and weights of fish; Carlander (1953) lists nine studies in which slight shrinkage was noted. Since the fish in this case were all treated alike and interest was not in absolute size but in changes, no correction was felt necessary. In addition to the sampling with seines and gill nets which has already been described, a few small young-of-the-year were collected with dip nets.

The fish were measured with dividers to the nearest millimeter, and weighed to the nearest 0.1 gram. Standard length was used. In samples containing more than 100 fish, only the first 100 were weighed, and the remainder were only measured. Some excessively large samples containing over 500 fish were subsampled. Since the fish had never been arranged according to size, it was thought they were randomly distributed in the jars in which they were preserved, so that they could be subsampled simply by taking them as they came. Some of the fish collected in 1952, 1953, and early 1954 were not weighed at the time they were measured. A sample of about 50 from each of these was measured and weighed subsequently. Carlander (1956) pointed out the necessity for using large samples to determine the average lengths of fish with accuracy. In the present study, 31,098 seine-caught fish of the 1953 year-class were measured: 4,750 in 1953; 7,832 in 1954; 11,296 in 1955; and 7,220 in 1956. An additional 12,398 fish taken in gill nets

TABLE 31
Sample Sizes and Average Lengths and Weights of Bairdiella From the Salton Sea

Date	SEINED				GILL-NETTED			
	Number Measured	Average Length in mm	Average Weight in gr	Number Weighed	Number Measured	Average Length in mm	Average Weight in gr	Number Weighed
1952 YEAR-CLASS								
1952								
Aug.	11	70	6.0	11				
Sept.	81	80	13.2	81				
Oct.	28	90						
1953								
Apr.	117	110	27.7	88				
May	204	109	28.4	20				
June	215	111	37.0	39				
July	11	145	64.8	11				
Oct.	1	135	—	0				
Dec.	16	136	32.4	16				
1954								
Feb.	7	143	42.3	7				
Apr.					549	162	65.5	53
June	2	153	—	0	294	166	63.9	9
July	10	149	46.2	10	118	162	67.4	85
Aug.	3	158	53.1	3	88	160	57.9	53
Sept.					12	166	57.8	11
Oct.	2	141	32.5	2	44	157	58.1	44
Nov.	2	148	38.7	2	28	160	65.3	28
Dec.					4	165	66.6	4
1955								
Jan.					1	158	65.5	1
Feb.					55	156	61.2	55
Mar.					238	157	71.8	185
Apr.					8	156	85.5	6
May					3	160	72.0	3
June					1	141	60.8	1
July					32	158	72.0	29
Aug.					4	171	85.6	4
Sept.					13	165	71.1	13
Nov.					5	151	63.1	5
1956								
Jan.					22	160	76.5	22
Mar.					1	150	72.1	1
Apr.					1	144	54.0	1
May					51	166	—	0
June					11	159	—	0
1953 YEAR-CLASS								
1953								
June	478	20	0.1	54				
July	1,444	46	3.0	51				
Aug.	655	59	4.1	51				
Sept.	452	70	5.9	51				
Oct.	685	71	5.8	51				
Nov.	680	72	6.0	50				
Dec.	356	76	6.7	75				
1954								
Jan.	664	76	6.6	143				
Feb.	348	75	7.2	51				
Mar.	419	75	7.4	51				
Apr.	626	77	8.4	51	14	83	10.6	1
May	318	86	11.1	51				
June	121	87	11.1	51	12	90	11.9	1
July	1,199	86	11.3	835	78	99	16.1	7
Aug.	145	88	10.8	145	192	89	9.9	10
Sept.	237	88	10.3	237	28	88	10.4	2
Oct.	1,674	89	12.6	1,051	506	90	13.9	48

TABLE 31—Continued

Sample Sizes and Average Lengths and Weights of Bairdiella From the Salton Sea

Date	SEINED				GILL-NETTED			
	Number Measured	Average Length in mm	Average Weight in gr	Number Weighed	Number Measured	Average Length in mm	Average Weight in gr	Number Weighed
1955								
Jan.	10	91	12.8	10	33	92	14.1	33
Feb.	8	89	11.0	8	431	96	17.1	431
Mar.	587	93	16.9	201	1,188	98	20.3	734
Apr.					256	103	25.2	178
May					271	104	24.3	178
June	58	105	21.0	58	115	108	28.9	115
July	1,785	102	19.5	1,232	407	100	22.1	302
Aug.	3,122	104	20.9	1,452	622	102	20.1	397
Sept.	2,482	103	20.8	1,470	33	105	22.9	33
Oct.	2,246	105	20.9	1,169	224	103	19.8	189
Nov.	635	105	21.6	519	579	109	23.4	240
Dec.	363	104	20.7	296	160	106	23.7	160
1956								
Jan.	461	105	21.0	401	901	114	30.0	653
Feb.					203	110	26.1	170
Mar.	431	104	20.1	207	675	112	29.0	309
Apr.	301	109	25.1	264	129	119	34.2	120
May	419	112	26.4	417	822	120	34.3	518
June	1,089	113	24.8	710	122	119	31.0	122
July	1,412	115	25.8	819	1,413	118	34.0	1,151
Aug.	1,860	113	24.0	914	54	115	26.8	54
Sept.	631	114	24.0	442	32	119	30.6	32
Oct.	384	114	23.8	342	867	121	34.5	503
Nov.	232	116	24.6	196	769	120	33.3	560
Dec.					176	124	35.6	176
1954 YEAR-CLASS								
1954								
July	78	14	0.2	78				
Sept.	7	46	1.9	7				
Oct.	26	49	3.2	26				
Nov.	31	57	4.2	31				
1955								
July	5	81	14.3	5				
Aug.	1	92	13.8	1				
Sept.	2	95	—	0				
Oct.	1	90	—	0				
1955 YEAR-CLASS								
1955								
May	18	8	—	0				
June	214	11	—	0				
July	571	35	1.3	566				
Aug.	187	48	3.4	163				
Sept.	140	72	8.9	110				
Oct.	33	84	12.7	33				
Nov.	1	76	—	0				
Dec.	2	78	13.4	1				
1956								
April	50	92	—	0				
June	1	89	15.2	1				
July	2	89	15.4	2				
1956 YEAR-CLASS								
1956								
May	40	10	0.1	40				
June	36	25	0.5	36				
July	16	29	0.6	1				
Aug.	52	63	5.7	52				
Sept.	35	58	10.5	35				
Oct.	104	71	7.4	104				
Nov.	17	85	13.3	17				

provided a comparison of the two methods. Also measured were 710 seine-caught fish of the 1952 year-class and 1,598 from the same year-class taken in gill nets. Various numbers of fish of the other year-classes were measured and weighed. These will be discussed in detail below. The samples of 1953 year-class fish were in sufficient numbers that their growth could be followed on a monthly basis. The same was attempted for the other year-classes, though the samples were smaller and as a consequence less reliable. Sample sizes and the average lengths and weights of the fish are shown in Table 31.

When the length-frequencies of fish of particular year-classes taken in the same sample are graphed, the frequencies can not be satisfactorily described using the normal distribution (Figure 43). They differ from the normal distribution in that there appears to be more than one maximum point, and they are flattened and skewed. There is also some indication in Figure 43 that the nature of the distribution changed with time. As the fish grew, their range of sizes narrowed from about 40 mm in July to about 30 in November 1953.

It is not difficult to imagine how this type of distribution could develop. The bairdiella spawns over a period of about three months and variable success of hatches within that period would be expected. In addition, there is a strong schooling tendency, particularly among the young-of-the-year. Differences in length resulting from variable spawning success would tend to be maintained by this schooling behavior.

An illustration of how this might come about can be taken from some samples collected in 1955. On June 7, 1955, four different schools of young-of-the-year bairdiella were observed in the vicinity of the Fish Springs boat channel. Each school was sampled with a dip net and the fish kept separate. Samples of 32, 44, 54 and 84 fish were collected and there was considerable difference between the average lengths of the fish in the schools: 11.5, 8.0, 14.0, 11.0 mm (Figure 44). Assuming the normal distribution is appropriate to describe their lengths, analysis of variance can test the significance of the difference between the lengths of fish in the schools (Table 32). A subsample of 50 fish was randomly selected from the sample of 84 for the analysis. Highly significant differences between the lengths of fish in the schools are indicated. The schools when sampled were clearly separated but were along a shoreline of about 200 yards. It is natural to assume that as these small fish increased in size and mobility, mixing would occur. The result

TABLE 32

Analysis of Variance to Test Differences in Average Lengths of Bairdiella From Four Schools, Salton Sea

Source	Degrees of Freedom	Sums of Squares	Mean Square
Between Schools	3	924	308
Within Schools	176	348	2
Total	179	1,272	

$F=154$, df 3 and 176, highly significant.

would be as in the combined samples in Figure 44, a distribution with three or more modes, closely resembling the one observed in the older fish.

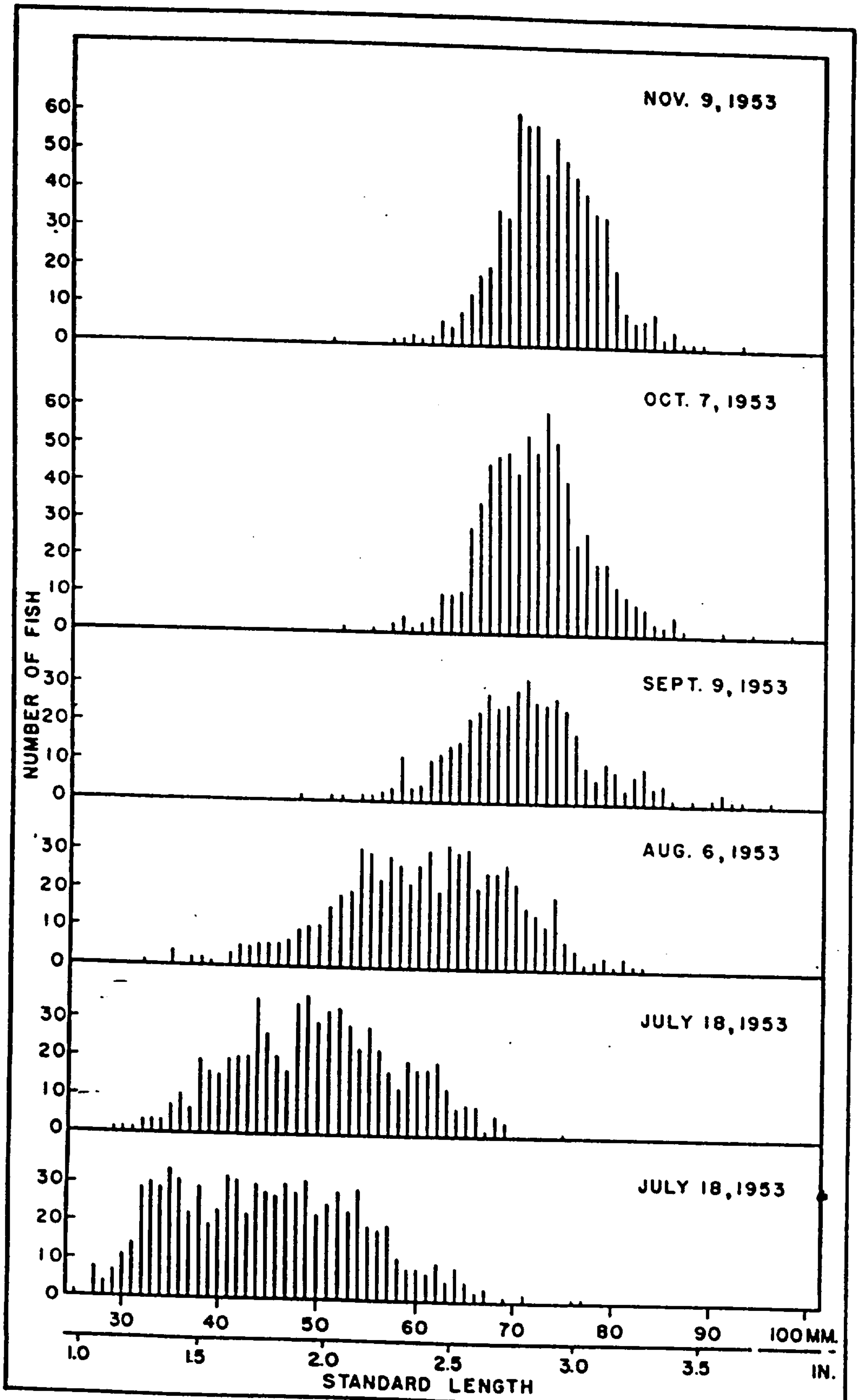

FIGURE 43. Length-frequency distribution of the 1953 year-class bairdiella caught in six seine hauls, Salton Sea.

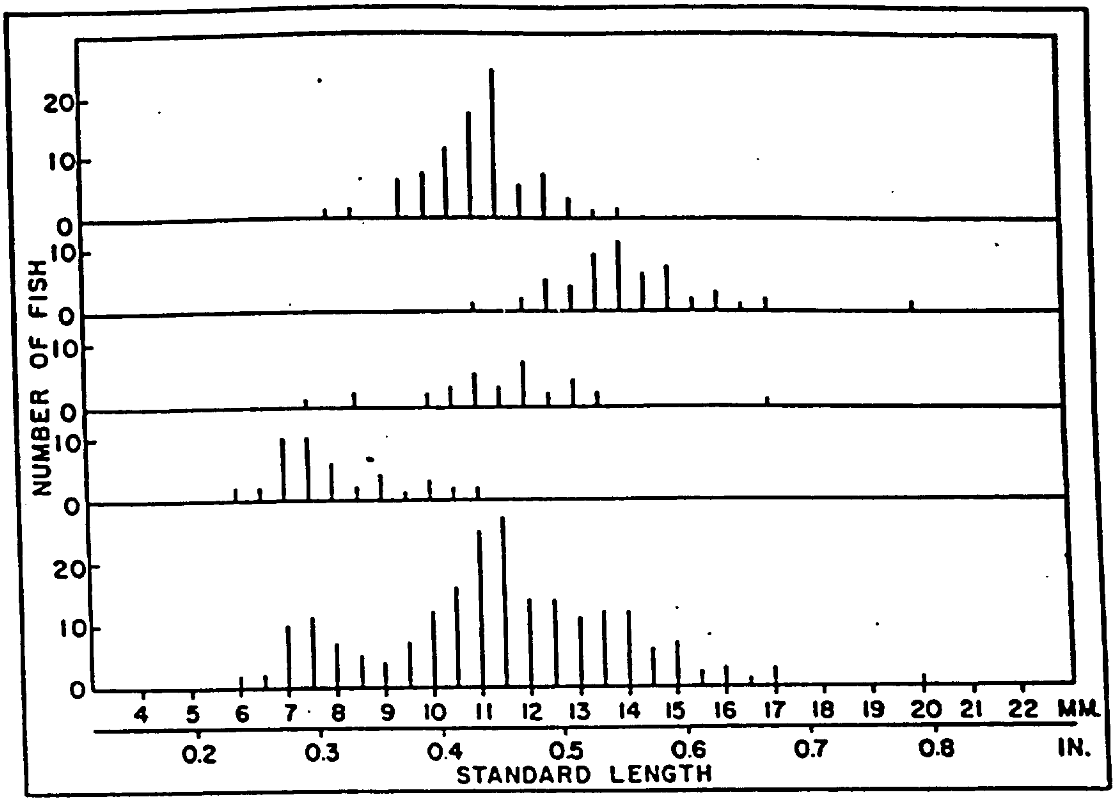

FIGURE 44. Lengths of young-of-the-year bairdiella from four different schools sampled on June 7, 1956, Salton Sea. Schools combined at bottom.

