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(*Sphyraena argentea*)

(With six graphs)

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For the past two years, 1927 and 1928, the writer has made observations in the fresh fish markets of San Pedro on the California barracuda, a food fish of considerable importance to the fresh fish industry of the state. The work was initiated and the preliminary investigation was begun in 1926 by the International Fisheries Commission, United States and Mexico, but no data for that year are here included. This paper is published as one phase of the barracuda investigation, which will be reported upon fully at a later date.

Market observations in 1927 were not begun until June first, and 16,500 fish were examined during the remainder of the summer. In 1928, 18,000 fish were examined, and the work extended from March until October.

In studying the spawning season, the method employed was to make daily observations and records of the degree of maturity of each fish in samples taken in the markets, which degrees in the females were classified into the following four groups:

Group *a*. Fish immature, or only partially mature, the ovaries revealing either few visible eggs or none at all.

Group *b*. Fish in which maturity is well advanced, and in which the ovaries are full of opaque eggs.

Group *c*. Fish with running spawn.

Group *d*. Spent or partially spent fish.

The ovaries of the barracuda are approximately one-third the total length of the body, are paired, and in shape cylindrical, with tapering ends. The diameter of the ovary of immature fish is about one-fiftieth the length; of the mature fish about one-eighth. Ovaries of immature fish (group *a*) show no granulation, are pinkish in color, somewhat gelatinous in texture, rather translucent, and slender in girth. As maturity approaches, the eggs appear as small, yellow granules, increasing in number until the gonad becomes considerably enlarged and full of yellow eggs, of which the largest average about 1.3 mm. (group *b*). This is the stage in which the ovaries are of commercial importance as roe, a valued table delicacy. At spawning time, the eggs lose their yellow color and become translucent, assuming the appearance of cooked sago (group *c*). They become enlarged until they average about 1.6 mm. and when the belly is pressed, the eggs flow forth freely from the gonoduct. At this stage, the gonads are of no value as food and lose their commercial importance. After spawning is completed, the remaining developed eggs are probably reabsorbed, and the ovary rapidly diminishes in girth; its substance becomes flaccid, its color pink, and finally its appearance and structure become the same as in the immature fish of group *a*. These stages in the spent

* Contribution No. 76 from the California State Fisheries Laboratory, January, 1929.

fish appear only late in the season, and describe the condition classified as group *d*. There is, however, no line of demarcation between spent fish (group *d*) and immature fish (group *a*) and the spent of the end of one season become the immature of the beginning of the next. With such simple and obvious classes of degrees of maturity, it has been an easy matter to make records each day in the markets while the fish were being cleaned by the market butchers.

The testes are approximately the same size as the ovaries, but differ in their shape, which is roughly prismatic. The classification of the males according to degree of maturity is somewhat more difficult and includes three divisions: immature, mature and spent.

The testes of the immature male are firm in texture, slender and pale brownish or greenish in color (group *A*). As the sperm mature, the gonads become larger in size, whiter in color, and less firm in texture (group *B*). When the belly of a mature male is pressed, the lactescent milt exudes through the gonoduct. After spawning is completed, the testes rapidly become spent (group *C*), diminishing in size and changing their color, until their appearance is the same as in the immature fish.

The method of recording was to tabulate each observation in its appropriate space on a prepared data sheet which was divided into sections for each classification in each sex.

The samples which were taken each day consisted of the first one hundred females with the accompanying number of males which we saw opened. If necessary, the samples comprised fish from several markets. The reader will of course question whether the samples were representative of the entire catch. It seems probable that if most of the fishermen make their catches in the same general localities fairly close to each other, as usually appears to be the case, daily samples consisting of the first several fish selected at random in the markets might be a representative sample of the daily catch. Each day we asked the fishermen of as many boats as possible where their catches were made. In nearly all cases, the replies agreed with each other as to general location each day, and it would seem, provided the replies were truthful, that the boats are all inclined to fish together in about the same localities. Skogsberg, in recounting the shifting in places of capture of the barracuda[1] in 1922, obtained the same results as the writer[2] by questioning the fishermen, and this would seem to substantiate the reliability of the replies. There is, of course, the unavoidable danger of selection in the fishing, if, for example, the nets should gather only the fish in the top layer or only one edge of the schools; or perhaps in the sampling itself, if there should be a size selection by the market butchers, in which case sexual dimorphism might possibly detract from the significance of the data.

