1963

Age and Growth of the Rio Grande Mountain Sucker, Pantosteus Plebeius (Baird and Girard).

Richard R. Raush

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AGE AND GROWTH OF THE RIO GRANDE MOUNTAIN SUCKER, *PANTOSTEUS PLEBEIUS* (BAIRD AND GIRARD)

By

Richard R. Raush

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Biology

The University of New Mexico

1963

This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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Date

Thesis committee

William V. Koster
Chairman

William C. Martin

C. Clayton Hoff

ABSTRACT

Seven hundred and forty-four specimens of the Rio Grande mountain sucker collected in Jemez Creek, a tributary in the Rio Grande system, were measured, sexed, and aged. Both length-frequency and scale methods were used to determine the age of these specimens. The oldest males were six years of age, at which time they averaged 134 mm in standard length. The oldest females were seven years of age, and averaged 159 mm in standard length. First spawning for both males and females occurred in the spring after they had completed three full years of life. The onset of senescence, expressed as a relatively sharp reduction in growth rate, occurred in the fifth growing season in males and the sixth growing season in females.

ACKNOWLEDGMENTS

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Dr. William J. Koster, Dr. K. R. Coburn, and Mr. Robert Bradley assisted in collecting the specimens used in this study.

TABLE OF CONTENTS

Chapter		Page
I	INTRODUCTION	1
II	HISTORICAL SURVEY	5
III	MATERIALS AND METHODS	7
IV	RESULTS AND DISCUSSION	12
V	SUMMARY	26
	TABLES	28
	FIGURES	29
	LITERATURE CITED	60

LIST OF TABLES

Table		Page
1.	Numbers of males and of females in each year class from each collection; juveniles included.	28
2.	Number of individuals in each year class from each collection; expressed as percentages.	28
3.	Number of males and of females in each year class compared to the number in the entire collection; expressed as percentages; juveniles excluded.	29
4.	Sex ratios for each year class of each collection; expressed as percentages; juveniles excluded.	29
5.	Mean standard lengths of males and of females for each year class of each collection; juveniles included.	30
6.	Position of annulus formation on the anterior-median radii of the scales.	31

LIST OF FIGURES

Figure		Page
1.	1-year scale.	33
2.	2-year scale.	33
3.	2-year scale.	33
4.	2-year scale.	33
5.	2-year scale.	33
6.	2-year scale.	33
7.	2-year scales.	34
8.	2-year scales.	34
9.	2-year scales.	34
10.	3-year scales.	35
11.	3-year scales.	35
12.	3-year scales with regenerated foci.	35
13.	3-year scale.	36
14.	3-year scale with rotated focus.	36
15.	3-year scale.	36
16.	Double, 3-year scale.	36
17.	3-year scale.	37
18.	4-year scale.	37
19.	4-year scale.	37
20.	4-year scale.	37
21.	4-year scale.	38
22.	5-year scale.	38
23.	5-year scale.	38

24. 5-year scale. 38

25. 5-year scale. 39

26. 6-year scale. 39

27. 6-year scale. 39

28. 6-year scale. 39

29. 6-year scale. 40

30. 6-year scale. 40

31. 6-year scale. 40

32. 6-year scale. 40

33. 7-year scale. 41

34. 7-year scale. 41

35. 7-year scale. 41

36. 7-year scale. 41

37. 7-year scale. 42

38. Regenerated, 7-year scale. 42

39. Standard length frequencies of November 1960 males; juveniles included. 43

40. Standard length frequencies of November 1960 females; juveniles included for comparison. 44

41. Standard length frequencies of May 1961 males; juveniles included for comparison. 45

42. Standard length frequencies of May 1961 females; juveniles included for comparison. 46

43. Standard length frequencies of May 1949 males. 47

44. Standard length frequencies of May 1949 females. 48

45. Absolute growth. Average standard length in millimeters in relation to number of growing seasons, and the annual increments in standard length for each growing season. November 1960 collection. 49

46. Relative growth (semi-log). Average standard length in millimeters in relation to number of growing seasons. November 1960 collection. 50

47. Absolute growth of median-anterior scale radius (unweighted, over-all average of all year classes of all collections). 51

48. Relative growth of median-anterior scale radius (unweighted, over-all average of all year classes of all collections). 52

49. Relative growth (log-log) of median-anterior scale radius and standard length. November 1960 and May 1961 collections combined. 53

50. Average, absolute growth at the anterior edge of the scale compared with average increase in standard length. By year classes. November 1960 collection. 54

51. Average, absolute growth at the anterior edge of the scale compared with average, absolute increase in standard length. By 10-mm groups. November 1960 collection. 55

52. Average, absolute growth at the anterior edge of the scale compared with average, absolute increase in standard length. By 10-mm groups. May 1961 collection. 56

53. Average, absolute growth at the anterior margin of the scale compared with average, absolute increase in standard length. By 10-mm groups. November 1960 and May 1961 collections combined. 57

54. Average, absolute growth at the anterior margin of the scale compared with average, absolute increase in standard length. By 10-mm groups. May 1949 collection. 58

55. Average, absolute growth at the anterior margin of the scale compared with average, absolute increase in standard length. By 10-mm groups. All three collections combined. 59

Chapter I

INTRODUCTION

The Rio Grande mountain sucker, Pantosteus plebeius (Baird and Girard), is an endemic fish in the Rio Mimbres and Rio Grande basins and has become established in parts of the Gila basin (Koster, 1957, p. 46). In most of its range, P. plebeius shares its habitat with both introduced, brown and rainbow, and endemic, native cutthroat, trout. The relationship between P. plebeius and these economically more important forms is one of public as well as scientific interest. Jemez Creek, Sandoval County, New Mexico, a tributary of the Rio Grande system, is, mainly because of its close proximity to Albuquerque and Santa Fe, one of the most important trout streams in New Mexico. The Rio Grande mountain sucker is the dominant member of the fish fauna of this stream. In order to understand better the ecological position of P. plebeius within this fauna, a knowledge of its age and growth is essential. Since the description of P. plebeius in 1854, there have been no publications on these topics. The purpose of this paper is to describe and to discuss growth in this species in Jemez Creek.

Methods used in the determination of age and growth can be placed in three categories: known-age techniques, length-frequency techniques, and techniques that involve the interpretation of annular lines of growth as they appear on certain skeletal elements (Koster, 1955, p. 145).

In the application of known-age methods, two approaches may be taken. Juveniles of a given species may be isolated by either placing them in a natural stream free of this species or in an artificial, rearing enclosure. When a homogeneous group is so segregated, it may be

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observed by the investigator and its growth characteristics at any age noted. The other approach to this method involves the marking of fish, either individually or as a group, in their natural habitat. Such marked individuals are distinguishable at later dates and their growth may then be determined. The obvious advantage of the known-age method is its almost complete accuracy. However, since the fish in an experiment of this type are subjugated to unnatural conditions that result from being displaced from their ecological community or in some way mutilated, there may be danger of altering the usual growth pattern of the fish and, hence, presenting an unreal picture of this pattern.

Length-frequency methods are based on the premise that fish hatched at about the same time tend to be more nearly the same size than are fish hatched at distinctly different times. Length-frequency determinations are especially useful in tracing the growth of fish-of-the-year during their first season. This method may continue to be useful in subsequent seasons, but as time progresses the degree of overlapping of the distribution curves of each year class or group increases. As a result, the effectiveness of the method decreases.

Determination of age by the interpretation of the growth of skeletal elements involves the identification of annular marks. It is assumed that the marks are formed once and only once each year, and that when they are formed they then remain discrete throughout the life of the individual. It is also assumed that there is a discoverable relationship between the growth of the part (or a portion thereof) used for the determination of age and the growth of the fish as a whole (usually the increase in length). Scales, otoliths,

opercles, dentaries, vertebrae, fin elements, and various portions of the pectoral girdle and skull have been used. The scales are, because of relative ease in handling, the most convenient and most often used. The great advantage of this method is that the growth history of an individual fish, reared in the wild under natural conditions and otherwise unimpared in its growth or movements, can be determined. Furthermore, if scales are used, the fish need not be killed. Often, however, growing conditions are such that either a multiplicity of "annular" marks are laid down each year or no such marks are produced. Then, too, individual annular marks may be omitted or otherwise laid down in an irregular fashion.

The scale method was used in the determination of the age and growth of P. plebeius, and, hence, a knowledge of the nature of their scales is critical. The scales of P. plebeius are cycloid, that is they lack ctenii, small spines, on their posterior portion. In general, this type of scale is found on fishes that have soft-rayed fins. Ctenoid scales are usually associated with fishes that have spiny-rayed fins. All scales originate as the cycloid type, but in most spiny-rayed fish ctenii develop (Rounsefell and Everhart, 1953, p. 303). Both cycloid and ctenoid scales are composed of two layers, an upper, bony layer and a lower, fibrous layer. It is on the upper layer that the surface features, those that are important in age determination, are found. These features include the circuli, concentric ridges about the central focus of the scale, and the radii, which in the scales of P. plebeius are enclosed canals, rather than simple grooves, that radiate out from

the focus and extend to the margin or periphery of the scale. Not all of the radii originate at the focus. Some arise between the focus and the margin. Compared with other species, *P. plebeius* has scales with numerous radii. With respect to an individual scale, radii are more numerous in the anterior portion of the scale than in the posterior and least numerous in the dorsal and ventral portions. As the scales grow, they lose their circular shape and become more rectangular. This change in shape is probably the effect of increased crowding of the scales. Imaginary lines that extend from the focus to the four corners divide the surface of the scale into quadrants or fields: anterior, posterior, dorsal, and ventral. Annuli or annular checks appear as interruptions in the spacing and form of the circuli.

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Chapter II

HISTORICAL SURVEY

The Rio Grande mountain sucker was first described by Baird and Girard (1856) and designated *Catostomus plebeius*. The description was based on eight specimens collected during the U. S. and Mexican Boundary Survey of 1851. Girard (1859) reclassified the fish and placed it in the genus *Minomus*. Jordan (1886) changed it to the genus *Pantosteus*:

> The type of *Catostomus plebeius* is a *Pantosteus*, allied to *P. generosus*, but with the scales before the dorsal larger.

There have been no age and growth studies of fish in the genus *Pantosteus*. However, studies of this nature within the Catostomidae include those by Stewart (1926) and Spoor (1938) on the white sucker, *Catostomus commersoni* (Lacépède); Underhill (1940) on the chub sucker, *Erimyzon oblongus oblongus*; Raney and Lachner (1946) on the rustyside sucker, *Moxostoma hamiltoni* (Raney and Lachner); Raney and Lachner (1946) on the northern hog sucker, *Hypentelium nigricans* (LeSueur); Brown and Graham (1954) on the longnose sucker, *Catostomus catostomus* (Forster); and Bucholz (1957) on the river carpsucker, *Carpiodes carpio* (Rafinesque).

The technique of age determination by a study of a fish's scales was first used by Antony van Leeuwenhoek (1686, cited from Van Oosten, 1929, p. 276) in connection with a study on the scales of the eel. The potentialities of this technique were not completely realized, however, until Hoffbauer (1898, 1900, 1901, 1904, 1905, 1906, cited in Van Oosten, 1929, p. 294) did experimental work on the carp. He is generally credited with being the first to apply successfully and convincingly the

scale method in age determination. Literature on this topic is voluminous, and a survey of it is not within the scope of this paper. Some of the more useful studies and literature surveys are those by Lee (1920), Creaser (1926), Van Oosten (1929), Neave (1940), Hile (1941), and Beckman (1942).

Chapter III

MATERIALS AND METHODS

This study was based on an examination of 744 specimens, 290 juveniles, 244 males, and 210 females, of the Rio Grande mountain sucker taken from Jemez Creek, Sandoval County, New Mexico. The 244 males and 210 females include both subadult and adult specimens. Three collections were made; each from the same site, 2 miles above the entrance of Guadalupe Creek. The first collection was made by Professor William J. Koster and Dr. K. R. Coburn on May 29, 1949; the second by Professor Koster, Mr. Robert Bradley, and myself on November 25, 1960; and the third by Professor Koster and a class of students on May 19, 1961. The fish collected in 1949 were picked up from the stream bank and were in a state of partial decomposition. The other two collections were made with a Power Bug electric shocker, which was used in conjunction with a 4-ft x 10-ft seine of $\frac{1}{4}$-inch mesh and small, hand-held dip nets. The seine was stretched across the stream downcurrent from the electrodes. When the fish were stunned from the electric shock, they were swept downstream and collected in the seine. Fish that remained on the bottom were collected with the aid of the dip nets, or simply dislodged and then carried by the current into the seine. Juvenile fish were collected in the shallows with a small seine of finer mesh without the aid of the shocker.

The specimens were hardened in a 10% solution of commercial-grade formalin for a period of 2 days after which they were washed in tap water for another 2 days and finally placed in a 70% solution of ethyl alcohol. There was no apparent decalcification of the scales from the

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Sexing, measuring, and tagging were done in one operation. The sex and the state of maturity of the fish were determined by an examination of the gonads. Three distinctions were made with regard to state of maturity: juvenile, subadult, and adult. For the males, color, size, and shape of the gonads were the criteria used in determining the state of maturity. The criteria for the females were the color and size of the ova. In general, if the condition of the gonads prevented determination of sex by macroscopic examination, the fish was classified as a juvenile. If by such an examination the sex could be determined, but the development of the gonads indicated that the fish would probably not be ready to spawn during the next spawning season or had never spawned, the fish was classified as a subadult. If, however, the gonads indicated that the fish would be ready to spawn at the next spawning period or had already spawned, the fish was classified as an adult.

Measurement of standard length, rather than fork length or total length, was chosen because the caudal fins of many of the specimens (especially the dead specimens collected in 1949) were damaged. Each fish was placed on a board, extended to its full length, and the measurement then made with a pair of dividers. One point was placed at the line of flexure at the end of the caudal peduncle, just posterior to the hypural plate, and the other at the tip of the snout. The distance between the points of the dividers was measured on a millimeter scale. This method was selected because it was convenient to apply to juvenile fish. After determining the sex, state of maturity, and

length of the specimen, a small numbered tag was tied on the caudal peduncle, and the data recorded on a 3-in x 5-in index card.

The scale method was used to determine the age of all of the specimens except those which were easily distinguished as first-year juveniles by size alone. The determination of a site for taking scales, the selection and preparation of scales taken from this site, and the examination of scales so prepared are basic steps in the application of this method.

The site from which scales were removed was selected by preliminary studies on scale formation and appearance. Juvenile fish ranging in size from 23 to 51 mm (average 31 mm) were examined. Because all of the scales on these fish were not grossly visible, the bony structures were stained following the technique of Hollister (1934). A subsample of 10 of the 290 juveniles was first treated with a dilute solution of KOH and irradiated with ultraviolet light to clear the epidermis, then stained in a basic, alcoholic solution of alizarine. When the larger members of this subsample were examined, they were found to have a full complement of scales along the lateral line. In the smallest specimens of this group, scales were found in a strip that extended along the sides from halfway between the tip of the snout and the origin of the dorsal fin to a region halfway between the insertion of the dorsal fin and the caudal peduncle. This strip was from a few, at the ends, to about a dozen, in the middle, scale-rows wide. In the region selected for scale removal, the standard length of the fish when scales are initially formed is thought to be between 10 and 20 mm. This length is suggested by the graphs of scale growth

(Figs. 50, 51, 53, 55) plotted on growth in standard length. When the length of the median-anterior radius of the scale is represented on the ordinate and the standard length of the fish on the abscissa, the resulting slope intersects the abscissa at a point to the right of the origin which represents a standard length of 18 mm (Fig. 50). Creaser (1926, p. 55) and other workers have noted similar phenomena in other species. As a result of this preliminary investigation, a site on the left side just above the lateral line and directly below the origin of the dorsal fin was selected for scale removal. Six scales were taken from each fish.