In spite of this complication, it is sufficient for the present to assume that, since interest is in their growth in the Sea as a whole, some complex frequency distribution could be devised to describe the length of the general population of bairdiella in the Salton Sea. No matter what the nature of this frequency distribution, it can be shown that the distribution of the mean approaches a normal distribution as the sample size increases. Since rather large samples have been used, the mean of the samples should be indicative of some population characteristic.

Growth in the Gulf of California

Bairdiella growth has not been studied in their native habitat, the Gulf of California. We had only one sample of 43 specimens from San Felipe, Mexico. These ranged from 117 to 183 mm in standard length (Table 33). They were taken in March and April 1956, when an annulus

TABLE 33
Standard Lengths of Bairdiella Taken at San Felipe, Mexico, March and April 1956

Age*	No. of Specimens	Standard Length in mm: Range	Standard Length in mm: Average
I	17	117-137	131
II	18	146-166	154
III	7	165-183	172
IV	1	173	173

* Determined by number of annuli

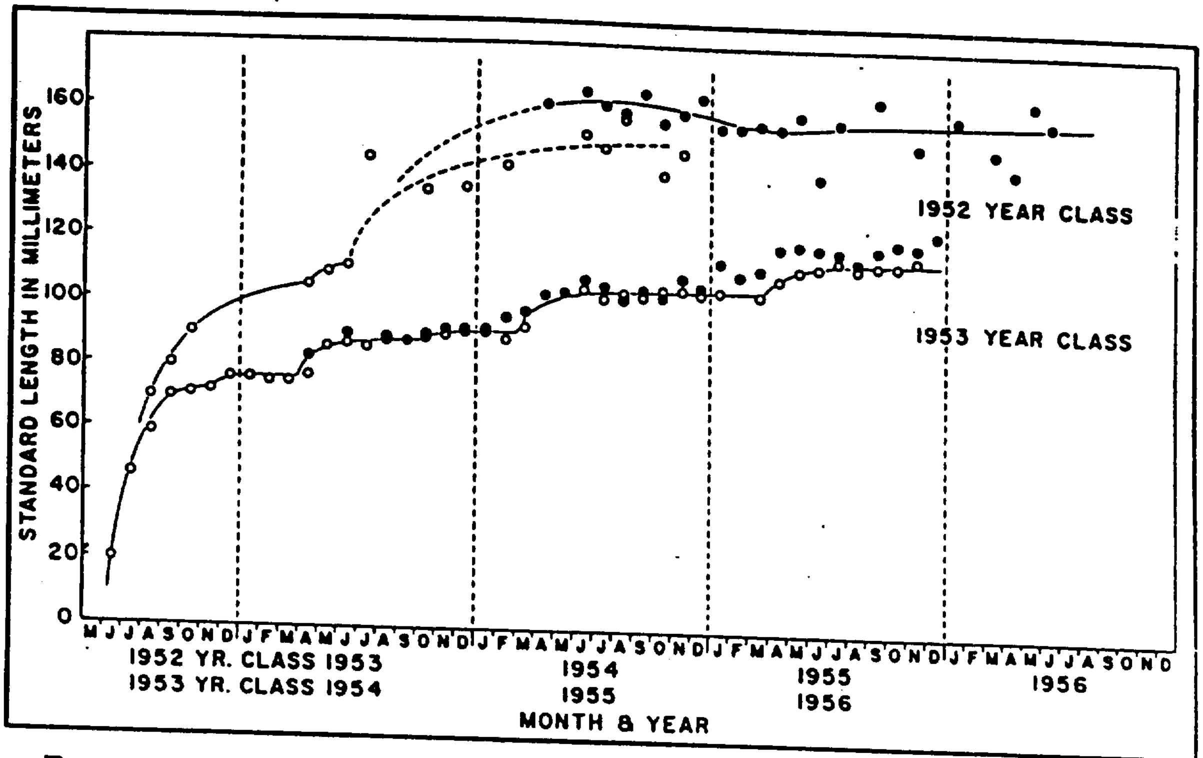

FIGURE 45. Growth of the 1952 and 1953 year-classes of bairdiella in the Salton Sea. The graph was drawn, for ease of comparison, as though the year-classes started growth at the same time (points joined by eye). ○ = Average length in seine samples; ● = Average length in gill-net samples.

was just beginning to form at the edges of their scales. The average lengths of the groups, therefore, probably represented only a slight overestimate of the length achieved at the particular annulus. Accordingly, fish from the Gulf of California reach an average length of 131 mm at the time of the first annulus, 154 mm at the second, and 172 at the third.

Growth of the 1952 Year-Class in the Salton Sea

The 1952 year-class grew rapidly in 1952 and 1953, apparently in response to their low population level and an abundant food supply. After April 1954 however, fish of this year-class showed no increase in length (Figure 45). In fact, 238 fish taken in March 1955 were slightly smaller than fish of the same year-class taken in 1954. This might be partly explained by the fact that the 1952 year-class could no longer be clearly separated from the 1953 year-class at this time. By March 1955, a few of the 1953 fish were 130 to 140 mm long so there was some overlap in the length frequencies of the two year-classes (Figure 46). For the 1955 data, a separation point of 140 mm was arbitrarily used. Even using this point, no growth was indicated for the 1952 year-class between 1954 and 1955. The length-frequencies of the larger fish did not shift, while the smaller fish obviously increased in length.

In general, year-classes could still be distinguished by examining the scales. Even in cases where subsequent annuli were not formed, the 1952 year-class could be recognized by the great distance from the focus of the scale to the first annulus. In dealing with the 1956 samples, it was necessary to examine scales in order to identify members of the

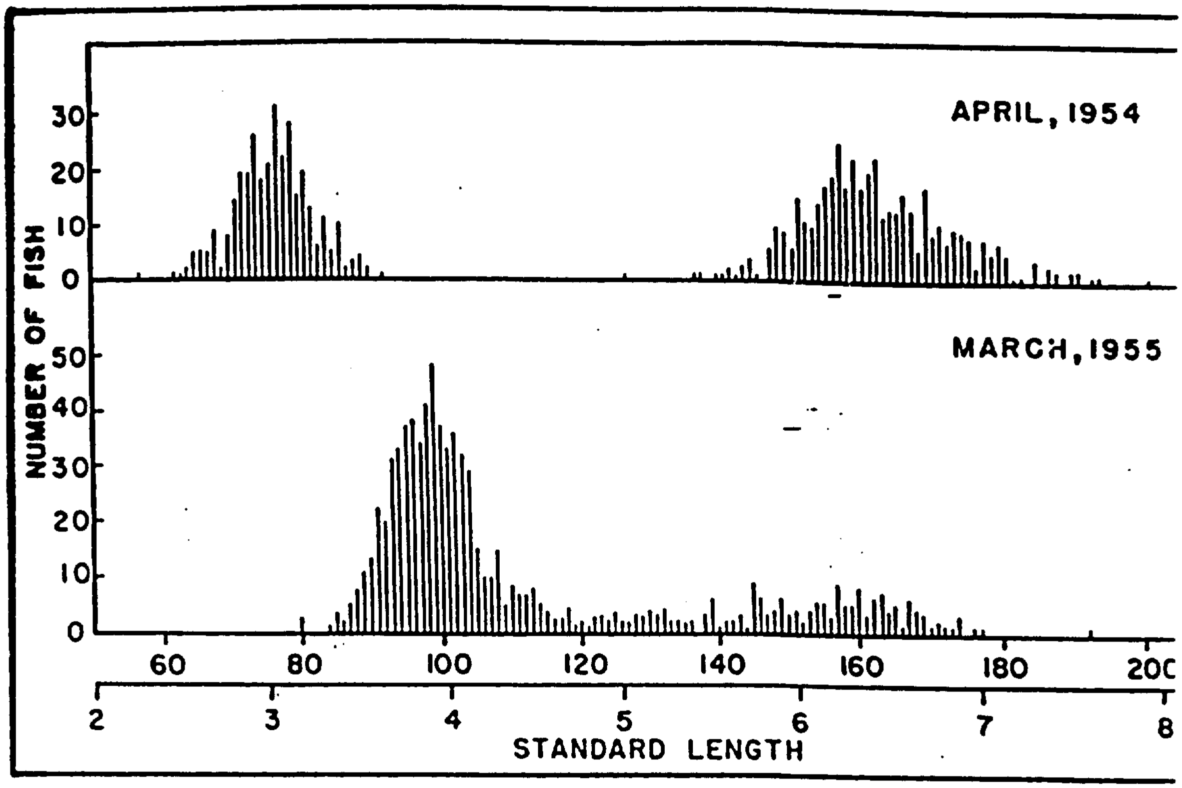

FIGURE 46. Length frequencies of bairdiella from the Salton Sea in a 1954 sampl and a 1955 sample, showing separation of the 1952 and 1953 year-classes in 195 and overlap in 1955.

Only very few 1952 fish were taken in 1956. Of 149 bairdiella collecte on May 24, 1956, ranging from 130 to 186 mm in standard length, onl 51 were identifiable from the large center area on the scales as 195 year-class fish. These ranged from 142 to 186 mm and averaged 16(The remaining 98, ranging from 130 to 164 mm, were identified as 195 year-class fish by the small area between the center of the scale and th first annulus.

Very few larger fish were taken again until October 1956. Scales wer removed from all fish over 144 mm long in one sample. Of the 26 fis in this category, only three seemed to be 1952's judging by the scale but only two annuli were apparent. One fish measured 163 mm and th other two 167. The remaining 23 fish had three, evenly-spaced annu on their scales, and were probably 1953's since the first annulus w much closer to the center of the scale. In another sample taken in Oct ber 1956, every fish about 140 mm or longer was scale sampled. Th included 65 fish, of which only eight were identifiable as 1952's. The ranged from 146 to 165 mm standard length and averaged 157. The other fish, probably members of the 1953 year-class, ranged from 1 to 168 mm.

The fact that only small numbers of the 1952 year-class were tak in 1955 and 1956 would seem to indicate that their population was bei sharply reduced, probably as a result of competition with the 1953 yea class. No great reliance can be placed on the estimated growth fro these small samples, but they all showed cessation of growth in 19 and 1956.

It has already been mentioned that the fish of the 1952 year-class moved out to deeper water in 1953. Few of them were taken in seines after June 1953, while many were taken in gill nets in deeper water in 1954. Since there is a gap in the samples between June 1953 and April 1954, their growth during that period can not be adequately described. It appears, however, that the fish which moved to deeper water grew longer than did the few stragglers that stayed near shore.

Growth of the 1953 Year-Class in the Salton Sea

It is evident that the 1953 year-class grew more slowly than the 1952's (Figure 45). During the first few months of life growth was quite rapid and probably compared favorably with that inferred for the 1952 year-class. A plateau was reached by the 1953 fish in September, however, when they averaged 70 mm. This was far below the 80 mm reached by the 1952 year-class in a comparable period. Furthermore, the samples indicate that the fish had continued to grow during this period of their lives, and had reached 90 mm in October. Members of the 1953 year-class stopped growing in September of their first year. From that time on, growth was confined almost exclusively to the spring months of April, May, and June. As already mentioned, this corresponded with the time of maximum spawning of *Neanthes*, which was virtually their sole food in the Salton Sea. No growth occurred during the summer of any year after 1953. A slight upward trend in their average lengths took place during the fall of each year. This was also apparently related to the increased availability of *Neanthes* in October and November. Catch-effort data from gill nets implied increased bairdiella activity at those times. No growth took place during the winter.

Also shown in Figure 45 is a series of points representing the average lengths of bairdiella taken with gill nets. The pattern of growth is the same as for the seine samples, though the gill nets consistently took slightly larger fish. It would seem that the fish sampled with gill nets began their spring growth before those sampled with seines near shore.

Weight Increase of the 1953 Year-Class

The preceding discussion emphasized length because of the less variable nature of the measurements, and the greater ease with which they were obtained. However, fish weights might at times be a more sensitive indicator of population condition because losses can occur.

Weight increases took place primarily in the spring months when the fish were also increasing in length (Figure 47). Assuming the gill nets and seines sampled different groups, the gain in weight for either group from 1954 to 1955 was about 10 grams, representing a 50 percent increment to the original weight, and from 1955 to 1956 the gain was five grams or 20 percent of the 1955 weight.

