DIVISION OF FISH AND GAME OF CALIFORNIA
FISH BULLETIN No. 16
The Life History of the California Jack Smelt, Atherinopsis californiensis[1]

BY
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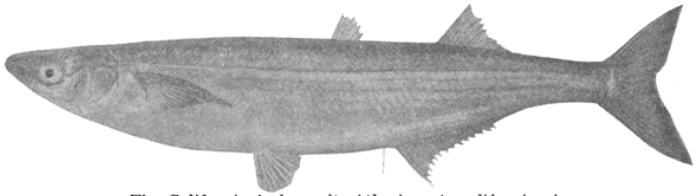
CONTENTS



The California jack smelt, *Atherinopsis californiensis.*

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1. I. INTRODUCTION

1. Commercial catch statistics. While the smelt fishery of California is considered one of the minor fisheries of the state, the average yearly landings exceeded 800,000 pounds during the five-year period from 1923 to 1927, and smelts ranked twelfth in importance among fishes sold exclusively for the fresh fish trade.

Smelt are taken along the entire coast of California, but, during 1923–1927 period, 62 per cent of the landings occurred in southern California and 52 per cent of the state's smelt catch passed through the markets of Orange and Los Angeles counties. In figure 1, the data, which were secured from the records of the Bureau of Commerical Fisheries, Division of Fish and Game of California, represent the average yearly smelt catch from 1923 to 1927, inclusive. The landings

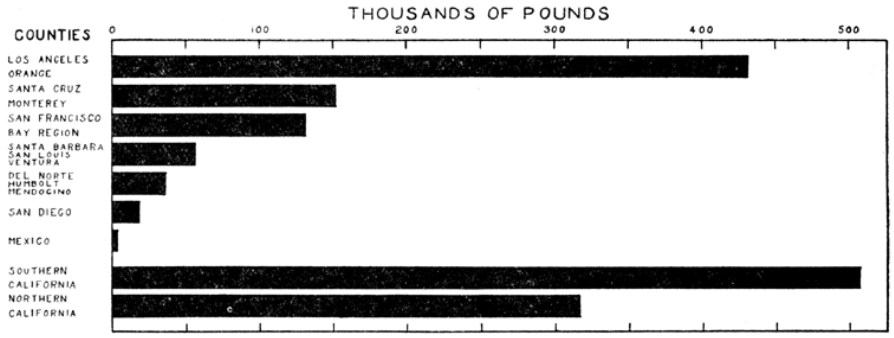

FIG. 1. Average yearly smelt catch by districts for the five-year period, 1923–1927.

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were recorded by counties and, for the lower graph of this figure, the records north of the San Luis Obispo-Monterey county line were grouped under the heading northern California and south of this point, under southern California. Figure 1 demonstrates the important position that the fishery, off the coasts of Los Angeles and Orange counties, holds in the entire smelt fishery of the state. These two adjacent counties are supplied from the same fishing region.

The smelt catches for northern and southern California are compared in a different manner in figure 2. For this graph, the catch over the same five-year period was averaged by months and the results expressed in percentages, thus making the data from the two districts directly comparable. Figure 2 shows that the seasonal fluctuations were reversed in the two regions. In northern California the peak occurred during the late summer months and in southern California during the early winter.

This reversal of the seasonal trend of the smelt fishery in the northern and southern regions of the state, may have been due in part to the fact that different species comprise the catch in the two districts. The statistics for the smelt catch include fishes of two different families and of several species within each family. The true smelts, family Osmeridae, occur along the coast of northern California as far south as Monterey Bay, while the silversides, family Atherinidae, are taken along the entire coast from its northern to its southern boundary. The smelt catch of northern California comprises, therefore, both the true smelts and the silversides, while the southern California catch is composed of the Atherinidae only.

Three genera of silversides are taken in California: the bay smelts or panzarotti, Atherinops; the jack smelt, Atherinopsis californiensis; and the grunion, Leuresthes tenuis. The genus Atherinops in California comprises several subspecies, now referred to two species.

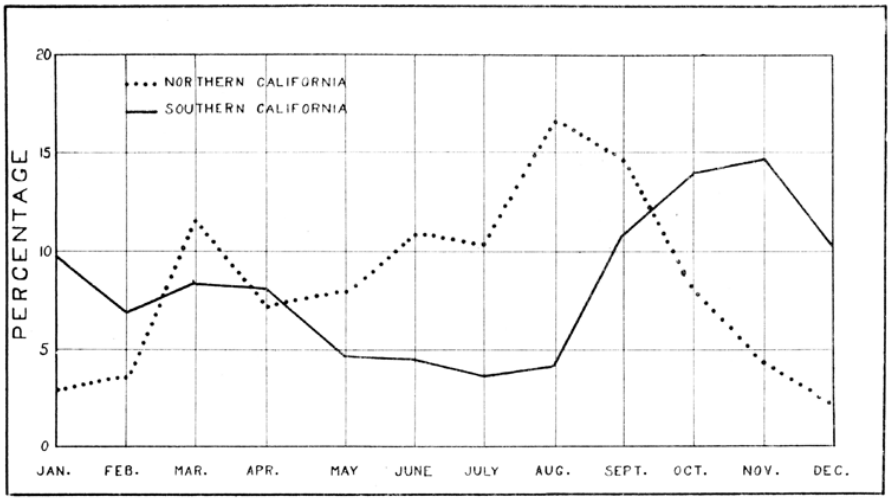

FIG. 2. Average monthly smelt catch by districts for the five-year period, 1923–1927.

FIG. 2. Average monthly smelt catch by districts for the five-year period, 1923–1927

Leuresthes is rarely taken north of Point Concepcion, but Atherinops and Atherinopsis are found in the commercial catch of both northern and southern California.

To ascertain the proportion of the various species of silversides brought in by the fishermen of Los Angeles County, a survey[2] of the smelt catch of the San Pedro markets was made during 1926 and 1927. This survey showed that at least 90 per cent of the smelts landed in Los Angeles County were jack smelts. The landings in Orange County are obtained almost entirely from a beach seine fishery at the town of Newport. As this fishery is supported exclusively by jack smelt, 90 per cent may also be considered a conservative estimate of the proportion of jack smelt in the Orange County landings. The catch of Los Angeles and Orange counties comprises 62 per cent of the entire smelt catch of the state, and since jack smelt make up 90 per cent of the catch for these two counties, the entire catch for the state is composed

[2] Clark, Frances N. The smelts of the San Pedro wholesale fish markets. Calif. Fish and Game, Vol. 14, (1928) pp. 16–21.

of at least 56 per cent jack smelt. But as jack smelt are taken in northern California, also the true proportion of jack smelt for the state is undoubtedly much higher. No actual figures covering the proportion of species are available, however, for any other region than Los Angeles and Orange counties.