After the scales were removed, they were placed in water and cleaned. Scales that showed evidence of regeneration, distinguished by a checkered central portion (Figs. 12, 38); extensive "central resoprtion," which appeared as an irregular, clear area at the focus (Fig. 37); or rotation of the focus (Fig. 14) were rejected and others substituted so that six "normal" scales were mounted on each slide. Apparently the circuli near the focus of these scales can be resorbed, removed, or obliterated in some other fashion. This phenomenon seems to affect only the outer layer of the scale (that layer on which are produced the circuli). When probed with the tip of a dissecting needle, the inner layer is, at least in part, intact. A scale with a focus in such a condition is extremely flexible. Whether this added flexibility is in some way beneficial to the fish or simply a by-product of metabolic recycling of the scale substance is not known. Careful selection of the scales was imperative because as many as 25% of the scales from some of the fish showed signs of regeneration.

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After the scales were cleaned, they were placed in a drop of water on a standard microscope slide and oriented in rows to facilitate measuring. Excess water was blotted from the slide with a small roll of cheese cloth, and with a glass rod brown Karo syrup was dropped on the scales, and a cover slip was set in place. Best results were obtained when the upper surfaces of the scales were allowed to remain moist after blotting. This prevented air bubbles from being trapped between the circuli of the scales when the cover slip was set. Waterproof glue was applied to the edges of the cover slips.

A Bausch and Lomb Tri-Simplex microprojector, which provided a magnification of 56X, was used in reading the scales. The distances of the annuli and of the margin of the anterior field from the focus were measured along the midline of this field and marked on 2-in x $4\frac{1}{2}$-in slips of paper. Every scale on each slide was read and measured six times. To facilitate recording, the slips of paper marked with the slide number were folded after each measurement, and the next measurement was then marked on the folded edge. In order to minimize any bias that might occur, the slips were kept separate from the data cards, and the latter were not consulted at this time. The six series of measurements on the slips of paper were translated into millimeters and averaged. These averages, one for each annulus and one for the margin, were recorded on the data cards. Because there is little appreciable growth between November and June, the margin in all three collections approximately corresponded to the last annulus.

Chapter IV

RESULTS AND DISCUSSION

The scales of P. plebeius are all of the cycloid type (Figs. 1-38). They cover the entire body with the exception of the fins and head. During the first year of life, the scales are roughly circular with their foci closer to the anterior than to the posterior margins. (For convenience in the discussion, fish will be designated first year, second year, third year, etc. if they had completed or were in their first-, second-, or third-growing season at the time of their capture.) At this stage of growth the scales are translucent, and they remain so for the first four years. However, from the fifth year on, unless central resorption has occurred, they become progressively more opaque, especially near the foci.

Radii are found in all four quadrants of the scales. Most originate at or near the focus, primary radii, while many, secondary radii, arise throughout the entire distance from the focus to the margin. Thus as the scale grows, the radii become more numerous. Often radii arise at an annulus. In other forms, this has been used in annulus identification; however, in P. plebeius this situation occurred with such irregularity that it was of little value in determining age.

The circuli also extend through all four quadrants. In the anterior field of the scale, which remains smaller than the posterior field throughout the entire life of the fish, the circuli show more pronounced, cyclic variation in the distance that separates them. It was here that the annuli could best be identified, although they

could, with some difficulty, be traced around the entire scale.

Characteristics that define an annulus include approximation, cutting across, and marginal calcification. The phenomenon of approximation was the most consistent, distinguishing characteristic of the annuli. Approximation is the periodic reduction in the distances separating consecutive circuli. This reduction is associated with a reduction in growth rate. The recognition of annuli by means of approximation became more difficult as advanced ages were reached; in the sixth and seventh years only a few circuli may be laid down each year. However, cutting across could often be detected at the junctions of the anterior field and adjacent fields. After scale growth begins or increases in the spring, the first circulus formed abuts against the ends of incompleted circuli formed during the preceding fall or winter. This is most distinct in the first, second, and third annuli, but, as it appears in the scales of *P. plebeius*, it is not as distinct as it is in the scales of certain other species. In the fifth, sixth, and seventh years, calcified ridges often distinguish the annuli. Apparently during the winter calcium salts continue to be deposited at the periphery of the scales even though change in the diameter of the scale is negligible. This deposition is most apparent at the anterior field. Another possible explanation of the marginal calcification is that it is associated with marginal resorption that occurs in the scales of some fish during periods of severe stress. Such an explanation was not supported by the measurements of the *P. plebeius* scales. On some

scales, annuli that were produced as a result of this process were formed so closely together that age determination became extremely difficult. None of the above criteria by itself was sufficient in every case to distinguish an annulus, but when used together, they provided an effective means of age determination.

Incidental check marks are marks that resemble annuli but are not formed as the result of the annual, winter reduction in growth rate. One of the most consistent characteristics that distinguish them from "true" annuli is that they seldom extend completely around the scale. In the scales examined, sometimes a mark was found that in all discernible respects resembled an annulus, but was out of phase with corresponding annuli on other scales taken from fish of the same year class. In such a case, the mark could have been an <u>incidental check</u>, the result of disease or parasitism or some similar stress that caused a temporary retardation of growth. If this aberrant position appeared in all of the fish of a given year class (Table 6), it was assumed to be the result of unusual growing conditions. If, however, its position were unique, it could be judged only on its form.

Sometimes a scale rotated partially in its pocket. This usually occurred only during the first two years of life. If it happened at any time other than late winter or early spring when annuli were forming, rotation produced an incidental check. Such marks were easily distinguished from annuli by the unusual orientation of the central portion with respect to the rest of the scale (Fig. 14).

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became so closely crowded together that as they grew they fused to one another. Figure 16 is a photograph of two scales that coalesced along their lateral margins. This union occurred near the end of the first year of growth, and in subsequent growth the circuli produced became aligned and continuous.

Because the scale method has been shown to be inapplicable to some species of fish or sometimes ineffective in age determination when used on fish living in certain environments, it must, when applied to a species for the first time, be demonstrated to provide consistent and valid results for this species. Van Oosten (1929, p. 278) described certain criteria that should be met for the effective application of the method:

> 1. That scales remain constant in number and identity throughout the life of the fish.
>
> 2. That the annual increment in the length (or some other dimension which must then be used) of the scales maintains, throughout the life of the fish, a constant ratio with the annual increment of body length.
>
> 3. That the annuli are formed yearly and at the same time each year.

These requirements were used as a guide to the interpretation of the scales of P. plebeius.

Pantosteus yearlings collected in November 1960 were examined for the presence, location, and number of scales on the body (see above). Scales were removed from eight of these fish (Fig. 1) and mounted on slides. The distance from the focus to the anterior margin was measured along the midline. The average of these measurements closely agrees with the average value for the distances of the

first annuli from the foci measured on the scales of the advanced-year classes (Table 6). Furthermore, the appearance of these fish-of-the-year scales closely resembles the appearance of the central portions, contained within the first annuli, of the scales from fish of advanced age (Figs. 1-38). Thus, the scales retain their identities throughout the life of the fish.

In P. plebeius, increment in length of the anterior-median radius of the scale does not maintain a constant ratio with the annual increment in standard length (Figs. 49-55), but relative growth of these parts is predictable as these figures (the slopes of Figures 51-55 were determined by the least-squares method) illustrate. The difference in the points at which the slopes of these graphs intersect their axes is due to the difference in the size-groups represented rather than to variation in growth characteristics among the collections. When smaller size-groups are included, the slope intersects the abscissa somewhere between 10 and 20 mm. When they are not included, the slope intersects the ordinate at a point which is again dependent upon the size-groups included. The relationship between increase in the length of the anterior, scale radius and increase in standard length when plotted as absolute growth (Figs. 50-55) cannot accurately be expressed as a straight line. Neither a simple, proportional expression, the dotted line in Figure 50, nor an adjustment of this expression to account for an intercept between 10 and 20 mm on the abscissa gives close enough approximation of the growth relationship to be useful. Increase in the length of the anterior field of the scales when compared to the increase in standard length is first

relatively rapid, until the end of the fourth growing season, and thereafter less rapid. That is, the decline in the growth rate of this portion of the scale (Figs. 47, 48) is more rapid after the fourth growing season than is the decline in the growth rate of body length (Figs. 45, 46). Figure 49 (log-log plot) is the best expression of the relationship; the graph is a sigmoid curve. First the rate of the relative growth of the scale at the anterior margin increases, then it decreases with respect to relative increase in standard length. The curvilinear expression does not rule out the use of the scale method in the determination of age or growth history. Figure 49 can be used directly to calculate lengths during previous years if the length of the fish at the time of capture and the length of the scale radius are known. If the values for the average distance of each annulus from the focus given in Table 6 are applied to the curve in Figure 49, the determined standard length that corresponds to the annulus chosen compares closely to the mean standard length from Table 5 of fish of this age. For example, the average distance from the focus to the first annulus on scales taken from fifth-year fish collected in November 1960 was 6.2 mm for both males and females. If this value is applied to the curve in Figure 49, it is found that the corresponding standard length is approximately 31 or 32 mm, a value that compares closely with the first-year standard lengths of 31.7 mm and 34.9 mm (Table 5). This procedure, of course, works as well with individual scales. The length of the fish at any age during any season can be determined.

Annuli are formed in late April or early May. The term annulus

is here limited to mean a line on the scale interior (toward the focus) to which approximation and similar phenomena have been completed and exterior (toward the margin) to which the rate of growth, as reflected in the spacing of the circuli, has been increased. Such marks are laid down once each year and they indicate a periodic decrease or cessation of growth. The time of annulus formation in the Jemez Creek population of Pantosteus was determined by an examination of scales from all three collections. Scales from fish of the third- and fourth-year classes proved to be the most valuable in this determination. The scales from about 10% of the fish collected on May 29, 1949, showed an increase in the spacing of the circuli exterior to a line that marked the culmination of approximation. A few scales from the fish collected on May 19, 1961, showed such an increase. On the other hand, most of the scales from fish collected on November 25, 1960, exhibited increasing approximation of circuli. Annulus formation, then, is begun in the fall and completed in the spring. This agrees with Beckman's findings for certain Michigan game fishes (Beckman, 1943).

Perhaps the most critical question that must be answered in any application of the scale method is whether or not the results present a logical and accurate picture of age and growth for the form under consideration.

All of the fish collected were aged either by the length-frequency (juveniles) or the scale (subadults and adults) method. As there was no overlap in the length-frequency distributions of the first-year fish and fish in subsequent year classes (Figs. 39-42), is more limited to form a line on the scale interior (toward the focus) to which approximation and similar phenomena have been completed and exterior (toward the margin) to which the rate of growth, as reflected in the spacing of the circuli, has been increased. Such marks are laid down once each year and they indicate a periodic decrease or cessation of growth. The time of annulus formation in the Jemez Creek population of *Pantosteus* was determined by an examination of scales from all three collections. Scales from fish of the third- and fourth-year classes proved to be the most valuable in this determination. The scales from about 10% of the fish collected on May 29, 1949, showed an increase in the spacing of the circuli exterior to a line that marked the culmination of approximation. A few scales from the fish collected on May 19, 1951, showed such an increase. On the other hand, most of the scales from fish collected on November 25, 1950, exhibited increasing approximation of circuli. Annulus formation, then, is begun in the fall and completed in the spring. This agrees with Beckman's findings for certain Michigan game fishes (Beckman, 1943).

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The specimens were measured, sexed, and aged. Their frequency distributions and absolute and relative growth were then plotted (Figs. 45, 46) and certain phenomena became apparent; there occurred a sexual dimorphism with regard to length; females lived longer than males; maturity in both males and females took place at about the same time; and the onset of senescence occurred sooner in males than in females. These topics will be discussed.

After the second growing season, at which time a sexual dimorphism in length was negligible, if present at all, the differences between the average standard lengths of males and females increased slightly. The average standard lengths of males collected in November 1960 were 68.4 mm, 87.8 mm, 109.3 mm, and 117.7 mm for the second-, third-, fourth-, and fifth-year classes respectively. The average standard

lengths of the females collected at the same time were 69.7 mm, 89.7 mm, 110.2 mm, 130.7 mm, 142.6 mm, and 162.0 mm for the second-, third-, fourth-, fifth-, sixth-, and seventh-year classes respectively. First-year fish averaged 31.7 mm in standard length. The numbers of males and females in each year class are given in Table 1. At the end of the second growing season, the females had gained a slight advantage in length. This advantage remained more or less constant until the end of the fourth growing season. At this point a decrease occurred in the absolute growth rate of the males while this rate in the females remained constant for another year before a similar decrease occurred (Fig. 45). Although no fifth-year males were collected in May 1961, the situation appears to be similar for this group (Table 5). The initiation of sexual dimorphism in P. plebeius is probably coupled with the onset of sexual maturity, and the terminal reduction in the growth rate of the males, one year sooner than in the females, serves to accentuate this initial difference.

In all three collections, the oldest fish were found to be females. The percentages of survival of the males and females (the number in each year class compared to their total number in the collection) collected in November 1960 and in May 1961 are listed in Table 3. In interpreting this table, it must be remembered that poor representation of the second-year fish in both collections causes representation, when expressed as percentages of other year classes, to be disproportionately high. If conditions were constant from year to year, representation of second-year fish would be expected leg[illegible]

89 [illegible]

thir[illegible]

Fifty-seven [illegible]

males and females [illegible]

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to be much larger, smaller than that of the first-year but larger than that of the third-year fish. Judging from the November 1960 and May 1961 collections, the time of greatest mortality for both males and females, after initial juvenile mortality, was probably during the fourth year (Table 1, 2, 3). (Specimens collected in May 1961 were taken just before spawning had occurred.) The third-year class includes 78% of all the males and 65% of all the females; only 12% of the males and 12% of the females comprise the fourth-year class (Table 3). However, in the May 1949 collection, 93% of the males and 92% of the females were fish four full years of age or older. This collection, because it is the result of a post-spawning die-off, is not, of course, directly comparable with the others, but the greater proportion of fish represented in the fourth-year class suggests that conditions for survival were better for the 1949 group. Within each group, although survival over the fourth year was probably higher in the 1949 collection, beyond the third-year class females survived in greater numbers than did males. There is evidence that this greater survival is associated with a greater mortality of the males after spawning.

Spawning has been observed in the spring but never in the fall of the year in the Jemez Creek population of P. plebeius (Koster, personal communication). These observations were supported by length-frequency distributions for each year class (Figs. 39-44). The distributions are typically unimodal rather than bimodal. The bimodal condition would be expected if spawning occurred both in the spring and fall as it does elsewhere with P. plebeius (Koster, 1957, p. 46).

The length-frequency distributions of the juveniles from the November 1960 and May 1961 collections are, however, somewhat skewed to the right. This could possibly be the result of a gradual build-up to a spawning peak, which occurred sometime after the middle of the spawning period, and after which an increasingly rapid decrease in spawning activity took place. Skewing to the right is less pronounced in the more advanced age groups (third-year class of the males and females of the November 1960 collection) and breaks down in the oldest groups. The breakdown of such a distribution pattern in groups beyond the third class might be due to differential survival, especially after spawning. Faster growing individuals within a group tend to die sooner than their slower growing companions (Comfort, 1961, p. 118). If the average standard lengths of the males and females of each year class from all three collections are compared (Table 5), it becomes apparent that the averages from the May 1949 collection are higher for both males and females in the third-, fourth-, and fifth-year classes. The differences between the averages of the 1960-1961 collections and those of the 1949 collection diminish as the age of the groups increases. Beyond the fifth-year class, no significant difference is noted. Either environmental conditions were more favorable during the time fish in the respective year classes of the 1949 group were growing (they would necessarily have been increasingly better for the fifth-, fourth-, and third-year classes), or there was a greater tendency for the more rapidly growing fish of each year class to die. The latter explanation is probably the better.