A comparison of the weights of fish taken with gill nets and those taken with seines showed a recurring pattern which cannot be explained by the selectivity of the gill nets, since they would be expected to catch heavier fish at all times. There is a definite indication that the fish caught in deeper water with gill nets were heavier in the spring than fish taken near shore with seines. While the fish near shore main-

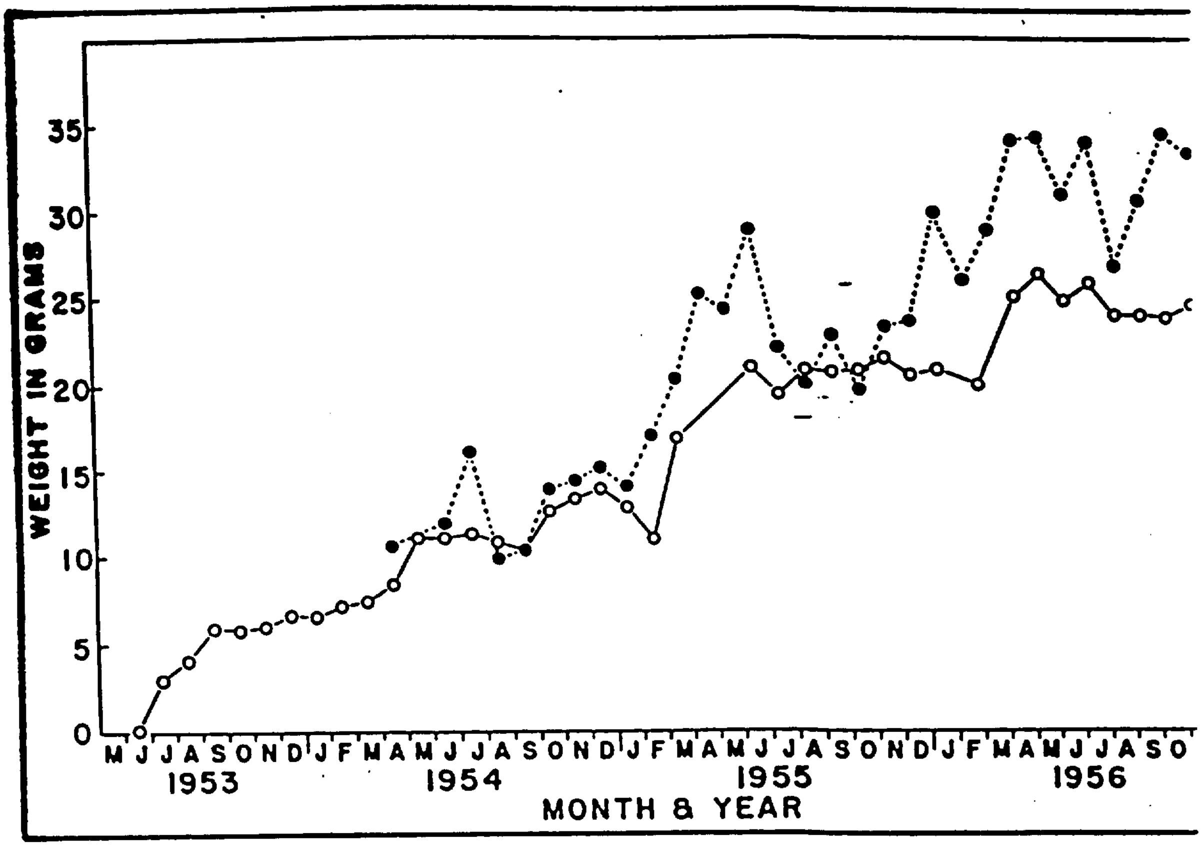

FIGURE 47. Increase in weight of the 1953 year-class bairdiella from the Salton Sea. ○ = Seine sample; ● = Gill-net sample.

only slightly, fish in deeper water showed striking weight losses i August and September, undoubtedly as a result of the failure of th food supply. It has been mentioned previously that the bairdiell moved away from shore more rapidly in the fall of 1956 than in 1955 In this connection, fish taken with gill nets in September and Octobe 1956 had increased considerably in weight, being about 10 gram heavier than fish taken near shore with seines at the same time. In 1955 the fish were slower to gain weight and slower to move away fron shore. This suggests that the movements inshore and offshore migh have been influenced by the available food supply.

Losses of weight in May 1955 and June 1956 might have been result of spawning. No such losses occurred in May or June of 1954 It is believed that the majority of the members of the 1953 year-clas did not spawn in 1954

Growth of the 1954 Year-Class

Bairdiella spawning in the Salton Sea in 1954 must have been on limited scale, since the members of both the 1952 and 1953 year-class were in poor condition throughout the spring months.

Only small samples of 1954 fish were taken. They were not produce in large numbers, and survival appears to have been poor from th beginning. As the season progressed, they became more scarce, pro ably because as they increased in size they began to depend more the *Neanthes* for food, which meant severe competition with the dor

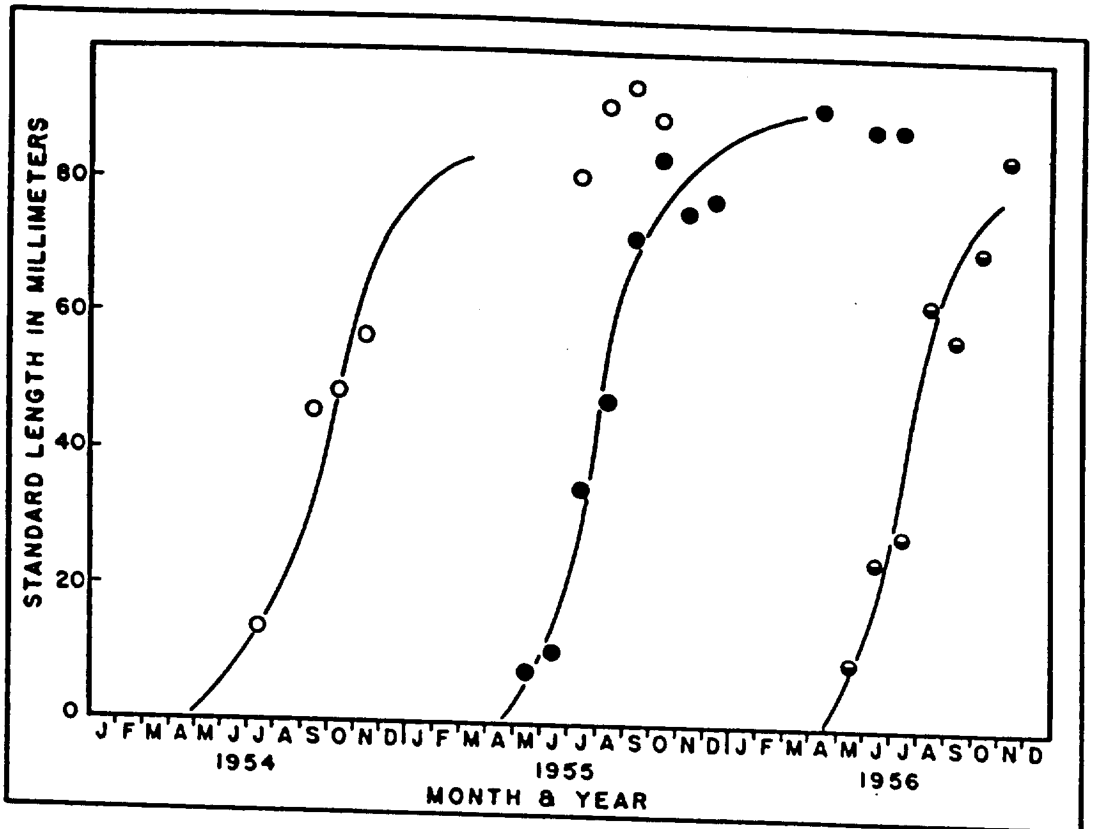

FIGURE 48. Average lengths of the 1954, 1955 and 1956 year-classes of bairdiella from the Salton Sea. Curves drawn by eye. ○ = 1954 year-class; ● = 1955 year-class; ◒ = 1956 year-class.

taken in the standard sampling with beach seines. From these, it appears that growth of the 1954 year-class was quite poor (Figure 48). Fish caught in November 1954 averaged only 57 mm, which was 13 mm less than the length reached by 1953 year-class fish at a comparable period in their lives. Representatives of this year-class in 1955 were identifiable only by reading their scales. Since they may have been included as members of the 1953 year-class in 1955 and 1956, they could have introduced some error in the length estimations of that group. This error would be extremely slight considering the very small numbers which might have been included. In November 1954, for instance, they totaled less than 0.3 percent of the catch in 50-foot seines, and this would probably be an overestimate of their true abundance. It is not realistic to project an estimate of their growth beyond November 1954.

Growth of the 1955 Year-Class

There was large-scale spawning in 1955, due to the maturation of 1953 fish. Large numbers of eggs and fry were produced and the young fish grew rapidly in June, July, and August 1955 (Figure 48). By October 1955, they had reached an average length of about 80 mm. As mentioned previously, their numbers were reduced as they increased in size. They declined from 21 percent of the seine catch in July 1955 to 0.2 percent in December. A few survived the winter and made up a small part of the 1956 catch.

Though their beginning was much more promising, their numbers were reduced as the season progressed until they contributed little more to the population than did the 1954 year-class.

Growth of the 1956 Year-Class

Spawning in 1956 was comparable with that in 1955. Members of the 1956 year-class showed an almost straight-line increase in length from May 1956 to November 1956 (Figure 48). The average length of 71 mm in October 1956 was less than had been achieved by fish of the 1955 year-class at a comparable period, and is about the same as was reached by members of the 1953 year-class. However, growth of the 1956 year-class apparently continued into November. In all the other year-classes except the 1952's, growth had stopped by October. There was also an indication that survival of the 1956 year-class was better than it had been for the 1954's or 1955's.

Discussion on Growth

Growth of the 1952 year-class in the Salton Sea was evidently comparable to that of bairdiella from the Gulf of California during their first two years. However, the fish from the Sea showed no growth after that, while the Gulf bairdiella added 20 mm in their third year. Certainly the 1952 year-class could not have been seriously crowded in the Salton Sea during their first year, since competition was not sufficient to eliminate abnormal individuals, and they reached spawning condition in one year. An oversupply of eggs was undoubtedly produced at that time, as shown by the extreme abundance and poor growth of the resulting fish. They were so abundant they forced the older fish out to deeper water.

The ensuing competition resulted in a cessation of growth among the 1952 fish, and a reduction in their numbers which affected the abnormal fish first. Competition between members of the 1953 year-class resulted in a slow rate of growth for them, and led to the virtual elimination of the 1954, 1955, and 1956 year-classes. Growth of the 1953's, after 1953, took place only in the spring months. This apparently related to increased availability of food at that time, though other factors might have been operating. Brown (1946) found that the growth rate of brown trout was greatest in the spring even when the food supply and temperature were constant.

Growth of the year-classes is compared in Table 34. The poorest first year growth was shown by the 1954 year-class, which was also the least successful group in terms of survivors. The next poorest growth, however, was shown by the 1953's, which were the most successful survivors They took three seasons to reach a length which the 1952's had attained in their first season. For the 1953 year-class, the greatest length increment after their first year was 15 mm, while the 1952's grew 40 mm or more in their second year. Considering the evident competition within the 1953 year-class, as demonstrated by their poor growth and condition, it is not surprising that none of the following year-classes was able to survive. The competition was apparently more acute as the fish approached the sizes of the 1953's. For example, in 1954 the fish of the 1953 year-class did not increase in length after May, and they los

TABLE 34
Comparison of the Growth of Year-Classes of Bairdiella in the Salton Sea *

Year-class	Standard Length in January (in mm)				
	in First Year	in Second Year	in Third Year	in Fourth Year	in Fifth Year
1952	>100	140 to 162	157	160?	160?
1953	76	91	105	116	---
1954	ca. 70	---	---	---	---
1955	ca. 84	---	---	---	---
1956	ca. 85	---	---	---	---

* See Table 31 for data.

washed up on shore. This kill occurred when fish of the 1954 year-class were reaching a size where they were beginning to shift their diets from copepods, etc., to *Neanthes*, which were already being heavily utilized by the 1953 year-class.

The failure of 1952 fish to increase in length after 1954 might have been related to their larger size and possible need for a greater volume of food to maintain themselves, since the smaller 1953 year-class fish were able to increase at least slightly each year. Most 1952 year-class fish formed an annulus on their scales in 1955, implying that some growth had taken place. Yet, no increase in their average length was demonstrated (Figures 45 and 46). Perhaps the larger fish of the year-class were eliminated and the smaller members grew slightly. This would explain the slight downward shift in the average length of the year-class between 1954 and 1955.

The difference in growth of the year-classes was associated with a difference in age at maturation. The fast-growing 1952's were mature after one year, while none of the females of the slow-growing 1953 year-class matured until after two years. Few members of either year-class appear to have matured in 1954, when fish of both groups were in poor condition. Alm (1953) found that perch, *Perca fluviatilis* Linnaeus, with exceedingly good growth matured at one year, while stunted populations did not mature at three years. Davidson and Vaughan (1941) suggested that more-abundant populations of pink salmon are slower growing and late in their spawning migrations. Laskar (1940) and Svardson (1943) as reported in Alm (1953) also found that slow-growing fish matured at a later age than fast-growing fish. This might not be a general rule, because the studies of Foerster (1947) and Alm (1952) indicate that slow-growing populations might mature earlier than fast-growing populations in certain situations.

BAIRDIELLA MORTALITIES IN THE SALTON SEA

Mortalities occured in the late summer or early fall of each year from 1953 to 1956. Dead fish were first observed in October and November 1953 by Wayne J. Baldwin and John E. Fitch (unpublished field notes). In November, they made counts of the dead fish washed up on shore. A total of 300 was tallied along an estimated 280 feet of beach. Apparently this kill continued until March 1954, since a few fish were in later years, the 1953 kill seems to have extended over a longer period of time.

The kill which took place in 1954 was the most severe; it began in August when large numbers of bairdiella washed up on shore. To get an idea of the duration and magnitude of the kill, sections of shoreline were cleared of fish in September 1954, and the fish appearing each day were counted. A 50-foot section of shoreline was chosen, since this seemed to promise a reasonable number of fish in daily counts. Four counting stations were selected. It was not possible to locate them at random from the total shoreline of the Sea, because the majority was not accessible. The four stations, two on the east and two on the west shore, were near roads but away from much-used beaches, so they were relatively undisturbed. The stakes marking one station were lost after one month, and it had to be relocated.

It was not always possible to make daily counts, but usually the interval between them was no more than three or four days. This made it possible to distinguish to some extent between newly dead fish and those washed in from other areas, since fish that had been on the beach for any length of time usually had dried out in the desert heat. Fish which appeared to have dried for periods longer than the interval between counts were not included.

Considerable variation showed up in the daily counts, though there was a general agreement between the areas with time (Table 35). The counts for August are merely the dead fish found when the sections were first cleared. Differences between the east and west shore stations may have been due to real differences in the kill or to the effects of wind. Strongest winds in the area are from the northwest which would tend to deposit more fish on the east shore.