The spawning season for jack smelt occurs during the winter months, and the higher percentage of smelt landed in southern California during these months may result to some extent from this factor. But economic conditions probably play a more important part in causing the seasonal fluctuations of the smelt fishery, as during the summer months there is a greater supply of other varieties of fresh fish, especially barracuda, and the demand for smelt is lessened. The fishermen state that smelt are always available but at times they limit their catch because of a slack market. On the other hand, a few scattering observations suggest that the smelt catch of northern California is largely composed of Atherinops. Since the spawning season for these fishes occurs in the summer months, the higher percentage of smelt landings for northern California from June to September may be caused in part by this fact.

2. Fishing methods. Jack smelt are caught on a variety of gear. Noncommercial fishing is carried on by means of hook and line, especially off the piers of southern California. In San Francisco Bay, a small commercial fishery is conducted with set lines, anchored and supported by floats so that the hooks are suspended near the surface of the water.

The major portion of the commerical catch, however, is taken in nets. Gill nets are used in various localities along the coast as are also bait or small round haul nets. In the region of Los Angeles County, the fishery is carried on almost exclusively by means of the round haul nets. The round haul boats operate from the port of San Pedro along the coast northward thirty miles to Santa Monica and southward twenty miles to Newport (see Fig. 3). Most of the fishing is done close to shore and frequently within the kelp beds.

In addition to the round haul nets, beach seines are employed in taking jack smelt at the town of Newport. This fishery is confined by law to the months from September to January, inclusive. At this time the jack smelt come close in toward shore to spawn and the fishermen run a seine out from the beach into the surf, surround a school of fish, haul the seine up on the beach with horses, and land their catch.

2. II. METHODS

1. Collection of material. The material used in this study was obtained by the California State Fisheries Laboratory from two sources: the commercial catch landed at San Pedro, and collections made by members of the Laboratory staff with a beach seine in Anaheim Slough, Orange County.

The material from the commercial catch consists of a few samples of a small number of individuals taken from the wholesale fish markets, and many samples of large numbers secured from one commercial fisherman operating out of San Pedro. The samples from the fish markets were composed chiefly or older fish, while those secured from the one fisherman consisted almost exclusively of the younger year classes.

This accounts for the larger proportion of the younger year groups shown in figures 11 and 12. This high proportion of young fish was due, therefore, to selective sampling and is not indicative of a greater abundance of younger year classes.

In addition to the samples taken from the commercial catch, observations were made from October, 1926, to January, 1927, on the individual maturity of the fish in the wholesale markets at San Pedro. For this study the markets were visited tri-weekly, twenty fish were examined on each visit, and notes made on the state of maturity of the gonads.

The collections from Anaheim Slough, a brackish slough lying between San Pedro and Newport, were composed almost entirely of fish less than a year old. These collections were made to ascertain the growth of the jack smelt during the first year. Because Atherinopsis under

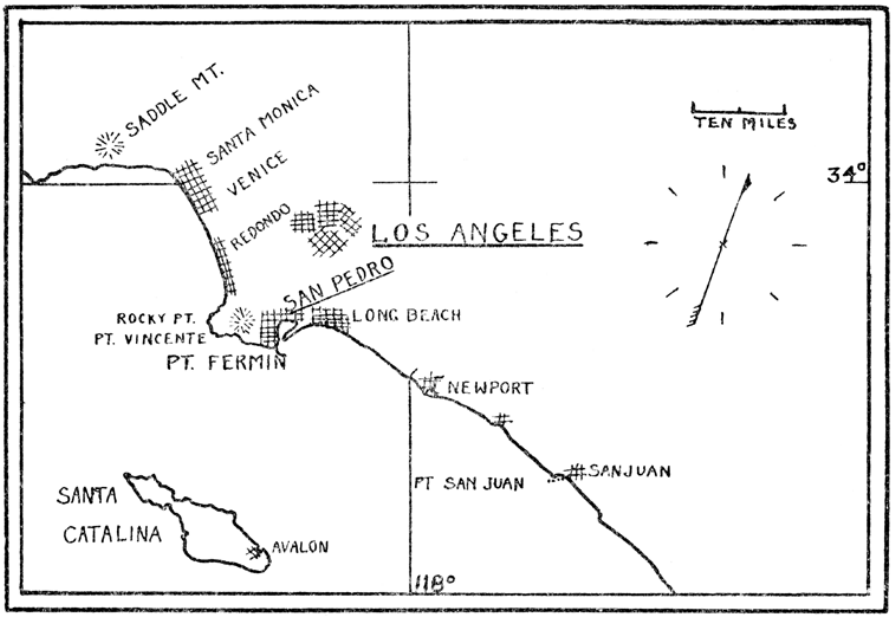

FIG. 3. Map showing the area in the vicinity of Los Angeles harbor in which the jack smelt fishery is carried on.

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one year of age seldom appear in the commercial catch, it was necessary to collect the younger stages by this means.

The collections made over a period of years from 1920 to 1927, consisted of 6090 specimens. The material was all taken within a radius of thirty miles from San Pedro and the conclusions drawn are applicable to the jack smelt of this region, but not necessarily to Atherinopsis of other parts of California.

2. Length measurements. All material was preserved in formaldehyde before the measurements were made. Two length measurements were taken on each fish, one from the tip of the snout to the base of the caudal fin and the other from the tip of the snout to the extremity of the tail. The first, or body length measurement, except where otherwise stated, has been used in this study. The measurements were made with dividers and millimeter rule and read to the nearest millimeter.

In the final study the lengths were combined to the nearest half centimeter.

3. Scale studies. For the scale readings, three scales were removed from each fish and mounted on a slide in a mixture of sodium silicate and glycerine. An additional scale sample was taken from each fish, and more scales were mounted when the three original scales proved unsatisfactory. Scales were removed just above or below the lateral band between verticles dropped from the origin of the first and second dorsal fins. In a few instances in which only a few scales remained on

