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Title

AGE-DETERMINATION OF THE NORTH AMERICAN PILCHARD, (SARDINA SAGAX) BY THE OTOLITH METHOD

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INTRODUCTION

Pilchards form a widely-distributed group members of which are found in the waters of the south Atlantic coast of Europe and the Mediterranean sea; in the coastal waters of South Africa, Japan, Australia, Chile, and the waters of the Pacific and eastern Atlantic oceans in the regions between the mean surface isotherms of 12 and 20 deg. C.

Generic relationships.

Regan (1916), considers the pilchards of Chile, North America*, Japan, and South Africa to form one species; Sardina sagax (Jen.); those of Australia and New Zealand to form the species Sardina neopilchardus (Steind.); and those of the European waters to form the species S. pilchardus (Walb.).

Although the species of Sardina listed above have many features in common the species are not of equal value, for S. sagax and S. neopilchardus resemble one another much more closely than either resembles S. pilchardus, these two differing from one another merely by the respective lengths of their maxillaries.

Accordingly Hubbs (1929), has proposed to split the two types of pilchards generically, supplying Sardinops as the generic name for sagax and neopilchardus. I can not see that any advantage accrues from so doing in as much as the life-history, habits and general appearance of these two types enables them to be recognized as pilchards or sardines wherever they occur. The following is a synopsis of the points of similarity and differences of the two types.

Apart from structural features which are in the main common to all the members of the subclass Clupeinae, and certain key-characteristics: short anal fin, upper jaw not notched, lower jaw not projecting, anterior supermaxillary

*The North American pilchard is generally referred to the species Sardina (or Sardinops) caerulea (Gir.) by the investigators of California and B.C.

bone present, scales on lobes of caudal, more than one radiating groove on opercular; the two types of pilchards have the following points in common.

1- Otoliths are identical yet indistinguishable from other members of the subclass.

2- The eggs are identical and appear to be peculiar to pilchards alone.

3- The gill-raker processes are similar if not identical and this type appears to be peculiar to the pilchards.

The points of difference involve certain colour marking, the scales, opercular bones, gill-rakers, and ventral scutes.

1- Large dark spots on the sides are typically present in the S. sagax type and typically absent in the S. pilchardus type, although these may be absent in the former "W.F. Thompson, 1926), and present in the latter (Couch, 1835 and Regan, 1916).

2- The scales in the first type are uniform and equally exposed, those of the second are large and small alternately, the smaller scales being nearly covered by the immediately anterior, larger scales. According to Day (1887), and Bateson (1890), a small proportion of the European pilchards are in part scales like specimens of S. sagax type. The scale count is approximately the same in the two types, and the scales apart from size difference are rather similar.

3- The bones of the operculum are different for each type: those of S. sagax type are rather rugged, expanded and deeply marked, while those of the second type are rather delicate and compressed. The interopercle in the latter type is scarcely exposed.

4- The gill-rakers of type S. sagax fold over each other at the angle, and four or five rakers of the lower limb are progressively shortened at this region.

5- The ventral scutes on S. sagax are much weaker in character than those of S. pilchardus and scarcely project beyond the scale bearing them posteriorly. The supporting scales are of different shape in the two types. These differences are illustrated in Plate I.

Distribution and early life-history of the North American pilchard.

The North American pilchard is found in an area some 2000 miles long and 200 miles wide; from Mexico north to southern Alaska. In California, where it is known as the California sardine, and in British Columbia, where it is called pilchard, this fish is netted in great numbers to supply reduction plants and canneries.

The early life-history has been worked out by E.C. Scofield (1934). He finds a very close resemblance in the eggs and larvae of this particular pilchard to those of the European species. The egg is 1.60 mm. in diameter, with large perivitelline space, reticulated yolk and single large oil globule. The larvae are typically clupeoid, long, slender and transparent. These pass into the young fish stage at approximately 35.0 mm. body length involving forward shift of dorsal and anal fin and backward shift of pelvic fins.

Spawning takes place from February to June mainly in the region between parallels 30 and 40 N. lat., with sporadic spawning north and south of this region when water temperatures permit it. The time of heaviest spawning is reported to be the months of April and May.

The age at which the pilchards reach maturity can only be surmised. Clark (1934), states that 50% of the females are maturing at a body length of 180 mm. and 100% are maturing at a body length of 200 mm. or more. (This would indicate a first maturity at three or four years for the females.) There

are no data available for the maturity of the males.

AGE-DETERMINATION BY OTOLITHS.

Some method of age-determination is essential to the investigation of a commercial fish population. Thompson (1926), reports the scale method to be both difficult and unreliable in the case of the North American pilchard. The present investigator encountered the same difficulty with the scales. This difficulty was somewhat augmented by our dependency on samples taken by purse-seine, in which many of the fish had lost most of their scales thus preventing the selection of scales always from the same region on the fish.

Accordingly, various structures; the opercular and sub opercular, the vertebrae and hypural plate; were examined and although these showed some evidence of growth zones, in none were these so definite as in the otoliths. Therefore the efforts were directed mainly toward the examination of these latter structures.

Historical outline of the method.

The otolith method has been developed mainly for fish with no scales or with scales difficult to interpret. Occasionally, however, this method has been used in conjunction with the scales method as a check on the latter. Reibisch (1899), in an investigation of the egg production of the plaice (Pleuronectes platessa), showed that rings on the otoliths corresponded with the groups of egg numbers, which he took to indicate year classes. Subsequent investigators of plaice are: Cunningham (1905), who investigated the time of formation of the zones.

Age-determination by otoliths has been applied to members of the follow-

ing groups of fish with some measure of success:

Flatfish - Maier (1906), Mohr (1918).

Gadidae; Cunningham (1906), Saemundsson (1923).

Scombridae; Nilsson (1914),

Zoarcidae; Clemens, W.A. and L.S. (1918).

Anguillidae; Tesch (1928).

Acipenseridae; Harkness (1924).

Salmonidae; McMurrich (1913), Oncorhynids only.

Clupeidae; Jenkins (1902), Cornish pilchard, herring and sprat.

Birtwistle and Lewis (1923), Irish Herring - Lissner (1925).

North Sea herring - and Rounsefell (1929), Alaska herring

With the exception of Jenkins the investigators of the last group also examined scales and in general report agreement between scale and otolith readings. Nilsson also reports agreement between scale and otolith readings for the mackerel.

Material and methods.

This present work is based on the examination of some 9942 otoliths collected over a period of four years. The time of capture and the locality of capture of the fish from which the otoliths were obtained are given in the following table.

TABLE I.

Number of specimens with locality and date of capture, from which otoliths have been examined.

Year & Season	Locality: Terminal Is. Cal.	Barkley Sd.	Nootka Sd.
1930-Summer		1600	490
" - Dec.	10		
1931-Summer		1050	1900
1932- "		625	1800
" - Dec.		7	
1933-Summer		625	425
1934-Jan.		100	
" -Summer			500
Total	10	4007	5525

The method of collecting the material was, with one or two exceptions, as follows:

one hundred pilchards were scooped at random from the scows or tenders in which the fish were delivered to the reduction plants. Otoliths were extracted from the first twenty-five; the remaining seventy-five were seced and their weight and "standard length" taken in connection with another phase of the pilchard investigation being carried on by Dr. J.L. Hart. It was considered that twenty-five specimens for each catch, although perhaps not altogether representative of that catch would be a representative sample, (as far as age-groups are considered), for the total catch of the year.

In connection with the collecting of the otoliths the following data were taken for each fish:

(a) Total length - from tip of snout to end of ventral ramus of caudal fin, in mm.

(b)"Standard length" - from tip of snout to end of hypural plate, in mm.

(c) Distance from tip of snout to insertion of first ray of dorsal fin, in mm.

(d) Head length - tip of snout to end of opercular membrane, in mm.

(3) Weight, in gms.

(f) Vertebral count - abdominal and caudal.

(g) Sex and condition of the gonads in some cases, together with the date, location and tonnage of catch.

The measurements were made on a "measuring board" similar to the one described by Rounsefell (1929).

In this work only the "standard length" and the sex of the fish are taken into consideration.

The otoliths were removed by making a transverse oblique cut through the skull immediately posteriorly to the eyes, with scissors, so that the sacculi and contained otoliths could be removed with forceps upon cleaning away the mid- and hind-brain. In most cases both otoliths, (i.e. sagittae) were retrieved. The otoliths were cleaned by rubbinb gently between thumb and finger and stored for examination, dry in small envelopes.

The otoliths were examined intact by means of a binocular microscope with magnification of fifty diameters. Throughout the examination they were immersed in a 50% aqueous solution of glycerol which medium appeared to give the best results in bringing out the zones and markings on the otolith. Reflected light was found to aid in the interpretation of the otoliths moreso than transmitted light, so the former method was adopted. Measurements were made by means of an occular micrometer.

Position and structure of the otoliths.

The otoliths or ear-stones are small petrous bodies of characteristic shape situated in the sacculus of the inner-ear apparatus, functioning presumably as accessory equilibria organs. There are two otoliths to each sacculus,

the sagitta and the asteriscus, respectively. The asteriscus is minute, shaped somewhat like a cock's comb, and is more-or-less transparent throughout. It occupies the posterior part of the sacculus which is imperfectly separated from the main part to form the lagena cochleae.

The sagitta, which is the only otolith applied to age determination in general, is somewhat the shape of an arrowhead as the name suggests. It is present in the young fish at hatching, and hence ranges in size from the microscopic dimensions of the larval fish to a structure about eight mm. long, by two mm. in its widest part.

The following is an account of the main features of the morphology of the sagitta; the posterior border is blunt, rounded and even; the dorsal border is generally even in outline; the ventral border is more inclined to be serrate; the anterior border is broken by a deep notch, the excisura ostii. This notch causes the sagitta to terminate anteriorly in two processes of which the ventral is the longer and stronger. This projection is termed the rostrum, the dorsal process the anti-rostrum.

The surfaces are median and lateral. The median surface is characterized by a deep groove, the sulcus, extending from the excisura ostii to about three-quarters along the body of the otolith posteriorly. The lateral surface is smooth, except for a series of shallow depressions and intervening low hummocks which follow the contour of the margin of the otolith. This is best demonstrated by means of a median sagittal section through the otolith.

The lateral surface of the body of the otolith when viewed by reflected light displays the following appearance; directly posterior to the excisura there is a dark or hyaline area which I will term the "nucleus"; this is bordered posteriorly, dorsally and ventrally, by nearly concentric alternating

areas, the one, white and glistening, the other, dark as in the case of the nucleus (ie. hyaline). In some specimens the hyaline areas are reduced to mere lines in the inner areas. Now these alternating areas correspond to the elevations and depressions mentioned above; the white areas occurring over the hummocks and the dark areas or lines in the shallow depressions. It is probable that these irregularities on the surface and the "colour" differences are products of the same mechanism.

By transmitted light the picture is reversed; the hyaline area, nucleus and others, being translucent now appear light, and the white areas being rather opaque appear dark.

With higher magnification the nucleus itself appears to be constructed from a series of minute, concentric, alternating light and dark "bands" of which the latter, the circuli, appear to be radially striated. This effect is possibly due to the diffraction of light by the material composing the circuli. Similar effects are seen again at the margin and to a lesser degree in the portion between the nucleus and the margin.

It would seem that wherever these circuli are close together an opaque or white area is formed, and where they are more scattered a hyaline area appears.

The complete picture is of necessity somewhat more complicated than this because the increase in size of the otolith takes place in three planes. The manner in which the otolith increases in size is not known by the author but it seems likely that the constructional material is layered on successively over the previous surfaces, the material itself possibly being secreted by the inner cell layer of the sacculus which is in close contact with the otoliths. If this be the case, it would explain why the hyaline areas nearer the nucleus

are prominent in the otoliths of smaller and presumably younger fish and partially obliterated in those of larger fish.

The nucleus is situated over the deepest part of the sulcus and hence the otolith is relatively thin at this place. The marginal area is likewise thin. At these two places the otolith presents the hyaline appearance. Similarly the other hyaline areas appear where the surface of the otolith is depressed and therefore relatively thin.

Thus the degree of scattering of the circuli and the relative thickness of the otolith at certain areas would appear sufficient to account for the zones appearing on the surface of the otolith.