Daily counts in September varied from 0 to 108 dead fish on a 50-foot section of beach; the average for the month was 8.8 fish per day per 50 feet. In October 1954, the counts varied from 1 to 98, and averaged 22.6 fish per day per 50 feet (Table 35).

Total mortality in 1954, estimated from these counts, might be of some interest. The expansion of the counts is not strictly legitimate, because of the nonrandom location of the counting sites. Nevertheless, some idea of the magnitude of the kill may be gained. Certainly not all fish which died were necessarily washed up on shore. However, as pointed out

TABLE 35

Number of Dead Bairdiella Counted on the Shore of Salton Sea, 1954

Location	Station No.	Number of Dead					
		Aug	Sept	Oct	Nov	Dec	Total
West Shore	1	34	240	314	38	2	628
	2	36	260	923	59	25	1,303
East Shore	3	670	273	lost	..	..	..
	4	615	283	868	108	8	1,882
	5	1,219	..	236	110	6	1,371
Average	..	515	264	585	79	10	1,346

previously, shoreward migration of the fish reached a maximum in August, so many were already near shore when the kills began. Receding water at that season might also have aided the deposition of fish on shore. The counting stations were on open stretches of beach, where currents would not deposit unusual numbers of fish. These sections were reasonably typical of the shoreline around the entire Sea. Scattered observations on other parts of the shore revealed dead fish in the same general degree of numerical abundance. The total shoreline was about 90 miles long, or about 9,400 sections 50 feet long. Thus, the total kill in 1954 could be estimated as 9,400 x 1,300, or about 12,000,000 fish. This would amount to 55 fish per surface acre of the Salton Sea, or, using the average weight of 12.5 grams, 1.5 pounds per acre.

After the kill of 1954, the beach was closely watched for dead fish. At times these checks showed no dead fish and counts were made at less-frequent intervals. During the spring and early summer of 1955, only one or two counts were made each month.

Figure 49 shows the average count per station per day for each month from August 1954 to September 1956. Dead fish were only rarely washed up during the spring and summer months. In the fall

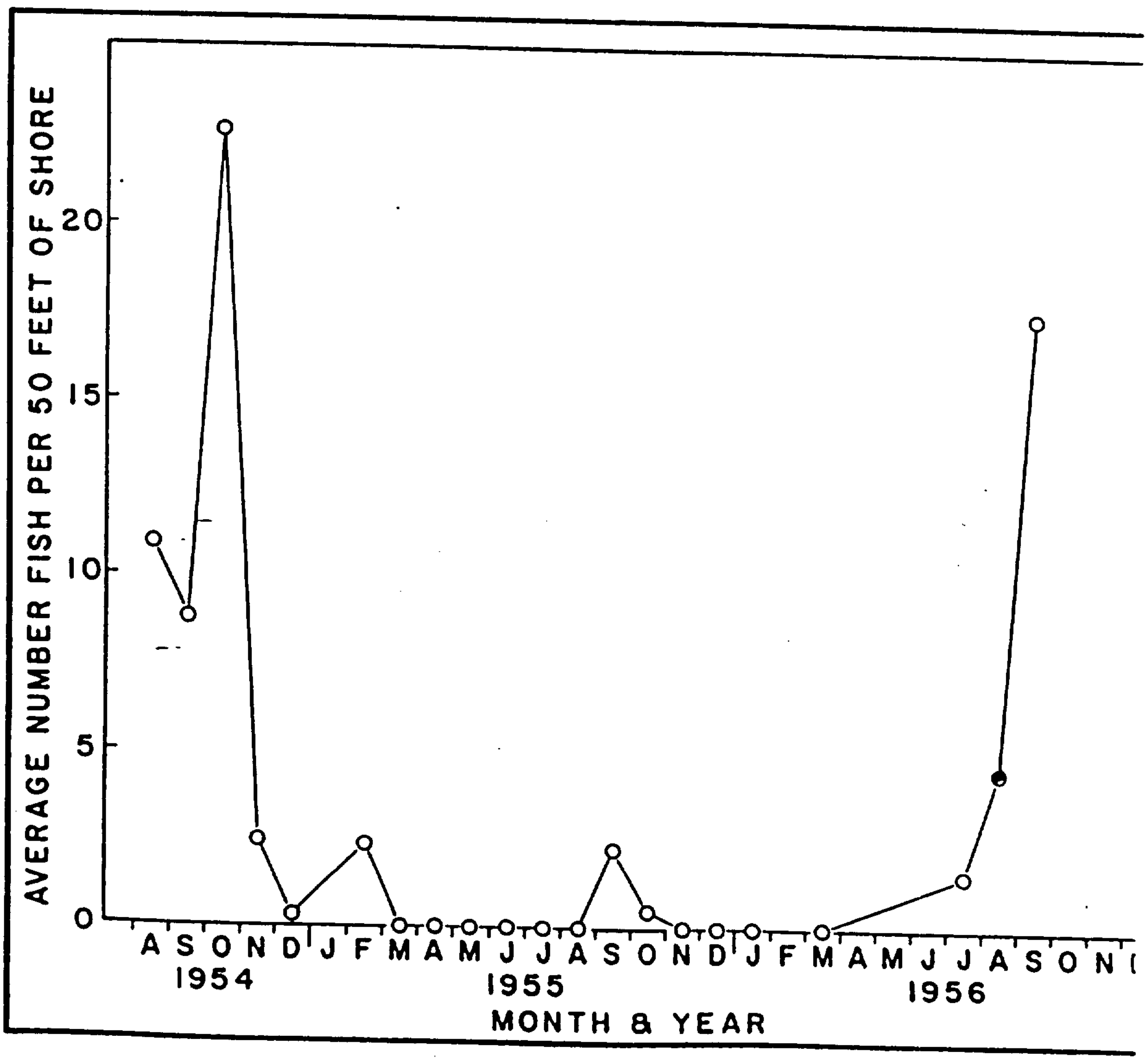

FIGURE 50. Comparison of a thin bairdiella (upper) with a normal bairdiella from the Salton Sea, 1955. Photo by R. H. Linsley.

of 1955, a very minor kill was observed. At that time the 50-foot sections of shoreline were deemed insufficient to provide a count of the dead fish, so a larger section 1,700 feet long was cleared and checked regularly. The counts were then put on a 50-foot basis for comparison with the other data. The kill was of short duration; very few dead fish were observed in October, and none in other counts up to July 1956. In August and September 1956, a severe kill again occurred. Unfortunately, no counts were made in October, but observations indicated the peak of the kill was in September and that fewer dead fish were on the beach during October 1956. Dead fish were uncommon on a two-mile section of shoreline examined in November.

There can be no doubt that the bairdiella were using the available food supply in the Salton Sea to the fullest possible extent. This was indicated by the slow growth of the 1953 year-class, by the long periods of no growth, and by their close reliance on spawning *Neanthes* for growth. The food supply obviously is not constant. The elimination of *Neanthes* from deeper waters in late summer represents a real crisis for bairdiella, especially since it occurs when water temperatures are highest.

In the late summer and fall when the members of the 1953 year-class were showing no growth and were losing weight, noticeably thin fish began to appear in the samples. Extremely thin fish were observed at times (Figure 50). A fish was deemed thin if its dorsal muscles were reduced, leaving a sharp-edged crest in back of the head. Of course, this was present in varying degrees so judgment was subjective to a certain extent.

The samples with the highest percentage of thin fish occurred in the winter of 1953-54. For a period of three months, December, January, and February, over 50 percent of the individuals were thin (Figure 51). In a sample of 1,162 fish taken January 9, 1954, 94 percent

Each year after 1953 the percentage of thin fish was high in the late summer and early fall, corresponding to times of food shortage, and then decreased in the late fall after the spawning of *Neanthes.* Few thin fish were observed in the spring months. The occurrence of thin fish corresponded roughly with the periods of fish kills (Figures 49 and 51).

Since to record fish as being thin depends on subjective judgment, it might be better, in determining the condition of the population, to use data based on K or condition factor of the fish, where $K = \frac{W}{L^3} \times 10^5$; W being the weight in grams and L the length in millimeters. K factors for fish of the 1952 and 1953 year-classes computed from their average lengths and weights (Table 31) are shown in Figure 52. This provides an index to the average condition of the population at monthly intervals over the period investigated.

LeCren (1951) pointed out that on a mathematical basis, the K factor is not independent of the absolute length of the fish. The value of K would be expected to decrease with increased fish length. On the other hand, in some cases changes in body form of the fish more than counteract this tendency. For example, Sigler (1949) found that the K factor of white bass increased with increasing lengths of fish. Hansen (1951) found the same was true for white crappie.

In the present case, the problem was simplified by the fact that within each year-class the range of lengths was rather narrow. The observed changes in K factor go beyond anything which could be ex-

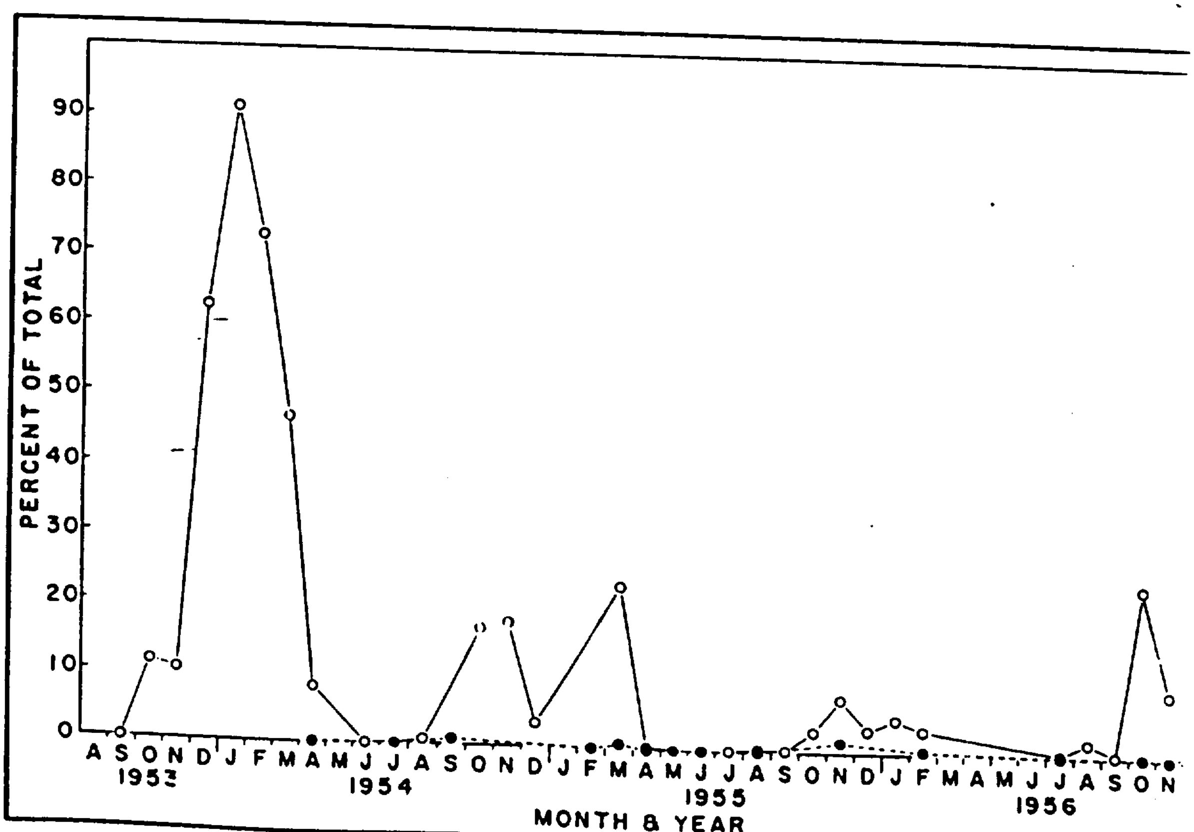

FIGURE 51. Percentage of bairdiella of the 1953 year-class recorded as thin in samples from the Salton Sea. ○ = Seine samples; ● = [illegible]

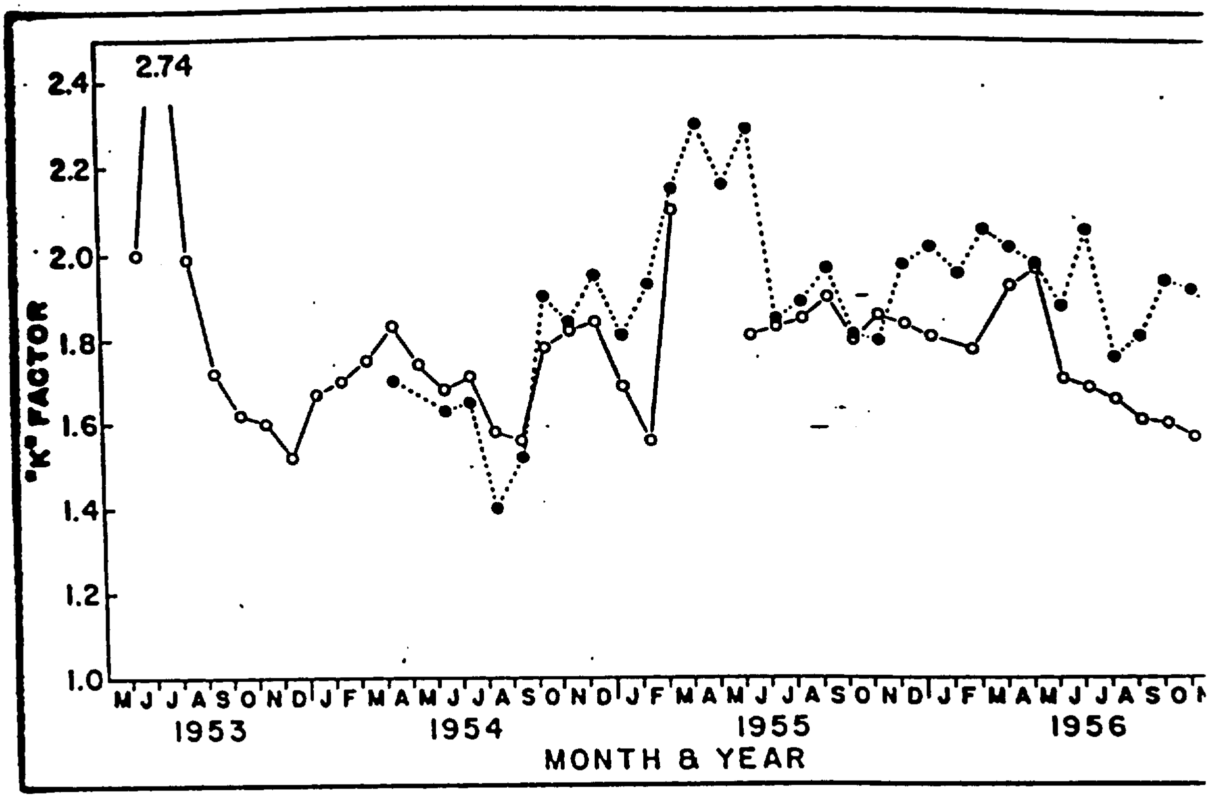

FIGURE 52. *K* or condition factors computed for bairdiella of the 1953 year-class from the Salton Sea. ○ = caught in seines; ● = caught in gill nets.

plained as having been caused by a relationship with lengths of the fish. This was particularly true of changes during the summer, fall, and winter months in the years when the lengths of the 1953 fish were constant. During such periods, the changes in weight alone were sufficient to indicate changes in their condition. The usefulness of the *K* factor in comparing the condition of fish in different years is shown by the rather good agreement of Figures 51 and 52. At times when fish were described as thin, the *K* factor was also low. Thus, in October, November, and December 1953, and January 1954; September 1954; January and February 1955; and October and November 1955, the *K* factor was low when more than 10 percent of the fish were described as thin.