The barracuda fishery is carried on locally from April until September, and during the rest of the year the fishing occurs south of an extension of the international boundary line. Throughout the winter months we questioned the captains of the boats which brought up barracuda from the south, concerning the presence or absence of roe or

[1] Skogsberg, Tage. Preliminary Investigation of the Purse Seine Industry of Southern California. Fish and Game Commission of California, Fish Bulletin No. 9, 1925, p. 34.

[2] Walford, L. A. Barracuda. Division of Fish and Game of California, Fish Bulletin No. 15, Pt. 9, 1929.

milt in the fish. The earliest record of maturing fish which we have for 1928 is of March 22, when the *California II* landed a large load of cleaned fish, most of which had had roe or milt in them, according to the captain. On March 26, about a ton of barracuda was landed, only fifteen fish of which were not cleaned. These fifteen fish all seemed to be rather close to maturity. Beginning April 2, barracuda were brought in round (not cleaned), and from then on throughout the 1928 season, market observations were made daily or whenever

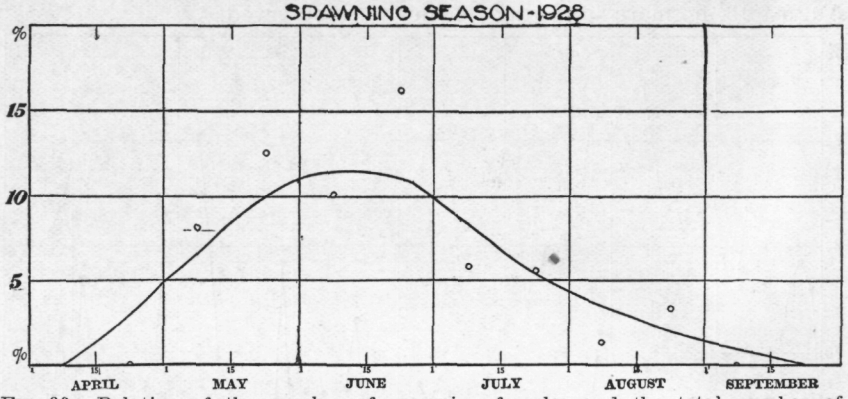

FIG. 33. Relation of the number of spawning females and the total number of females expressed in percentage. The observations are grouped in bi-weekly periods and represented by the small circles. The data are smoothed to show the general trend.

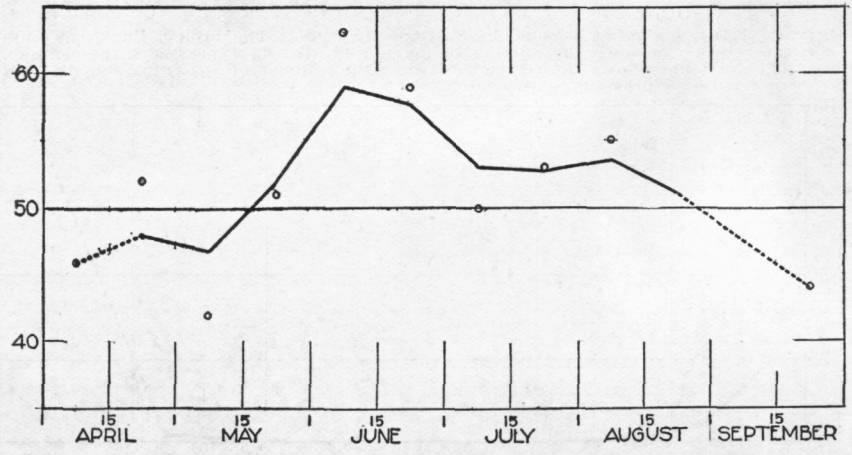

FIG. 34. Relation of the number of males to the total number of fish (1928) expressed in percentage. The observations are grouped in bi-weekly periods and represented by the small circles. The data are smoothed to show the general trend, which is represented by the heavy line.

fish were available. Figure 33 shows the relation between the number of spawning females and the total number of females expressed in percentage, by bi-weekly periods. The original figures, shown by the small circles, were smoothed to show the general trend of the season. The span of the season in 1928 was from between April 1 and 15 to between September 1 and 15. The height of the season occurred between May 15 and June 30.

An interesting and puzzling feature of the spawning season of the barracuda is that at no time of the year are all of the females spawning at once, according to our market observations. The relative number of spawning females changes from day to day, sometimes quite radically. The daily spawning season observations for 1927 are shown graphically in figure 35, in which the ratio of spawning females (group *c*) to all females is represented by the solid line. There is no apparent periodicity or regularity in the occurrence of the highest ordinates. After August 13, no more spawning females were observed.