The chemical composition of the pilchard otolith has not been determined but it is quite possible that the constituents are the same as those of otoliths of other species, namely, calcium carbonate with an organic matrix.

VALIDITY OF THE OTOLITH METHOD

General considerations.

The otolith method of age-determination depends on two conditions; first that two types of areas are laid down alternately, and secondly that these areas each correspond to definite periods of the year cycle.

The first condition is readily demonstrated by the examination of the otolith: the second condition is more difficult of demonstration due to the fact that most of the fish were taken during the months of July and August. Furthermore the marginal area always appears to be rather hyaline because the otolith is thin in that region and hence it is difficult to ascertain the exact time at which one type of area succeeds the other.

From various indications it would appear that the opaque areas are deposited during the months of greater growth activity and the hyaline areas during those of lesser activity. The former period would correspond roughly to the spring and summer months and the latter to the autumn and winter months. The evidence for this point of view is: first, the opaque bands are much more broad than the hyaline bands and secondly, Cunningham (1905), and Wallace (1905), have shown that the summer ring is opaque in various species of cod, plaice and whiting.

Graham (1928), has advanced an hypothesis concerning the cause of the periodic structure of otoliths, scales, and bones. He considers the formation of these structures to be dependent on two factors, one of these he terms "metabolism-rate" and the second, "calcium-secretion-rate", which is one of the manifestations of metabolism-rate. The first factor depends in part on food supply and temperature yet these conditions being optimum, a high metabolic-rate need not result in a high growth rate or high calcium-secretion-rate. The second factor may depend on a number of conditions among which may be the availability of certain accessory food stuffs. Under this hypothesis it is conceivable that conditions occur in which growth takes place with little or no calcium salts deposited and conversely deposition of calcium salts with little or no growth.

In pilchards otoliths are occasionally found which are, apart from a small area around the nucleus, entirely hyaline in appearance. These otoliths are of characteristic shape and of the same size as the normal otolith of the other side. The fact that these peculiar otoliths occur in fish which generally have the remaining otolith perfectly normal would indicate that the conditions causing this abnormality were local rather than general.

From a series of otoliths exhibiting varying degrees of this abnormality I have observed that the median surface is in no way altered, whereas the lateral surface is abruptly terminated at the margin of the opaque area and the otolith then extends as a thin plate. My interpretation of this is that for some reason, possibly through rupture or pulling away from the otolith, the cells of the lateral wall of the sacculus have ceased deposition of calcium salts while the cells of the medial wall remain active, secreting a substance high in organic matter. Thus, in a restricted area it is possible that growth occurs without deposition of calcium salts. Needless to say, such otoliths are worthless in age-determination work for they exhibit no periodic structure apart from the small nuclear area.

With the exception of those investigating Clupeidae, Salmonidae, Anguillidae and Scombridae, and the forementioned experiments of Cunningham, the various workers on age-determination by otoliths attribute the opaque areas to winter growth and the hyaline areas to summer growth. Although this may be the case it appears strange that two opposed sets of conditions are present in the same group of animals. In the examination of otoliths from widely divergent species I find that these always present the same appearance as those of pilchards.

VALIDITY OF THE METHOD

Special considerations.

Size increment in otoliths with reference to zones.

A zone is used here as including one opaque area together with the hyaline area immediately posterior. The measurements of each zone were made along the line connecting the mid-point of the nucleus to the farthest projection of the

posterior margin of the otolith. Thus, the distance from the nucleus to the end of any one zone, represents approximately one-half the total length of the otolith, when it terminated at that particular place.

In Table II only the widths of the individual zones are given but the length of the otolith at the end of any particular zone can be obtained by the addition of the widths of the zones.

The following method is used for typing the otoliths with reference to the number of zones appearing: 3R*, possessing three complete zones with a terminal zone not necessarily complete: 4R*, 5R*, etc.

TABLE II.

Average widths of zones in mm. for otoliths with different zone numbers

Type	No.	1	2	3	4	5	6	7	8
3R*	24	0.72	0.22	0.20	0.10				
4R*	4	0.60	0.25	0.26	0.18	0.08			
5R*	10	0.71	0.24	0.23	0.14	0.12	0.08		
6R*	10	0.70	0.23	0.23	0.20	0.13	0.09	0.08	0
7R*	10	0.70	0.23	0.23	0.22	0.14	0.10	0.08	0.05

If the distance from the nucleus to the end of each zone be plotted successively against the number of zones included in the particular portion of the otolith, a type of curve (Fig. I) similar to a growth curve is obtained. In view of other biological growth phenomena the only interpretation of this curve is, that the time for the completion of each zone is the same but the growth-rate of the otolith is progressively slowing. It remains to be shown that the period necessary for the laying down of each zone is of one years duration.

It will be seen from Table II that the growth-rate of the otolith is relatively great for the first zone formation, lessened yet still rather great

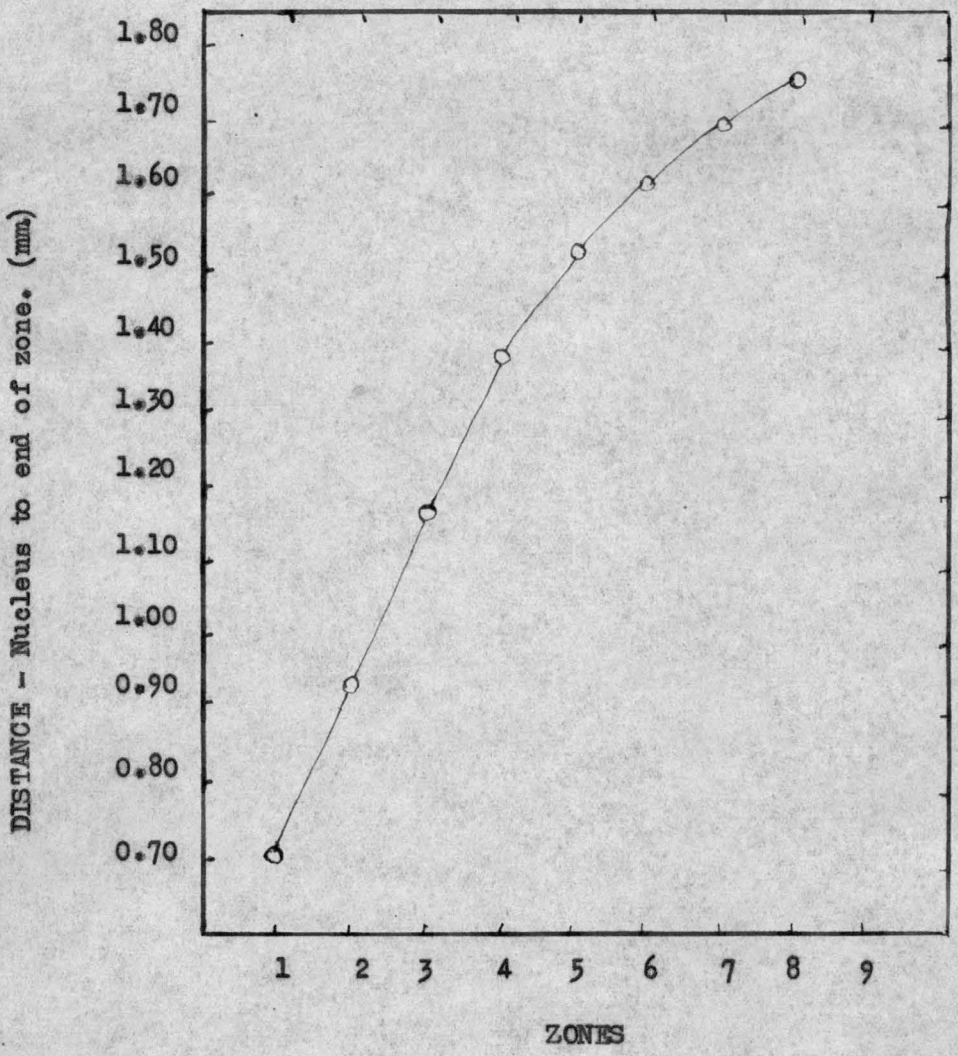

Figure 1

RATE OF GROWTH OF OTOLITH

for the next three zones and greatly lessened for subsequent zones. It will also be noted that, regardless of how many zones an otolith possesses, there is good agreement between the average widths of the same zone for different otoliths.

A noticeable exception to this statement is the terminal zone of otoliths of type 3R* and 4R*. I believe that in these otoliths in question the terminal zones are not yet completed for the specimens were captured in August. The terminal zones of the other types of otoliths may likewise be incomplete but due to the low growth-rate of these zones it is not very evident.

The three innermost zones represent the size of the otolith when the fish was small and immature and therefore cannot be interpreted as spawning checks. The zones more peripheral may be spawning checks but I believe this not to be the case.

Evidence for the yearly formation of zones from the consideration of closely related species.

Although agreement in age-readings between scale and otolith can hardly be cited as evidence as to the validity of either method the fact remains that in herring investigations where the scale method is generally accepted, many of the investigators have reported fair agreement between readings by scale and readings by otolith. Rounsefell (1929), reports agreement in 40 cases out of 45. The five cases of non-agreement occurred in fish six and seven years old in which cases the otolith gave the age of the fish as one year younger than the scale reading. These discrepancies probably occurred through the failure to detect the first hyaline area on the otolith which is almost or quite obliterated in the ear-stones of older fish.

Evidence from the record of a special population.

In early summer months of the year 1930 many of the pilchards taken in the first hauls in the Barkley Sound region were in a state of sexual maturity. In these fish the gonads filled most of the body cavity and in the ovaries the eggs were transparent and approximately 1 mm. in diameter. The first catch was made on July 15 some 50 miles south-west of Cape Beale and about 50% of the fish in this haul were ripe but not spawning. Subsequent hauls nearer to shore were made on July 29 and throughout August. These showed a greatly lessened percentage of maturing fish and a considerable percentage of "spent" fish wherein the gonads were slack and blood-shot. In the ovaries a few mature eggs were visible.

Although it is possible that these fish attained a state of sexual maturity but did not spawn and the females subsequently absorbed the mature eggs, the state of the ovaries from "spent" fish indicated that these fish did spawn in the neighbourhood of Barkley Sound. This opinion is further strengthened by the report of Scofield (1934), in which he states that the pilchards were spawning north of San Francisco in 1930 but have not been observed to do so since that year. The first catches for Barkley Sound region in subsequent years have never presented fish in any advanced stage of maturity.

In December 1932 a school of young pilchards were reported in the Barkley Sound region. I obtained otoliths from seven members of this school and the otoliths all showed two well-defined hyaline areas or "rings" and a terminal "ring" not so well-defined. In August of the following year a number of these small pilchards were caught in the same region. The otoliths of these showed three well-defined "rings" and an opaque peripheral area somewhat hyaline at its extreme margin. In January of 1934 otoliths were obtained from two small

pilchards taken in the same region but with a number of larger pilchards. The otoliths of these showed three well-defined "rings" and a peripheral "ring" in the process of being formed.

Various fishermen in the district reported this school of small pilchards from time to time since 1932 and always in the same region. Thus, there can be little doubt that the specimens examined came from the same school of fish, or that the school was homogeneous and composed of fish resulting from eggs spawned in the early summer months of 1930.

The data for these pilchards are given in Table III.

TABLE III.

Giving data on specimens of small pilchards taken in Barkley Sound region.

Date of capture	Dec. 1932	Aug. 1933.	Jan. 1934.
Number	7	293	2
Average stand. length (mm.)	151.9	178.8	198.5
Number of "rings"	3	3	4
Approx. age in years.	2 1/2	3	3 1/2

Thus, there is very good agreement between the actual age of the fish and the number of "rings" present on the otolith. There is also a corresponding increase in the average size of the fish for the half-yearly intervals recorded here.

Unfortunately larger samples of the fish taken in the winter months were not available and hence comparable measurements on the otolith increment could not be made. The otoliths of 3R* type in Table II are from fish of the August, 1933 catch of Table III.

An examination of the otoliths of ten small pilchards taken from California waters at Terminal Island in December of 1930, showed each otolith in the process of forming a first definite terminal hyaline area. These fish

ranged from 83 - 93 mm. standard length with an average length of 88.2 ± 0.7 mm. and were reported to have been fish from the spawning of the same year and hence from 1/2 to 3/4 years old.