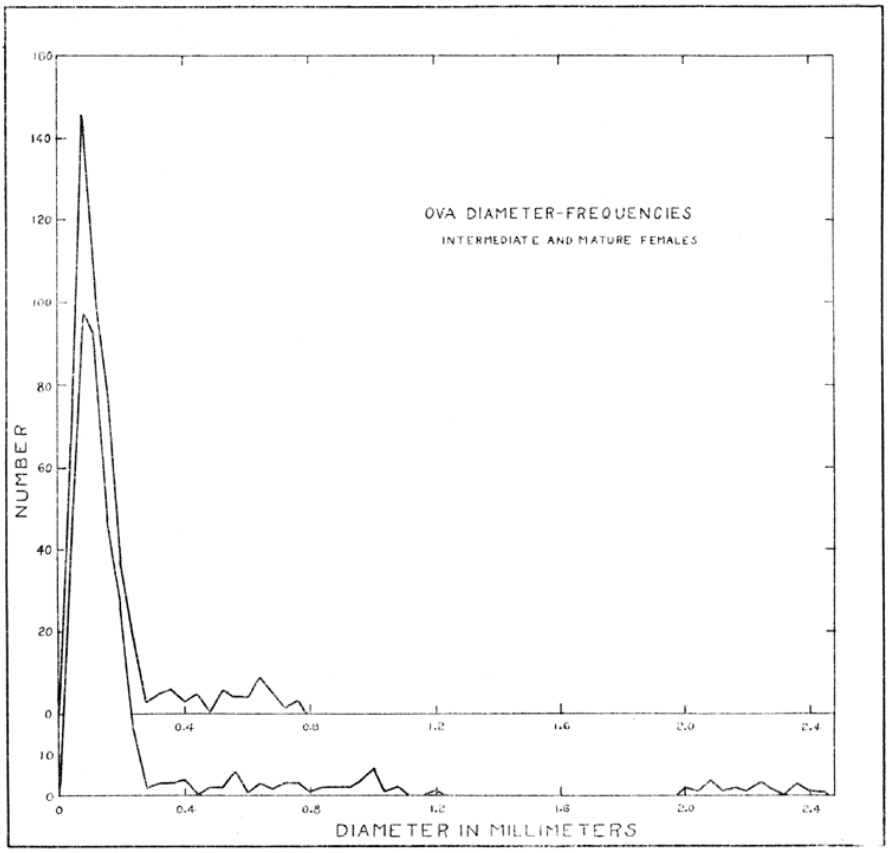

FIG. 4. Frequency polygons of the diameters of 500 ova measured from female jack smelt. Upper graph, an intermediate fish 178 mm. in length, taken January 26, 1921. Lower graph, a mature fish 268 mm. in length, taken February 21, 1921.

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the fish, a scale sample was taken wherever scales could be found. All scale readings were made without reference to the length of the fish.

4. Ova measurements. The diameters of the eggs were measured by means of an eye-piece micrometer in a compound microscope. The value of each micrometer unit was 0.04 mm. After preservation in 10 per cent formaldehyde, a small portion of an ovary was teased out on a slide, and the diameter of each egg measured and recorded. The micrometer was placed in a horizontal position in the eye-piece and the

egg measured along an axis parallel to the micrometer. As the ova due to preservation were seldom spherical in shape, this method gave at times the greatest diameter of the egg, at other times the smallest, or some measurement intermediate between these two. In a previous study[3] this method of measuring the ova was found to be the most satisfactory.

3. III. SPAWNING SEASON

1. Description of a mature ovary. The length of the spawning season was determined by a gross examination of the gonads of all fish studied, and by detailed measurements of the diameters of the eggs from a large number of females. As a result of these measurements it was found that a spawning female jack smelt had eggs of three separate size groups in the ovary: first, a large quantity of immature eggs ranging in diameter from 0 to 0.4 mm.; second, an intermediate group ranging from 0.4 to 0.8 mm.; and finally, mature eggs varying in diameter from 2.0 to 2.5 mm. A frequency of the diameters for 500 eggs measured from the ovary of a typical spawning female is shown in the lower graph of figure 4. The upper graph of this figure represents a diameter-frequency of the eggs from a female with only immature and intermediate eggs in the ovary.

The immature group of eggs persisted in the gonad at all times of the year, but the intermediate and maturing groups were found only during the breeding season. At the approach of spawning, the intermediate group was first differentiated and from this group the maturing class developed. Also during the time of spawning, adult females were found with only immature and intermediate groups of eggs. This condition indicated either that the fish had not yet developed a maturing group of eggs or that the maturing class had been recently spawned out and a second group had thus far not been differentiated. By measuring ova from the ovaries of different individuals, the growth of the maturing eggs could be traced from their first origin from the intermediate class until they reached a mature size, averaging slightly more than 2 mm. in diameter. When the eggs are entirely mature, they burst from their follicles and become segregated in the lumen of the ovary.

The mature jack smelt egg, orange in color, with numerous oil droplets at one pole, is covered with filaments from one to two centimeters in length. While the ovum develops in the follicle, these filaments are wrapped tightly around the egg in a zig-zig pattern, but when the egg bursts from the follicle, the distal end of the filaments are freed, become entangled with the filaments from other eggs, and hold the mature ova together in a mass.

2. Time of spawning. As a result of the egg measurements, a knowledge of the appearance of the ovary was attained which made possible the classification of the females by a gross examination into immature, intermediate or maturing groups. Immature ovaries contained no eggs visable to the naked eye; intermediate ovaries contained small, creamy-white, opaque eggs large enough to give the sex gland a granulated appearance; while maturing ovaries contained larger eggs, orange in color and translucent rather than opaque. All the females

[3] Clark, Frances N. The life-history of Leuresthes tenuis, an Atherine fish with tide controlled spawning habits. Calif. Fish and Game Commission, Fish Bull. No. 10, p. 5.

examined were placed in one of these three classes, while the males were classified only as immature or maturing. Since the intermediate and maturing groups of eggs were never found in the gonads except during the spawning season, the presence of either one or both of these classes indicated that the fish would spawn within the next few months. Consequently, to determine the dates of the spawning season, fish of the intermediate class were grouped with those of the maturing class and only two categories used, immature and maturing.

The material on which the study of the spawning season was based, consisted of observations made at the San Pedro fish markets and of the sample collections secured from the commercial fishermen. The market observations were carried on during the winter of 1926–1927, while the samples from the commercial catch were obtained over a period of years from 1920 to 1927. All these data were groped together without regard to sex, and the percentage of adult fish in the maturing group was calculated for each month. The results are shown in figure 5. Only a few fish were found maturing in September, about 30 per

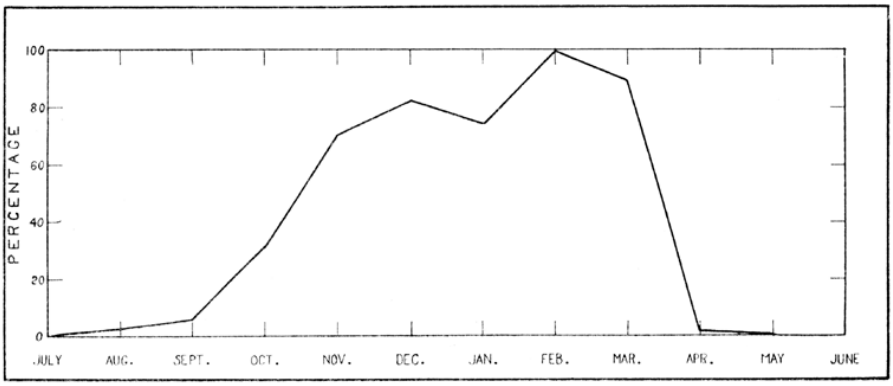

FIG. 5. Percentage of maturing jack smelt recorded by months.

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cent were maturing in October, while most of the spawning occurred during the months from November to March. of the 70 adult fish examined in April, only one female was found maturing. The jack smelt of southern California spawn, therefore, during the winter months from October to the last of March or early April.