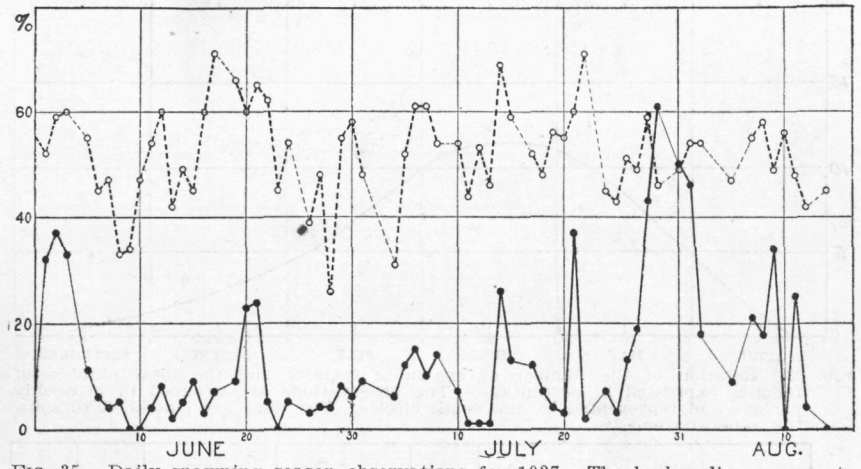

FIG. 35. Daily spawning season observations for 1927. The broken line represents the relation between the number of males and all fish, expressed in percentage. The solid line shows the relation between the number of spawning females and all females expressed in percentage.

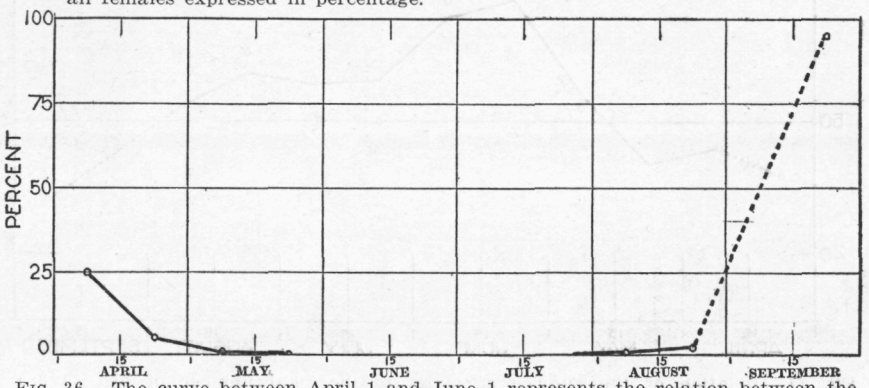

FIG. 36. The curve between April 1 and June 1 represents the relation between the immature females and all females expressed in percentage. The curve between July 15 and September 30 shows the relation between spent females and all females expressed in percentage.

In 1927, the first spent fish (group *d*) appeared in the markets on September 7 near the close of the spawning season. However, no samples had been taken since August 26, and it is possible that spent fish would have appeared sooner had fish been in the markets. In 1928, the first spent fish appeared in the markets August 13. Figure 36 shows the relation of immature females (group *a*) and spent females (group *d*) to all females in 1928. The fish classified as immature are

those which had not yet reached maturity that year, and occurred between the first part of the season and the last two weeks of May. Those classified as spent are those which apparently had already spawned that year. These appeared in the markets from about the first two weeks of August to the end of the season. It will be seen that in the beginning of the season only twenty-five per cent of the legal sized females were immature. After the first two weeks of May, no more immature fish (group *a*) were seen. In the latter part of July, the first spent fish (group *d*) appeared. Then the percentage of spent females rose rapidly, and by the time all of the females were spent the fish had apparently disappeared and the season was over.

The immature and spent stages of the males (groups *A* and *C*, respectively) occur during the same period as the corresponding stages in the females. If graphed, the relation of these stages to all males examined, as expressed by percentage, would present a picture similar to figure 36. This fact is borne out in the following table:

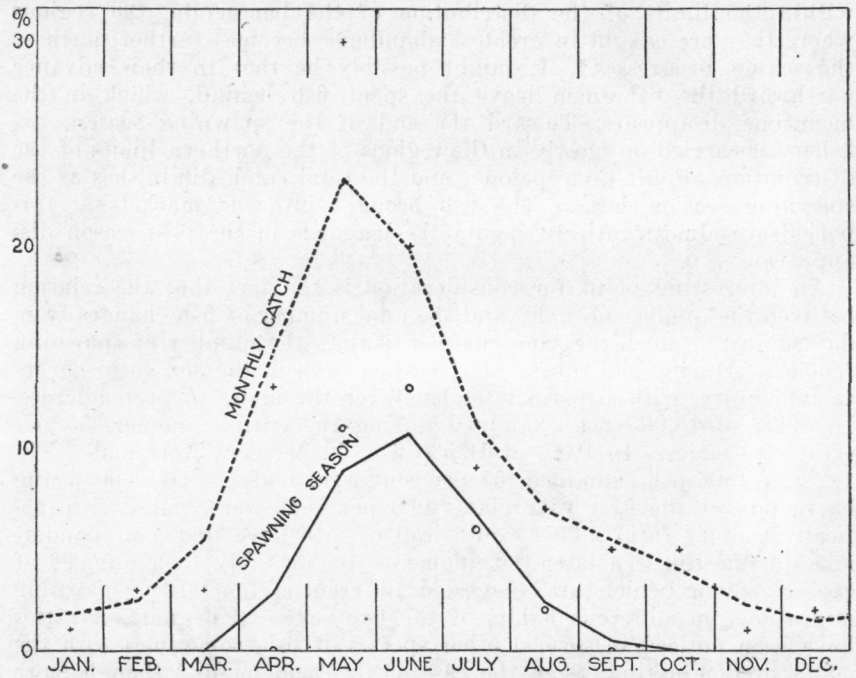

FIG. 37. Comparison between the monthly catch and the spawning season.

OCCURRENCE OF IMMATURE AND SPENT MALES

(The figures are percentages of the total number of males.)

Date	Immature males (Group *A*)	Spent males (Group *C*)
April 1–15	39	0
April 16–30	4	0
May 1–15	0	0
May 16–31	0	0
June 1–15	0	0
June 16–30	0	0
July 1–15	0	0
July 16–31	0	0
Aug 1–15	0	1
Aug. 16–31	0	19
Sept. 1–15	no data	no data
Sept. 16–30	0	93

It is worthy of note that the barracuda fishing season is concurrent with the spawning season. Figure 37 compares the monthly catch of local fish delivered to Los Angeles and Orange counties with the spawning season. The monthly catch is represented by the relation between the average monthly catch and the average yearly catch, expressed in percentage, averages being for the five-year period, 1923 to 1927. The spawning season is represented by the relation between the spawning females (group *c*) and all females, expressed in percentages. The spawning season observations are by monthly periods. The data were smoothed to show the general trends of the two curves. It will be noticed that the highest ordinates of both curves occur during the months of May and June, and that the rise and fall in the spawning season curve is reflected by a similar rise and fall in the monthly catch curve. Whether there is a causal relationship here, we shall not venture to say. The fact that no spent fish (group *a*) appear in the markets while the fish are spawning may be due to the fact that within the limits of the distribution of the barracuda, the regions where they are caught in greatest abundance becomes farther north as the season progresses.[3] It might possibly be that in their advance northward the fishermen leave the spent fish behind, which in the meantime disappear. Toward the end of the spawning season, the fishery is carried on mostly in the regions of the northern limits of the distribution (Point Concepcion), and the total catch diminishes as the spawning season closes. The fish brought into the markets at this period are almost entirely spent—the laggards in the post-season disappearance.

An interesting point for consideration is the fact that the relation between the number of males and the total number of fish changes from day to day in much the same manner as does the number of spawning females. During the course of the whole season, the sex ratio hovers around unity, with a distinct tendency for the males to preponderate. In 1928, of 18,005 fish examined during the entire summer, 55 per cent were males. In 1927, of 16,530 fish, 52 per cent were males. In 1922, of 1806 fish examined, 55 per cent were males.[4] Of 9000 young barracuda of the first year class, 49.5 per cent were males, or practically a unity ratio. This would lead us to believe that a preponderance of one sex is a later development, due possibly to a number of causes, among which are suggested differential mortality, spawning migrations, or different habits of the two sexes. Unequal sex ratios have been noticed in several other species of fish, sometimes with the males predominating, as in the case of the true smelts,[5] though more frequently with the females predominating, as of the California sardines, *Sardina caerulea;* California jack smelt, *Atherinopsis californiensis;* grunion, *Leuresthes tenuis;*[6] or in the European plaice, *Pleuronectes platessa.*[7]

There is a strong tendency for the ratio of males and all fish to vary as the ratio of spawning females and all females. This is illustrated

[3] Walford. loc. cit.
[4] Skogsberg. loc. cit., p. 37.
[5] Kendall, William Converse. The Smelts. Bulletin, U. S. Bureau of Fisheries, Vol. XLII, 1926 (1927), p. 299.
[6] From the records of the California State Fisheries Laboratory.
[7] Hefford, A. A. The Proportionate Distribution of the Sexes of Plaice in the North Sea. Rapports et Procés-Verbaux, Conseil Permanent International pour l'Exploration de la Mer, Vol. XI. 1909, pp. 137–175.