In Jemez Creek, almost all of both male and female P. plebeius spawn after completing three growing seasons. Four lines of evidence support this view. First, by an examination of the gonads of the three-year fish collected on November 25, 1960, and May 19, 1961, it was found that these three-year fish were mature; that is, they would spawn during the next spawning season. Second, three-year fish were included in the collection of dead, spent fish taken from the stream bank on May 25, 1949. Third, there occurred a relatively sharp reduction in the absolute growth rate of both male and female fish during their third growing season (Fig. 45). Such a reduction at this stage of life is typically associated with the onset of sexual maturity. Fourth, there is a critical reduction in the numbers of both males and females between the third- and the fourth-year class. This reduction, at least in part, is probably associated with the advent of spawning at the end of the third year. None of these lines of evidence applies to the first-year class, all of which were subadult. One male, the smallest, and one female, the second smallest, from the November 1960 collection and two males and five females from the May 1961 collection were classified as subadults.

The onset of senescence occurred one year earlier in the males than it did in the females. As stated above, this physiological change, expressed as a reduction in the absolute growth rate, took place during the fifth growing season in the males and during the sixth in the females of the November 1960 collection (Fig. 45). The annual increment in growth for both males and females dropped from

approximately 20 mm per year to about 10 mm per year. Despite this reduction, both males and females continued to spawn. The gonads of both the oldest males and the oldest females in the November 1960 collection were approaching ripeness. Furthermore, the gonads of the oldest members of both sexes in the May 1949 collection were found to be spent. No males were found to be older than the sixth-year class, and no females were older than the seventh-year class.

The type of fishing equipment and the way in which it was used may have had an effect on the numbers and the sizes of fish caught. Electric shocking is more effective on larger than on smaller fish, and more effective in shallow, quiet water than in deep, swift water. Because the stream bed was extremely rough and the water so swift in the riffles that seining alone was ineffective, the use of the shocker was necessary. Because Jemez Creek is an important trout stream, other collecting methods involving poison, dynamite, or the obstruction or diversion of the stream's course had to be rejected. Whether selectivity against smaller fish was, in fact, a reality, is doubtful. The average standard length of the second-year fish was 68 mm. Such an average suggests that all of the fish in the second-year were well within the effective capacity of the shocker. An attempt was made to extend the fishing effort to include all habitats, but because of possible variability in the effectiveness of the shocker under different water conditions consistency of effort can only be supposed. However, general agreement in the relative numbers of fish of each year class caught in November 1960 with those caught in May 1961 suggests that gear and method selectivity were not major factors

in the size composition of the catches. There is little chance the size composition of the May 1949 collection was biased. These fish were found lying dead along the stream bank.

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Chapter V

SUMMARY

1. This age and growth study was based on the examination of 744 specimens: 290 juveniles, 244 subadult and adult males, and 210 subadult and adult females, collected at Jemez Creek, Sandoval County, New Mexico.
2. The ages of all of the specimens collected were determined. Both the length-frequency method and the scale method were used in these determinations.
3. The oldest females captured had completed seven growing seasons; the oldest males had completed six.
4. Both males and females became sexually mature and spawned after three full years of life. Spawning in this population of Pantosteus occurs in the spring (May). The greatest number of spawners are fish that have completed three growing seasons, fish of the third-year class.
5. Sexual dimorphism with regard to length appeared after two growing seasons. Females were larger than males. The onset of senescence occurred one year earlier in the males, in the fifth growing season, than it did in the females. This condition, expressed as a relatively sharp reduction in growth rate, accentuated the sexual dimorphism.
6. The average lengths attained by the end of each growing season are 33 mm, first-year juveniles; 66 mm, second-year males; 71 mm, second-year females; 87 mm, third-year males; 89 mm, third-year females; 109 mm, fourth-year males; 110 mm fourth-year females;

118 mm, fifth-year males; 129 mm, fifth-year females; 134 mm, sixth-year males; 143 mm, sixth-year females; and 159 mm, seventh-year females.

Table 1. Numbers of males and of females in each year class from each collection; juveniles included.

Numbers of Individuals

Collection*	Sex	Year Class 1	2	3	4	5	6	7
A	Male	242	7	120	20	10		
	Female		12	86	16	13	5	2
B	Male	48	2	22	1			
	Female		6	34	5	3	3	
C	Male			4	44	9	5	
	Female			2	6	4	11	1

Table 2. Number of individuals in each year class from each collection; expressed as percentages.

Percent of Group

Collection	Year Class 1	2	3	4	5	6	7
A	45.4	3.6	38.6	6.8	4.3	.9	.4
B	38.4	6.4	44.8	5.6	2.4	2.4	
A&B	44.1	4.1	39.8	6.5	3.9	1.2	.3
C			7.0	58.1	15.1	18.6	1.2

* In all tables, the letters A, B and C designates the collections made on November 25, 1960, May 19, 1961, and May 25, 1949 respectively and combinations thereof.

Table 3. Number of males and of females in each year class compared to the number in the entire collection; expressed as percentages; juveniles excluded.

Percent of Group; Sexes Treated Separately

Collection	Sex	Year Class 2	3	4	5	6	7
A	Male	4.5	76.4	12.7	6.4		
	Female	9.0	64.2	11.9	9.7	3.7	1.5
B	Male	8.0	88.0	4.0			
	Female	11.5	65.4	11.5	5.8	5.8	
A&B	Male	4.9	78.0	11.5	5.4		
	Female	9.7	64.5	11.8	8.6	4.3	1.1
C	Male		6.5	71.0	14.5	8.1	
	Female		8.3	25.0	16.7	45.8	4.2

Table 4. Sex ratios for each year class of each collection; expressed as percentages; juveniles excluded.

Sex Ratios Expressed as Percentages

Collection	Sex	Year Class 2	3	4	5	6	7
A	Male	37	58	56	39	0	0
	Female	63	42	44	61	100	100
B	Male	25	43	14	0	0	0
	Female	75	57	86	100	100	100
A&B	Male	33	55	49	38	0	0
	Female	67	45	51	62	100	100
C	Male		67	88	69	31	0
	Female		33	12	31	69	100

Table 5. Mean standard lengths of males and of females for each year class of each collection; juveniles included.

		Mean Standard Length in Millimeters						
Collection	Sex	Year Class						
		1	2	3	4	5	6	7
A	Male	31.7	68.4	87.8	109.3	117.7		
	Female		69.7	89.7	110.2	130.7	142.6	162.0
B	Male	34.9	64.5	87.0	112.2			
	Female		72.2	88.8	110.5	127.0	139.0	
C	Male			94.8	114.8	122.6	133.6	
	Female			92.5	119.5	132.6	142.5	156.0

Table 6. Position of annulus formation on the anterior-median radii of the scales.

Average Distance of Each Annulus from the Focus in mm X56

		1st		2nd		3rd		4th		5th		6th		7th	
Yr.	Col.	m	f	m	f	m	f	m	f	m	f	m	f	m	f
1	A														
	B														
	C														
2	A	6.6	7.3	24.7	25.0										
	B	7.0	8.7	27.0	26.7										
	C														
3	A	6.4	6.6	16.0	15.9	32.7	33.0								
	B	6.7	6.7	16.5	16.5	34.9	35.8								
	C	6.3	4.5												
4	A	6.5	6.3	15.3	14.7	35.8	30.8	43.8	45.8						
	B	6.0	5.5	13.0	13.8	28.0	31.2	44.0	47.3						
	C	6.8	6.8	19.0	17.3	33.9	33.5	51.1	52.8						
5	A	6.2	6.2	13.5	14.9	25.8	30.6	39.2	43.0	46.2	49.0				
	B		6.3		15.3		34.3		54.3		61.7				
	C	6.7	7.5	16.9	17.0	31.9	29.3	43.9	40.3	52.7	50.3				
6	A		5.8		12.2		22.4		42.8		50.4		56.4		
	B		7.3		17.0		40.3		45.3		50.3		55.3		
	C	6.4	6.7	18.0	17.4	34.8	32.7	48.0	45.1	55.0	53.7	61.6	60.7		
7	A		6.0		12.0		26.5		40.0		50.5		56.5		60.5
	B														
	C		7.0		14.0		26.0		38.0		45.0		51.0		58.0
Ave.		6.5	6.6	18.0	16.7	32.2	31.3	45.0	45.0	51.3	51.4	61.6	56.0		59.3
Over-all Ave.		6.5		17.2		31.6		45.0		51.3		56.9		59.3	

Figures 1 through 37 are photographs of scales taken from specimens of Pantosteus plebeius. In all of these photographs, the scales are shown at a magnification of 36 times. As the photographed scales are a random subsample of all of the scales prepared, they are typical representatives of these scales. The anterior field of the scale is at the top of the figure.

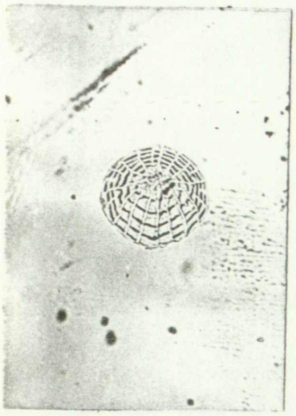


Fig. 1. 1-year scale.

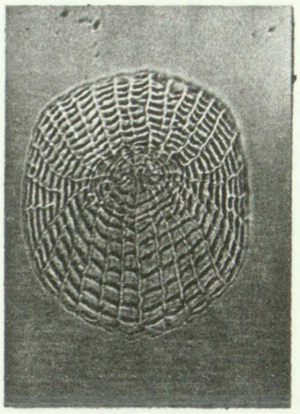


Fig. 2. 2-year scale.

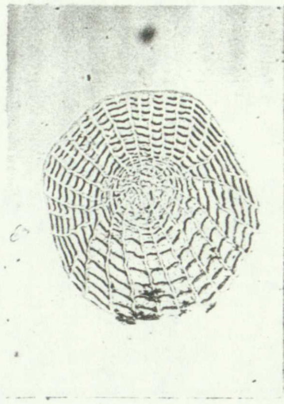


Fig. 3. 2-year scale.

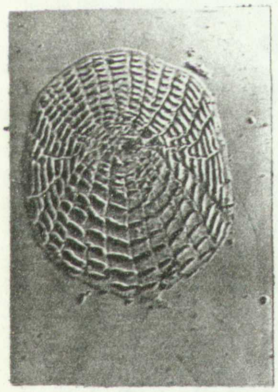


Fig. 4. 2-year scale.

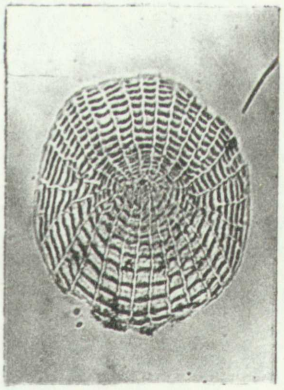


Fig. 5. 2-year scale.

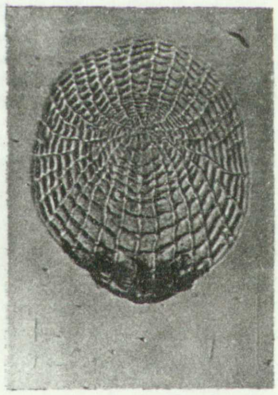


Fig. 6. 2-year scale.

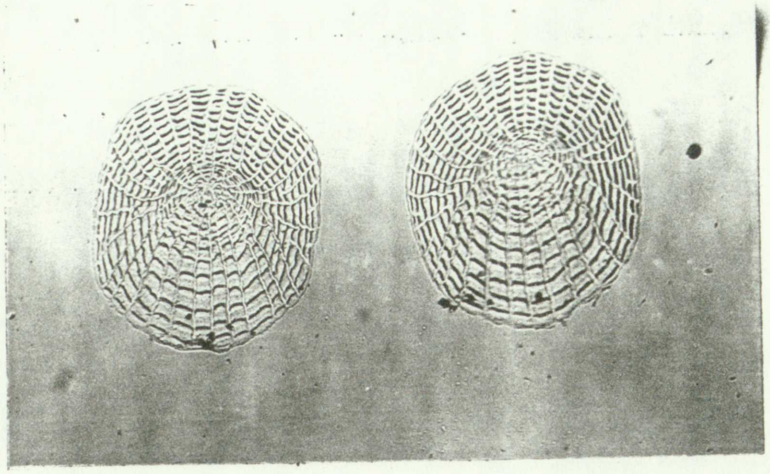


Fig. 7. 2-year scales.

Fig. 8. 2-year scales.

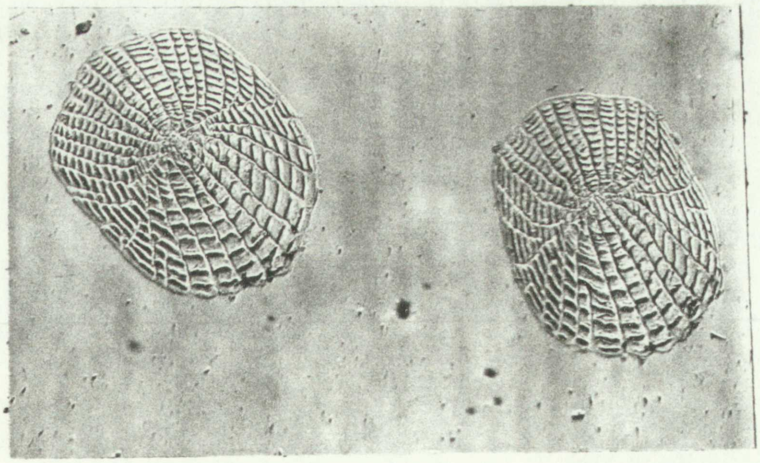


Fig. 9. 2-year scales.

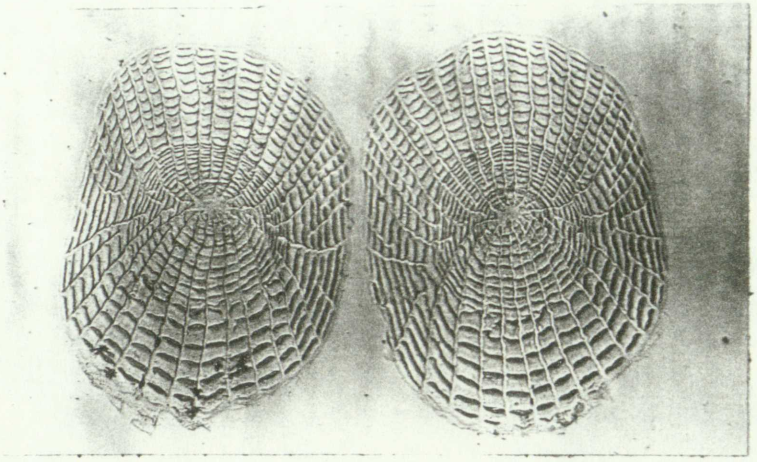


Fig. 10. 3-year scales.

Fig. 11. 3-year scales.