In the case of young pilchards therefore, it is a certainty that hyaline zones or rings are formed sometime during the winter months, opaque areas sometime during the summer months. The exact date at which one type of area succeeds the other can not at present be ascertained owing to the impossibility of obtaining specimens throughout the year.

It may be mentioned here that most of these otoliths from small pilchards showed a secondary faint "ring" between the first winter "ring" and the nucleus. This was taken to be a summer check or "ring" caused perhaps by a change in feeding habits (Cf. E.C. Scofield 1934).

Various investigators, Higgins (1926), Godsil (1931), of the pilchard taken in California waters, give modes of 100 mm., 150 mm., 190 mm. approximately for the standard lengths of young fish taken in the commercial catches of the winter months. These are believed to represent the fish of three consecutive age-groups, the first being from one-half to three-quarter years old.

In consideration of this interpretation of the modes, by the California workers - an interpretation with which I am in full agreement - it would appear that those fish spawned and reared in California waters, grew at a faster rate than those reared in British Columbia waters (inasmuch as the former at 2 years are as large as the latter at three years of age). The zone measurements given in Table II for type 3R* appears to bear out this contention with the exception of the first season's growth.

The fact that the schools of small British Columbia pilchard inhabited mainly fjords and basins may have some bearing on the retardation of the growth

rate, either from the standpoint of temperature or available food.

Evidence from dominant year-classes.

Commercial catches have been sampled for a period of four years and age-determinations have been made on these samples. The percentage frequency of the age-groups as determined by otoliths is given in Table IV. It is assumed that these percentages represent the approximate proportion of each age-group in the commercial catch.

The data of the following table are presented as histograms in fig. 2.

TABLE IV.

Giving the percentage of the various age-groups in the commercial catch of Nootka and Barkley Sounds for the years 1930-1933.

Locality.			Barkley Sound			
Age-group	3.	4.	5.	6.	7.	8.
1930	0.	2.42	20.43	48.56	25.39	3.20
1931	10.46	30.10	38.72	20.42	0.29	0.
1932	3.37	20.24	51.09	22.60	2.70	0.
1933	0.	0	15.63	71.87	12.50	0.

Locality			Nootka Sound.			
Age-group	3.	4.	5.	6.	7.	8.
1930	0.	11.14	56.16	29.86	2.84	0.
1931	5.88	30.27	40.81	22.19	0.85	0.
1932	0.64	7.08	46.11	40.08	6.09	0.
1933	0.	0.48	17.83	75.91	5.78	0.

In 1931 the percentage of fish in their fifth year (4+) is relatively high, and in the next year 1932, this same group of fish now in their sixth year (5+) are seen to compose over fifty percent of the fish taken. The following year 1933, this group contributes about seventy percent of the fish taken. Hence, a dominant year-class entered the fishery for the first time in 1931 and has continued in the fishery for a period of three years or more. Hart (1935), from a study of vertebrae

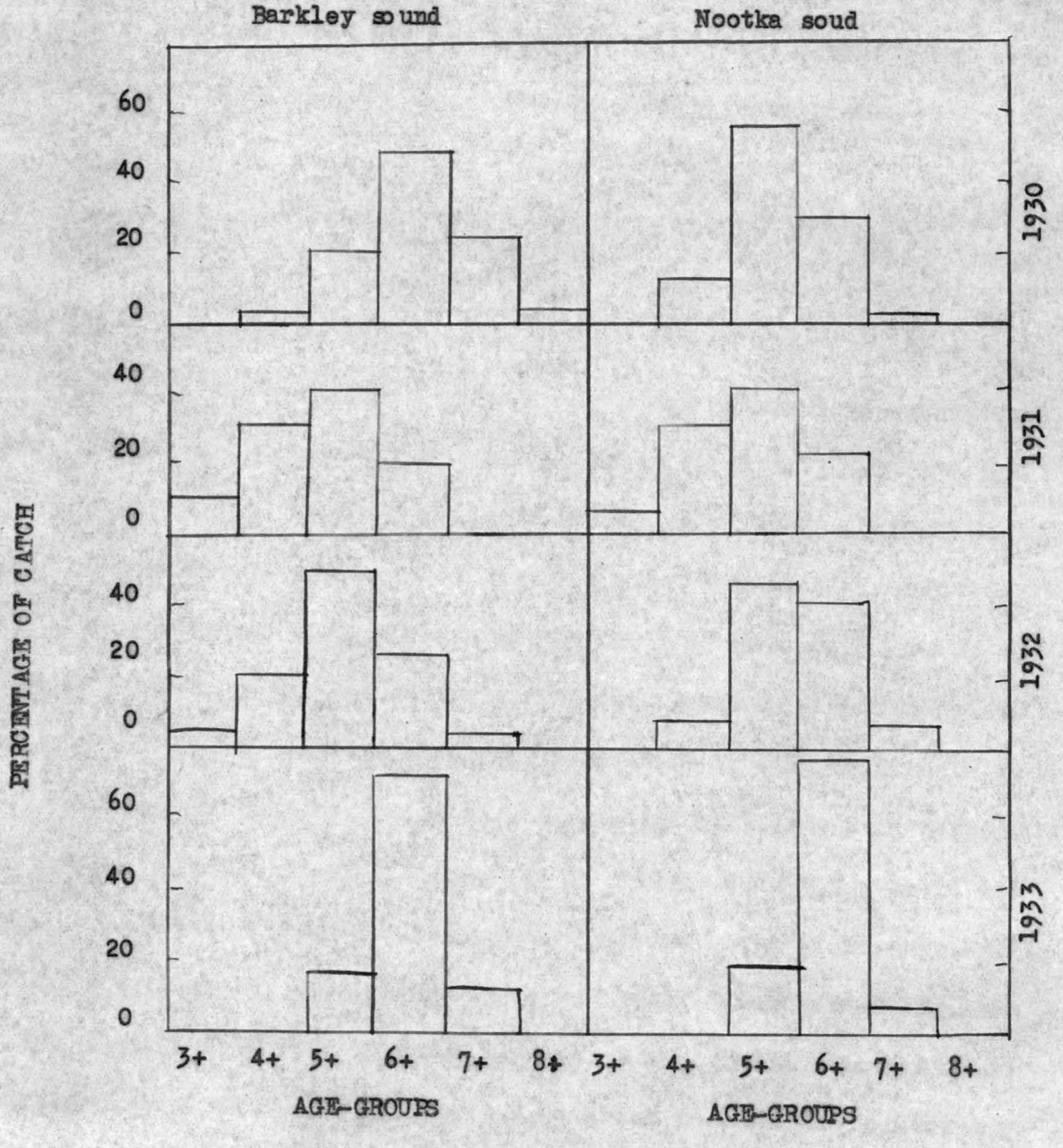

Figure 2

HISTOGRAM COMPILED FROM
TABLE IV

numbers in these same fish has suggested the possibility that a dominant year-class entered the British Columbia fishery in 1931. The otolith readings were made prior to the date of Hart's paper and with no knowledge of the results of this particular investigation, hence, it is evident that these results confirm the possibility suggested by Hart.

The case is further strengthened by the work of Clark (1931). She shows by Peterson's method, that dominant year-classes have occurred in the California fishery every three of four years over a period of ten years. The dates for the appearance of these groups are the winters of 1919-1920; 1922-23; 1926-27; and 1929-30. The fish first appear at a mode of 200 mm. approximately and represent fish in their third year. (Clark 1935).

Now the dominant group does not enter the British Columbia fishery until it is in its fifth year (4) and the time of entry in the summer of 1934, hence the cycle for the dominant group of the fish in the waters of British Columbia is in phase with that of California pilchards. Figure 3 is taken directly from Clark's data (1931) to illustrate this point Cominant year-classes A. B. C. and the first point on D. represent the modes of the dominant group for the combined fisheries of Monterey and San Pedro. The subsequent points on D. are from my data which will be presented in the next section. Owing to the fact that the fisheries of California and British Columbia are one-half year out of phase the progression of the last group (D.), does not appear to be as regular as the other groups.

Since the progression of the dominant year-classes precludes the possibility of including two years growth in one, and the fact that the year-class is in phase with the dominant classes of California (where the age at the first appearance is definitely known), there is but one interpretation to make from

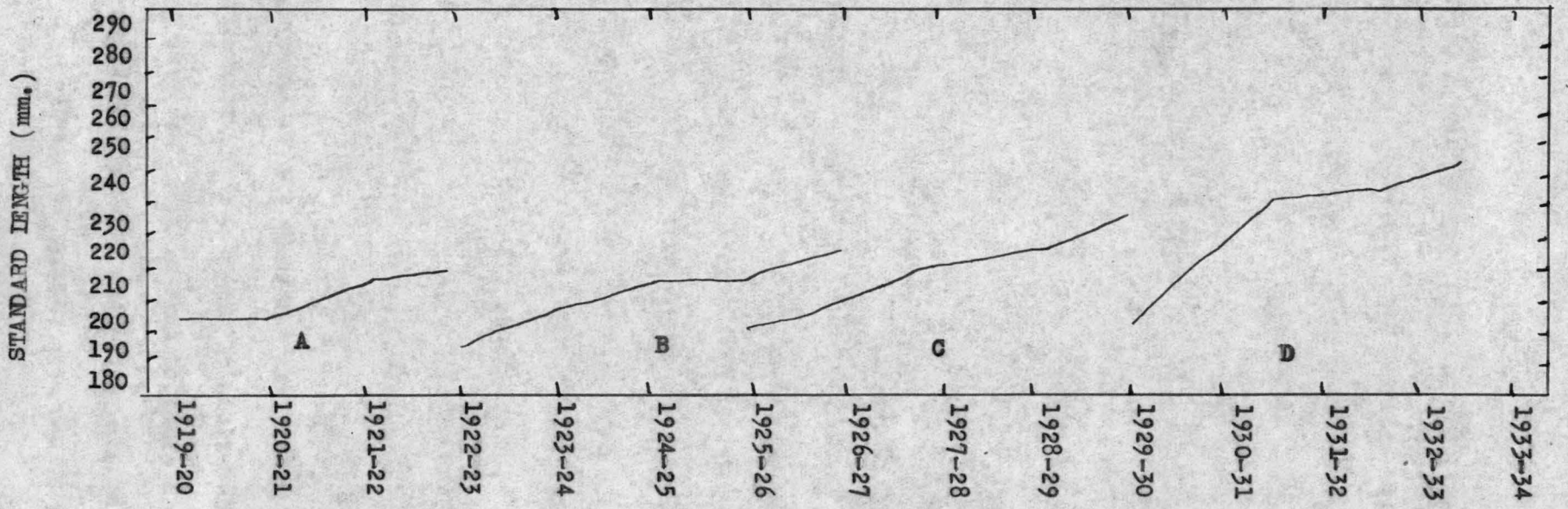

Figure 3

SEASONAL PROGRESSION OF DOMINANT YEAR-CLASSES

A,B,C and first point on D from Clark's (1931) data on California pilchards. Subsequent points on D from data on British Columbia pilchards.

the evidence: this is, that the otolith method is valid in the majority of cases for all fish entering into the British Columbia fishery and possibly for the fish of the California fisheries. Furthermore, the possibility that these two fish populations are really one and the same population is very great - a possibility which is rather to be suspected from the results obtained from the work done on spawning areas by Scofield (1934).

Unfortunately, a statistical study of the vertebrae of the populations supplying these two fisheries is able neither to support nor contradict this possibility (Hart 1933).

Discussion.

In order to find to what degree double readings of the same otoliths checked, one thousand otoliths were re-read after an interval of one year. All but four percent of the double readings were in agreement.

Thus, the otoliths are fairly legible, exhibit regular alternate light and dark areas and in general would appear suitable for age-determinations. However, since the direct demonstration of the validity of the method would involve the removal of the otolith of one side and subsequent recapture of the fish for examination of the remaining ear-stone - practically a physical impossibility - certain indirect evidence has been brought forward in support of its validity. These are:

(1) The otolith has a typical growth-curve and hence the zones are laid down over equal periods of time but with progressively slower rates of deposition.

(2) From a study of fish of known hatching time the period of zone formation is fixed at one year - the hyaline area being formed during the winter months and the opaque area during the summer.