Starvation was again suggested as a cause of the kills because when the *K* factor of 1953 year-class fish fell to values of 1.6 or lower, dead fish were observed on shore; as in November and December 1953, and January 1954; August and September 1954; February 1955; and September and October 1956. The relationship was not always direct, however. For instance, the *K* factor improved in October 1954, when the observed kill was at a maximum. Though of a minor nature, a kill did occur in 1955, while the *K* factor remained at a fairly high level. Also in 1956 the *K* factor, as computed from seine samples, declined through November, although observations indicated that the kill reached a maximum in September and was not seriously affecting the fish in November. In the latter case, however, the reduced November catch indicated that offshore movement of the fish may have left only a few weak individuals inshore.

Also in Figure 52 is a series of K factors computed from the gill-net samples. The pattern is quite similar to the series computed from the seine samples, though from October 1954 to November 1956 the K factor for gill-netted bairdiella exceeded that determined from seine samples in every case but one. LeCren (1951) felt that gill nets might be selective in regard to K factor.

During the early phases of growth in 1953, the value of K for seined 1953 fish decreased drastically from August through December, although lengths showed little change after September.

Conditions improved in February 1954, a trend that continued into the spring. Declines occurred in the summer of 1954 followed by gains in the fall. The lowest values of K occurred in August and September when dead fish were first observed.

The declines in K factor in May 1955 and 1956 were due in part to spawning, but continued losses in the summer and fall must be regarded as having been due to shortages of food. In each of the three years, 1954, 1955, and 1956, the fish showed a decline in K factor during May even though growth in length and weight seemed to have continued.

The K factors for the 1952 year-class show possible effects of the absolute lengths of the fish; values which in 1954 never exceeded 1.6 (Figure 53). Since no increase in average length of 1952 year-class fish

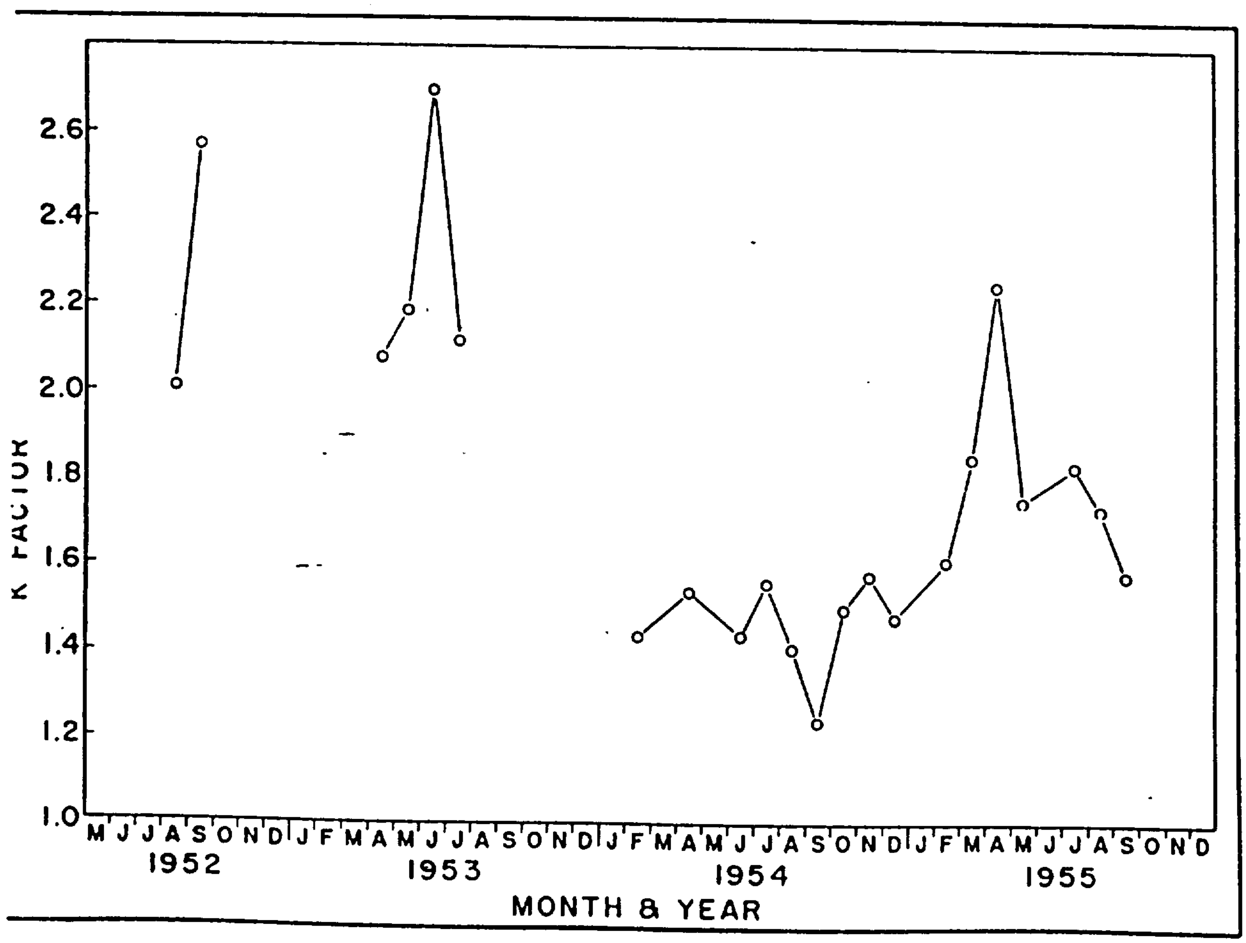

FIGURE 53. K or condition factors computed for bairdiella of the 1952 year-class from the Salton Sea.

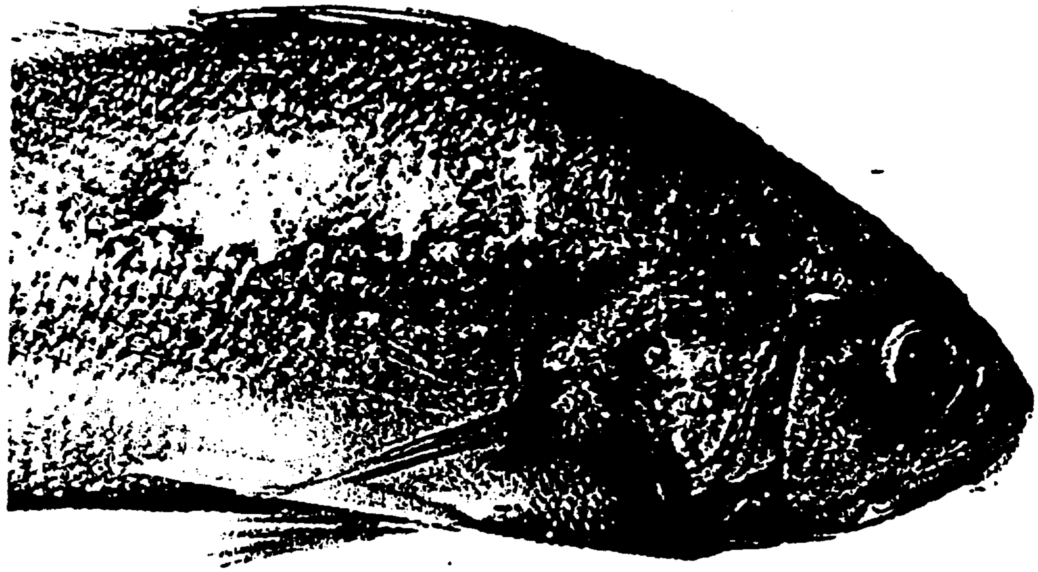

FIGURE 54. Bairdiella from the Salton Sea with injury to head and lateral line, 1956. Photo by R. H. Linsley.

was observed after April 1954, the length may be considered constant from then on. There was real improvement in condition of the 1952 year-class in 1955 as compared to 1954.

Values of *K* for the 1952 year-class in 1952 and 1953 were 2.0 and more. In April and July 1955 the *K* factors for the two year-classes were nearly equal. This indicates that the 1952 year-class fish must have been in very poor condition in 1954 compared to their condition in 1953 and 1955. It is also evident that they were not in as good condition in 1954 as fish of the 1953 year-class. This would be expected, since they showed little or no growth, while 1953 year-class fish increased in length and weight.

The excellent agreement between the loss of weight in the fish and the times of kills leaves little doubt that the two were associated. Furthermore, since the weight losses occurred at times of food shortage it is reasonable to suppose that starvation was a contributing factor to the kills. However, not all of the fish observed on shore were thin. It certainly is possible that factors other than starvation contributed to the kills.

Also observed with the thin fish were some with open sores on the dorsal portion of their heads. In some cases, this condition affected the lateral line and extended for some distance along it (Figure 54). Some fish were observed with the skin and muscle tissue of the head missing and the bone exposed. The wounds generally resembled bacterial infections. Some of these fish showed a general loss of equilibrium, and swam weakly in spirals or circles near shore.

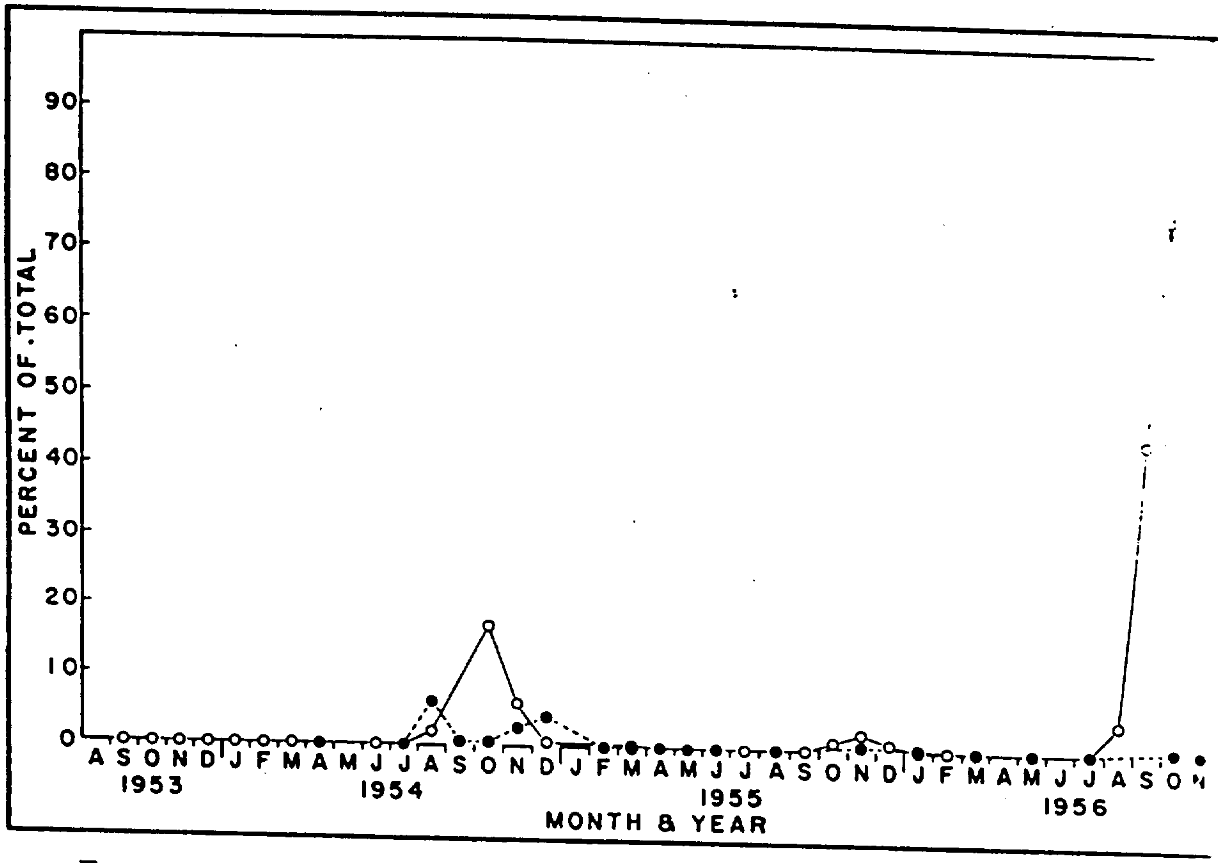

FIGURE 55. Percentage of bairdiella of the 1953 year-class from the Salton Sea with injuries to the head and lateral line. O = Seine samples; ● = Gill-net samples.