3. Frequency of spawning. In several instances, females with a maturing group of eggs in the ovary had also a few mature eggs lying in the lumen of the gonad. These eggs were undoubtedly the remnant of a previous spawning, since they were few in number and much larger in size than the group of maturing eggs developing at the time the fish was captured. In a few cases, the mature eggs showed evidence of degeneration. Because of the presence in the ovary of these mature degenerating eggs at the same time that a new batch of eggs was developing toward maturity, the conclusion has been drawn that individual jack smelt spawn more than once during a spawning season.

Even more conclusive evidence of multiple spawning was found in the fact that by the time a group of eggs had attained maturity, a second maturing group was distinguishable at the upper range of the intermediate group. Such a group of maturing eggs appears

between 0.8 and 1.2 mm. in the lower graph of figure 4. This second maturing group gradually develops from the intermediate class as the first maturing eggs increase in size, and by the time the first eggs are ready to be spawned the second lot can be clearly distinguished, as in figure 4. This relation between the upper size-limit of the intermediate group of eggs and the average size of the maturing ova was further demonstrated by means of the scatter diagram in figure 6, and by calculating a coefficient of correlation. The abscissas of figure 6 represent the maximum range in average size of the maturing eggs, and the ordinates, the range of the upper size-limit of the intermediate class at such times as a maturing group of eggs was clearly separable from the intermediate group. Until a maturing class of eggs had

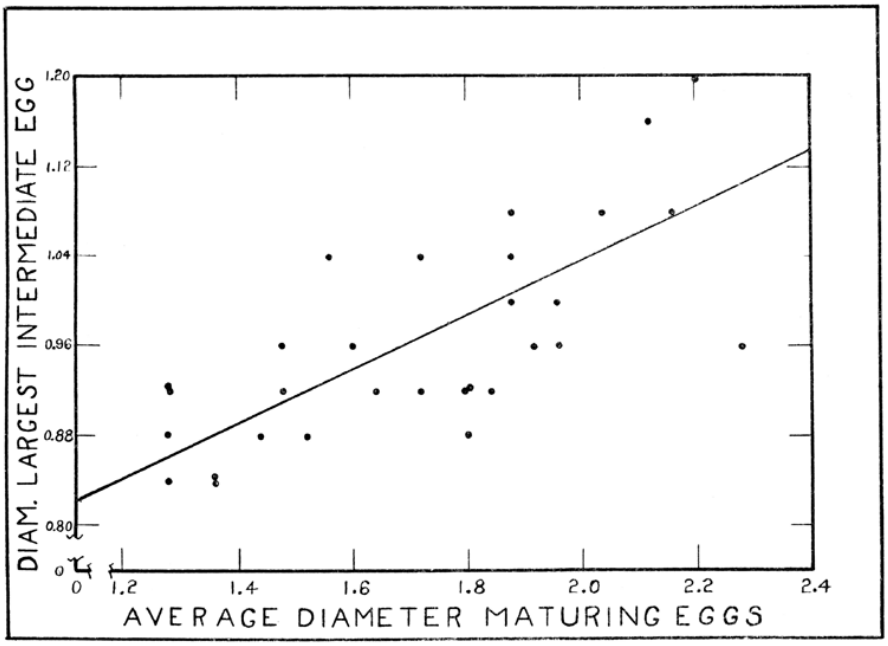

FIG. 6. Average diameter of the maturing group of ova related to the upper limit of the intermediate group.

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reached an average size of 1.2 mm. or greater, the lower size-limit could not be separated definitely from the upper size-limit of the intermediate group. Each dot of figure 6 indicates, for one individual, both the average diameter of the maturing eggs and the diameter of the largest intermediate egg. The data for this diagram and for the coefficient of correlation were obtained from two sources. When 500 ova were measured from one ovary, as in figure 4, the average size of the maturing eggs was based on the diameters of all the maturing eggs found among the 500 eggs measured, and the upper limit of the intermediate group, on all the intermediate eggs occurring in these 500 measurements. This resulted in the measurement of approximately 45 intermediate ova from each female. Ova from 17 fish were treated in this manner, and in addition, for 13 females the average size of the maturing eggs was determined from the measurement of 100 maturing

ova from each fish and the upper size-limit of the intermediate class, from the measurement of 45 eggs larger than 0.4 mm. but clearly not as large as the maturing eggs.

That a close relationship exists between the average size of the maturing eggs and the maximum size of the intermediate ova is apparent. As the maturing eggs increased in size the intermediate group increased in dispersion, due to the origin and growth of a second group of maturing eggs at the upper size-range of this intermediate class. The correlation coefficient was 0.746 with a probable error of 0.054. This large coefficient, exceeding its probable error by nearly 14 times, indicates a close correlation between the growth of the maturing and intermediate group, and establishes with a fair degree of certainty the fact that individual jack smelt spawn more than once during a spawning season. A similar condition[4] has been demonstrated for Leuresthes tenuis, another fish of the same family.

In this latter species individuals not only spawn more than once during a season, but spawning occurs periodically in approximately two week intervals. To determine whether the spawning of the jack smelt occurred periodically or whether spawning individuals could be found at all times during the season, observations were carried on in the fish markets and detailed measurements were made on maturing

TABLE I

The Average Diameter of the Ova of the Maturing Group for Individual Jack Smelt Taken on Various Dates

Average diameter mm.	II:5:1920	XII:14:1920	XII:27:1920	I:6:1921	I:11:1921	II:21:1921	I:10:1927
0.84							
0.88			x		x		
0.92				xx			
0.96							
1.00						x	
1.04	xx						x
1.08				x	x		x
1.12			x				xx
1.16	xx	x			x		
1.20			x		x		
1.24				x			
1.28	x		x			x	x
1.32			x				
1.36	x		xxx		x		x
1.40			x				xx
1.44				xxx			x
1.48		xx	x				x
1.52	x			xx			xx
1.56			x			xx	x
1.60				x		xx	x
1.64							xx
1.68				x	x	x	xx
1.72						x	x
1.76				x			
1.80							x
1.84					x		xx
1.88		xx			x	x	xx
1.92						x	xxx
1.96							xx
2.00							
2.04							
2.08							
2.12							
2.16						x	
2.20						x	
2.24							
2.28							x

[4]Clark. *loc. cit.*, pp. 16-21.

TABLE 1

The Average Diameter of the Ova of the Maturing Group for Individual Jack Smelt Taken on Various Dates

[4] Clark. *loc. cit.*, pp. 16–21.

ova. If spawning were periodic, the maturing group of eggs for all individuals taken on one date should be approximately the same size. Such a condition held for Leuresthes. If spawning were not periodic, a single sample of maturing fish should contain females with a group of eggs just starting to mature, others with a group almost or quite mature and still others with maturing groups at various intermediate stages.