(3) The demonstration of a dominant year class in the fishery and the discovery that this is in phase with a similar dominant year-class in California waters, and in which the age of entry into the fishery is known.

However, in view of the fact that the pilchards of the British Columbia fishery are on the average longer than those of the California fishery and the growth increments of the former as determined by myself appear to be much greater than those of the latter as determined by Clark, it might be argued that the British Columbia pilchards should be much older than the southern pilchards. In answer to this I point out the fact that Clark used a method in which it is very hard to determine the exact length of the mode - in fact a method that is not held to be accurate beyond the first few years. Furthermore, as the northern fishery is one-half year later in the season than the southern a period of active growth has intervened in the case of the northern fish.

A third point is suggested but is without much supporting evidence. This is that the northern fish actually have a higher growth-rate in their later years due to their failure to attain to a state of sexual maturity in most cases. In this case the retardation of body growth to accommodate gonad growth would not take place.

Age-analysis of the fish populations supporting the British Columbia fishery.

The Tables immediately following are compiled from the record of the samples taken from the commercial catch during the summer months of five years (1930-1934).

From 85 to 90 percent of the otoliths collected were found capable of being interpreted.

An examination of each sagitta of a number of pairs of otoliths showed these structures - left and right, respectively - to be mirror images of one another, and the otoliths could be separated into correctly matched pairs when a number of pairs were mixed together indiscriminately.

Thus in practice, only one otolith of the pair was examined, except in the rare cases when the first otolith examined was not normal.

The locality given in the Tables is the locality of the plant to which the fish were delivered rather than the actual locality of each catch, which latter could not always be ascertained.

The average standard length (in mm.) is represented in these Tables by - Av. L.-; the standard error of the mean by S.E.[1]

The age-groups are represented thus:- fish in their fourth year by 3*, those in their fifty year by 4*, etc.

The following points concerning the populations of pilchards supplying the fishery of British Columbia are noted from Tables V - IX:

(1) In most cases the average standard length of each age-group is separated from that of the other groups by a well-defined interval.

(2) The females of one age-group are slightly longer than the males of the same group in the majority of cases, and hence, in the general population the average length of the females is slightly larger than that of the males.

(3) Similarly the number of females is slightly higher than that of the males of the same age-group, except in a few instances where the numbers of each sex is rather small and perhaps not representative of the population.

[1] $S.E. = \frac{Efd^2}{n(n-1)} = \frac{O_M}{n}$

where Efd^2 is the sum of the squares of deviations from the arithmetic mean and n is the number of measurements O_M is the standard deviation of.

4. A dominant year-class enters the fishery in 1931 and continues to supply it for two or three years subsequently (Cf. Fig. 2).

5. The fish appear to enter the fishery in their fourth year but at this stage do not contribute greatly to the fishery. This may be due to the selection of the purse-seines used in their capture or may be due to their relative scarcity in the waters frequented by the older fish.

6. The fish in their ninth year (8+) were relatively more numerous than usual in the fishery of 1930. These fish in question may have been the remnants of a dominant year-class but if so the dominacy was not in phase with the pilchard populations of California. Those fish in their eighth year (7+) in the fishery of the same year are more probably the final appearance of a dominant year-class, for Clark (1931) notes the beginning of a dominant year-class in California for the winter of 1925-1926. Since the California fish were in their third year when first entering the winter fishery and hence in their fourth year the following summer (1926), it will be seen that both these fish populations were spawned the same year, namely the spring or summer of 1923.

It may be further noted that there is marked agreement between the fisheries of the two localities - Barkley Sound and Nootka Sound - one year, and less marked agreement another year. This may be due partly to the number of fish in the respective samples, and partly to the fact that often the boats from the two plants fish, side by side, on the same grounds. At intervals, generally at the beginning of the season, one plant may fish heavily from an

Growth rate of the British Columbia pilchards.

In order to show the rate of growth of the various year-classes, Table X has been constructed from the data of Tables V - IX. The length of each age-group given in this Table, is the averaged standard length for the two localities.

Table V. - Age analysis of the commercial catches for 1930. (samples of 1532 and 422 fish).

Locality	Barkley Sound.			Kildonan Plant.	
Age-group.	4	5	6	7	8
No.	18.	143.	328.	168.	21.
Av. L. (mm.)	240.2	245.4	247.4	248.5	253.1
S.E.	2.20	0.74	0.96	0.89	1.64
No.	19.	170.	416.	226.	28.
Av. L. (mm.)	244.7	250.6	252.0	254.6	256.5
S.E.	1.10	0.99	0.44	0.49	1.99
Av. L. of Age group	242.4	248.0	249.8	251.6	254.8
Total No. " "	37.	313.	744.	389.	49.

Locality.	Nootka Sound.			Nootka Plant.	
Age-group	4	5	6	7	8
No.	23.	114.	54.	4.	-
Av. L. (mm.)	238.3	245.4	251.7	253.2	-
S.E.	0.89	0.54	1.25	-	-
No.	24.	123.	72.	8.	-
Av. L. (mm.)	239.8	248.8	257.1	265.2	-
S.E.	0.96	0.63	1.03	-	-
Av. L. of Age-group	239.1	247.1	254.4	259.2	-
Total No. " "	47	237.	126.	12.	-

Table VI. - Age-analysis of the commercial catches for 1932 (samples of 1033 and 1870 fish).

Locality.	Barkley Sound			Ecole Plant.	
Age-group	3	4	5	6	7
No.	53.	144.	165.	77.	2.
Av. L. (mm.)	226.4	239.3	243.9	251.8	271.0
S.E.	1.47	0.62	0.53	1.00	-
No.	55.	167.	232.	134.	1.
Av. L. (mm.)	229.3	240.9	247.8	256.3	266.0
S.E.	1.43	0.59	0.49	0.98	-
Av. L. of age group	227.8	240.1	245.8	254.1	268.5
Total no. " "	108.	311.	400.	211.	3.

Locality	Nootka Sound			Nootka Plant.	
Age-group	3	4	5	6	7
No.	58.	286.	341.	169.	7.
Av. L. (mm.)	226.5	238.4	243.8	247.1	261.4
S.E.	1.39	0.49	0.53	0.86	-
No.	52.	280.	422.	246.	9.
Av. L. (mm.)	230.5	240.6	248.6	251.6	264.4
S.E.	1.52	0.47	0.50	0.92	-
Av. L. of age-group	228.5	239.5	246.2	249.4	262.9
Total no. " "	110.	566.	763.	415.	16.

Table VII. - Age analysis of the commercial catches for 1932. (samples of 593 and 1709 fish).

Locality	Barkley Sound			Ecole Plant.	
Age-group	3	4	5	6	7
No.	8.	67.	127.	52.	3.
Av. L. (mm.)	220.6	237.7	243.4	247.8	249.6
S.E.	-	1.00	0.77	1.13	-
No.	12.	53.	176.	82.	13.
Av. L. (mm.)	217.5	242.7	247.8	253.4	256.5
S.E.	-	1.19	0.70	0.90	-
Av. L. of age-group	219.1	240.2	245.6	250.6	253.1
Total no. " "	20.	120.	303.	134.	16.

Locality.	Nootka Sound			Nootka Plant.	
Age-group	3	4	5	6	7
No.	8.	61.	353.	287.	38.
Av. L. (mm.)	199.0	232.5	242.5	248.3	256.3
S.E.	-	1.53	0.45	0.47	1.17
No.	3.	60.	434.	398.	66.
Av. L. (mm.)	199.6	233.9	246.5	253.0	257.2
S.E.	-	2.04	0.43	0.42	1.01
Av. L. of age-group	199.3	233.2	244.5	250.6	256.7
Total no. " "	11.	121.	788.	685.	104.

Table VIII. - Age-analysis of the commercial catches for 1933. (samples of 96 and 415 fish).

Locality	Barkley Sound.		Ecole Plant.	
Age-group	4	5	6	7
No.	-	12.	28.	2.
Av. L. (mm.)	-	244.3	251.3	265.5
S.E.	-	1.51	0.94	-
No.	-	3.	41.	10.
Av. L. (mm.)	-	242.7	256.0	266.3
S.E.	-	-	1.23	1.90
Av. L. of age-group	-	243.5	253.6	265.9
Total No. " "	-	15.	69.	12.

Locality	Barkley Sound		Nootka Plant	
Age-group	4	5	6	7
No.	1.	32.	132.	7.
Av. L. (mm.)	216.0	231.6	246.7	262.1
S.E.	-	1.20	0.62	-
No.	1.	42.	183.	17.
Av. L. (mm.)	223.0	238.2	249.5	265.9
S.E.	-	0.03	0.52	1.59
Av. L. of age-group	219.5	234.9	248.1	264.0
Total no. " "	2.	74.	315.	24.

Table IX. - Age-analysis of the commercial catches for 1934. (494 fish).

Locality	Nootka Sound			Nootka Plant.		
Age-group.	3	4	5	6	7	8
No.	-	12.	39.	135.	33.	-
Av. L. (mm.)	-	235.5	241.3	250.2	253.0	-
S.E.	-	3.61	1.03	0.51	1.34	-
No.	2.	14.	27.	181.	58.	3.
Av. L. (mm.)	215.0	237.5	246.5	251.6	260.4	271.2
S.E.	-	-	1.42	0.58	0.93	-
Av. L. of age-groups	215.0	236.0	243.9	250.9	256.7	271.2
Total no. in "	2.	16.	66.	316.	91.	3.

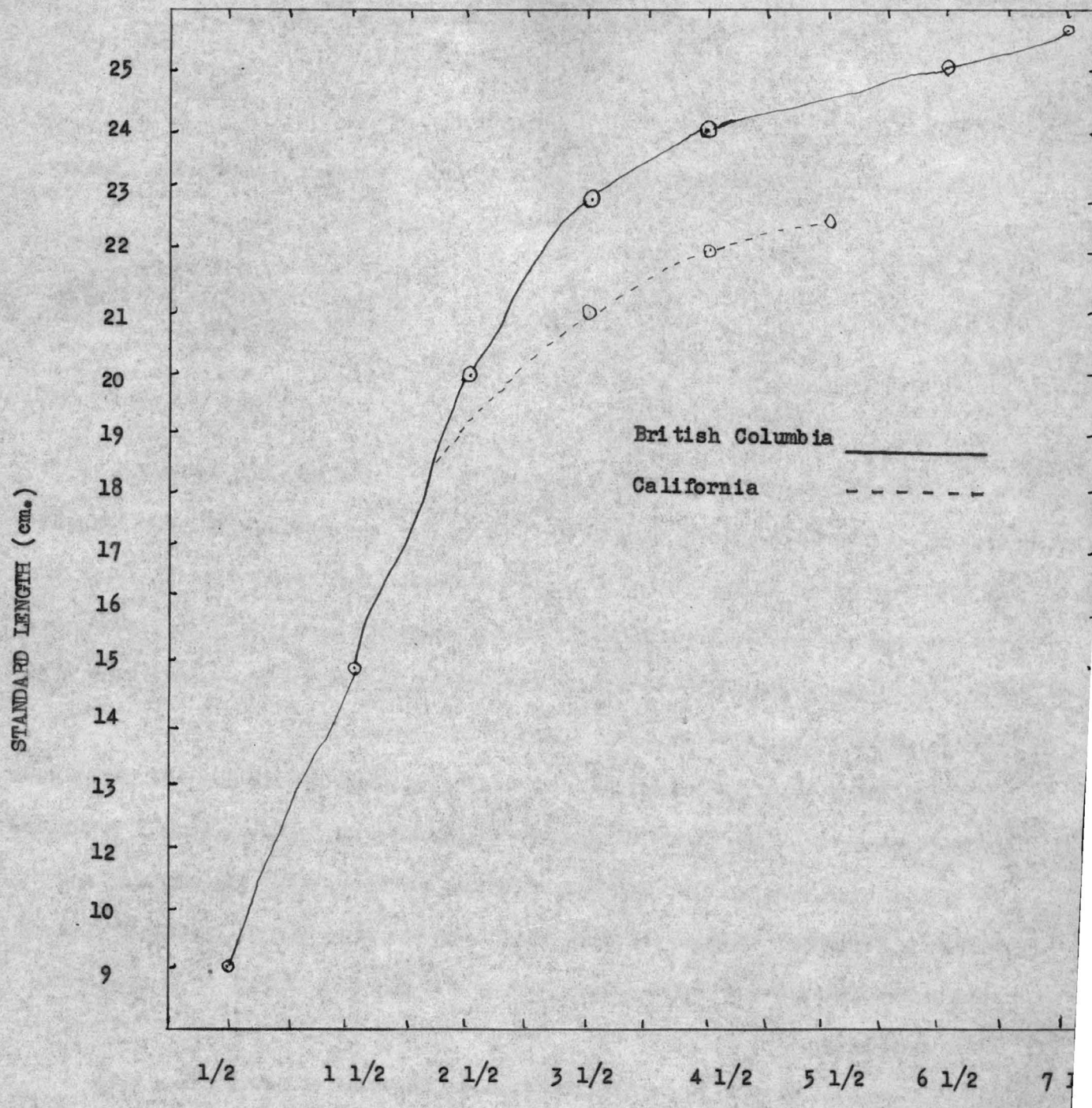

Figure 4.