Fish with this condition were observed only in the fall and winter months (Figure 55). It affected large percentages of the fish in the late fall of 1954 and 1956. In 1955, however, such fish never amounted to more than five percent of any sample. There was not a perfect agreement between the time of maximum occurrence of this disorder and the maximum kill, though the general agreement as to time of year and severity from year to year was good. Not all of the fish washed up on shore showed external evidences of this disorder. It might not be unreasonable to speculate that thin fish, suffering from malnutrition and crowded inshore, would be more subject to disorders or infections of this sort. Fish taken in gill nets rarely showed evidence of this disorder even when, as in the fall of 1956, over 40 percent of the seined fish were affected (Figure 55). As already mentioned, fish in gill-net samples also had higher *K* values than those in seine samples. It is possible to associate both of these differences with the selective action of gill nets, weak fish perhaps being less apt to be caught in gill nets than in seines, but it is more likely that the differences are real.

At least one kill occurred which cannot be ascribed to starving. On July 20, 1955, several thousand fishes washed ashore at Sandia. The tioned at Sandia, large numbers of bairdiella appeared at the surface on the evening of July 19, about two or three miles southeast of Sandia. Their behavior was typical for fish suffering from lack of oxygen. No dead fish were observed at that time in parts of the Sea other than in this immediate vicinity. Fifty-one bairdiella were collected from the shore, preserved in formalin, and later measured and weighed. All were in excellent condition, with an average *K* factor of 2.0 and none had external sores or other indication as to the possible cause of the kill. The *K* factor agrees quite well with the average *K* of 2.5 observed from gill-net samples at that time. Although no certain explanation for this kill is available, it seems probable that it was caused by a local anoxic condition.

ABNORMALITIES

A great many abnormal individuals were noted in the samples of *Bairdiella* taken in the early stages of the population buildup in the Salton Sea (D. C. Joseph, personal communication). Whether produced genetically or environmentally, such abnormal individuals evidently are eliminated under ordinary conditions by interspecific or intraspecific competition or predation at least when the abnormality is such as to put the individual at a disadvantage in the struggle for survival. The relative frequency of occurrence of different abnormalities in succeeding year-classes would seem, therefore, to give a rough index to the degree of competition and predation taking place during the development of each year-class.

In determining the frequencies of abnormalities, no attempt was made to use the entire sample of bairdiella that had been collected. Effort was concentrated on samples containing large numbers of individuals, so as to reduce somewhat the manipulative labor involved. Thus, the size of the sample jars became a criterion in deciding whether to examine for abnormalities. A total of 1,443 members of the 1952 year-class was inspected for abnormalities, 122 from samples collected in 1952 (the entire collection), 651 from 1953, and 670 from 1954. Samples of the 1952 year-class taken in 1955 and 1956 were too small to provide an estimate of frequencies of abnormalities. Also inspected were 37,324 members of the 1953 year-class, 9,437 from samples collected in 1953, 7,145 from 1954, 10,834 from 1955 and 9,908 from 1956. Anal spine abnormalities were determined from a smaller sample because this feature was not noted until after the work had progressed into 1955.

Blindness

Blindness as considered here refers to external evidences of blindness. Such evidences ranged from eyes of normal size but with no apparent pupil, or with the eye clouded (Figure 56), to eyes reduced to a very small size and even completely missing. In the latter cases, the bone structure around the eye was also affected, being misshapen or absent (Figure 57).

Blindness in the 1952 Year-Class

The year-class of *Bairdiella* produced in 1952 was at first apparently unaffected by predation or competition of any consequence. The sample from 1952 was small, consisting of only 122 individuals, but of these,

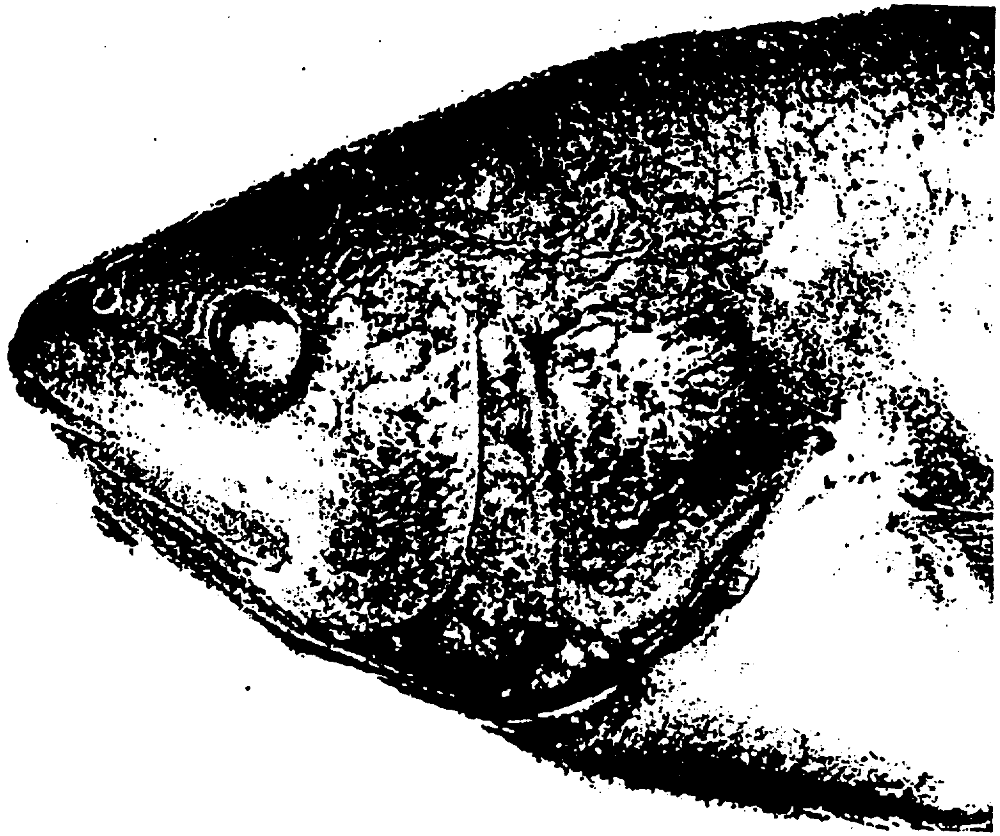

FIGURE 56. Blind bairdiella, with the eye clouded, from the Salton Sea. Photo by R. H. Linsley.

If this same year-class is followed into 1953, however, it can be seen that the samples are not uniform in their estimates for blindness in the population (Table 37). One wishes for a larger sample to compare. At any rate, local populations of this year-class of *Bairdiella* showed percentages of blind which differed from those of other local populations (chi-square = 50.9, df 2, highly significant). There is no reason to believe that this was due to any factor other than failure of the fish to mix. The samples were all taken within three months of one another and show no trend in percentage blind with time.

Further information on the lack of agreement of the samples in 1953 comes from comparing the number of fish blind in the right eye with those blind in the left eye (Table 38). Logically, a ratio of 50:50 might be expected. The sample of May 4, 1953, however, had more fish blind in the right eye than in the left. This may have been an unusual sample, since there were no differences in the other samples or in the combined samples (Table 38).

Because of the variability of the early samples in their estimates of blindness in the 1952 year-class, it is not surprising that the totals for 1952 and 1953 differed. An increase in blindness is indicated, but is to be interpreted merely as unusual sampling variation, particularly con-

TABLE 36

Blindness in the 1952 Year-Class of Bairdiella From the Salton Sea in 1952

Date	Locality	Sample Size	Blind One Eye		Blind Both Eyes		Total Percent of Blindness
			Number	Percent	Number	Percent	
5 Aug. 1952	Salton Sea Beach	30	--	--	--	--	0.0
29 Aug. 1952	Sandia	11	1	9.1	--	--	9.1
4 Sept. 1952	Durmid	53	3	5.7	2	3.8	9.5
27 Oct. 1952	Salton Sea	28	1	3.6	1	3.6	7.2
Total		122	5	4.1	3	2.4	6.5

TABLE 37

Blindness in the 1952 Year-Class of Bairdiella From the Salton Sea in 1953

Date	Locality	Sample Size	Blind One Eye		Blind Both Eyes		Total Percent of Blindness
			Number	Percent	Number	Percent	
2 Apr. 1953	Salton	86	4	4.6	--	--	4.6
10 Apr. 1953	Salton Sea Beach	275	24	8.7	--	--	8.7
4 May 1953	Fish Springs	203	59	29.0	--	--	29.0
13 June 1953	Fish Springs	15	4	26.7	1	6.7	33.4
13 June 1953	Salton Sea Beach	145	21	14.5	--	--	14.5
17 June 1953	Salton Sea Beach	50	2	4.0	--	--	4.0
18 July 1953	Salton Sea Beach	5	--	--	--	--	--
Total		779	114	14.6	1	0.14	14.7

sidering the small size of the 1952 sample. The samples indicate that between 6 and 15 percent of the fish were blind in 1952 and 1953.

In contrast to the samples of 1952 and 1953, only two percent of the 1952 fish were blind in 1954 (Table 39). None was blind in both eyes. Blind fish were so uncommon that, although more fish were examined than in either of the two previous years, only two samples produced enough blind fish to be suitable for comparison. They were obviously quite similar in the percentages blind, and did not differ from the grouped samples from the rest of the year. The highest percentage in a single 1954 sample, 3.1 percent, was lower than the lowest of the two previous years, 3.6 percent. In spite of the variability in the earlier samples, it seems clear that a decrease in the percentage blind occurred between 1953 and 1954, including a decline in the number blind in both eyes.

Blindness in the 1953 Year-Class

Blindness in the 1953 year-class was extremely rare, in striking contrast to the common occurrence in the 1952 year-class. Only about 0.1

TABLE 38

Comparison of Number Blind in Right Eye Versus Left Eye in the 1952 Year-Class of Bairdiella, Salton Sea

Date	Number Blind Right Eye	Number Blind Left Eye	Chi-square
1952	4	1	--
2 April 1953	3	1	--
10 April 1953	15	9	1.5
4 May 1953	39	20	6.1 (Significant)
13 June 1953 (a)	1	3	--
13 June 1953	10	11	0.0
14 June 1953	0	2	--
1954	4	5	0.1
Total (Except 1952)	72	51	Sum 8.1, df 5 (Nonsignificant) Pooled chi-sq. 3.6, df 1 (Significant) Interaction chi-sq. 4.5, df 4 (Nonsignificant)

TABLE 39

Blindness in the 1953 Year-Class of Bairdiella, From the Salton Sea in 1954

Date	Locality	Sample Size	Number of Blind	Percent of Blind	Total Percent of Blindness
23 April 1954	Salton Sea Beach	266	4	1.5	1.5
8 June 1954	Salton	292	9	3.1	3.1
Others	Various	445	7	1.3	1.3
TOTAL		1,003	20	1.99	2.0

percent were blind in one eye (Table 40). The numbers of blind fish in particular samples of the 1953 year-class were too low to permit a test of homogeneity within any of the years. Since samples in 1953 were taken mainly at one location, there is some danger that they might not have been representative of the population in general. No obvious differences occurred, however, in the few samples taken at other places, so that it is probably reasonable to assume they were representative.

There was no difference in the number of fish blind in the right and left eyes. Of the 39, 18 were blind in the right eye and 21 in the left.

Comparison of the 1952 and 1953 Year-Classes With Respect to Blindness

The year 1953 found two year-classes of *Bairdiella* in the Salton Sea differing radically in the percentage blind. There were about 50 to 100 times as many blind among the 1952's as 1953's (6 to 15 percent of the 1952 year-class were blind as compared to 0.16 percent of the 1953's). Apparently the 1953 year-class was produced in such numbers that the effects of competition were almost immediate.

It was undoubtedly during late 1953 that the reduction in percentage blind (from 15 to 2 percent) in the 1952 year-class was taking place. Though a few totally blind fish of the 1952 year-class survived in 1952 and early 1953, none was found in later years and no member of the 1953 year-class was ever found that was blind in both eyes.

The frequency of blindness in 1954 was 2 percent in the 1952 year-class compared to 0.1 percent in the 1953 year-class (chi-square > 12.0, df 1, highly significant). The initial stress of competition was therefore within the 1953 year-class, and its effects on the 1952 year-class came later.

Malformed Mouths

Abnormalities of the mouth included underdeveloped, poorly developed, and twisted lower jaws; and one or both maxillaries missing, vestigial, or reduced. Several fish had the maxillaries and premaxillaries twisted inward so that they lined the inside of the mouth. Various combinations of the abnormalities occurred.

If the fish suffering from missing, vestigial, or slightly reduced maxillaries or premaxillaries, or combinations of these, are considered to

TABLE 40

Blindness in the 1953 Year-Class of Bairdiella From the Salton Sea, 1953-1956

Year	Sample Size	Blind One Eye		Small Eye or Pupil	
		Number	Percent	Number	Percent
1953	9,437	16	0.17	15	0.16
1954	7,145	7	0.10	3	0.04
1955	10,834	6	0.06	7	0.06
1956	9,908	10	0.10	3	0.03
Total	37,324	39	0.10	28	0.08

To test significance of differences in percent blind in one eye between the years, chi-square = 6.8, df nonsignificant

TABLE 41

Occurrence of Abnormal Maxillaries and Premaxillaries in Bairdiella From the Salton Sea

Year	Sample Size	Number With Abnormal Maxillaries and Premaxillaries	Percent Abnormal
1952 Year-class			
1952	122	1	0.82
1953	651	12	1.84
1954	670	2	0.30
Total	1,443	15	1.03
1953 Year-class			
1953	9,437	35	0.37
1954	7,145	37	0.52
1955	10,834	39	0.36
1956	9,908	31	0.31
Total	37,324	142	0.38

gether, it appears that a considerable reduction in frequency occurred (in the 1952 year-class) between 1953 and 1954 (the 1952 sample was too small to be used). A decline from 1.8 to 0.3 percent took place at that time (Table 41). Yearly counts were quite similar for the 1953 year-class and gave a combined estimate that about 0.4 percent of the population possessed abnormal maxillaries or premaxillaries or both. The two year-classes probably were quite similar with respect to the frequency of this characteristic by 1954.