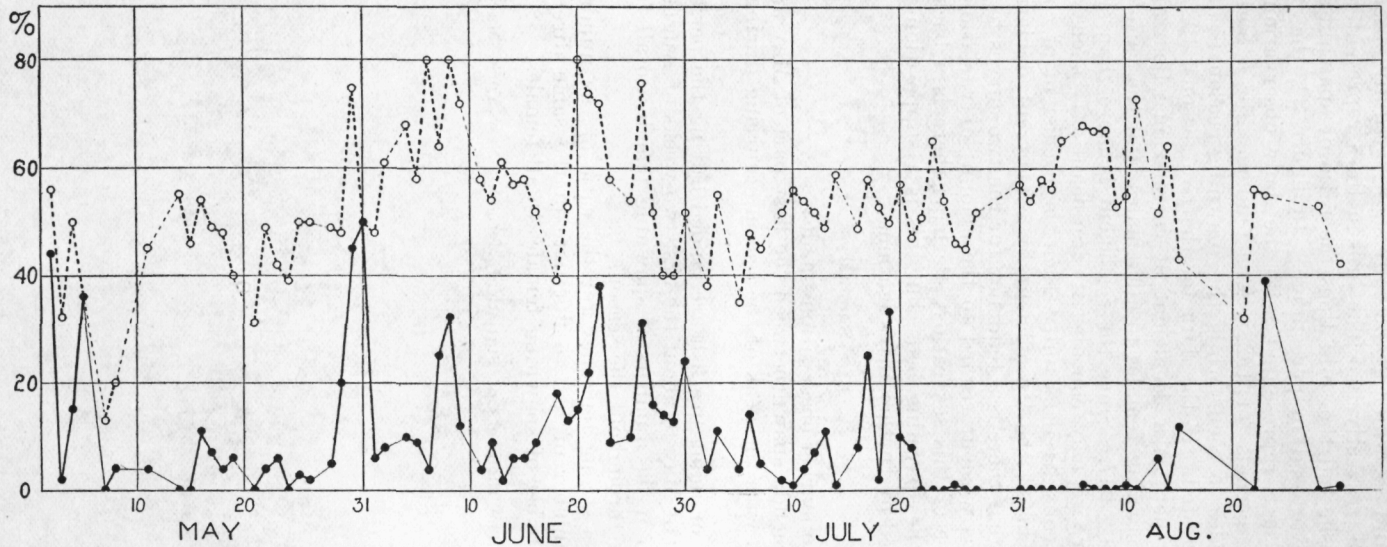

FIG. 38. Daily spawning season observations for 1928. The broken line represents the relation of the number of males to all fish. The solid line shows the relation of the number of spawning females to all females. Relations are expressed in percentage.

in figures 35 and 38, which graphically show the daily observations for 1927 and 1928, respectively. The broken lines represent the ratio of males to all fish, and the solid lines the ratio of spawning females to all females, expressed in percentage. In figure 34, the ratio of the males to all fish is represented, with the daily observations combined into bi-weekly periods for 1928. The tendency for a higher preponderance of males to occur while the spawning season is at its height is clearly suggested. If the data for the two seasons, 1927 and 1928, be combined, there is a coefficient of correlation (Pearson) between the ratio of spawning females to all females, and the ratio of males to all fish of .304±.047. Since the coefficient is more than six times the probable error, we may consider it significant. If each variation in the curves be considered as unity, then the coefficient of correlation is .394±.049. This is the "coefficient by concurrent deviations,"[8] and merely shows that there is a tendency for the two curves to vary in the same directions without regard to the amount of variation. What is the significance of this sex ratio? Perhaps there is a back and forth migration to the spawning beds, but this is a supposition which must be substantiated by further investigation.

Summary

According to market observations made:

1. The barracuda spawn between the first part of May and the middle of August, with the peak of the season occurring during the month of June.

2. No spent or immature fish are landed during the period from the last two weeks of May to about the first two weeks of August.

3. The ratio of the numbers of spawning females to all females fluctuates sharply throughout the season.

4. There is a strong tendency for the ratio of the number of males to the total number of fish to fluctuate in the same direction as the ratio of the number of spawning females to all females.

[8] King, W. I. The Elements of Statistical Method. New York, MacMillan. 1919, p. 207.

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