GROWTH-RATE OF BRITISH COLUMBIA AND CALIFORNIA PILCHARDS

The age-groups are arranged under their respective year-classes.

TABLE X.

Length (in mm.) of each year-class for each year of appearance in the fishery.

Year of Capture.	Year of hatching (Year-classes) 1928	1927	1926	1925	1924	1923
1930	-----	-----	240.7	247.5	252.1	257.0
1931	228.1	239.8	246.0	251.7	265.7	-----
1932	236.7	245.0	250.6	254.9	-----	-----
1933	239.2	250.8	265.0	-----	-----	-----
1934	250.9	256.7	271.2	-----	-----	-----

With the exception of the year-class of 1928 and those fish in their eighth year in each year-class, there is a good agreement between the lengths of each age-group in the respective year-classes. In the case of the eighth year groups the actual numbers in the sample may not be equally representative for each year or possibly the longer members of the older age-groups have more chance of survival in these upper limits.

In the case of the year-class of 1928 where the growth for the fifth year is noticeably less than that of other year-classes at the same age, I offer the following explanation. In the year of their capture (1933) the fishery was almost a failure. Accordingly many local schools were fished to supply the plants and hence it is quite probable that a large proportion of slow-growing fish were taken.

A general growth-curve for the British Columbia pilchards has been attempted and is presented in Fig. 4. This is of composite nature, for the mid-points 1/2, 1 1/2 and 2 1/2 are from the data of the California State Fisheries Laboratories, and mid-point 3 1/2 is that of fish in their fourth year (3+) in 1931 (year-class of 1928). The subsequent mid-points are those from the year-class of 1927 and represent the progression of a dominant year-

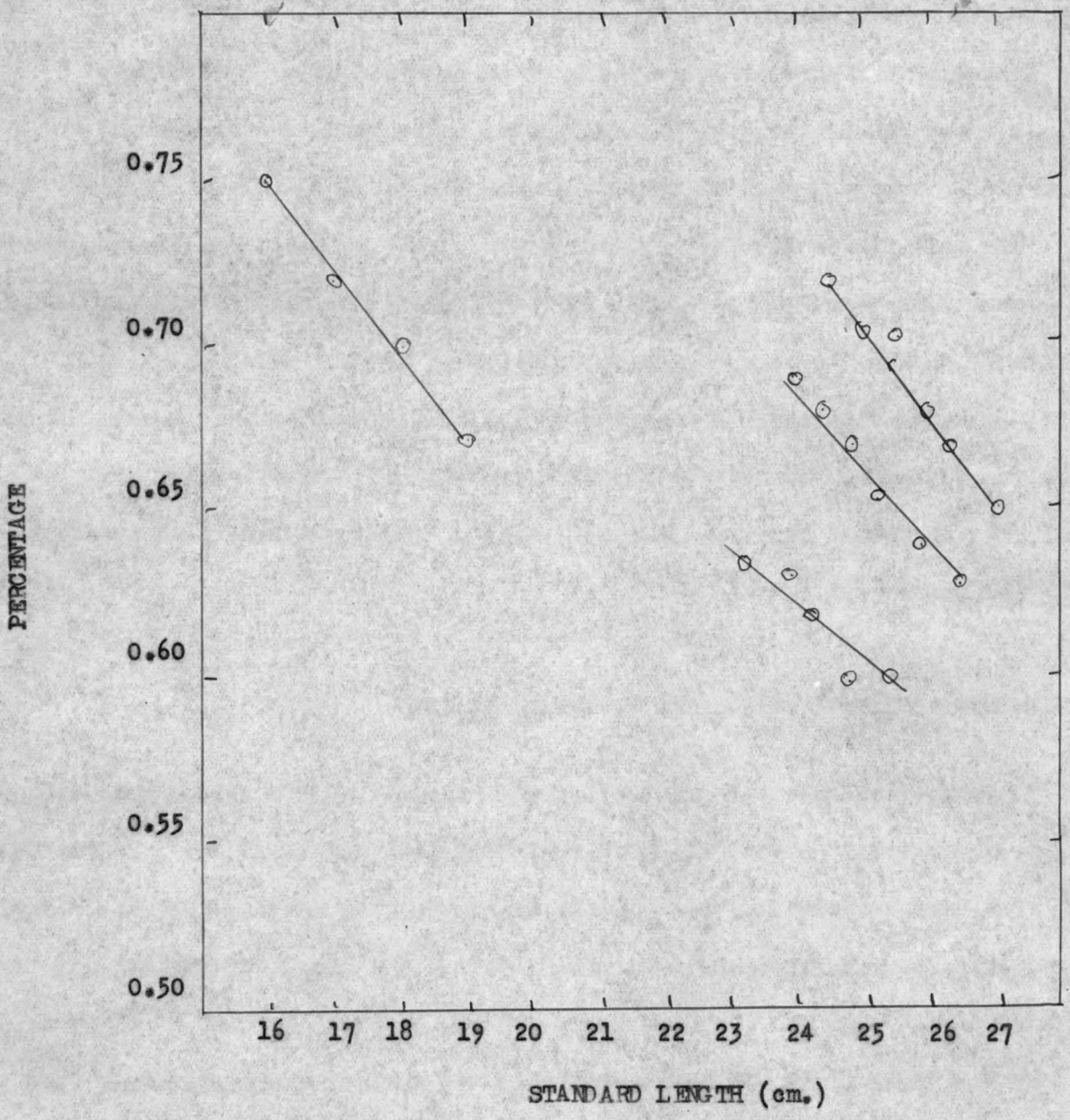

Figure 5

HALF-LENGTHS OF OTOLITHS EXPRESSED

AS PERCENTAGE OF BODY LENGTHS FOR AGE-GROUPS

class through the fishery.

In the same figure is presented a curve obtained from Clark's data (1931). These are her highest values for the modes representing the progression of a dominant year-class through the San Pedro fishery.

From this figure it would appear that the fish of the north have higher growth-rate than those of the south. However, since the methods of handling the data pertaining to these two populations were not the same, subsequent investigation is necessary to discover if this difference in growth-rate is actually a true one. It will be noticed from Figure 4 that the fish grow rapidly for the first three years, less rapidly during the next year and quite slowly for subsequent years.

Relationship of length of otolith to length of fish.

In connection with the examination of the otoliths for age-determination the general observation was made that the large fish had large otoliths and the small fish, small otoliths. Accordingly an attempt was made to find the actual relationship, if any, between these two factors - the length of otolith and length of fish.

In the first place the relationship is not simple, for if the fish are separated into their respective age-groups and the ratio, half length of otolith / standard length of fish found, it is noticed that the smaller fish of each age-group have a relatively large otolith. This phenomenon is represented graphically in Figure 5.

It is suspected that the size of the otolith depends on the size of the head and hence the smaller fish of any one age-group would have a relatively

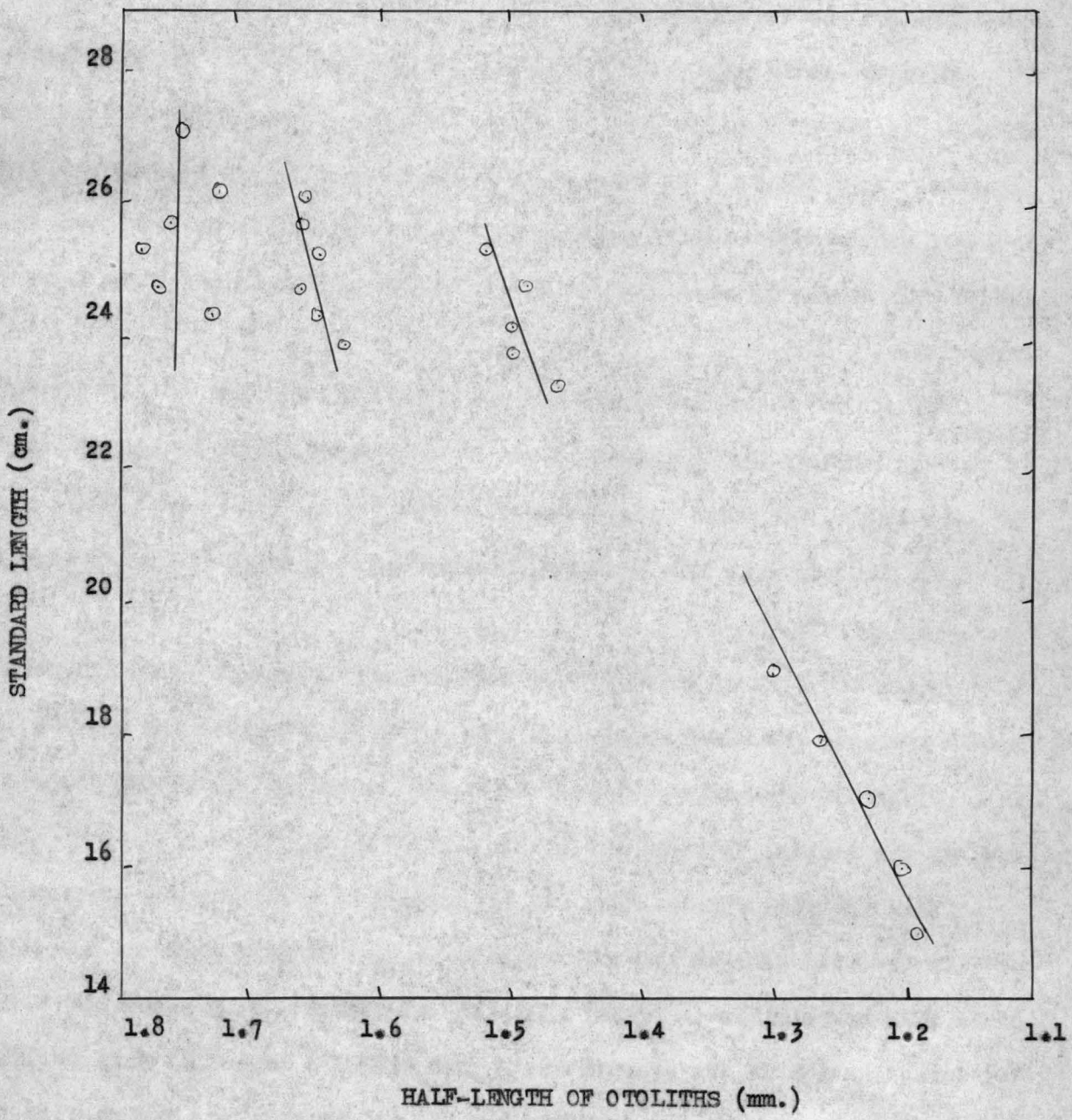

Figure 6

RELATIONSHIP OF LENGTH OF OTOLITH TO LENGTH OF FISH

larger head than the larger fish of the same age. Unfortunately there are no data available for the study of the growth of the head parts and hence this suspicion can not be confirmed.

When the half-length of the otolith is plotted against the respective standard length of the fish, and this for each age-group a series of curves is obtained. From Figure 6 it is seen that the slope of the curves is progressively lessened as the older age-groups are approached and in the case of fish in their eighth year (7+), the smaller fish have otoliths almost as large as those of the larger fish.