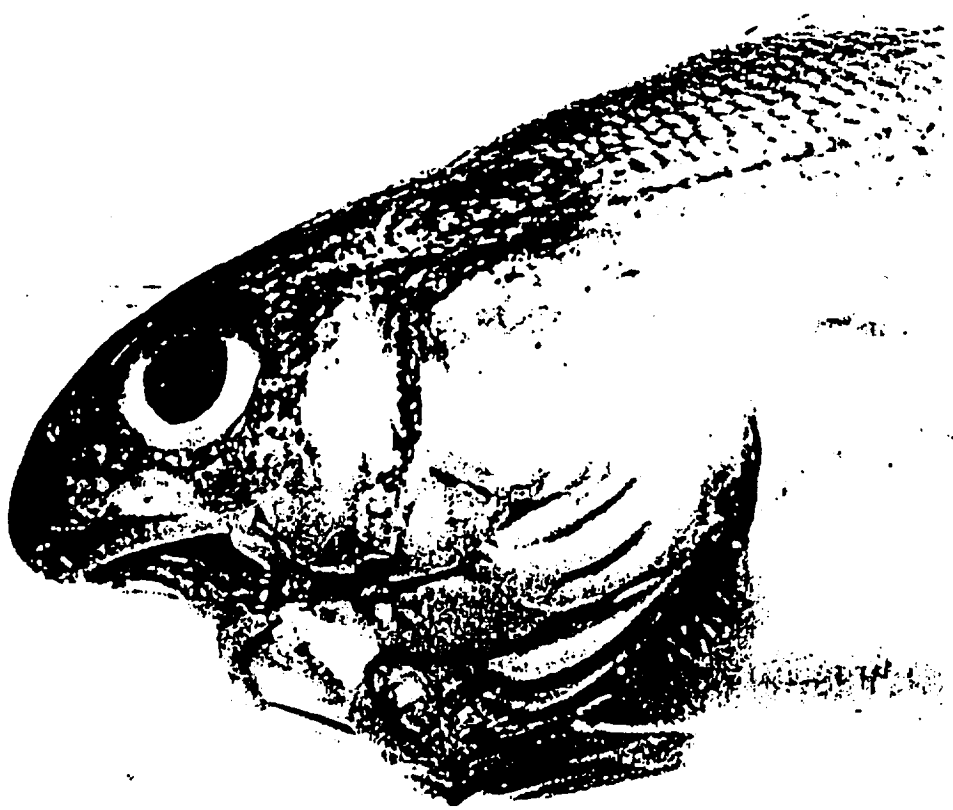

FIGURE 58. A bairdiella of the 1952 year-class from the Salton Sea with the lower

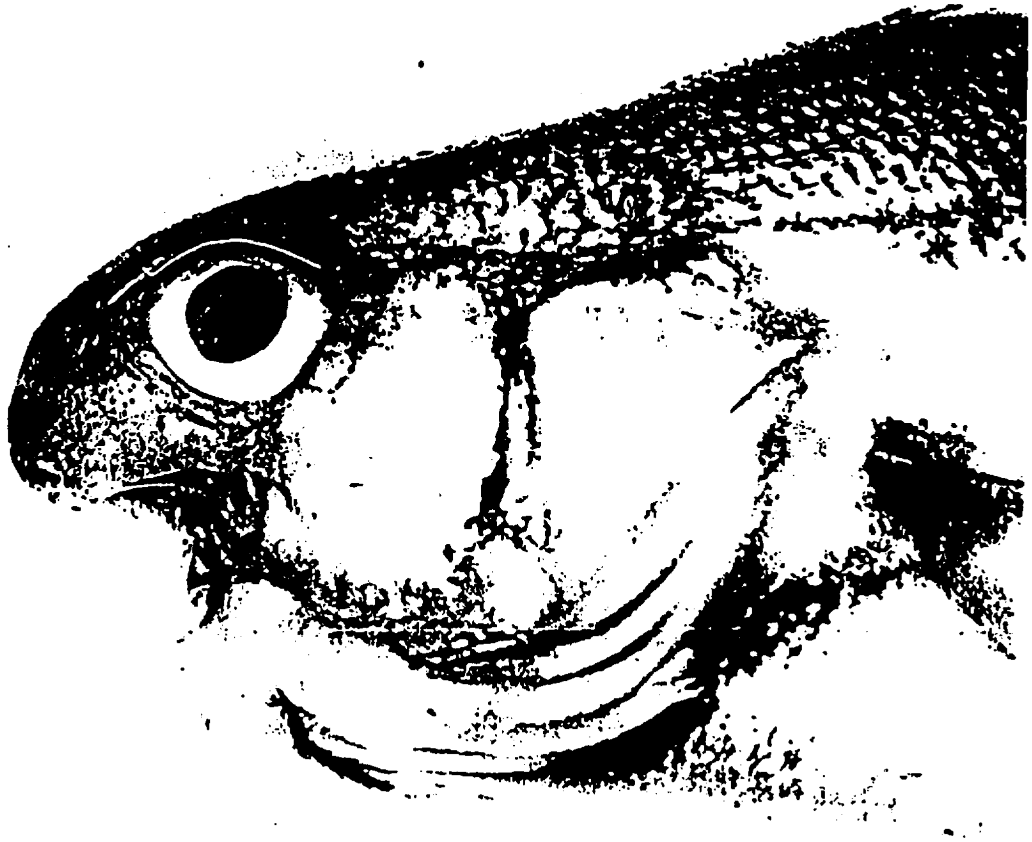

FIGURE 59. A bairdiella of the 1952 year-class from the Salton Sea with a cartilage knob in place of the lower jaw. Photo by R. H. Linsley.

Malformations of the lower jaw were so severe in some fish of the 1952 year-class that it was impossible for them to close their mouths. In fact, four fish completely lacked functional lower jaws, and four others had severely reduced lower jaws, very nearly non-functional (Figure 58). There was an apparent relationship between this type of abnormality and another that affected the cartilage in the lower jaw. All of the fish with missing lower jaws had masses of undifferentiated and twisted cartilage at the isthmus. One with a poorly-developed lower jaw had the cartilage drawn out to a blunt point which extended beyond the end of the jaw (Figure 59). Three fish with normal jaws had a knob of cartilage extending downward at the isthmus. The knob was associated with the ends of the gill arches. In some fish the lower jaws, otherwise normal, were twisted to one side or the other.

There was an apparent difference between the year-classes in the percentage of fish with abnormal jaws; they were more common in the 1952 year-class. Also apparent was a reduction in this type of abnormality among the 1952's between 1953 and 1954 (Table 42).

Malformed Preorbital

This malformation was also associated with abnormalities of the mouth. Often the maxillary or mandible would be twisted to fill the gap left by a reduced or missing preorbital. In severe cases, the maxillary came in direct contact with the lower edge of the eye and caused some distortion in its shape. In one fish, the maxillary was so reduced that the lower jaw closed against the lower edge of the right eye. No apparent injury had been done to the eye. Malformation of the preorbital was quite rare, affecting only 25 fish out of the 37,324 of the 1953 year-class examined (Table 43). No member of the 1952 year-class was observed with this feature

Deformed Gill Cover

Quite rarely *Bairdiella* were encountered with the branchiostegal rays twisted inward and sometimes involving the subopercle and opercle so that portions of the gill were exposed (Figure 60). Only 9 of the 37,324 fish of the 1953 year-class were thus disfigured. One was observed among the 1,443 of the 1952 year-class.

Snub-nose (Pug-head)

Another rare disorder involved the snout. In some fish the snout bluntly terminated just in front of the eye, leaving the lower jaw protruding beyond the upper, while in others the snout was only mildly reduced. There was a certain variability in the pointedness of the snout among the normal fish, as well as a variability in the position of the

TABLE 42

Frequency of Occurrence of Abnormal Lower Jaws in Bairdiella From the Salton Sea

Year	Sample Size	Number With Twisted Jaws	Number With Missing Jaws	Number With Reduced Jaws (Severe)	Total	Percent Abnormal
1952 Year-class						
1952	122	1	0	0	1	0.82
1953	651	2	5	6	13	1.99
1954	670	0	0	0	0	0.00
Total	1,443	3	5	6	14	0.9
1953 Year-class						
1953	9,437	3	2	5	10	0.10
1954	7,145	6	0	11	17	0.24
1955	10,834	4	0	4	8	0.07
1956	9,908	6	1	7	14	0.41
Total	37,324	19	3	27	49	0.12

TABLE 43

Malformed Preorbitals in the 1953 Year-Class of Bairdiella From the Salton Sea

Year	Sample Size	Number With Malformed Preorbitals	Percent Malformed
1953	9,437	7	0.07
1954	7,145	8	0.10
1955	10,834	7	0.06
1956	9,908	3	0.03
Total	37,324	25	0.06

FIGURE 60. A bairdiella of the 1952 year-class from the Salton Sea with a deformed gill cover. Photo by R. H. Linsley.

mouth relative to the snout. In the final analysis, by considering only those fish which were obviously malformed and "dolphin-like", 27 (.06 percent) were snub-nosed. No difference was indicated from year to year in the 1953 year-class, but a decline is indicated between 1953 and 1954 in the 1952 year-class (Table 44).

Deformed Vertebral Column

Variations ranged from fish with a mild horizontal or vertical flexure of the spine to those with badly twisted and distorted bodies. A system of grading was employed in an attempt to separate the degrees of abnor-

TABLE 44

Occurrence of the Snub-nose Conditions in Bairdiella From the Salton Sea

Year	Sample Size	Number With Snub-nose	Percent Snub-nose
1952 Year-class			
1952	122	0	0.0
1953	651	6	0.9
1954	670	0	0.0
Total	1,443	6	0.4
1953 Year-class			
1953	9,137	1	0.01
1954	7,145	3	0.04
1955	10,834	9	0.08
1956	9,908	8	0.08
Total	37,324	21	0.05

To test the difference between the years 1953 and 1954 for the 1952 year-class, chi-square = 4.8, df 1, significant.
To test the difference between the [illegible]

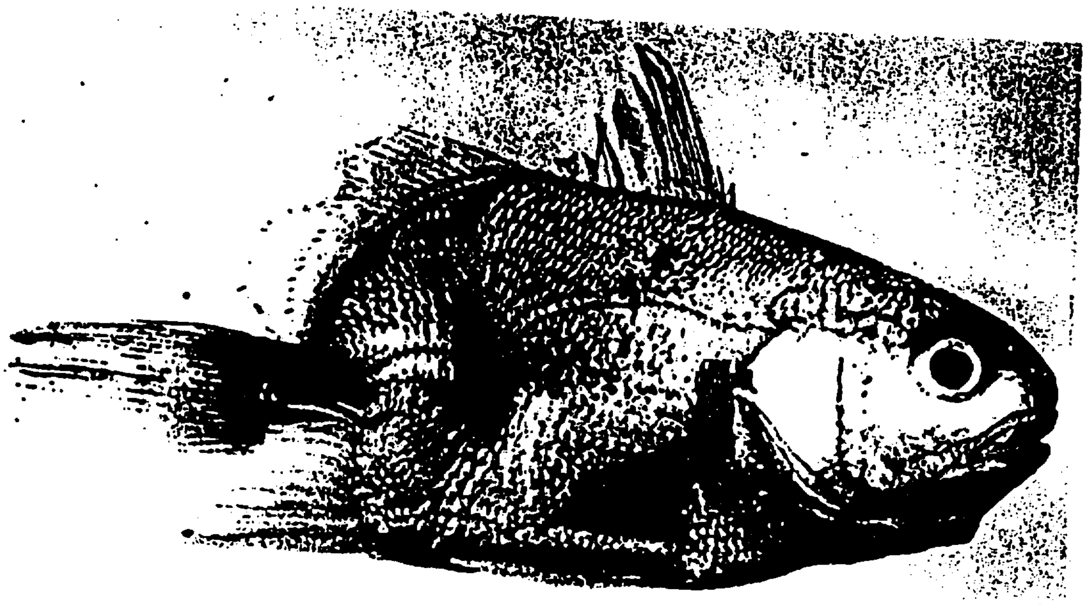

FIGURE 61. A bairdiella of the 1952 year-class from the Salton Sea with a severe distortion of the vertebral column. Photo by R. H. Linsley.

mality Grade 1 fish had serious deformations of the vertebral column (Figure 61). Grade 3 included those with any slight, but fixed, horizontal or vertical flexure. Those placed in Grade 2 were intermediate.

Two distinct trends appeared in the frequency of occurrence. In the 1952 year-class there was a drastic decline from 3.0 percent occurrence in 1953 to 0.14 percent in 1954. Again this corresponded with the initial impact of competition between the year-classes. The frequency was probably about the same in both year-classes in 1954. Unfortunately, later samples of the 1952 year-class were too small to determine the frequency of an abnormality as uncommon as this.

In the 1953 year-class, there was an unexpected increase in the occurrence of vertebral anomalies from year to year (Table 45). If the deformed vertebrae were genetically induced then it must be that the effects were slow to appear, and that the initial action of selection was more severe than its later action, thus allowing an increase in the population. In place of hypothesizing a latent genetic background for de-

TABLE 45

Occurrence of Abnormal Vertebral Column in Bairdiella From the Salton Sea

Year	Sample Size	Degree of Abnormality			Total	Percent Abnormal
		Grade 1	Grade 2	Grade 3		
1952 Year-class						
1952	122	0	0	0	0	0.00
1953	651	1	4	15	20	3.07
1954	670	1	0	0	1	0.15
1953 Year-class						
1953	9,437	0	1	4	5	0.05
1954	7,145	1	1	7	9	0.12
1955	10,834	0	5	24	29	0.26
1956	9,908	1	5	[illegible]	[illegible]	[illegible]

formed spines, it might be theorized that they were environmentally induced, perhaps by the effects of prolonged malnutrition in the 1953 year-class. The increase that occurred was mainly in the mild twisting, graded "3" and "2". Perhaps twisted spines are more easily observed in larger fish, so that more were noted as the fish increased in length. Increases in length were not great after 1953, however.

Lateral Line Anomalies

Ordinarily, the lateral line on bairdiella extends in a smooth curve from the head to nearly the end of the caudal fin. A few of the Salton Sea fish were unusual in this respect, and probably others with unusual lateral lines escaped notice. Nine fish in the 1953 year-class had interrupted or branched lateral lines. The most common defect observed was a sudden upturning at the hypural plate, so that the lateral line entered the caudal fin at an approximate 45 degree angle. In other cases, the lateral line ended abruptly and then continued at a level two or three scale rows below. These may have resulted from physical injury, as regenerated scales commonly were associated with them. Four fish had lateral lines ending at the hypural plate, and 24 had the lateral line upturned or downturned at the hypural plate, so that it extended onto the tail at an angle. No 1952 year-class fish were observed with this defect.