During the four months that observations were carried on in the San Pedro fish markets, the latter situation was found to be true most frequently, and at no time were a large number of females found with maturing groups of ova of uniform size. As a further check, the average diameter of the maturing class of eggs was calculated for individual females from collections made on seven different dates. These averages were based on the measurement of 100 eggs from the maturing group from each fish. The smallest average diameter of eggs in a maturing class was 0.88 mm. and the largest average 2.24 mm. The first average represented eggs barely distinguishable from the intermediate group and the latter average, mature eggs ready to be spawned. In table I, the average diameters are listed in the first column and the dates of collection at the heads of succeeding columns. The crosses indicate the average size of the maturing eggs for individual females of each collection. In all cases the individual maturing groups were scattered throughout practically the entire range. The four collections taken between December 14, 1920 and January 11, 1921, were secured at frequent intervals and should show a progressive increase in size of the maturing class, if spawning were periodic. There was no evidence of such a progressive size increase nor was there any other evidence of periodicity in the spawning of the jack smelt. It must be concluded, therefore, that individual jack smelt are spawning at all times during the breeding season.

4. IV. AGE AND RATE OF GROWTH

1. Age determination. The age determination for the jack smelt was based chiefly on length frequencies, although scale readings were used in ascertaining the maximum ages. After the fish had passed the second winter the annular rings on the scales were quite distinct and scale reading would have been quite simple and accurate were the first annulus equally well marked.

To determine the time of the formation of the first annulus, a large series of scales was studied from young fish taken at intervals from August, 1924 to June, 1925. These fish spawned in the winter of 1923–1924, were several months old in August, 1924. No annulus was found on any of the scales until January 24, 1925. On this date 8 per cent of the scales showed an annulus near the margin; on March 13, 45 per cent of the individuals had an annulus; on May 22, 67 per cent; and on June 6, 60 per cent. Since the fish in the May and June collections averaged about two centimeters larger than the January and March collections, and the smallest fish of the latter months were two centimeters larger than the smallest fish of January and March, all fish must have been growing by June and should have formed an annulus provided there had been a previous cessation of growth. As only 67 per cent of the May collection and 60 per cent of the June collection showed

an annulus on the scales, it was evident that from 30 to 40 per cent of the jack smelt did not form an annulus during the first winter.

This first annulus, when present, differed in clarity on scales from various fish. In some cases it was clear cut, in other individuals faint

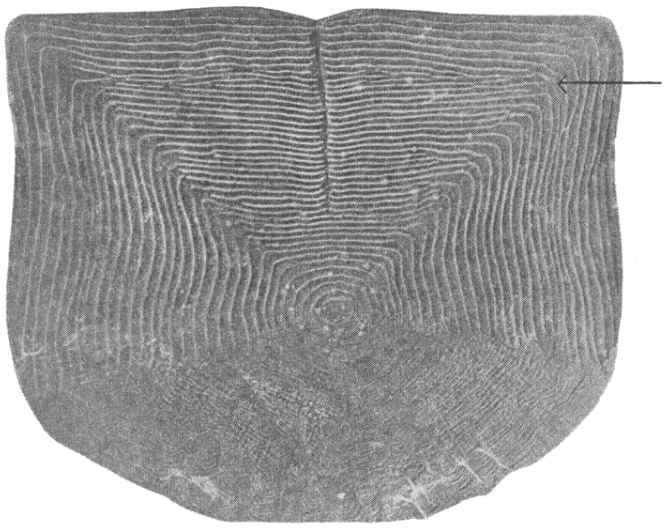

FIG. 7. Scale showing a definite annulus, from a male jack smelt, 162 mm. in length, taken May 22, 1925

and at times represented by a mere trace. The above percentages include all fish whose scales had even a trace of an annulus. Figures 7, 8 and 9 are from photomicrographs of a scale with a definite annulus, one with a trace of an annulus and one with no annulus.

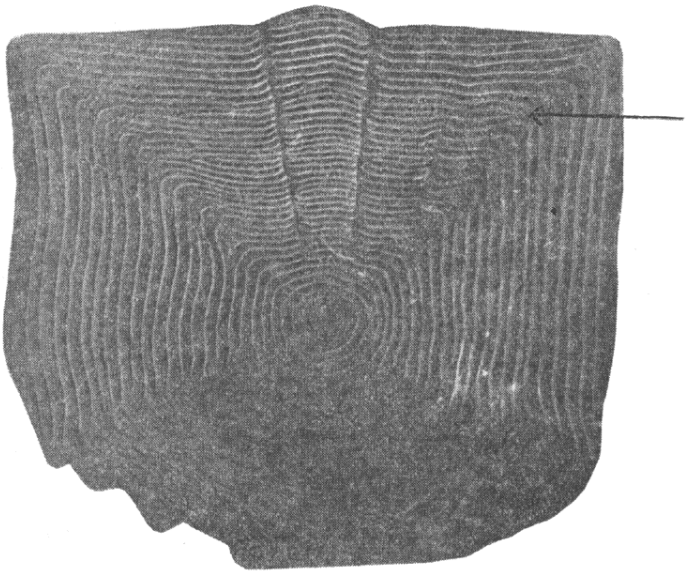

FIG. 8. Scale showing a trace of an annulus, from a male jack smelt, 131 mm. in length, taken May 22, 1925

To demonstrate that the fish taken in May and June with no annulus on the scales did not belong to a younger group than did fish with an annulus on the scales, the length-frequency curves for fish with an annulus were compared with the curves for fish without an annulus.

These curves are shown in figure 10. In both graphs, the frequencies were expressed in percentages of the total, thus making the curves directly comparable. The data were smoothed once by a moving average of five. In the May collection 328 fish had an annulus on the scales, varying from a mere trace to a definite mark and 162 fish showed no annulus of any description. In the June collection 122 showed an annulus and 82 were without.

The length-frequency curves of figure 10 are very similar for fish with and without an annulus. But while the range is practically identical, there is a tendency for more of the larger than of the smaller fish to have an annulus. Although it may be possible that larger fish of a year class are more affected by the adverse conditions of the winter months and thus show a greater tendency to form an annulus, a more plausible explanation is that some of these larger fish showing one annulus were in reality two years old and the annulus was formed during the second

FIG. 9. Scale with no annulus, from a female jack smelt, 135 mm. in length, taken May 22, 1925.

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and not the first winter. Since the jack smelt spawn in the winter months and, as will be shown later, breed during their second winter, the annuli formed after the first winter result from the influence of the spawning season as well as from the effect of the colder temperature. This harmonizes with the fact that the second and succeeding annuli are much more definite than the first.

Since at least 30 per cent of the jack smelt formed no annulus during the first winter and since in some instances it is impossible to determine whether the first annulus was formed during the first or second winter, it has seemed wise to base the age determinations and growth studies of the jack smelt chiefly on the length frequency curves rather than on the scale readings.