Now if the logarithm of the average length of the fish of each age-group is plotted against the logarithm of the average half-length of the otolith for the same group, the points representing groups 5+, 6, and 7+ fall along a straight line but this line extended does not pass through the point representing group 3+ (Fig. 7).

Since the fish of group 3+ are immature and therefore on a different growth cycle to the older age-groups this is to be suspected and must be taken into account if any method, comparable to the method of estimating the size of fish by the scales, is to be attempted.

Much material representing all age-groups is necessary for the completion of this investigation on the relationship between otolith size and length of fish. Since this material is in no way available at present, I am compelled to leave the investigation in its present state, but with the hope that this preliminary work may aid any subsequent investigator who attempts to use the otolith for estimating the length of the fish at different stages of its life-history.

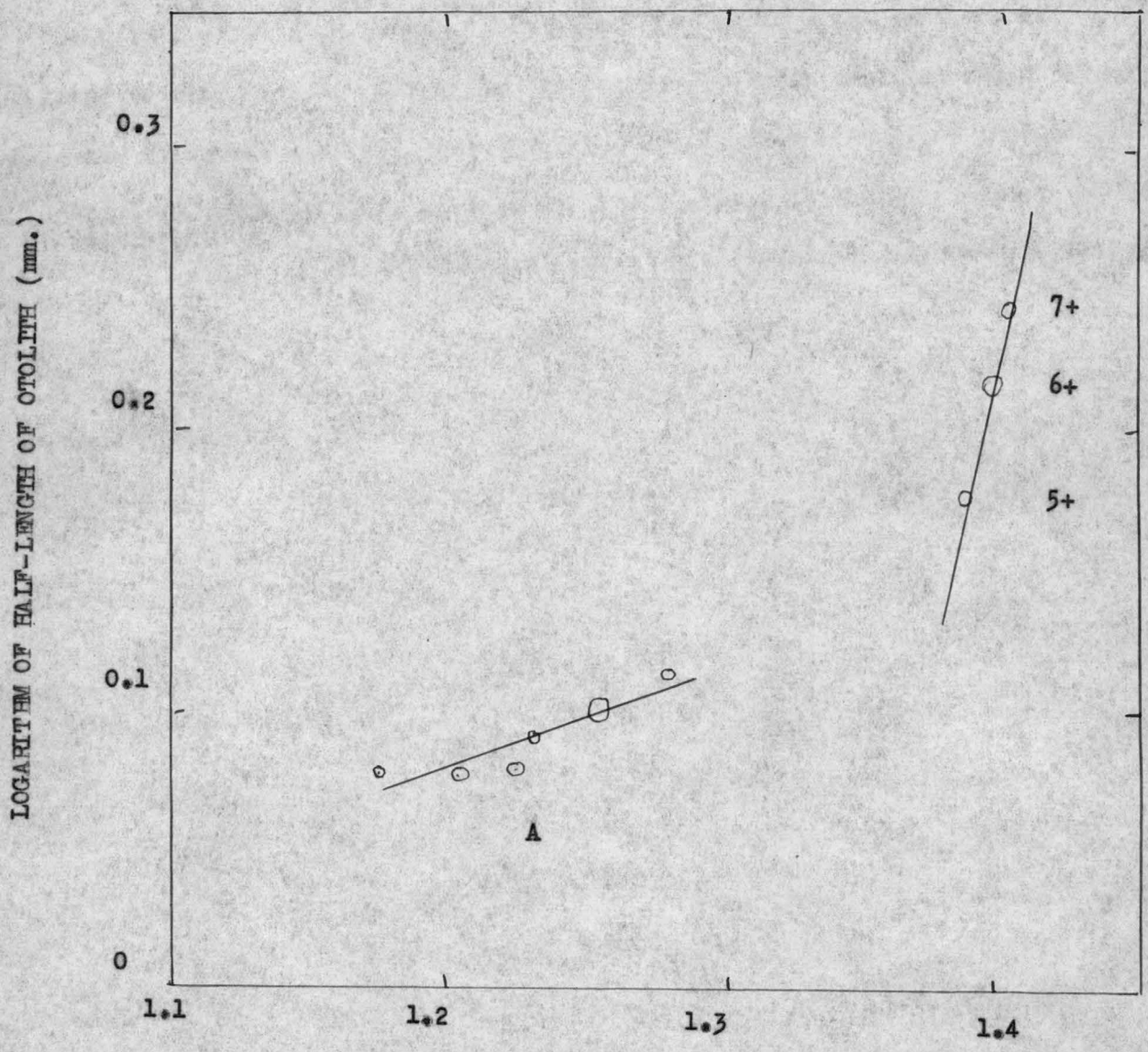

Figure 7

RELATIONSHIP OF HALF LENGTH OF OTOLITH TO LENGTH OF FISH

A. Curve representing fish of age-group 3+.
B. Curve representing average half-lengths of otoliths and average body lengths for fish of age-groups 5+, 6+ and 7+.

CONCLUSION

The otolith method of age-determination is shown here to be reliable for the North American pilchard. Since investigations of this fish by British Columbia and California workers, have been hindered to some degree by the lack of any reliable method of age-determination, it is hoped that the account presented here will aid greatly in future investigations.

SUMMARY

1. A snyopsis is given of the generic relationships and early life-history for the North American pilchard.

2. The reason for applying the otolith method of age-determination is stated as being due to the unreliability of the scale method for this species.

3. A short account is given on the use of the otolith method in various species of fish.

4. The structure and appearance of the pilchard otolith are described.

5. The validity of the method for the North American pilchard is deduced from the following considerations.

a.- agreement of otolith and scale in closely related species where the scale method is held valid.

b.- from the periodic nature of the growth of the otolith.

c.- from the record of fish of known age taken at half-yearly intervals.

d.- from the record of one dominant year-class which is in phase with a dominant year-class of California.

6. Reasons are given for considering the fish supplying the fisheries of California and British Columbia, to be drawn from the same populations - those hatched in California waters.

7. An age analysis of the British Columbia populations is made with the following points noted:

a.- the fish enter the fishery in their fourth year but the bulk of the fishery is drawn from fish in their fifth, sixth and seventh years, any one of the last two age-groups predominating.

b.- the females are slightly more numerous than the males in the general population and in most age-groups.

c.- the females of one age-group are on the average slightly larger than the males of the same group.

d.- the passage of a dominant year-class through the fishery is noted.

8. The growth-rate of the British Columbia pilchard populations is discussed and compared to that for California populations.

9. The relationship of the size of otolith to size of fish is investigated with the finding that this relationship is complicated.

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Table I - Size distribution of small fish taken at Terminal Is., California Dec. 1930.

Stand. length in mm.	Males and Females Age-group 1
83	1
84	-
85	-
86	3
87	2
88	-
89	-
90	1
91	-
92	2
93	1
Total	10

Av. length - 88.2

Table II - Size distribution of small fish taken at Barkley Sd., British Columbia, Dec. 1932.

Stand. Length in mm.	Males and Females Age-group 3.
141	1
148	3
156	1
158	1
164	1
Total	7

Av. length - 151.9

Table III - Size distribution of small fish taken at Barkley Sd. in one catch, Aug. 1933.

Stand. Length in mm.	Males	Females
	Age-group 3.	
153	1	-
154	-	1
158	-	1
162	-	1
163	-	1
164	1	-
166	2	4
167	3	1
168	1	5
169	4	4
170	5	2
171	4	4
172	5	5
173	7	6
174	3	9
175	5	2
176	4	3
177	5	8
178	3	5
179	8	6
180	9	8
181	7	3
182	6	6
183	7	10
184	10	9
185	7	9
186	2	7
187	6	4
188	5	7
189	5	4
190	5	3
191	4	2
192	3	7
193	1	3
197	1	-
198	-	1
199	2	1
Total	141	152
Av. length	180.2	179.5

Table IV -

Size distribution of pilchards with reference to age-group, Barkley Sd. region; season of 1930.

Stand. Length in mm.	Males					Females				
	Age-groups									
	4	5	6	7	8	4	5	6	7	8
220	1	-	-	-	-	-	-	-	-	-
222	-	-	-	-	-	-	-	1	-	-
224	-	-	1	-	-	-	-	-	-	-
226	1	1	1	-	-	-	1	-	-	-
227	-	1	-	-	-	-	-	-	-	-
229	-	1	1	-	-	-	-	-	-	-
230	-	2	2	-	-	-	-	1	-	-
231	-	2	2	1	-	-	-	1	-	-
232	1	1	1	-	-	-	-	-	-	-
233	1	2	6	1	-	1	2	1	-	-
234	-	5	5	2	-	-	-	4	1	-
235	1	4	5	-	-	-	1	1	-	-
236	1	3	4	1	-	-	2	2	1	1
237	2	6	5	2	1	1	1	1	-	-
238	-	6	7	5	1	3	3	5	1	-
239	-	5	11	3	-	-	1	1	-	-
240	2	9	12	6	-	1	5	15	1	-
241	-	6	18	7	-	-	4	8	1	-
242	-	5	14	6	-	-	9	16	-	1
243	-	5	13	11	1	-	5	12	6	1
244	2	5	15	8	-	3	9	14	5	-
245	1	3	17	5	1	2	7	17	6	1
246	1	4	23	13	-	2	6	14	10	-
247	-	1	18	8	1	1	8	16	5	3
248	1	9	11	7	-	-	11	21	9	-
249	-	3	10	6	-	1	13	19	8	-
250	-	3	19	7	1	-	6	26	9	1
251	-	5	15	8	1	-	3	13	14	-
252	1	9	11	8	1	1	8	18	10	1
253	1	1	9	5	-	1	3	18	12	-
254	-	1	12	5	2	-	10	14	13	4
255	-	4	11	11	2	-	3	22	15	-
256	1	4	6	6	-	2	8	17	15	2
257	-	5	7	4	2	-	3	19	14	3
258	-	4	4	-	2	-	6	8	11	2
259	-	2	2	1	1	-	3	19	6	-
260	-	1	4	2	1	-	10	10	9	-
261	-	2	3	9	1	-	2	14	7	2
262	-	1	4	1	1	-	3	4	5	-
263	-	2	3	1	-	-	3	6	6	-
264	-	-	2	-	1	-	2	3	3	-
265	-	1	2	1	-	-	2	5	5	-
266	-	-	2	-	-	-	1	6	1	-
267	-	-	3	1	-	-	1	5	4	-
268	-	-	3	1	-	-	-	2	5	-
269	-	-	-	-	-	-	1	5	-	-
270	-	1	1	-	-	-	-	-	4	2

Table IV (cont'd)

Stand. length in mm.	Males					Females				
	Age-groups									
	4	5	6	7	8	4	5	6	7	8
271	-	-	1	-	-	-	-	3	-	1
272	-	-	-	-	-	-	2	2	-	-
273	-	-	-	-	-	-	1	-	1	-
274	-	-	-	-	-	-	-	1	1	2
275	-	-	1	-	-	-	-	-	1	-
276	-	-	-	-	-	-	1	-	-	-
278	-	-	1	-	-	-	-	-	-	1
279	-	-	-	-	-	-	-	-	1	-
280	-	-	-	-	-	-	-	1	-	-
283	-	-	-	-	-	-	-	1	-	-
285	-	-	-	-	-	-	-	1	-	-
287	-	-	-	-	-	-	-	1	-	-
288	-	-	-	-	-	-	-	2	-	-
Total	18	143	328	163	21	19	170	416	226	28

Table V - Size distribution of pilchards with reference to age-group Nootka Sd. region; season of 1930.