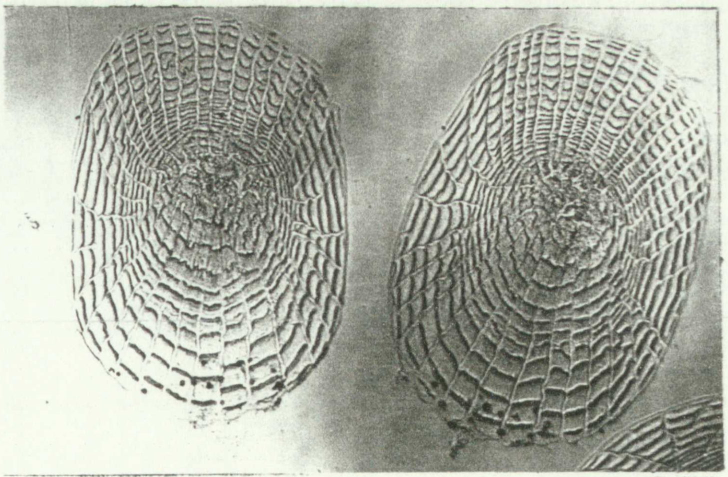


Fig. 12. 3-year scales
with regenerated foci.

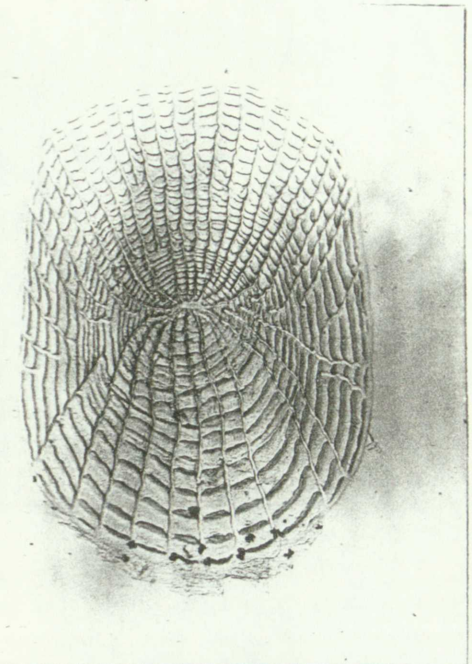


Fig. 13. 3-year scale.

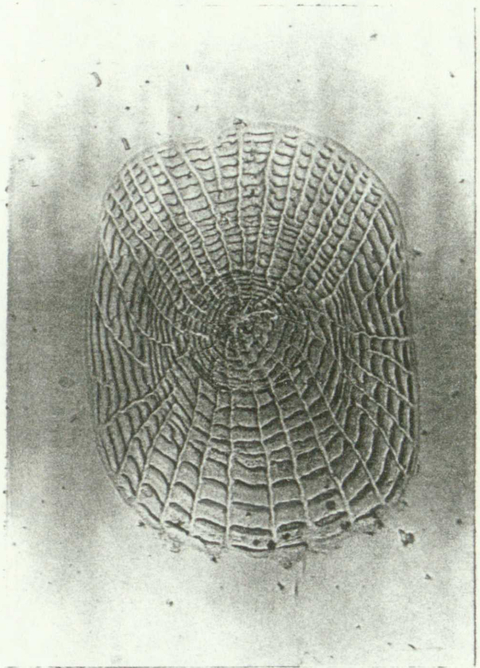


Fig. 14. 3-year scale with rotated focus.

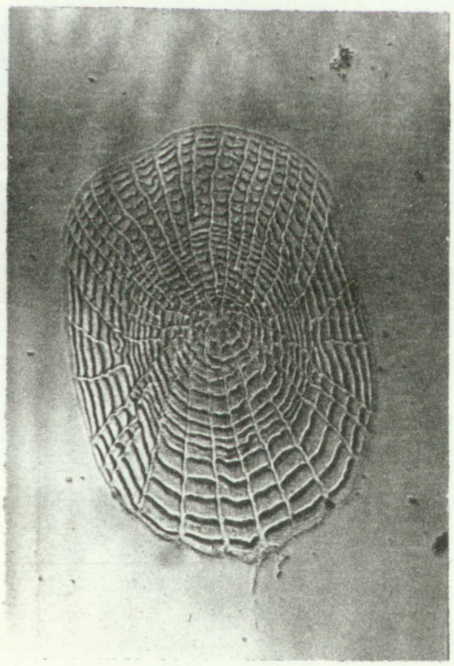


Fig. 15. 3-year scale.

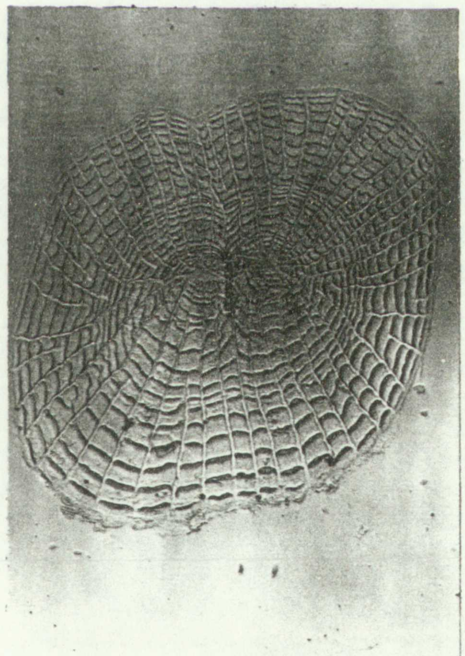


Fig. 16. Double, 3-year scale.

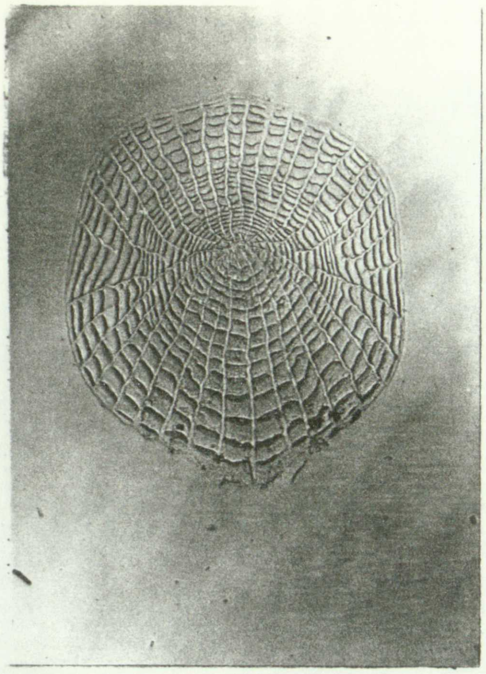


Fig. 17. 3-year scale.

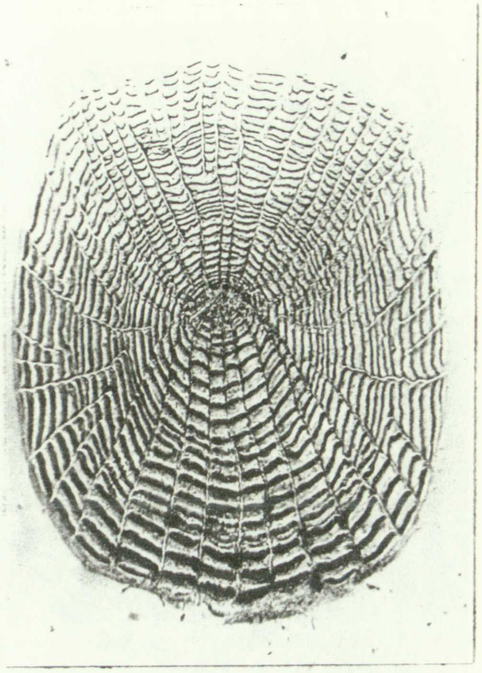


Fig. 18. 4-year scale.

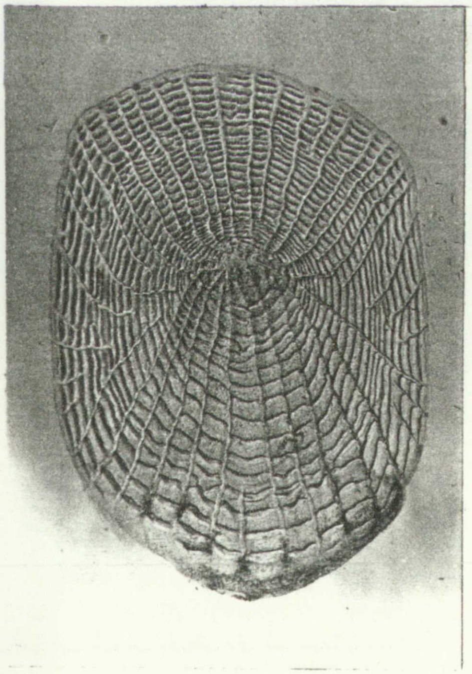


Fig. 19. 4-year scale.

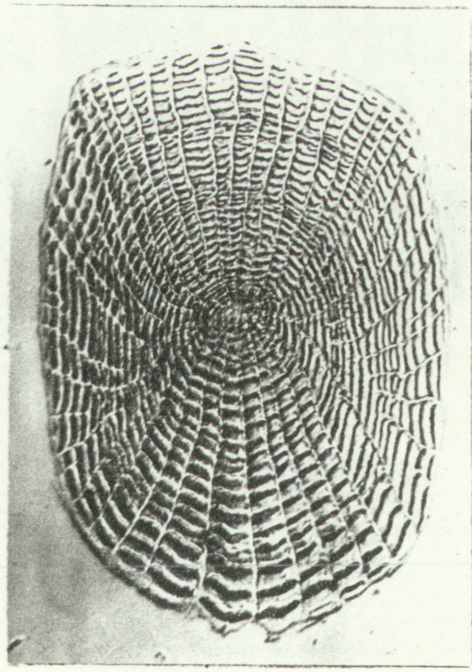


Fig. 20. 4-year scale.

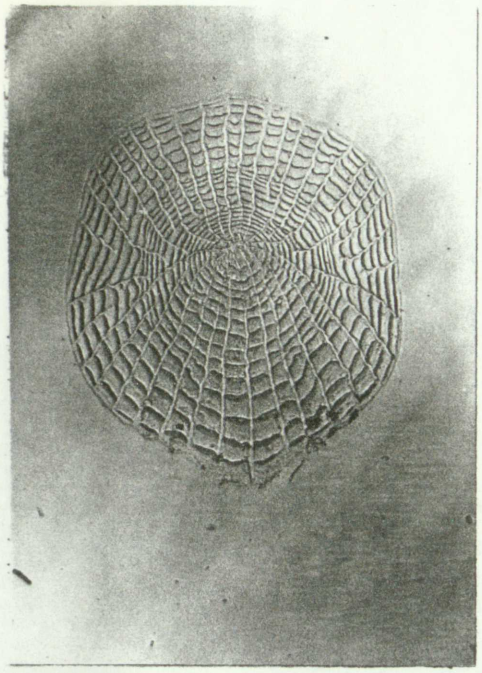
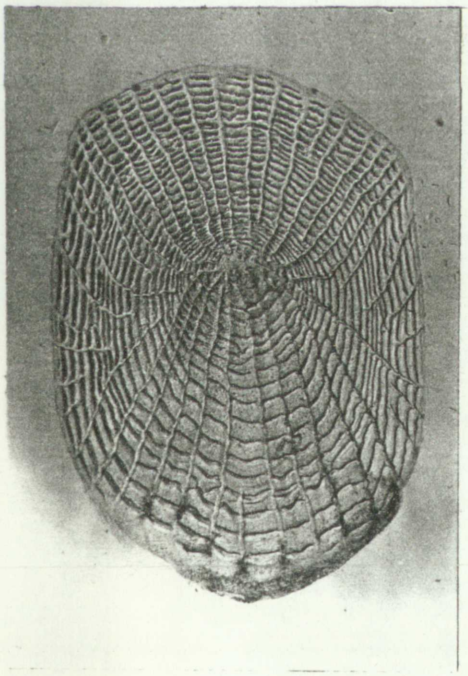


Fig. 17. 3-year scale.

Fig. 18. 4-year scale.



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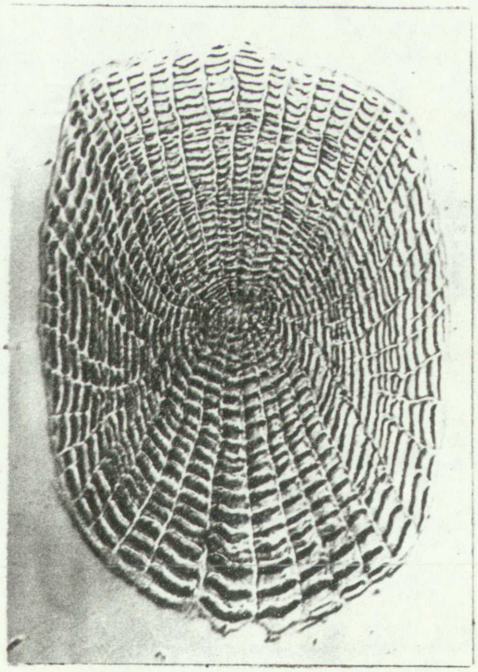


Fig. 20. 4-year scale.

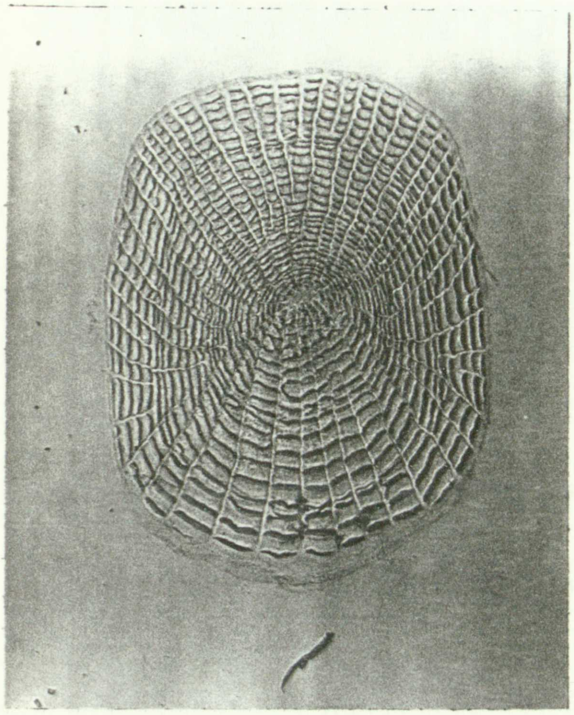


Fig. 21. 4-year scale.

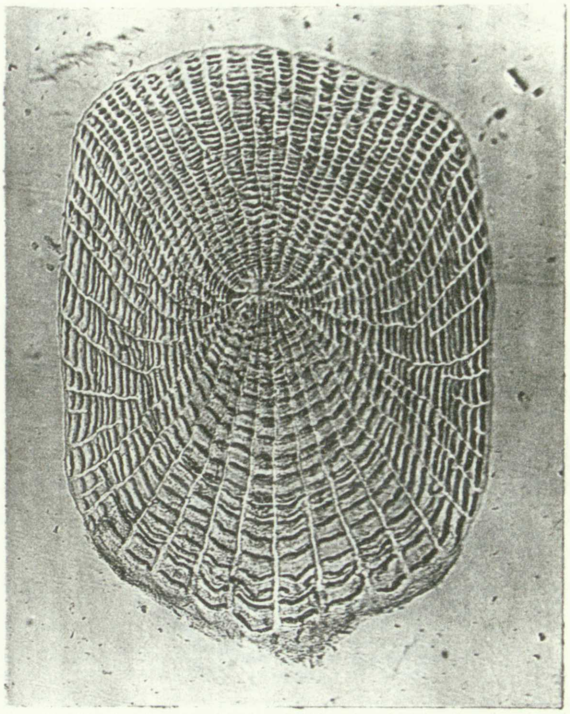


Fig. 22. 5-year scale.