2. Rate of growth. Because the material used in this study was taken at irregular intervals over a period of seven years, to ascertain the growth month by month of the different year groups, all data have been grouped by months regardless of the year in which the sample was

secured. For example, the length frequency curve for January was based on collections made on the following dates:

I: 6:1921
I:11:1921
I:26:1921
I:11:1924
I:15:1524
I:31:1924
I:24:1925
I:10:1927

During the preliminary studies, the sexes were recorded separately but no differences in growth between the males and females could be demonstrated, at least for the first two years. The numbers were insufficient to determine growth accurately after the second year. Since the growth discussion is confined to the first two years the length

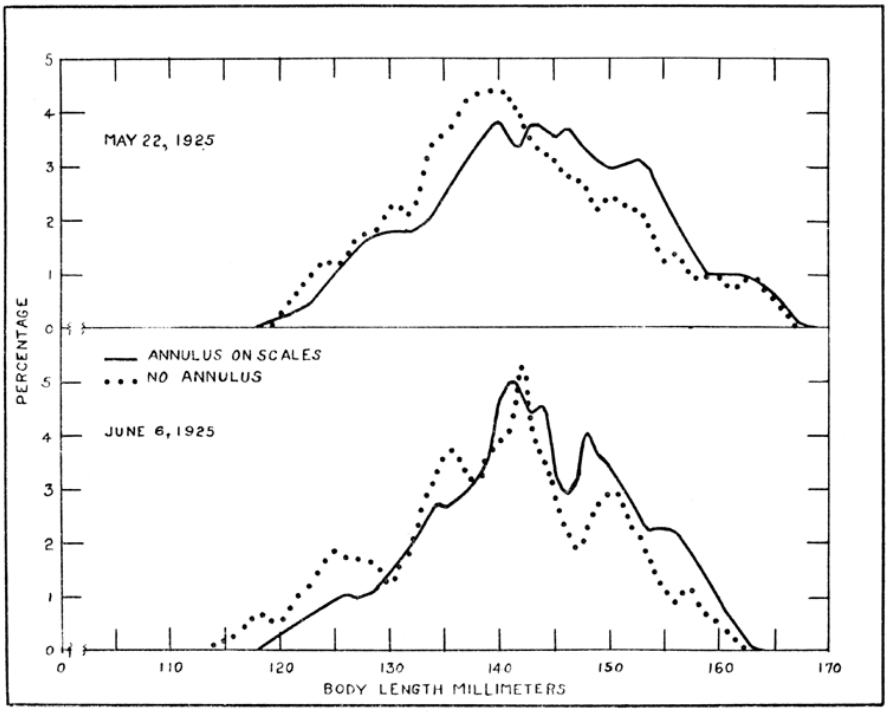

FIG. 10. Length-frequency polygons of jack smelt with and without an annulus on the scales.

FIG. 10. Length-frequency polygons of jack smelt with and without an annulus on the scales

measurements were combined without regard to sex. All data were grouped to the nearest half centimeter and each frequency expressed in percentages of the total for the specific month involved. These frequency curves for the twelve months are shown in figure 11.[5]

Spawning occurs during the months from October to March and fish of the year, or the O group, were taken first in February. These ranged in size from 2.5 to 4.1 cm. This collection was seined at Anaheim Slough, as fish of this size are not found in the commercial catch. The O group was not taken again until June, when the size range was 3.4 to 7.7 cm. This also was a collection made at Anaheim Slough. Fish of

[5] Due to the method of making the collections and combining the data, the frequency curves for figures 11 overemphasize the importance of the I group. Because of this selection, the data shown in figure 11 must not be considered as indicative of the abundance of the various size classes in the commercial catch.

the O group did not appear in the commercial catch before they attained a length of approximately 10 cm. Such fish were first collected in August and the length frequencies based on fish of this group and taken in the commercial catch samples in August, September and October, represent only the larger fish of this age class. In December,

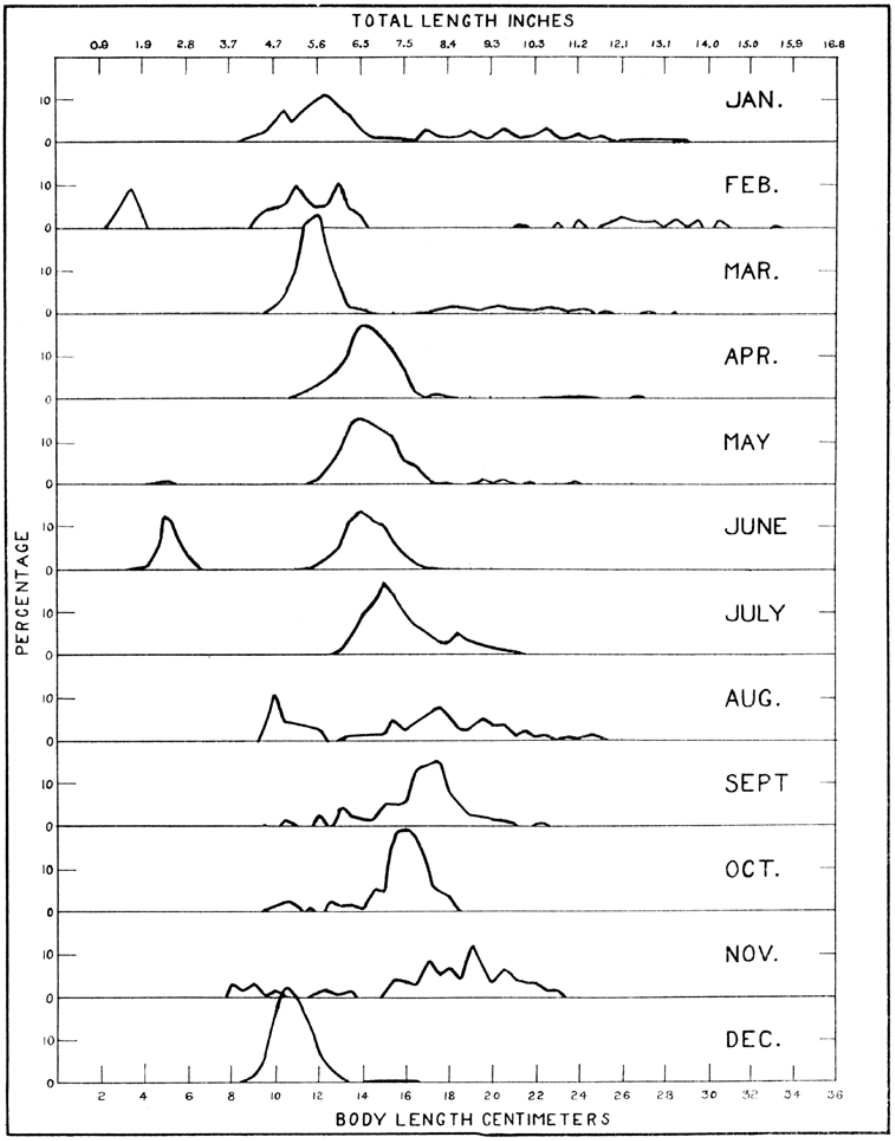

FIG. 11. Length-frequency polygons of jack smelt taken each month of the year.