Stand. length in mm.	Males. Age-groups 4	5	6	7	8	Females. Age-groups 4	5	6	7	8
229	-	1	-	-	-	-	-	-	-	-
230	-	-	1	-	-	-	-	-	-	-
231	1	-	1	-	-	1	-	-	-	-
232	1	-	-	-	-	1	-	-	-	-
233	1	1	1	-	-	-	-	-	-	-
234	-	-	-	-	-	1	2	-	-	-
235	2	4	1	-	-	2	1	-	-	-
236	6	1	1	-	-	2	1	-	-	-
237	1	5	-	-	-	-	3	-	-	-
238	2	3	1	-	-	2	-	1	-	-
239	-	3	1	-	-	4	4	-	-	-
240	2	3	1	-	-	-	6	-	-	-
241	-	5	-	-	-	1	1	1	-	-
242	3	8	-	-	-	3	2	-	-	-
243	1	10	1	-	-	2	2	2	-	-
244	2	8	1	1	-	1	5	-	-	-
245	-	6	1	-	-	-	4	1	-	-
246	-	11	1	-	-	2	12	2	-	-
247	-	7	2	1	-	1	8	1	-	-
248	1	7	1	-	-	1	10	1	-	-
249	-	4	-	-	-	-	7	1	-	-
250	-	3	3	-	-	-	8	3	-	-
251	-	6	4	-	-	-	2	4	1	-
252	-	4	5	-	-	-	6	4	-	-
253	-	3	3	-	-	-	9	5	-	-
254	-	5	2	-	-	-	6	3	-	-
255	-	2	1	-	-	-	5	3	-	-
256	-	-	6	-	-	-	7	2	-	-
257	-	2	6	-	-	-	2	3	1	-
258	-	1	1	-	-	-	6	4	-	-
259	-	1	1	-	-	-	2	3	-	-
260	-	-	1	-	-	-	-	6	-	-
261	-	-	1	2	-	-	-	2	-	-
262	-	-	-	-	-	-	1	4	-	-
263	-	-	2	-	-	-	-	3	2	-
264	-	-	-	-	-	-	-	3	-	-
265	-	-	-	-	-	-	-	2	-	-
267	-	-	-	-	-	-	-	3	2	-
268	-	-	1	-	-	-	-	-	-	-
269	-	-	-	-	-	-	-	1	-	-
270	-	-	1	-	-	-	1	1	-	-
271	-	-	-	-	1	-	-	-	-	-
272	-	-	-	-	-	-	-	1	-	-
273	-	-	-	-	-	-	-	1	-	-
274	-	-	-	-	-	-	-	-	1	-
275	-	-	1	-	-	-	-	-	-	-
280	-	-	-	-	-	-	-	-	1	-
295	-	-	-	-	-	-	-	1	-	-
Total	23	114	54	4	1	24	123	72	8	0

Table VI - Size distribution of pilchards with reference to age-group, Barkley Sd. region; season of 1931.

Stand. length in mm.	Males					Females				
	Age-groups									
	3	4	5	6	7	3	4	5	6	7
215	1	-	-	-	-	-	-	-	-	-
217	-	-	-	-	-	1	-	-	-	-
218	1	-	-	-	-	2	-	-	-	-
220	3	1	-	-	-	4	-	-	-	-
221	2	-	-	-	-	-	1	-	-	-
222	8	1	-	-	-	1	-	-	-	-
223	-	1	-	-	-	-	1	-	-	-
224	6	1	-	-	-	2	3	-	-	-
225	5	-	-	-	-	5	2	-	-	-
226	5	-	-	-	-	3	2	-	-	-
227	3	-	-	-	-	6	-	-	-	-
228	5	1	-	-	-	8	2	-	-	-
229	7	2	1	-	-	5	2	-	-	-
230	1	6	-	-	-	2	3	1	-	-
231	-	3	2	-	-	1	6	1	-	-
232	1	5	4	-	-	2	2	4	-	-
233	1	8	7	-	-	-	5	2	-	-
234	-	5	7	-	-	4	9	2	1	-
235	1	11	5	1	-	4	7	3	-	-
236	1	3	6	-	-	-	3	2	1	-
237	-	10	5	1	-	-	9	4	-	-
238	-	11	7	1	-	-	12	11	-	-
239	-	5	8	-	-	-	9	6	-	-
240	-	11	7	-	-	1	7	13	-	-
241	-	7	9	-	-	-	6	5	-	-
242	-	11	9	-	-	-	10	12	-	-
243	-	5	11	1	-	1	8	9	-	-
244	1	9	7	3	-	-	3	5	-	-
245	-	3	5	3	-	1	5	13	1	-
246	-	4	7	3	-	-	7	13	3	-
247	-	4	4	5	-	-	8	13	6	-
248	-	3	11	8	-	-	6	14	8	-
249	-	2	4	3	-=	-	4	6	6	-
250	-	3	9	7	-	-	5	4	7	-
251	-	-	4	5	-	-	2	14	6	-
252	-	1	3	7	-	-	3	8	11	-
253	-	2	4	2	-	-	-	5	9	-
254	1	1	1	4	-	-	4	8	5	-
255	-	1	3	3	-	-	4	9	6	-
256	-	1	2	1	-	1	3	6	6	-
257	-	1	1	-	-	-	1	6	10	-
258	-	-	-	5	-	1	-	5	7	-
259	-	1	8	1	-	-	-	1	5	-
260	-	-	2	5	-	-	-	5	5	-
261	-	-	1	3	-	-	-	6	8	2
262	-	-	-	2	-	-	-	2	5	-
263	-	-	-	1	-	-	1	2	1	-
264	-	-	-	-	-	-	1	3	4	-

Table VI (cont'd)

Stand. length in mm.	Males					Females				
	Age-groups									
	3	4	5	6	7	3	4	5	6	7
265	-	-	-	1	-	-	-	2	-	-
266	-	-	1	1	-	-	1	2	3	2
267	-	-	-	-	-	-	-	1	3	-
268	-	-	-	-	-	-	-	1	-	-
269	-	-	-	-	-	-	-	-	1	-
270	-	-	-	-	1	-	-	1	2	2
271	-	-	-	-	1	-	-	-	2	1
273	-	-	-	-	-	-	-	-	1	-
274	-	-	-	-	-	-	-	1	-	-
275	-	-	-	-	-	-	-	1	1	-
Total	53	144	165	77	2	55	167	232	134	7

Table VII - Size distribution of pilchards with reference to age-group, Nootka Sd. region; season of 1931.

Stand. length in mm.	Males					Females				
	Age-groups									
	3	4	5	6	7	3	4	5	6	7
202	1	-	-	-	-	-	-	-	-	-
208	-	-	-	-	-	1	-	-	-	-
211	-	-	-	-	-	1	-	-	-	-
213	1	-	-	-	-	-	-	-	-	-
216	1	-	-	-	-	-	-	-	-	-
218	2	-	-	-	-	-	-	-	-	-
219	1	-	-	-	-	-	1	-	-	-
220	3	-	-	-	-	2	1	-	-	-
221	2	1	-	-	-	1	-	-	-	-
222	3	3	-	-	-	1	-	-	-	-
223	3	3	-	-	-	3	-	-	-	-
224	1	4	-	-	-	4	1	-	-	-
225	4	3	-	-	-	4	5	-	-	-
226	5	4	-	-	-	3	2	-	-	-
227	7	4	2	-	-	3	5	-	-	-
228	5	9	-	-	-	4	8	-	-	-
229	5	5	-	-	-	2	3	1	-	-
230	1	7	3	-	-	2	10	4	-	-
231	1	12	6	-	-	2	7	1	-	-
232	1	9	9	2	-	1	7	-	1	-
233	2	17	15	22	-	2	11	2	2	-
234	1	12	8	2	-	3	8	6	-	-
235	1	10	11	2	-	1	13	5	1	-
236	1	13	12	7	-	1	9	2	2	-
237	-	13	10	7	-	2	17	18	3	-
238	2	14	17	5	-	1	14	10	4	-
239	-	12	18	7	-	-	11	9	3	-
240	-	21	7	8	-	-	17	14	1	-
241	1	17	12	3	-	2	9	7	7	-
242	-	15	23	8	-	-	10	18	4	-
243	1	10	21	5	-	-	4	19	9	-
244	1	8	19	9	1	-	12	13	11	-
245	-	8	22	9	-	1	11	21	12	-
246	-	4	12	7	-	-	9	26	14	-
247	-	10	14	8	-	-	9	18	15	-
248	-	5	18	7	-	1	10	23	15	-
249	-	8	9	8	-	-	11	14	8	-
250	-	5	9	5	-	1	9	25	12	-
251	-	3	7	6	-	1	7	19	11	-
252	-	3	12	8	-	1	7	21	10	-
253	-	3	5	6	-	-	3	15	6	-
254	-	2	5	5	-	-	6	20	9	-
255	-	2	7	3	1	-	1	7	7	1
256	-	-	5	5	-	1	2	13	11	-
257	-	-	2	2	1	-	2	9	8	-
258	-	-	2	5	-	-	2	7	6	-
259	-	-	5	3	-	-	4	13	6	-
260	-	3	2	8	-	-	-	6	9	1

Table VII (Cont'd)

Stand. length in mm.	Males					Females.				
	Age-groups									
	3	4	5	6	7	3	4	5	6	7
261	-	-	5	3	1	-	-	11	9	1
262	-	-	2	2	-	-	-	4	7	-
263	-	-	2	-	-	-	-	4	10	1
264	-	-	1	1	-	-	-	3	3	2
265	-	-	1	-	-	-	1	3	3	1
266	-	1	-	-	1	-	-	4	1	1
267	-	-	-	-	-	-	-	1	3	-
268	-	-	-	-	-	-	-	1	2	-
269	-	-	-	-	-	-	-	2	3	-
270	-	-	-	-	1	-	1	2	1	-
271	-	-	-	1	-	-	-	1	1	-
272	-	-	-	-	-	-	-	-	1	-
273	-	-	-	-	-	-	-	-	1	-
274	-	-	1	-	-	-	-	-	-	-
277	-	-	-	-	1	-	-	-	-	-
280	-	-	-	-	-	-	-	-	1	-
281	-	-	-	-	-	-	-	-	1	-
282	-	-	-	-	-	-	-	-	-	1
Total	58	286	341	169	7	52	280	422	246	9

Table VIII - Size and distribution of pilchards with reference to age-group, Barkley Sd. region; season of 1932.

Stand. length in mm.	Males					Females				
	Age-groups									
	3	4	5	6	7	3	4	5	6	7
193	-	-	-	-	-	1	-	-	-	-
195	-	-	-	-	-	1	-	-	-	-
198	-	-	-	-	-	1	-	-	-	-
201	2	-	-	-	-	-	-	-	-	-
203	-	-	-	-	-	1	-	-	-	-
205	-	-	-	-	-	1	-	-	-	-
209	1	-	-	-	-	-	-	-	-	-
214	-	-	-	-	-	1	-	-	-	-
220	-	-	1	-	-	-	-	-	-	-
221	-	1	-	-	-	-	-	-	-	-
222	-	-	-	-	-	1	-	-	-	-
224	1	1	-	-	-	-	-	-	-	-
225	-	3	-	-	-	-	-	-	-	-
226	-	3	2	-	-	-	1	-	-	-
227	-	-	-	-	-	1	-	-	-	-
228	-	3	1	-	-	-	1	1	-	-
229	1	3	2	-	-	-	1	1	-	-
230	-	-	1	1	-	1	1	1	-	-
231	-	3	-	1	-	-	1	-	1	-
232	1	1	1	1	-	1	-	1	-	-
233	1	1	3	-	-	-	1	4	-	-
234	-	4	6	2	-	-	3	3	-	-
235	-	2	3	-	-	-	3	3	-	-
236	1	4	3	-	-	-	1	4	-	-
237	-	5	7	1	-	-	1	6	-	-
238	-	3	8	2	-	-	4	9	1	-
239	-	5	11	-	-	-	2	3	-	-
240	-	2	6	-	-	-	4	4	2	-
241	-	3	3	2	-	1	3	3	-	-
242	-	2	5	4	-	-	2	12	2	-
243	-	2	7	2	-	-	3	6	2	-
244	-	1	3	3	-	-	1	4	3	-
245	-	1	5	1	-	-	3	8	2	1
246	-	3	2	-	-	-	2	9	6	-
247	-	-	6	2	1	-	-	4	4	1
248	-	3	6	2	1	-	2	7	2	1
249	-	-	6	3	-	-	2	10	1	-
250	-	5	8	4	-	-	-	10	5	2
251	-	2	3	6	-	1	1	6	2	1
252	-	-	4	2	-	-	2	10	3	-
253	-	-	2	-	-	-	-	5	6	-
254	-	-	-	2	1	-	2	4	6	2
255	-	-	1	2	-	-	-	6	2	-
256	-	-	-	1	-	-	2	2	2	-
257	-	-	3	1	-	-	-	8	4	-
258	-	-	2	1	-	-	-	-	4	-
259	-	1	1	2	-	-	1	-	1	-
260	-	-	1	1	-	-	2	1	5	1
261	-	-	-	1	-	-	-	3	1	-

Table VIII (cont'd)

Stand. length in mm.	Males					Females				
	Age-groups									
	3	4	5	6	7	3	4	5	6	7
262	-	-	-	1	-	-	1	3	2	-
263	-	-	1	1	-	-	-	3	3	-
264	-	-	-	-	-	-	-	1	3	1
265	-	-	-	-	-	-	-	5	1	-
266	-	-	-	-	-	-	-	-	2	-
267	-	-	1	-	-	-	-	-	1	1
268	-	-	1	-	-	-	-	2	1	-
269	-	-	-	-	-	-	-	-	-	1
270	-	-	1	-	-	-	-	1	-	-
271	-	-	-	-	-	-	-	1	1	-
273	-	-	-	-	-	-	-	-	1	-
275	-	-	-	-	-	-	-	2	-	-
276	-	-	-	-	-	-	-	-	-	1
Total	8	67	127	52	3	12	53	176	82	13

Table IX - Size distribution of pilchards with reference to age-group, Nootka Sd. region; season of 1932.