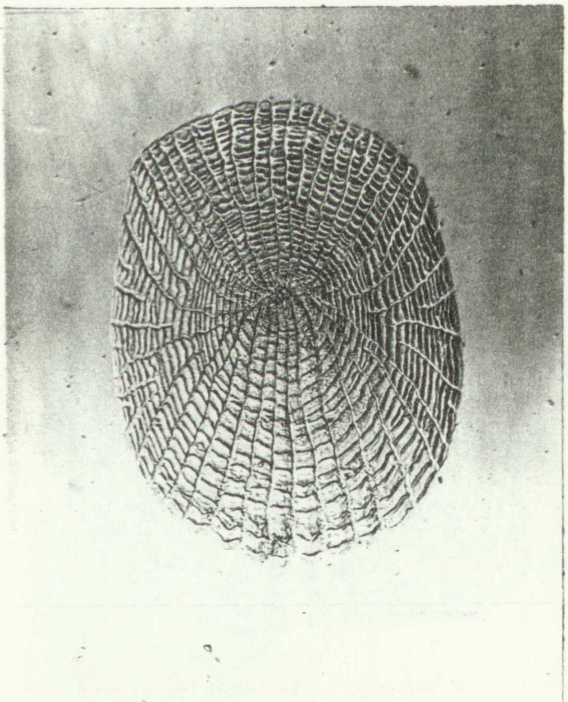


Fig. 23. 5-year scale.

Fig. 24. 5-year scale.

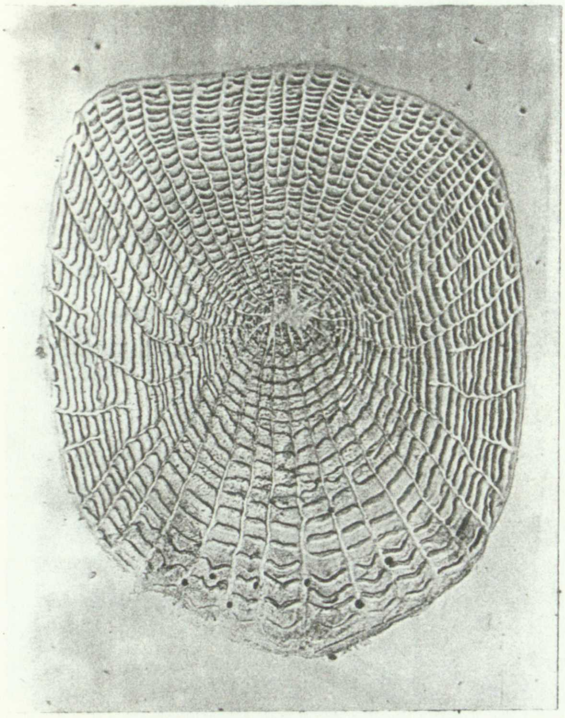


Fig. 25. 5-year scale.

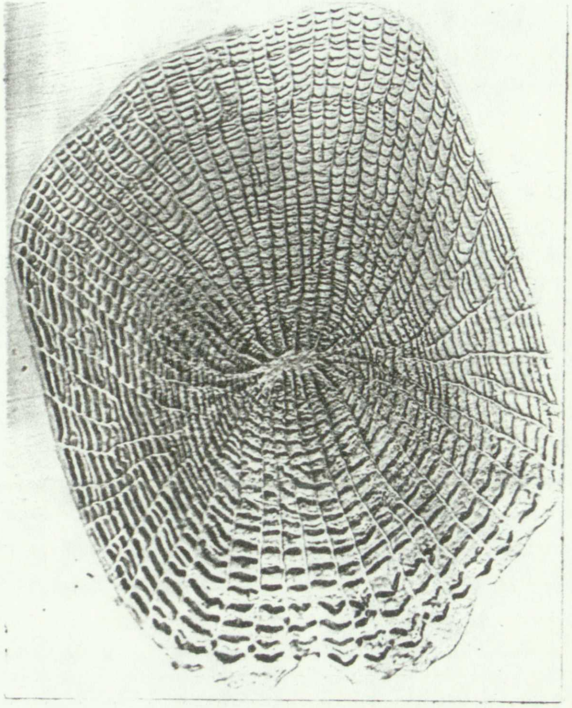
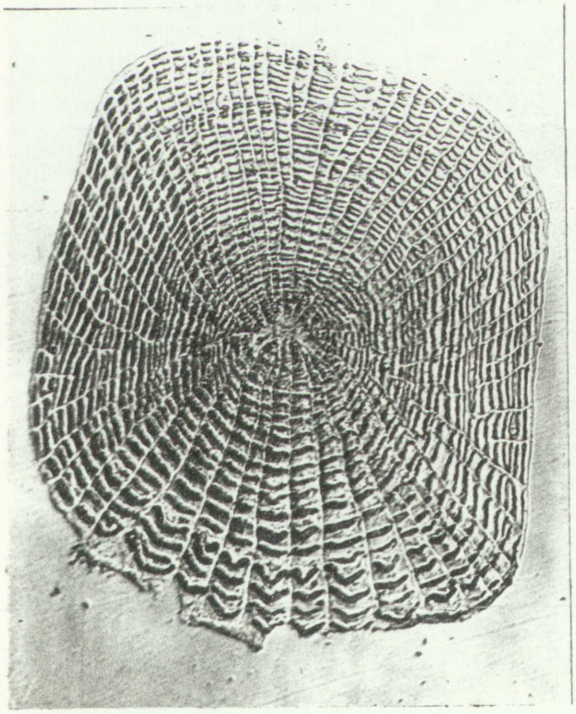


Fig. 26. 6-year scale.



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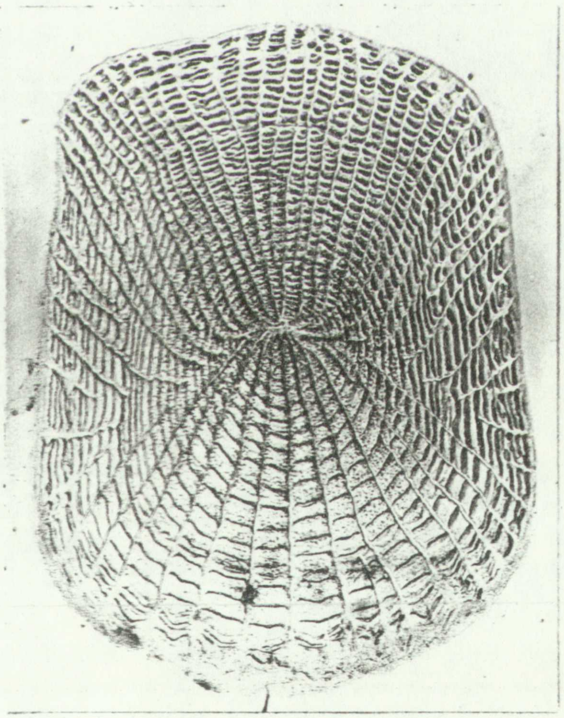

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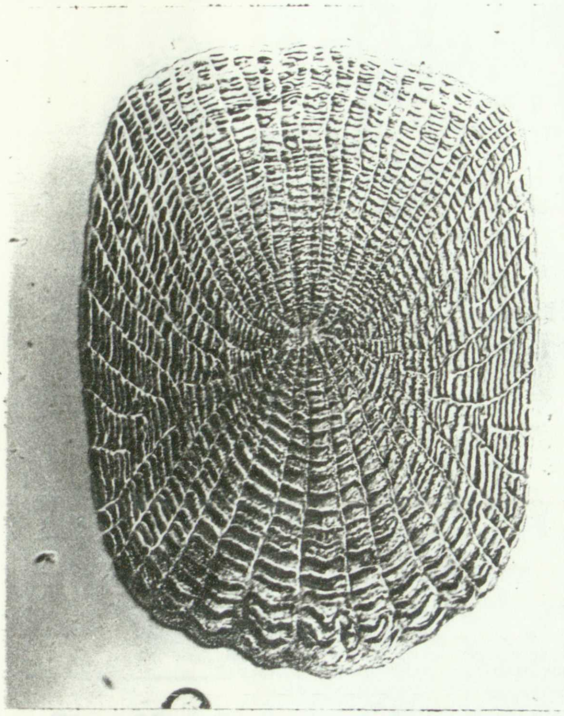


Fig. 29. 6-year scale.

Fig. 30. 6-year scale.

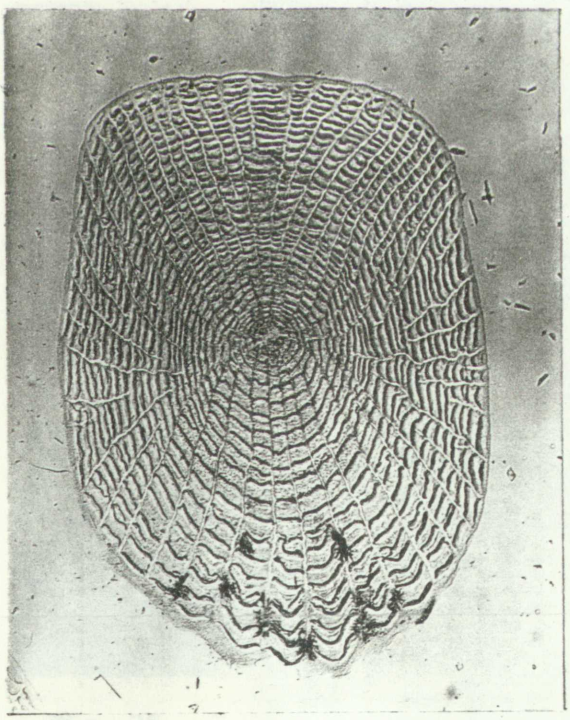


Fig. 31. 6-year scale.

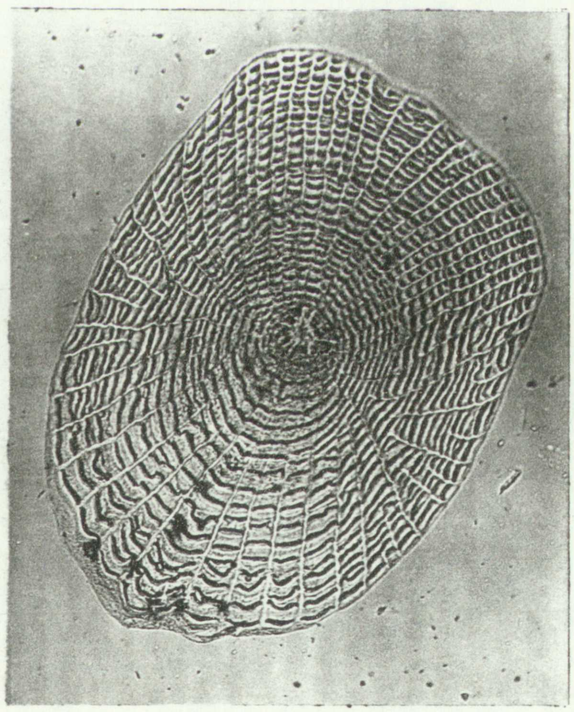


Fig. 32. 6-year scale.

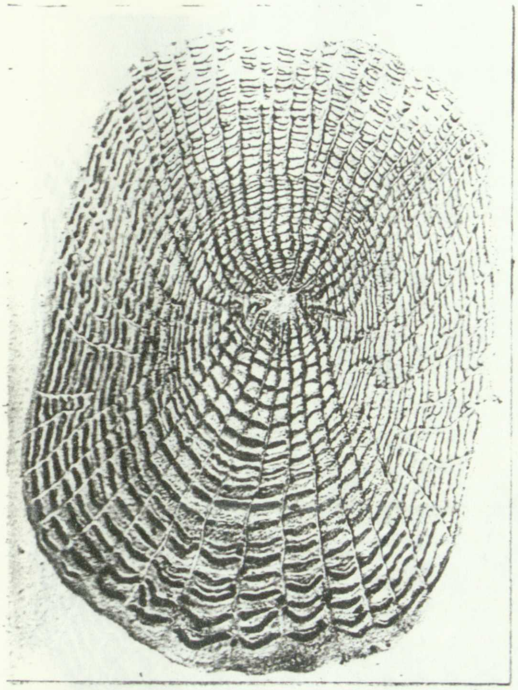


Fig. 33. 7-year scale.

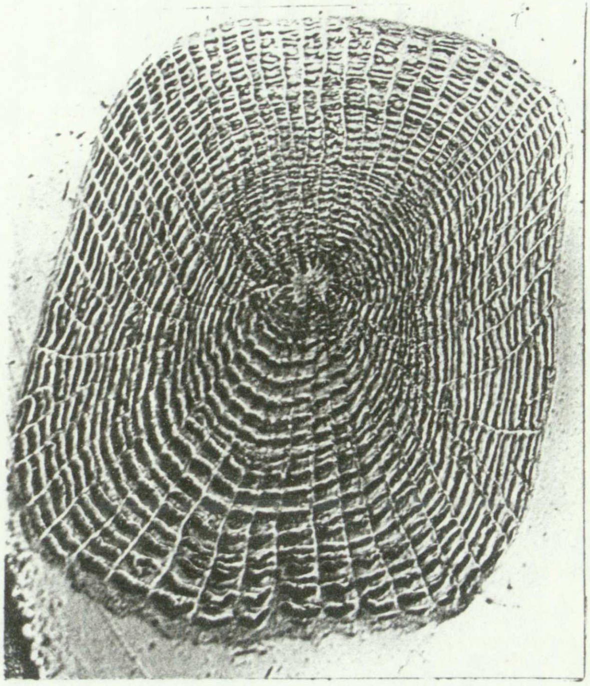


Fig. 34. 7-year scale.

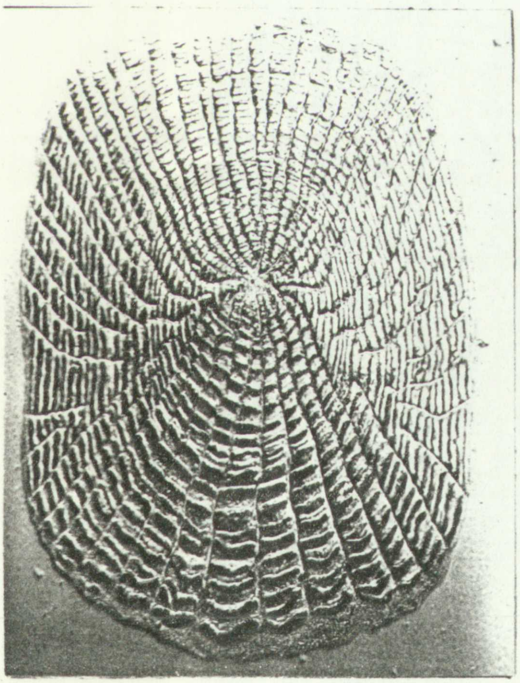


Fig. 35. 7-year scale.

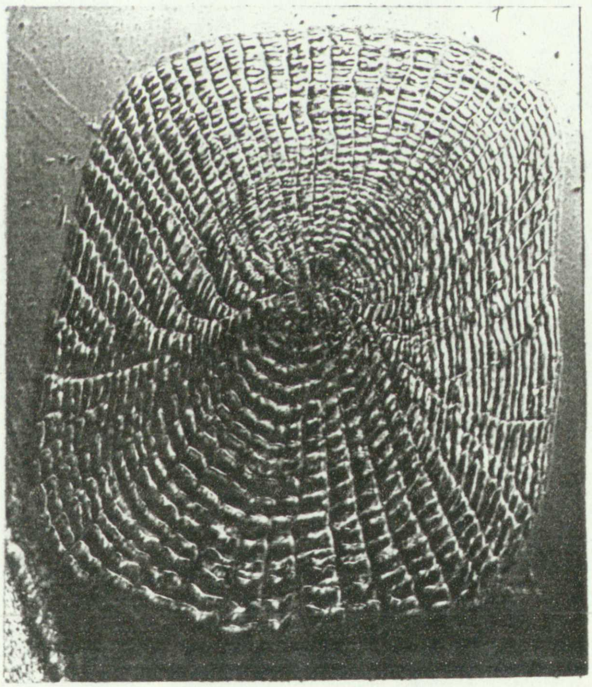


Fig. 36. 7-year scale.