FIG. 11. Length-frequency polygons of jack smelt taken each month of the year

a sample secured from a commercial fisherman was composed entirely of the O group and ranged in size from 8.6 to 13.0 cm. December was considered the end of the first year, and fish of the O group attained an average size of approximately 11.0 cm., body length, during their first year.

Considering January as the beginning of the second year, the growth of the I group may be followed through month by month. This year class was more completely represented in the data, not because the I group is the most numerous in the commercial catch, but because the method of collecting the material resulted in a selection of this age group. During the second year jack smelt grew from 11.0 or 12.0 cm. to 18.0 or 19.0 cm. Because of size selection in the sampling, the growth did not progress steadily from month to month. February and March fish were no larger than January fish, while fish taken in April, May and June showed a constant size range with a mode about 2 cm. greater than for the previous three months. In July, the mode was at 15.0 cm., in August and September, between 17.0 and 18.0 cm. and again at 16.0 cm. in October. In November the peak fell at 19.0 cm. This group was not represented in the December material. Disregarding these fluctuations, the data indicated that jack smelt attain an average length of 18.0 or 19.0 cm. at the end of their second year. Because of the overlapping of age classes and the scarcity of material, the rate of growth beyond the second year could not be determined.

3. Maximum size and age. The largest fish found in the samples was a female 33.4 cm. in body length or about 15.5 inches in total length. The scales of this fish showed seven annuli. Since the fish was taken in February, it is possible that the last annulus had not been formed at the time of capture. If this were true, the fish would have just completed its eighth year. If no annulus had been formed during the first year the fish would have completed its ninth year. Since only 9 fish were found greater than 30.0 cm. in body length, it is probable that 35 cm. represents the maximum size and nine or ten years the maximum age attained by the jack smelt.

4. Age at first maturity. The studies to determine the size and age at first maturity were based on collections made between November and March, inclusive. All females with an intermediate or maturing group of eggs and all males with gonads showing any indication of development were classified as maturing fish. Length-frequency polygons of the immature and of the maturing fish were then constructed. The frequencies are given in the upper graph of figure 12. The large preponderance of fish in the I group again resulted from selection due to the method of taking the samples. The lower graph of figure 12 shows the percentage of maturing individuals at each half centimeter of length. The dots indicate the actual data to which the solid line was fitted by inspection.

No fish were found maturing at 14 cm. or less, at 18 cm. 80 per cent of the individuals were maturing, while practically all fish were maturing at 20 cm. The length-frequency curves show that the upper limit of the I group fell at approximately 15 cm. and jack smelt do not mature before the close of their second year when they are in the II group. The immature individuals between 15 and 20 cm. in length were apparently in part two year fish. The small individuals of the second year class therefore would not mature until the end of the third year.

The fact that the jack smelt do not mature before the end of the second year offers an explanation for the failure of the scales to show a definite annulus at the close of the first winter. The winter temperatures

of the waters off the coast of southern California may not be sufficiently cold to pronouncedly check the growth of these fish. But during the second and succeeding winters most of the fish are breeding and the resulting check in the metabolism doubtless stops growth, since an annulus is formed in the spring when growth is resumed at the close of the breeding season. The annuli on the scale of the jack smelt, other than that formed the first winter, should be regarded, therefore, as combined breeding and winter annuli.

The grunion,[6] Leuresthes tenuis, in the same region passes through the winter without developing a distinct annulus, but forms an annulus in July or August at the close of the breeding season.

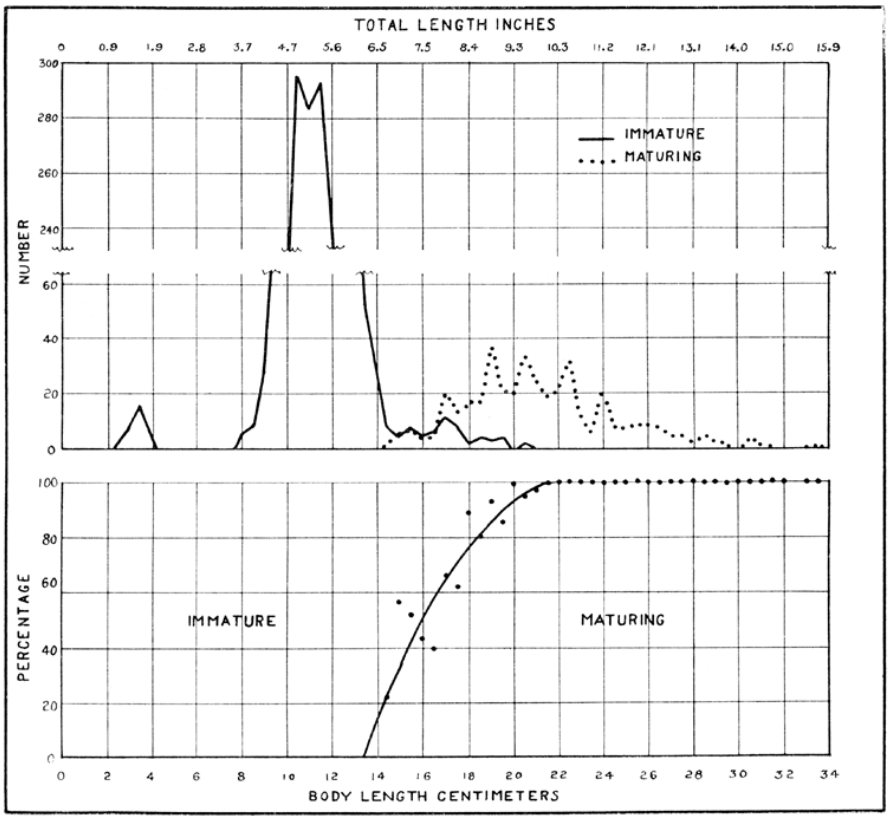

FIG. 12. Size at maturity of the California jack smelt. Upper graph, length-frequency polygons of immature and of maturing fish. Lower graph, percentage of individuals maturing at each half centimeter of length. Material taken from November to March.

FIG. 12. Size at maturity of the California jack smelt. Upper graph, length-frequency polygons of immature and of maturing fish. Lower graph, percentage of individuals maturing at each half centimeter of length. Material taken from November to March

5. V. JACK SMELT FROM MONTEREY AND SAN FRANCISCO BAYS

A collection of 160 young Atherinopsis made at Elkhorn Slough, Monterey Bay, on March 20, 1927, ranged in length from 0.7 to 1.5 cm. These tiny fish must have been spawned within the previous month or two, and the collection indicates that the jack smelt of the Monterey region are also winter spawners. Further conformation of a similarity in spawning time between the jack smelt from the San Pedro and

[6] Clark. *loc. cit.*, pp. 25–30.