Abnormal Anal Spines

An anal spine count of two or less is one of the characteristic features of the family Sciaenidae. Most species in the family, including *Bairdiella icistius*, invariably have two, but some have one or none. No species has more than two spines and there is no previous record of an abnormal increase in anal spine number in any sciaenid. It was particularly surprising, therefore, to find a significant number of bairdiella in the Salton Sea with other than the usual count.

TABLE 46

Occurrence of Three Anal Spines in Bairdiella From the Salton Sea

Year	Sample Size	Number With Three Anal Spines	Percent With Three Anal Spines
1952 Year-class			
1952	122	2	0.80
1953	772	1	0.13
1954	544	0	} 0.16
1955	59	1	
Total	1,497	4	0.26
1953 Year-class			
1953	1,454	19	1.30
1954	694	9	1.29
1955	9,432	141	1.49
1956	9,908	151	1.52
Total	21,488	320	1.48

As indicated in Table 46, 1,497 specimens of the 1952 year-class were examined for this characteristic. The sample size differed from that used in determining the frequency of some of the other abnormalities because fish possessing three anal spines were not noted until the work had progressed into 1955, and it was not deemed profitable to reexamine the entire early sample. An estimated 0.3 percent of the 1952 year-class had three anal spines. In addition, two fish were found with a double-pointed second anal spine and two with a triple-pointed spine.

An increase in the percentage of fish with three anal spines occurred in the 1953 year-class (Table 46). There was no change in frequency of occurrence within the year-class with time. A total of 320, or 1.5 percent of the sample, had three anal spines, an estimated five times as many percentage-wise as in the parent 1952 year-class. There is no apparent competitive advantage to possessing three anal spines. Probably this was an example of genetic drift resulting from chance retention of a gene or genes normally quite uncommon in *Bairdiella*. To believe that the formation of three anal spines was environmentally induced requires the assumption that there was a difference in the environment between 1952 and 1953. There is no evidence for this. It would have been interesting to observe the occurrence of three anal spines in future generations, but through 1956 it was not possible to study any other year-class in the Salton Sea since they were produced in such small numbers.

Besides those with three anal spines, one bairdiella had only one (the large spine), another had four (Figure 62), and one had five (Figure 63). Such fish must be considered extremely rare (3 out of 21,488 fish examined).

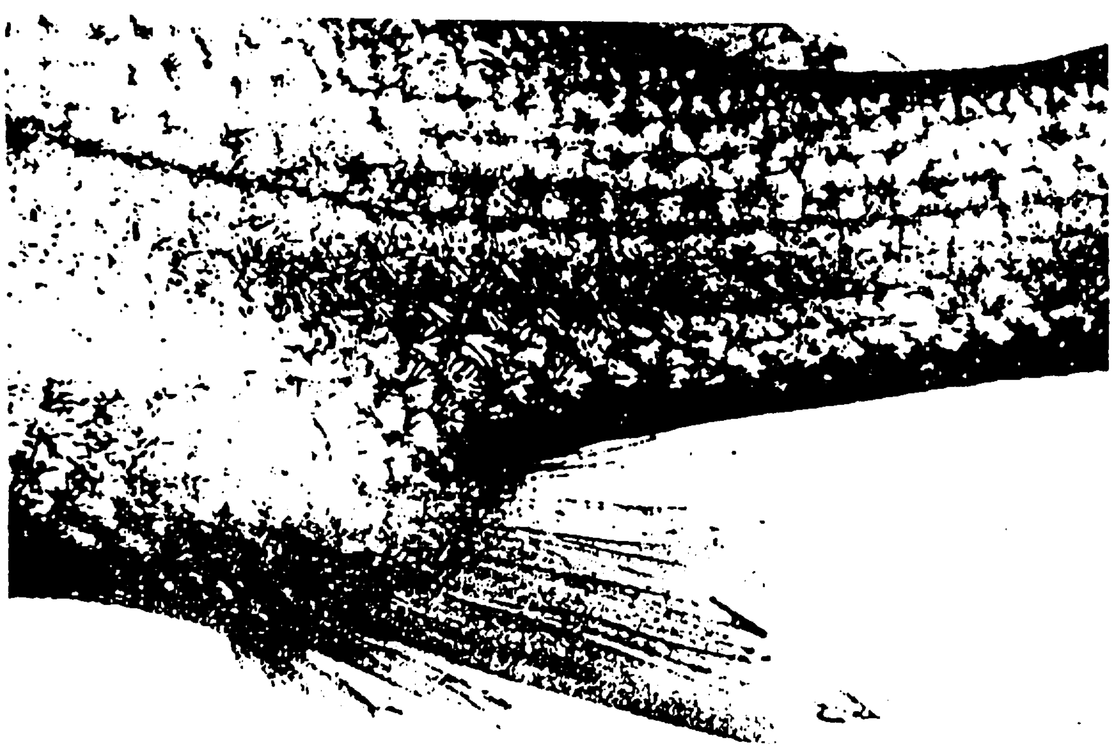

FIGURE 62. Four spines in the anal fin of a bairdiella from the Salton Sea. Photo

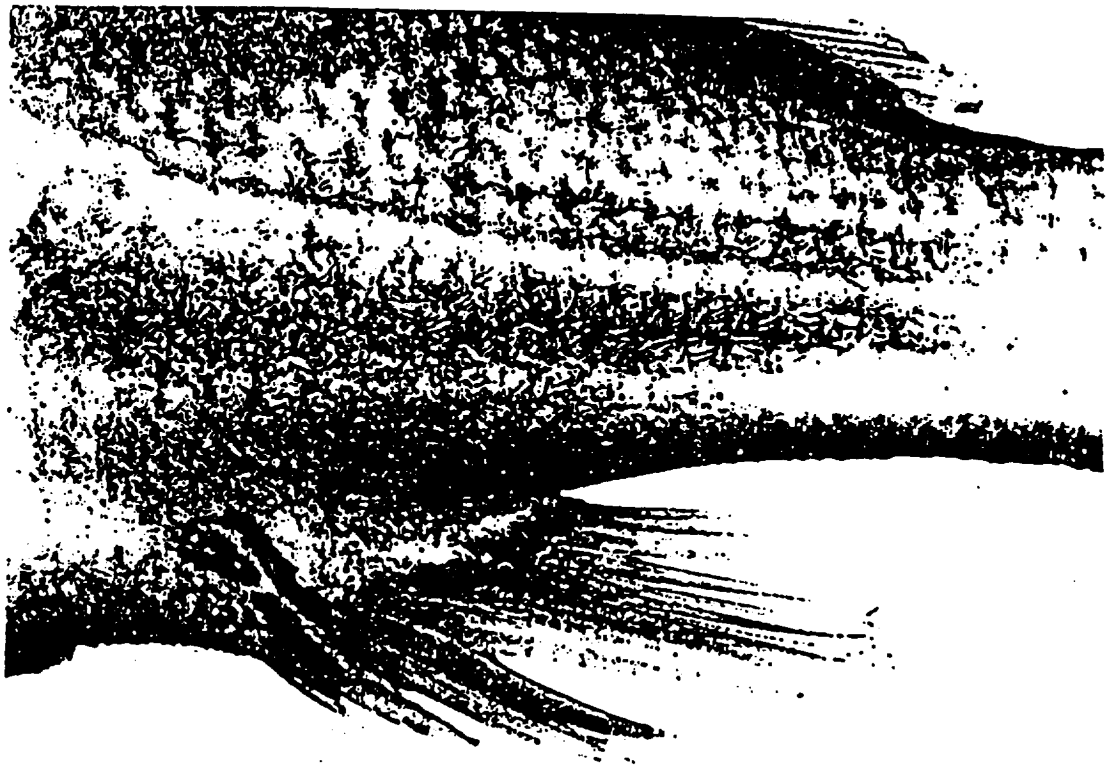

FIGURE 63. Five spines in the anal fin of a bairdiella from the Salton Sea. Photo by R. H. Linsley.

The 1953 year-class sample had three fish, or 0.01 percent of its members, with the second anal spine split at the end into two points, an apparent reduction from the two out of 1,497 or 0.13 percent of the 1952 year-class. No 1953 fish were found with triple-pointed anal spines although two of the 1952's were so adorned.

Anal fin ray counts of 121 bairdiella with three anal spines were compared with 121 having two anal spines. No difference was detected in the number of fin rays (7 to 10) between the groups (Table 47). However the fish with four and five anal spines had the number of rays reduced to five and six respectively. Thus it is not at all clear as to the source of the supernumery anal spines. The data on number of fin-rays occurring with three anal spines indicate the first ray did not develop into a spine (a situation normal in *Mugil*, *Eucinostomus*, *Sebastodes*

TABLE 47

Comparison of Anal Fin Ray Counts for Bairdiella With Two and Three Anal Spines From the Salton Sea

	Number of Anal Rays				Sample Size
	7	8	9	10	
Fish With Two Anal Spines	5	73	39	4	121
Fish With Three Anal Spines	3	70	37	2	121

To test the difference in anal fin ray counts chi-square = 0.8, df 1 nonsignificant. (Those with 7 and 10 anal rays not included in test because of small expected number. If grouped 7 and 8 vs. 9 and 10 [illegible]

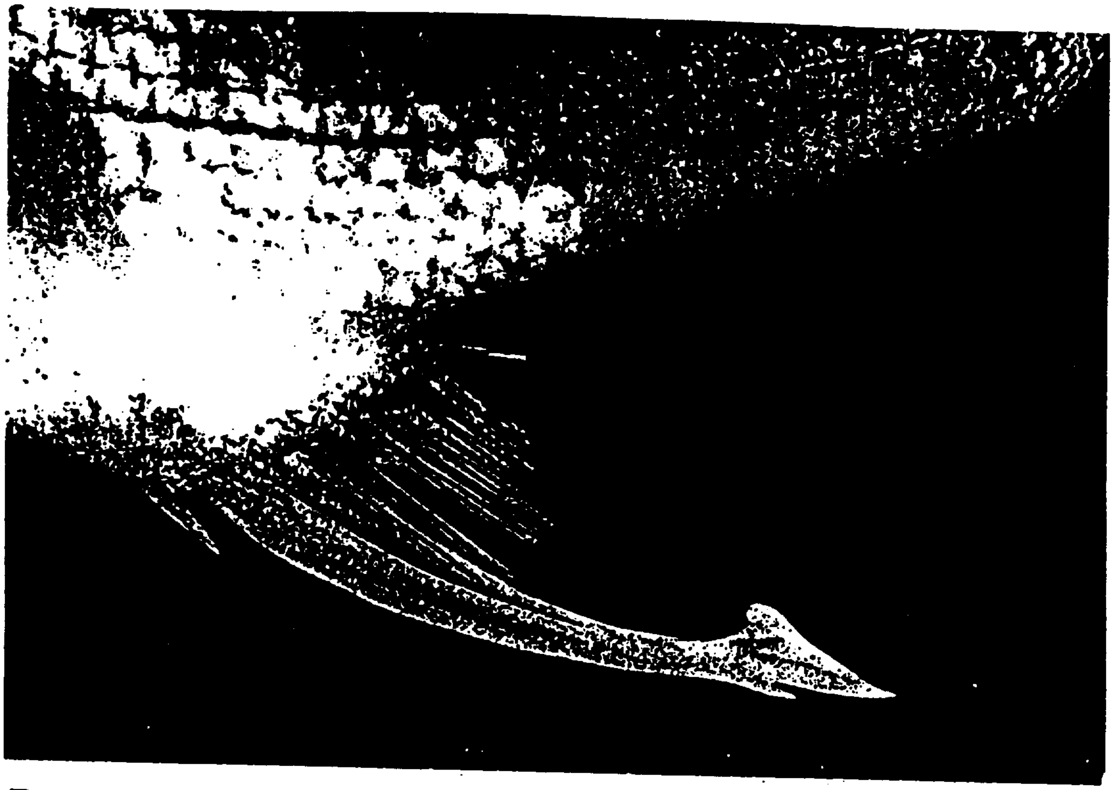

FIGURE 64. Knob on the second anal spine of a bairdiella from the Salton Sea. Photo by R. H. Linsley.

and other fishes). However, the reduction in ray number in the fish with four and five anal spines is strongly suggestive that the number of spines is related to a fixed total number of elements in the anal fin.

Rarely, other peculiarities of the second anal spine were noted in the sample studied. One fish had a flat, thin projection on the left side of the second anal spine. Another had a knob on the end of the spine (Figure 64) while one had a short, blunt second anal spine enlarged at the base. One fish had a thin spine that was stiff-jointed and curved downward.

Discussion

The 1952 year-class of *Bairdiella* which was produced in the Salton Sea obviously experienced little selection pressure during 1952 and 1953. The excellent growth of this year-class in those two years has already been described. Absence of competitors or predators allowed abnormal individuals to survive and these constituted an important percentage of the total population. In 1953, between 6 and 15 percent of the year-class were blind, about two percent had malformed maxillaries or premaxillaries, two percent had abnormal lower jaws, one percent were snub-nosed, and three percent had twisted vertebral columns, making 13 to 23 percent which were abnormal in some way.

At the same time, the 1953 year-class was produced in such large numbers that competition within it apparently eliminated abnormal individuals during an early stage in development, so that only about 0.3 percent were blind, 0.4 percent had malformed maxillaries or premaxillaries, 0.1 percent had abnormal lower jaws, 0.05 percent were snub-nosed, and at most 0.35 percent had twisted vertebral columns. In addition, 0.06 percent of the 1953 year-class had malformed preorbitals, making only slightly more than one percent of the members abnormal in some way.

The stress of competition with the younger more abundant 1953 year-class evidently led to a reduction of abnormalities in the 1952 year-class to about 2.5 percent in 1954. These consisted of 2 percent blind, 0.3 percent with malformed maxillaries or premaxillaries, and 0.15 percent with twisted vertebral columns. Thus, abnormal individuals were still slightly more common in the 1952 year-class than in the 1953's, the latter having about 0.7 percent of its members abnormal in some way. The only reduction of abnormalities in the 1953 year-class was in the frequency of blindness.

The sample of 1952 fish taken in 1955 was not large enough to permit comparison of frequencies. This was undoubtedly a reflection of declining abundance, since the fishing effort was about the same in 1955 as in 1954. The failure of the year-class to grow in 1955 and 1956 has already been mentioned. Apparently, competition began to eliminate even the normal individuals of the 1952 year-class when their larger size put them at a disadvantage due to their need for more food per individual than the smaller fish.