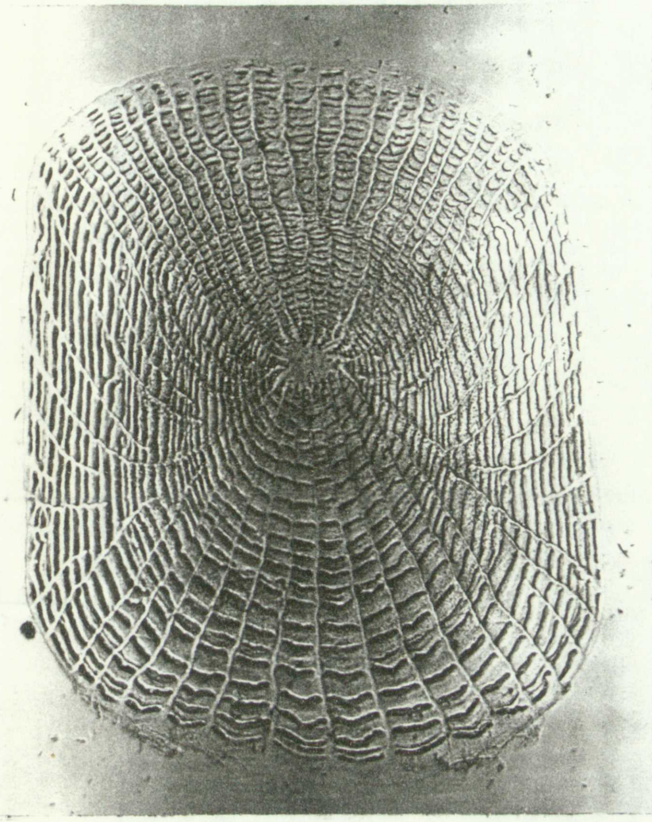


Fig. 37.

7-year scale.

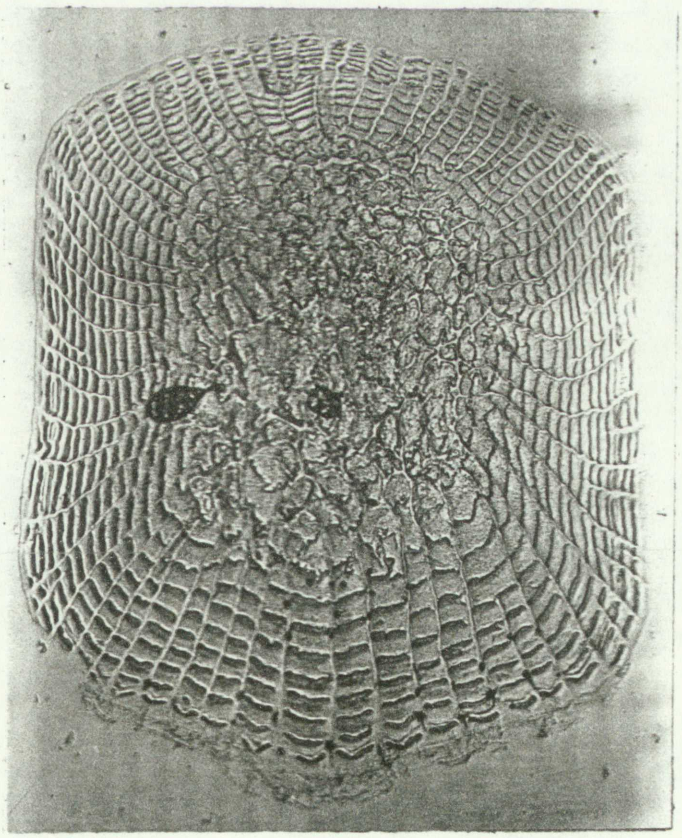


Fig. 38.

Regenerated,

7-year scale.

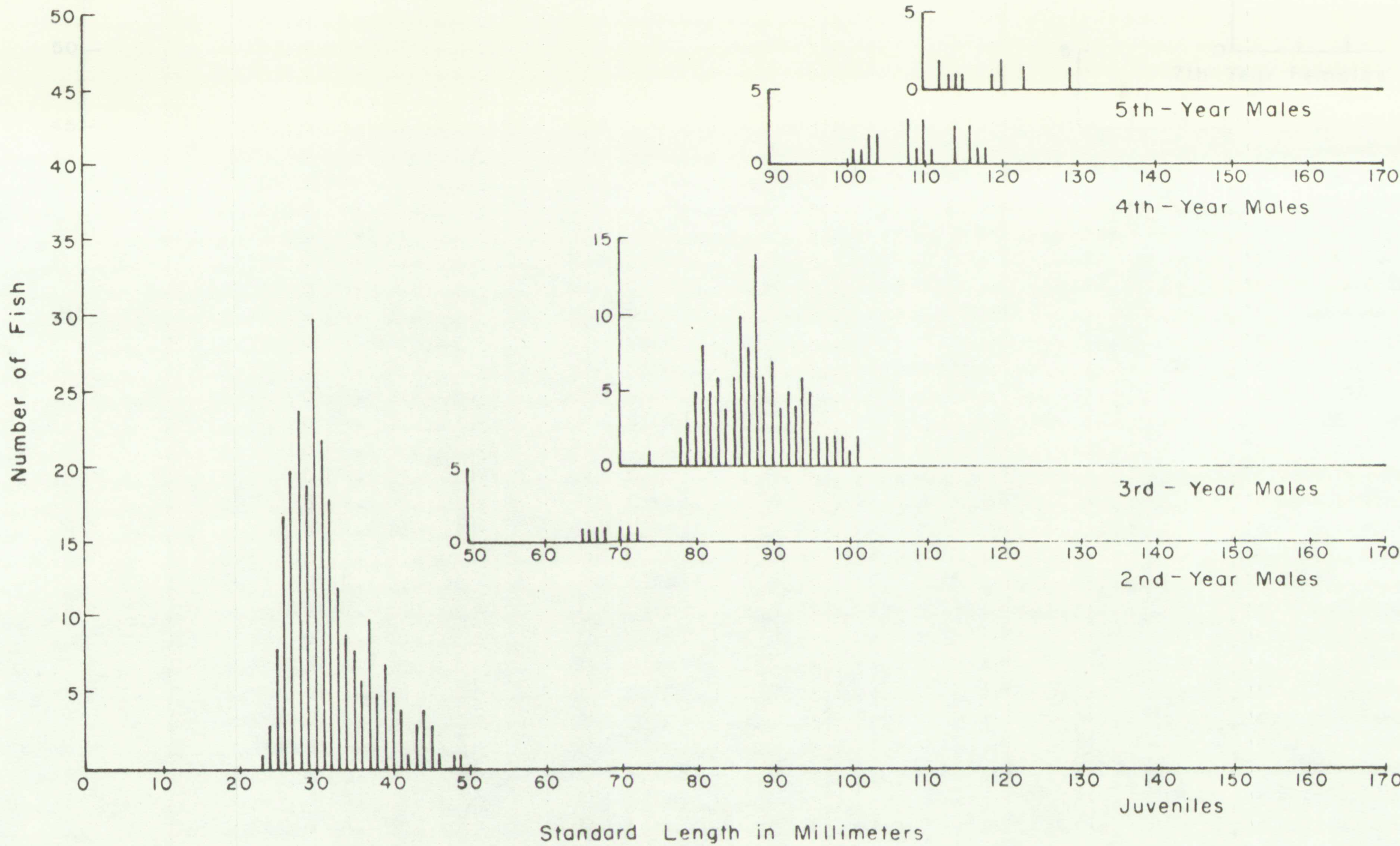


Fig. 39. Standard length frequencies of November 1960 males; juveniles included.

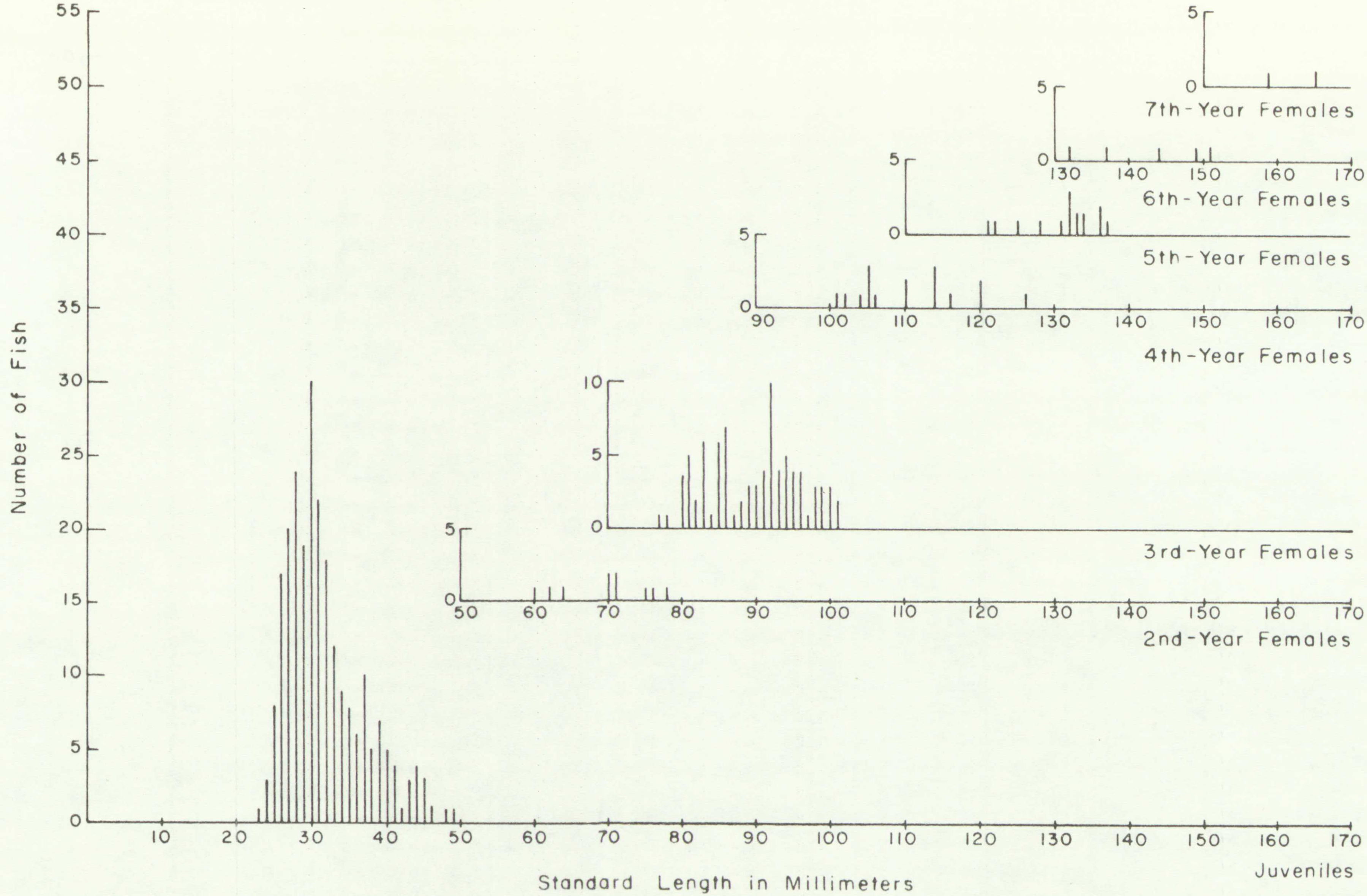


Fig.40. Standard length frequencies of November 1960 females; juveniles included for comparison.

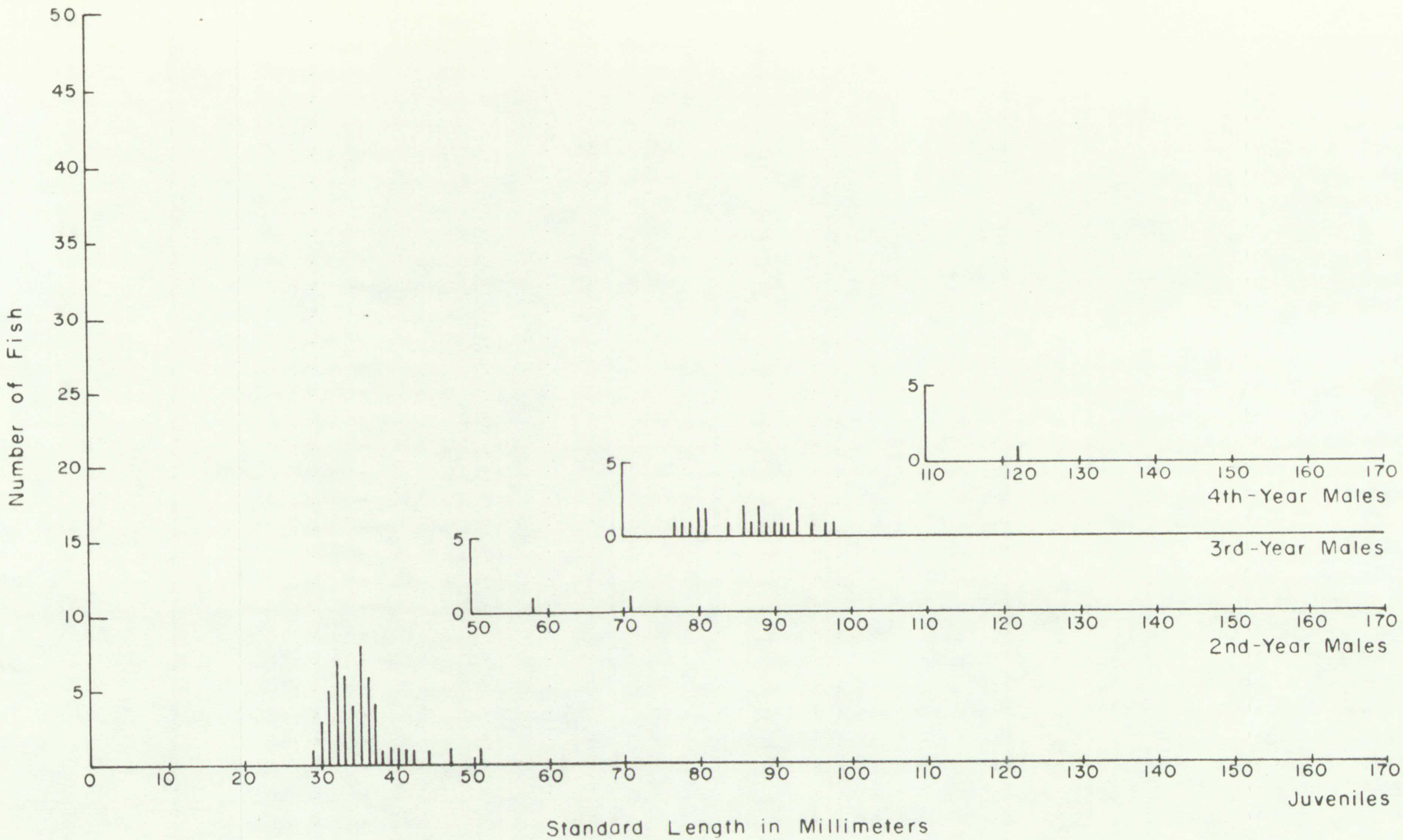


Fig. 41. Standard length frequencies of May 1961 males; juveniles included for comparison.