Monterey districts was found in a collection of 50 adult fish taken in Monterey Bay on November 8, 1926. These were all maturing fish with ova in the same stages of development as were the ova of fish taken at San Pedro in November. Another collection, consisting of 39 jack smelt seined in Elkhorn Slough August 10, 1925, ranged in size from 3.6 to 9.2 cm. The largest fish of this sample equaled in size the smallest fish of the O group taken at San Pedro (see Fig. 11). Since the San Pedro collection came from the commercial catch and represented only the extreme upper size-limit of the O group, the growth of this year class during the first summer is apparently similar for the two regions. A third collection of 5 fish taken from the commercial catch at Monterey on February 28, 1920, ranged from 9.2 to 11.4 cm. in length. These lengths coincided with the sizes of the fish in the I group for February at San Pedro, and the scanty data suggest a possible similarity between the growth rate of Atherinopsis from San Pedro and Monterey.

But scattered samples from San Francisco Bay indicate less correspondence between the growth rate from this latter region and that of San Pedro. Two collections of 49 fish seined in San Francisco Bay near Sausalito during October, 1922, ranged in size from 6.7 to 8.4 cm. These fish were smaller than fish of the O group taken in October at San Pedro, but because the San Pedro collections represented only the largest fish of this age class, a nonselected sample from the San Pedro region would probably have comprised fish as small as those taken from San Francisco Bay in October. A second collection made from the same locality on April 17, 1923, was even more difficult to harmonize with the San Pedro material. These fish, 11 in number and varying in length from 7.0 to 9.7 cm., were too small to be associated with the I group of southern California and too large to be classed as fish of the O group. This size difference between jack smelt taken in the spring from the two localties may have resulted from a slower winter growth rate for the San Francisco Bay fish. On the other hand, because of selective sampling the difference may have been only apparent. Possibly the collection from San Francisco Bay comprised only the very smallest fish of the I group, and if sufficient unselected material were available, the size of this year class would have corresponded with lengths for fish of the same age from San Pedro. More material from the San Francisco Bay region would be necessary to justify a comparison of the growth rate of the jack smelt from these two localities.

6. VI. SUMMARY

1. The smelt fishery of California is supplied by fishes from two families, the Osmeridæ and the Atherinidæ. The jack smelt, an Atherine fish, is the most important species in the smelt catch, and formed at least 56 per cent of the total catch of the state during the years from 1923 to 1927.

2. Jack smelt are caught by sport fishermen on hook and line, but almost all the commercial fishing is done by gill and round haul nets and beach seines.

3. The spawning season for Atherinopsis is from October to March.

4. Individual fish spawn more than once in a season, but no evidence of a periodicity in the time of spawning could be found. The data

indicate that individuals could be found spawning at all times during the breeding season.

5. The scales were not satisfactory for use in the age determinations, since at least 30 per cent of the individuals did not form an annulus during the first winter. After the first winter, the annuli resulted from the combined influence of winter and spawning.

6. Jack smelt attain an average of 11 or 12 cm., body length, at the end of the first year and 18 or 19 cm. at the end of the second year. The largest specimen taken was 33.4 cm. in length and eight or nine years old.

7. Jack smelt do not mature before reaching 14 cm. in length and an age of two years. Probably a few fish do not mature until the end of the third year.

CALIFORNIA DIVISION OF FISH AND GAME
FISH BULLETINS

* No. 1. Report on Fish Conditions. 1913; 48 pp., 3 figs. Contains:

The Abalone Industry in California. By Charles Lincoln Edwards.
The Towing of Salmon and Steelhead Fry from Sacramento to the Sea in a "Live Car." By N. B. Scofield.
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Investigation of the Clams of California. By Harold Heath.
Investigation of the Life History of the Edible Crab. (Cancer magister). By F. W. Weymouth.
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Trout and Black Bass Planting and Transplanting in the San Joaquin and Southern Sierra Districts. By A. D. Ferguson.

* No. 2. The Scientific Investigation of Marine Fisheries as Related to the Work of the Fish and Game Commission in Southern California. By Will F. Thompson. 1919; 27 pp., 4 figs.

* No. 3. The Spawning of the Grunion (Leuresthes tenuis). By Will F. Thompson, assisted by Julia Bell Thompson. July 15, 1919; 29 pp., 9 figs.

No. 4. The Edible Clams, Mussels and Scallops of California. By Frank W. Weymouth. Jan. 10, 1921; 74 pp., 19 pls., 26 figs.

* No. 5. A Key to the Families of Marine Fishes of the West Coast. By Edwin C. Starks. March 3, 1921; 16 pp., 4 figs.

* No. 6. A History of California Shore Whaling. By Edwin C. Starks. October, 1922; 38 pp., 22 figs.

* No. 7. The Life History and Growth of the Pismo Clam. By Frank W. Weymouth. 1923; 120 pp., 15 figs., 18 graphs.

* No. 8. Racial and Season Variation in the Pacific Herring, California Sardine and California Anchovy. By Carl L. Hubbs. February, 1925; 23 pp., 4 pls.

* No. 9. Preliminary Investigation of the Purse Seine Industry of Southern California. By Tage Skogsberg, 1925; 95 pp., 23 figs.

* No. 10. The Life History of Leuresthes tenuis, an Atherine Fish with Tide-controlled Spawning Habits. By Frances N. Clark. October, 1925; 51 pp., 6 graphs, 7 pls.

No. 11. The California Sardine. By the Staff of the California State Fisheries Laboratory. 1926; 221 pp., 74 figs.

Thompson, Will F. The California Sardine and the Study of the Available Supply.
Sette, Oscar Elton. Sampling the California Sardine: A Study of the Adequacy of Various Systems at Monterey.
Higgins, Elmer H. A Study of Fluctuations in the Sardine Fishery at San Pedro.
Thompson, Will F. Errors in the Method of Sampling Used in the Study of the California Sardine.
Scofield, W. L. The Sardine at Monterey: Dominant Size Classes and their Progression, 1919-1923.

No. 12. The Weight-Length Relationship of the California Sardine (Sardina caerulea) at San Pedro. By Frances N. Clark. 1928.

No. 13. The Seasonal Average Length Trends at Monterey of the California Sardine (Sardina caerulea). By Carroll B. Andrews. 1928; 13 pp., 6 figs.

No. 14. Reports on the Seals and Sea Lions of California. By Paul Bonnot. 1928; 61 pp., 38 figs.

No. 15. The Commercial Fish Catch of California for the years 1926 and 1927. By The Bureau of Commercial Fisheries. 1929; 94 pp., 52 figs.

No. 16. The Life-History of the California Jack Smelt, Atherinopsis californiensis. By Frances N. Clark. 1929; 22 pp., 12 figs.

These bulletins are offered in exchange for the publications of other bodies engaged in marine research. Address: California State Fisheries Laboratory, Terminal Island, California.

* Out of print.

The assistance of various members of the staff of the California State Fisheries Laboratory in the collecting of the material used in this study, is gratefully acknowledged, also the courtesy of Dr. Carl L. Hubbs and the Museum of Zoology of the University of Michigan in making available small collections of fish taken at San Francisco and Monterey.

No tables of actual figures have been included in this paper, but these data are on file at the California State Fisheries Laboratory and accessible to anyone wishing to carry on further studies.