Stand. length in mm.	Males					Females				
	Age-groups									
	3	4	5	6	7	3	4	5	6	7
191	1	-	-	-	-	-	-	-	-	-
192	2	-	-	-	-	1	-	-	-	-
194	-	-	-	-	-	-	1	-	-	-
195	-	1	-	-	-	1	1	-	-	-
197	-	1	-	-	-	-	-	-	-	-
199	1	1	-	-	-	-	1	-	-	-
202	1	1	-	-	-	-	-	-	-	-
203	-	-	-	-	-	-	1	-	-	-
204	1	-	-	-	-	-	2	-	-	-
205	1	-	-	-	-	-	-	-	-	-
206	-	-	-	-	-	-	1	-	-	-
207	1	-	-	-	-	-	2	-	-	-
212	-	2	-	-	-	1	-	-	-	-
213	-	-	-	-	-	-	1	-	-	-
217	-	1	1	1	-	-	-	-	-	-
218	-	-	-	-	-	-	1	-	-	-
219	-	-	1	-	-	-	-	-	-	-
220	-	-	-	-	-	-	-	1	-	-
221	-	1	-	-	-	-	-	-	-	-
222	-	-	1	1	-	-	-	-	-	-
224	-	-	1	-	-	-	-	-	-	-
225	-	1	2	-	-	-	-	2	-	-
226	-	2	5	-	-	-	-	1	1	-
227	-	-	5	-	-	-	1	1	-	-
228	-	-	5	-	-	-	2	2	1	-
229	-	2	1	-	-	-	-	2	-	-
230	-	4	8	-	-	-	3	3	-	-
231	-	1	4	1	-	-	2	5	-	-
232	-	5	11	1	-	-	-	10	1	-
233	-	1	8	2	-	-	1	5	-	-
234	-	3	9	2	-	-	1	9	3	-
235	-	1	13	2	-	-	3	11	2	-
236	-	8	11	3	-	-	1	9	-	-
237	-	2	11	8	-	-	4	15	1	1
238	-	7	13	12	-	-	2	12	5	1
239	-	1	14	3	-	-	1	11	6	-
240	-	3	14	8	1	-	3	19	6	-
241	-	1	19	13	1	-	1	13	9	-
242	-	2	15	13	-	-	3	22	6	-
243	-	4	25	11	-	-	4	12	6	1
244	-	1	14	9	2	-	3	12	9	-
245	-	-	15	12	-	-	1	16	12	2
246	-	1	12	10	-	-	2	15	10	1
247	-	1	12	24	-	-	1	23	16	1
248	-	-	11	14	1	-	2	17	17	2
249	-	1	17	13	-	-	3	21	18	3
250	-	-	17	18	3	-	2	13	22	2
251	-	-	6	10	1	-	-	14	24	4
252	-	-	8	9	3	-	1	18	25	1

Table IX (cont'd)

Stand. length in mm.	Males					Females				
	Age-groups									
	3	4	5	6	7	3	4	5	6	7
253	-	1	8	12	-	-	-	25	14	4
254	-	-	9	9	3	-	1	10	16	3
255	-	-	3	11	4	-	1	13	21	2
256	-	-	1	6	-	-	-	15	25	2
257	-	-	5	14	2	-	-	10	10	5
258	-	-	2	7	-	-	-	9	14	3
259	-	-	6	5	2	-	-	9	17	2
260	-	-	2	7	2	-	-	6	8	1
261	-	-	1	3	2	-	-	6	13	3
262	-	-	-	2	3	-	-	5	7	3
263	-	-	1	5	3	-	-	4	13	-
264	-	-	1	3	-	-	-	2	7	4
265	-	-	1	-	3	-	-	1	5	2
266	-	-	1	2	-	-	-	-	5	3
267	-	-	-	-	-	-	-	-	8	3
268	-	-	-	-	1	-	-	1	-	1
269	-	-	-	-	-	-	-	1	5	3
270	-	-	-	-	-	-	-	1	-	1
271	-	-	-	-	-	-	-	1	3	-
272	-	-	-	-	1	-	-	-	-	1
273	-	-	-	-	-	-	-	-	1	1
274	-	-	-	1	-	-	-	-	3	-
275	-	-	-	-	-	-	-	-	1	-
276	-	-	-	-	-	-	-	1	1	-
280	-	-	-	-	-	-	-	-	1	-
Total	8	61	353	287	38	3	60	434	398	66

Table X - Size distribution of pilchards with reference to age-group, Barkley Sd. region; season of 1933.

Stand. length in mm.	Males			Females		
	Age-group					
	5	6	7	5	6	7
254	-	-	-	1	-	-
235	1	-	-	-	-	-
239	1	-	-	-	1	-
240	1	-	-	-	1	-
241	-	-	-	-	-	-
242	2	1	-	-	-	-
243	-	2	-	-	1	-
244	-	1	-	-	-	-
245	3	-	-	-	1	-
246	-	-	-	1	-	-
247	-	-	-	-	2	-
248	3	1	-	1	-	-
249	-	2	-	-	1	-
250	-	6	-	-	1	-
251	-	2	-	-	3	-
252	-	3	-	-	4	-
253	-	3	-	-	3	-
254	-	-	-	-	3	1
255	1	4	-	-	2	-
258	-	1	-	-	1	-
259	-	1	-	-	2	-
260	-	-	-	-	2	-
261	-	-	1	-	-	-
262	-	-	-	-	3	1
263	-	-	-	-	1	2
264	-	-	-	-	2	-
265	-	1	-	-	1	-
267	-	-	-	-	2	2
268	-	-	-	-	4	-
270	-	-	1	-	-	2
273	-	-	-	-	-	1
274	-	-	-	-	-	1
Total	12	28	2	3	41	10

Table XI - Size distribution of pilchards with reference to age-group, Nootka Sd. region; season of 1933.

Stand. length in mm.	Males				Females			
	Age-groups.							
	4	5	6	7	4	5	6	7
216	1	-	-	-	-	-	-	-
213	-	1	-	-	1	-	-	-
224	-	1	-	-	-	-	-	-
226	-	1	-	-	-	-	-	-
227	-	2	-	-	-	-	-	-
228	-	-	-	-	-	2	-	-
230	-	4	1	-	-	2	-	-
231	-	1	-	-	-	1	-	-
232	-	1	-	-	-	-	-	-
233	-	4	2	-	-	5	-	-
234	-	1	5	-	-	1	2	-
235	-	2	4	-	-	5	3	-
236	-	2	2	-	-	3	2	-
237	-	4	3	-	-	3	-	-
238	-	1	2	-	-	3	2	-
239	-	1	4	-	-	4	4	-
240	-	1	4	-	-	2	7	-
241	-	-	2	-	-	-	7	-
242	-	-	6	-	-	2	3	-
243	-	1	5	-	-	-	7	-
244	-	2	7	-	-	-	11	-
245	-	-	9	-	-	1	6	-
246	-	-	12	-	-	2	9	-
247	-	-	6	-	-	-	14	-
248	-	1	5	-	-	3	15	-
249	-	1	4	-	-	1	5	-
250	-	-	7	-	-	2	8	-
251	-	-	1	2	-	-	4	1
252	-	-	9	-	-	-	11	-
253	-	-	6	-	-	-	7	-
254	-	-	8	-	-	-	7	-
255	-	-	2	-	-	-	11	-
256	-	-	5	-	-	-	8	1
257	-	-	4	-	-	-	4	-
258	-	-	3	-	-	-	5	-
259	-	-	-	1	-	-	6	-
260	-	-	1	-	-	-	5	1
261	-	-	2	-	-	-	1	1
262	-	-	-	-	-	-	2	1
263	-	-	-	1	-	-	-	-
264	-	-	1	-	-	-	3	1
265	-	-	-	-	-	-	2	1
266	-	-	-	1	-	-	2	-
267	-	-	-	-	-	-	-	2
268	-	-	-	-	-	-	-	3
269	-	-	-	1	-	-	-	1
270	-	-	-	-	-	-	-	1
273	-	-	-	-	-	-	-	2
276	-	-	-	1	-	-	-	-
278	-	-	-	-	-	-	-	1
Total	1	32	132	7	1	42	183	17

Table XII - Size distribution of pilchards with reference to age-group, Nootka Sd. region; season of 1934.

Stand. length in mm.	Males					Females				
	Age-groups									
	4	5	6	7	8	3	4	5	6	7	8
208	-	-	-	-	-	1	-	-	-	-	-
209	1	-	-	-	-	-	-	-	-	-	-
214	1	-	-	-	-	-	1	-	-	-	-
222	-	-	-	-	-	1	-	-	-	-	-
229	-	1	-	-	-	1	-	-	-	-	-
232	-	-	-	-	-	-	-	-	1	-	-
233	1	2	-	-	-	-	-	-	-	-	-
234	1	2	-	1	-	-	-	-	-	-	-
235	-	1	-	-	-	-	-	-	1	-	-
236	1	4	1	-	-	-	-	1	-	-	-
237	1	3	2	-	-	-	-	1	-	-	-
238	1	2	-	-	-	-	-	1	1	-	-
239	1	1	1	-	-	-	1	-	2	-	-
240	-	3	9	1	-	-	1	3	-	-	-
241	-	3	2	-	-	-	-	1	4	-	-
242	-	3	2	-	-	-	-	1	2	-	-
243	-	4	3	-	-	-	-	2	6	-	-
244	1	1	4	3	-	-	-	2	5	-	-
245	2	-	5	1	-	-	-	-	8	1	-
246	-	1	10	-	-	-	-	2	7	1	-
247	-	-	12	2	-	-	-	4	8	1	-
248	-	1	6	1	-	-	-	1	10	1	-
249	-	2	9	1	-	-	-	2	11	2	-
250	-	1	9	1	-	-	-	1	11	1	-
251	-	1	8	1	-	-	-	-	12	-	-
252	1	1	11	1	-	-	-	1	12	1	-
253	-	-	5	2	-	-	-	-	13	2	-
254	-	-	8	1	-	-	-	-	9	2	-
255	-	-	5	4	-	-	-	2	8	1	-
256	-	1	2	2	-	-	1	-	6	3	-
257	-	1	4	2	-	-	-	-	11	2	-
258	-	-	4	3	-	-	-	-	10	1	-
259	-	-	5	2	-	-	-	-	5	-	-
260	-	-	1	1	-	-	-	-	3	7	-
261	-	-	4	-	-	-	-	-	3	5	-
262	-	-	1	1	-	-	-	-	3	5	-
263	-	-	-	1	-	-	-	1	5	2	-
264	-	-	1	-	-	-	-	-	2	55	1
265	-	-	1	-	-	-	-	-	1	5	-
267	-	-	-	-	-	-	-	-	-	22	-
268	-	-	-	-	-	-	-	1	-	1	-
269	-	-	-	-	-	-	-	-	1	1	-
270	-	-	-	-	-	-	-	-	-	1	-
271	-	-	-	-	-	-	-	-	-	2	-
273	-	-	-	1	-	-	-	-	-	1	-
274	-	-	-	-	-	-	-	-	-	1	1
277	-	-	-	-	-	-	-	-	-	1	1
Total	12	39	135	33	0	2	4	27	181	58	3