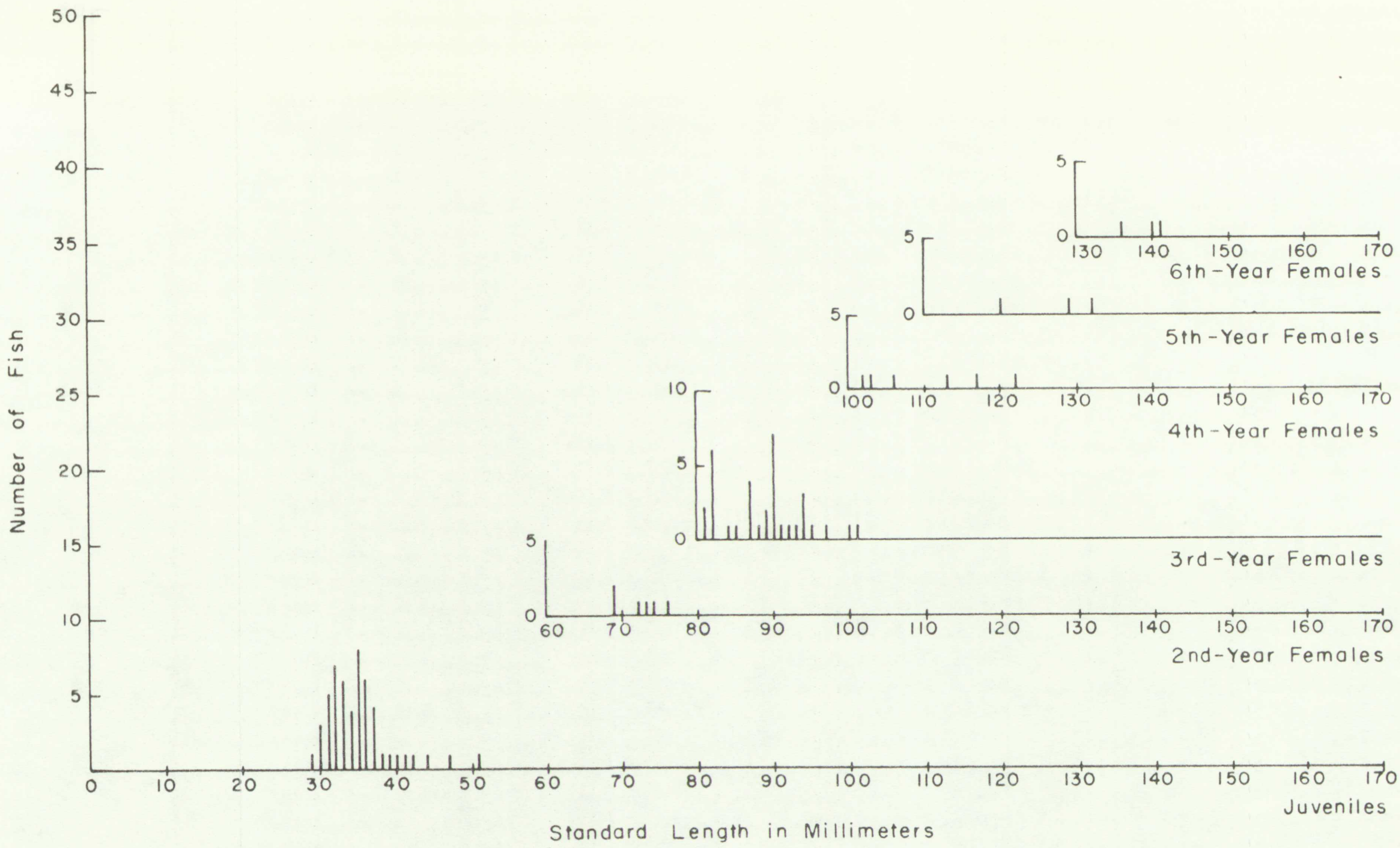


Fig. 42. Standard length frequencies of May 1961 females; juveniles included for comparison.

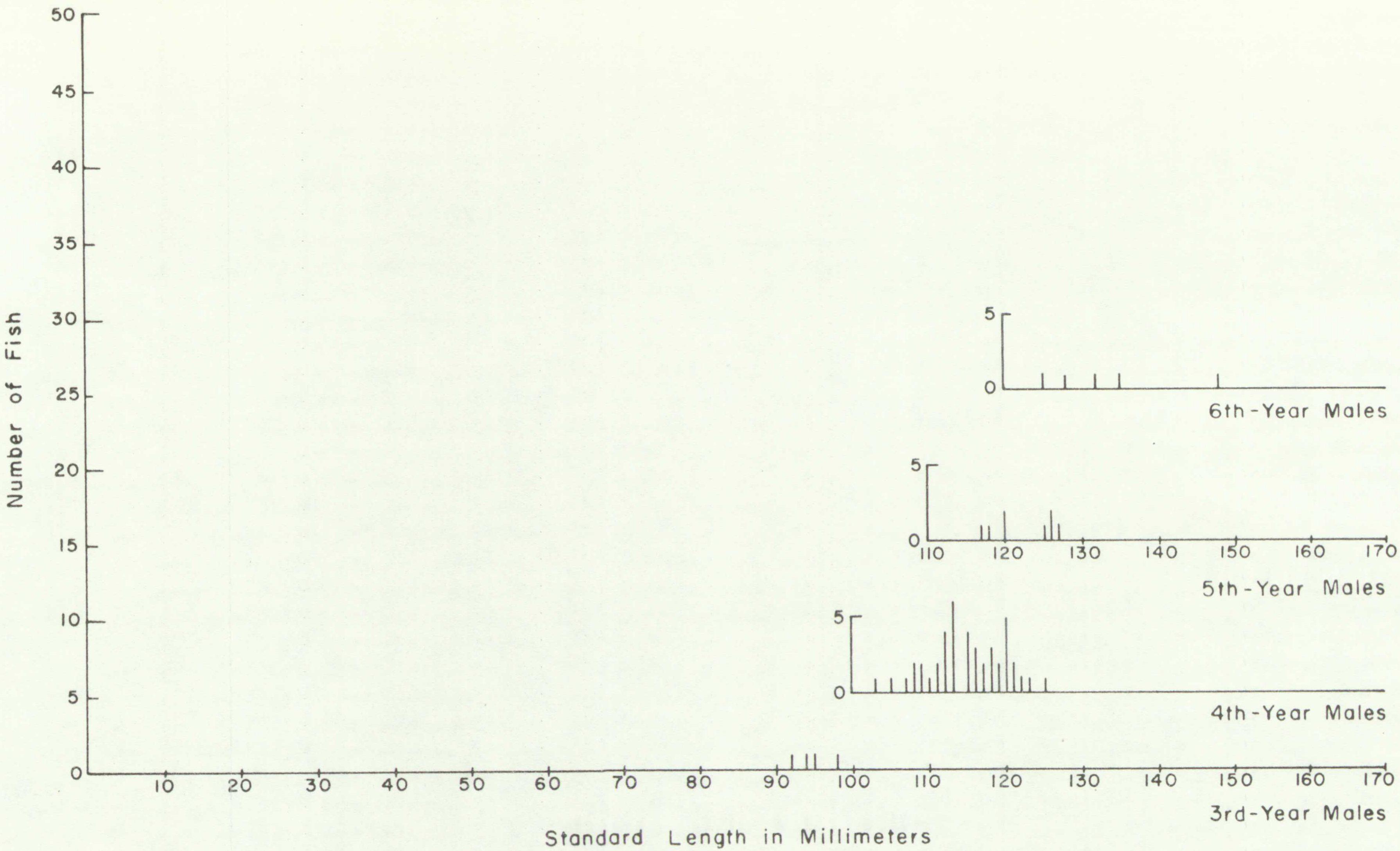


Fig. 43. Standard length frequencies of May 1949 males.

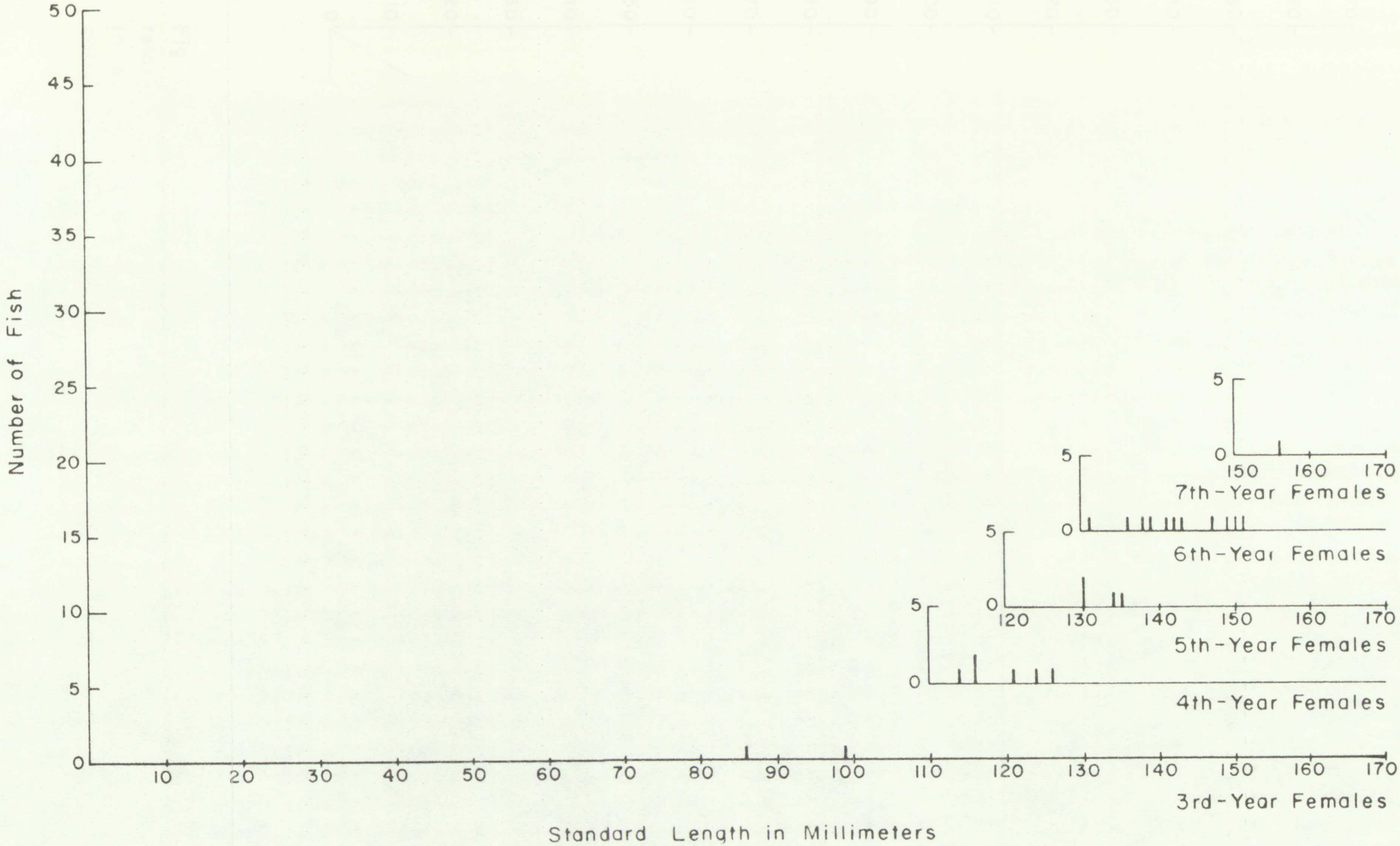


Fig. 44. Standard length frequencies of May 1949 females.

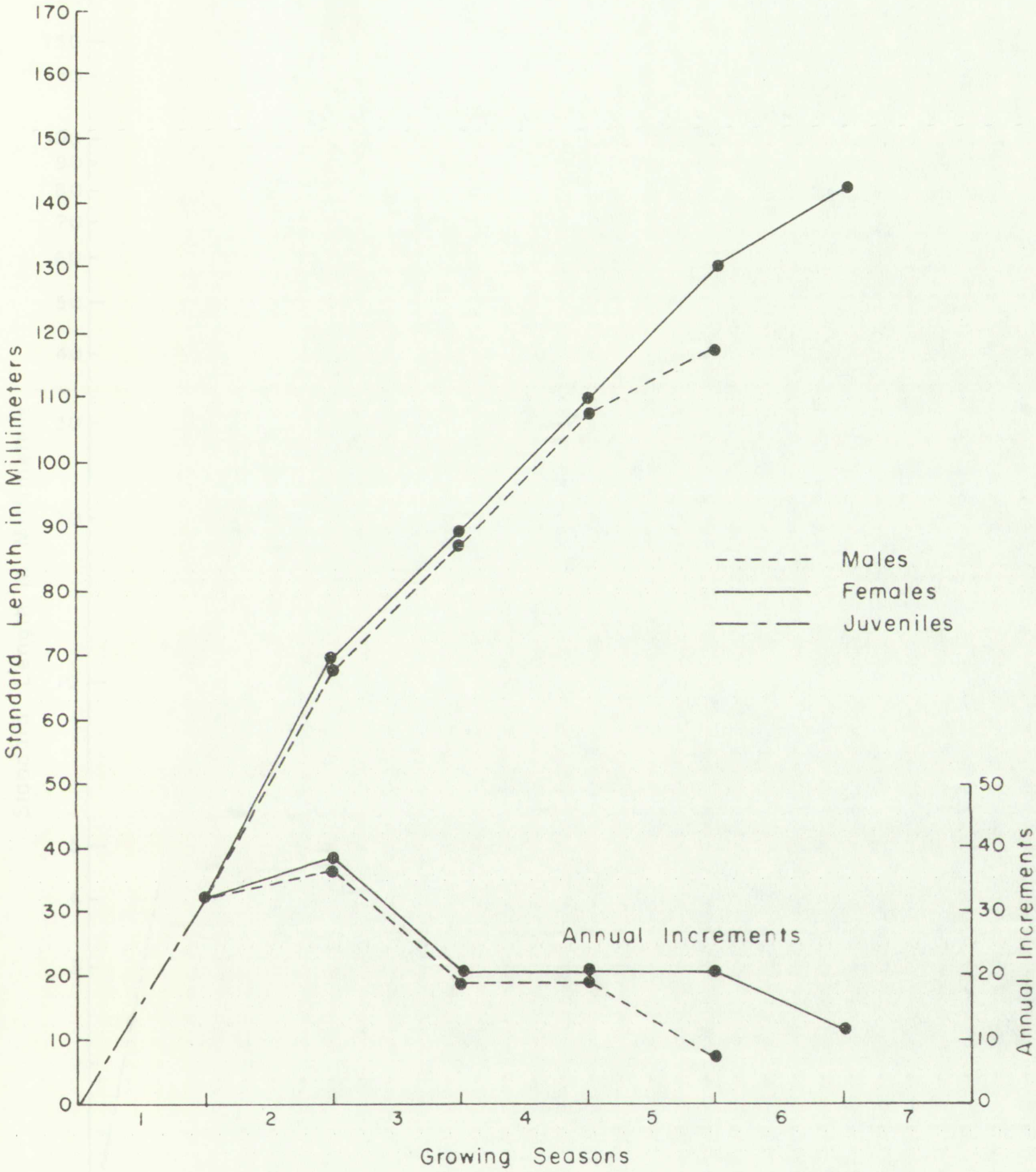


Fig. 45. Absolute growth. Average standard length in millimeters in relation to number of growing seasons, and the annual increments in standard length for each growing season. November 1960 collection.

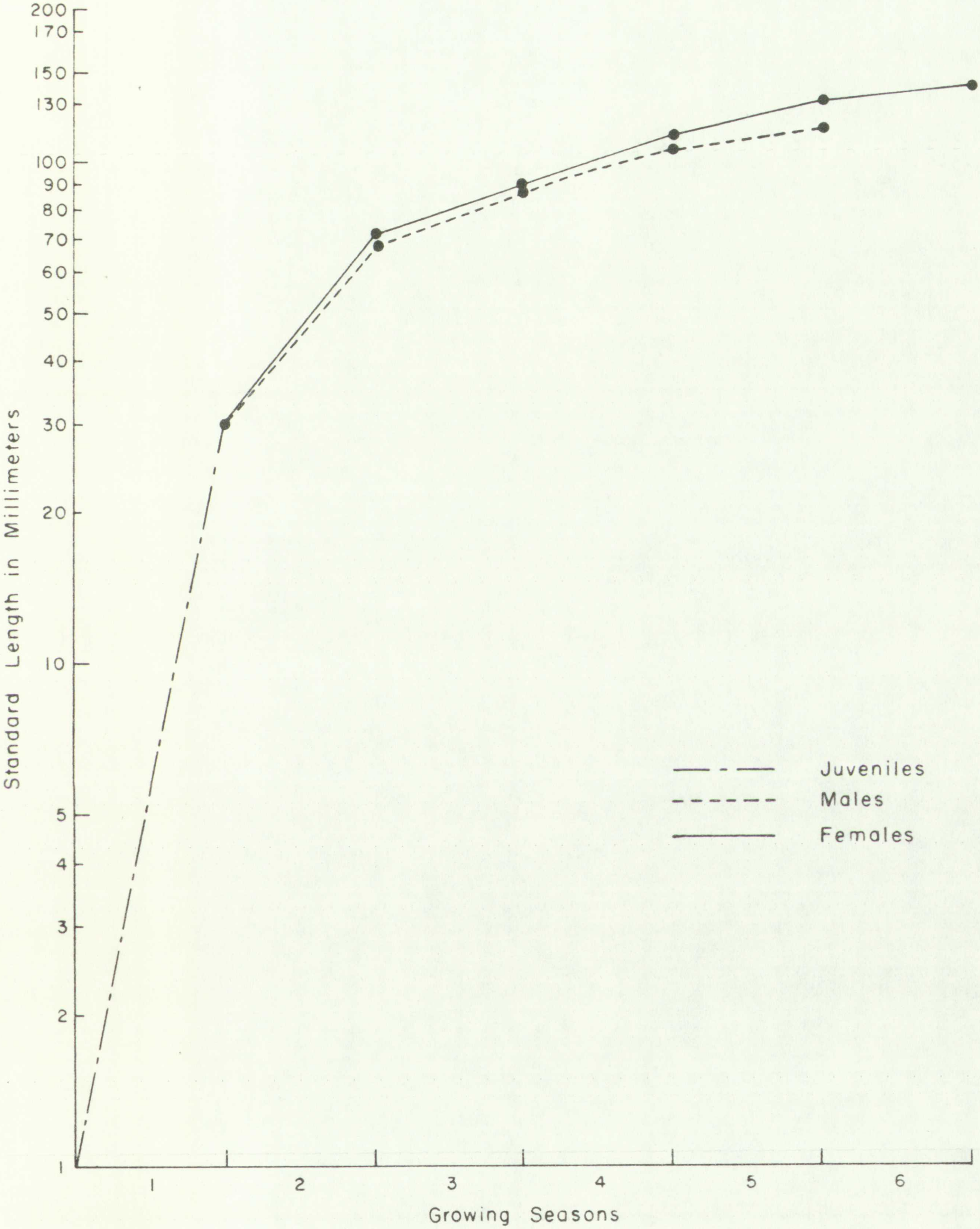


Fig. 46. Relative growth (semi-log). Average standard length in millimeters in relation to number of growing seasons. November 1960 collection.

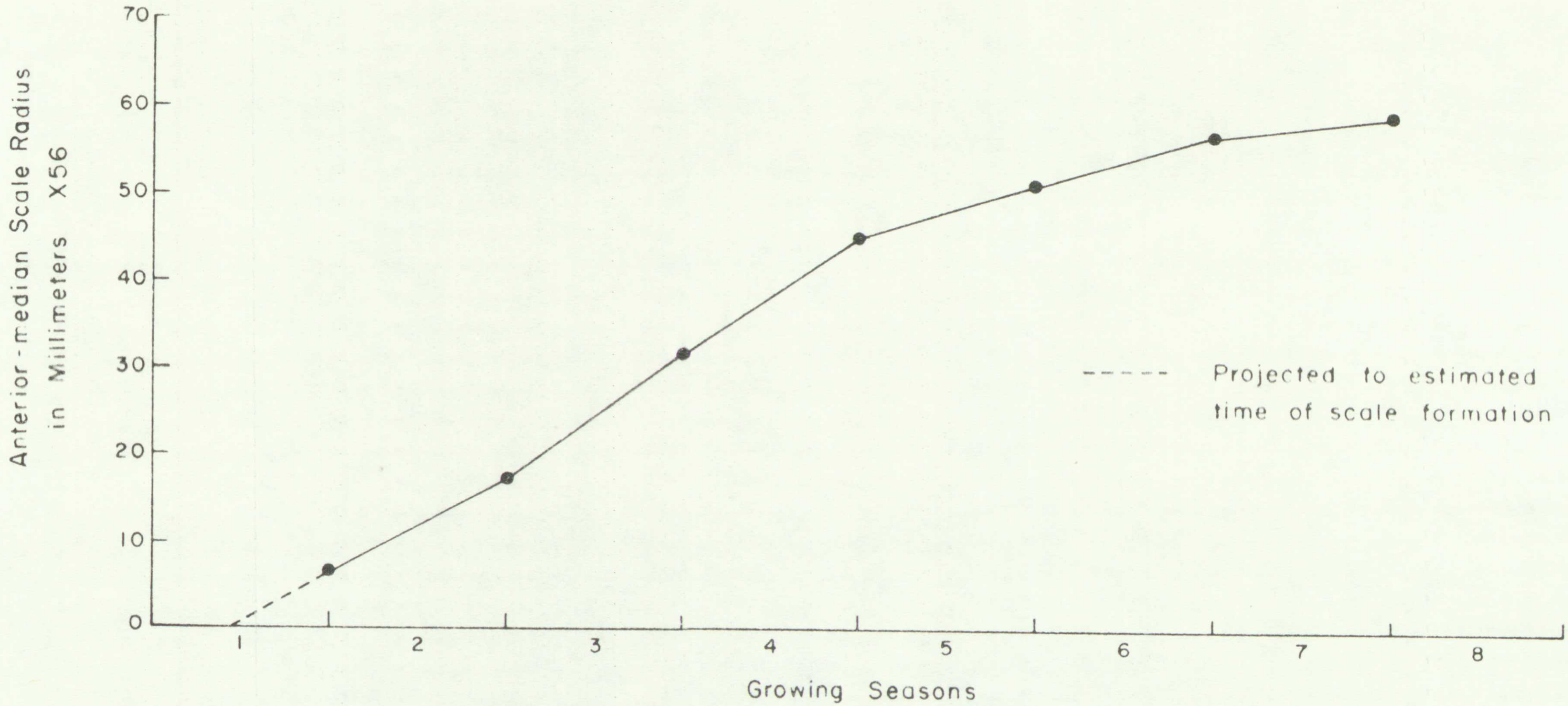


Fig. 47. Absolute growth of median - anterior scale radius (un-weighted, over-all average of all year classes of all collections).

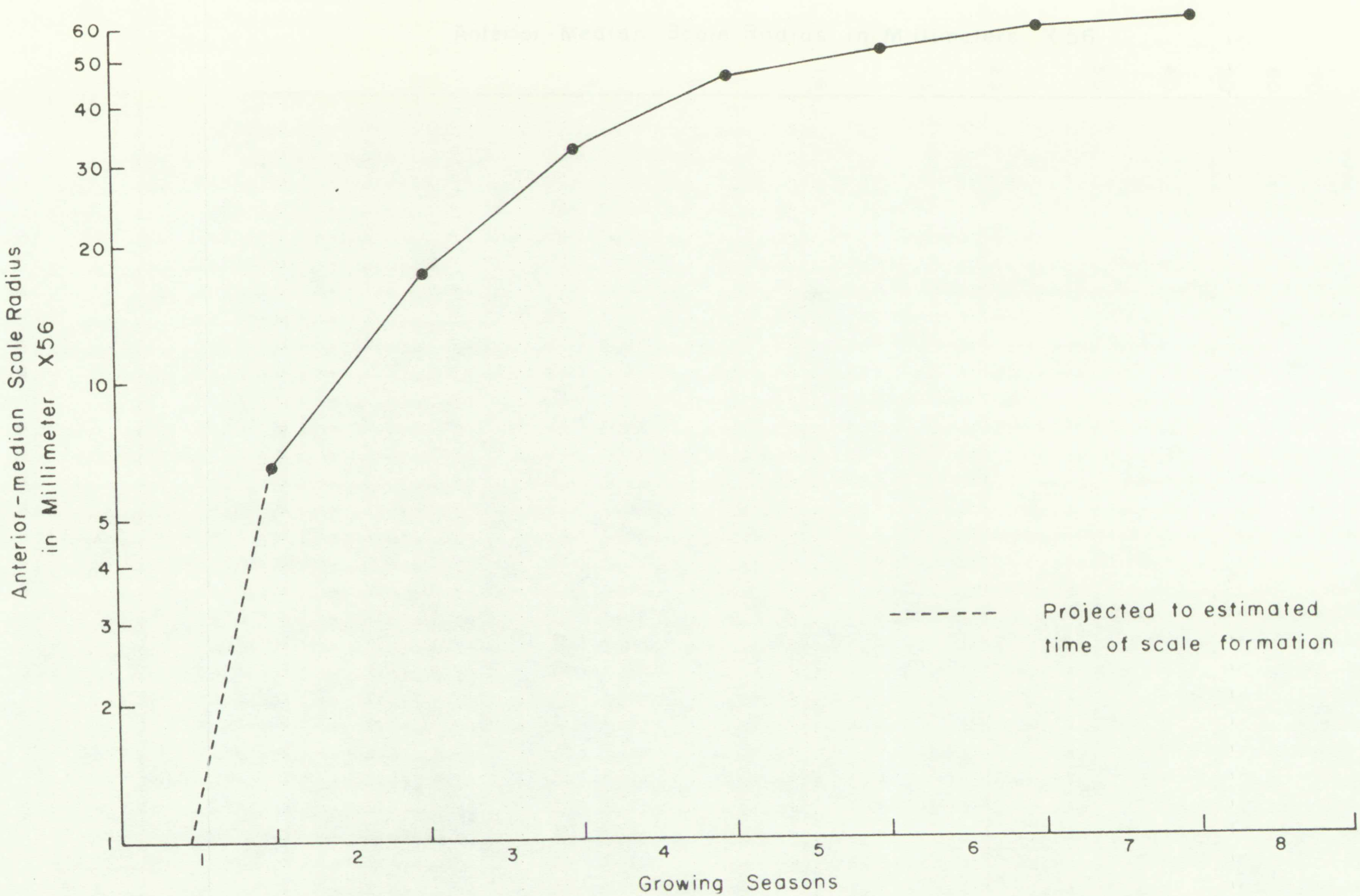


Fig. 48. Relative growth of median-anterior scale radius (unweighted, over-all average of all year classes of all collections).

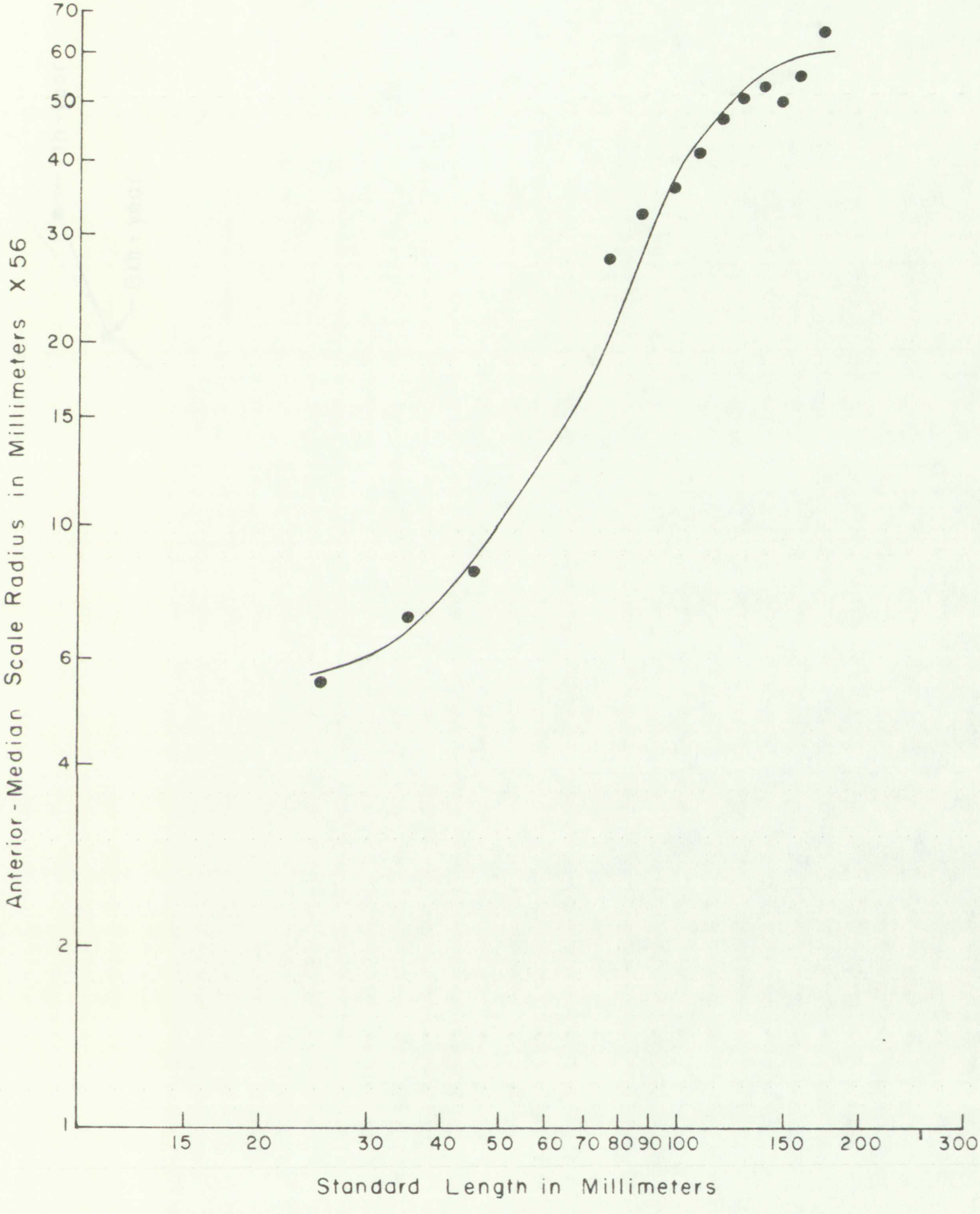


Fig. 49. Relative growth (log-log) of median - anterior scale radius and standard length. November 1960 and May 1961 collections combined.

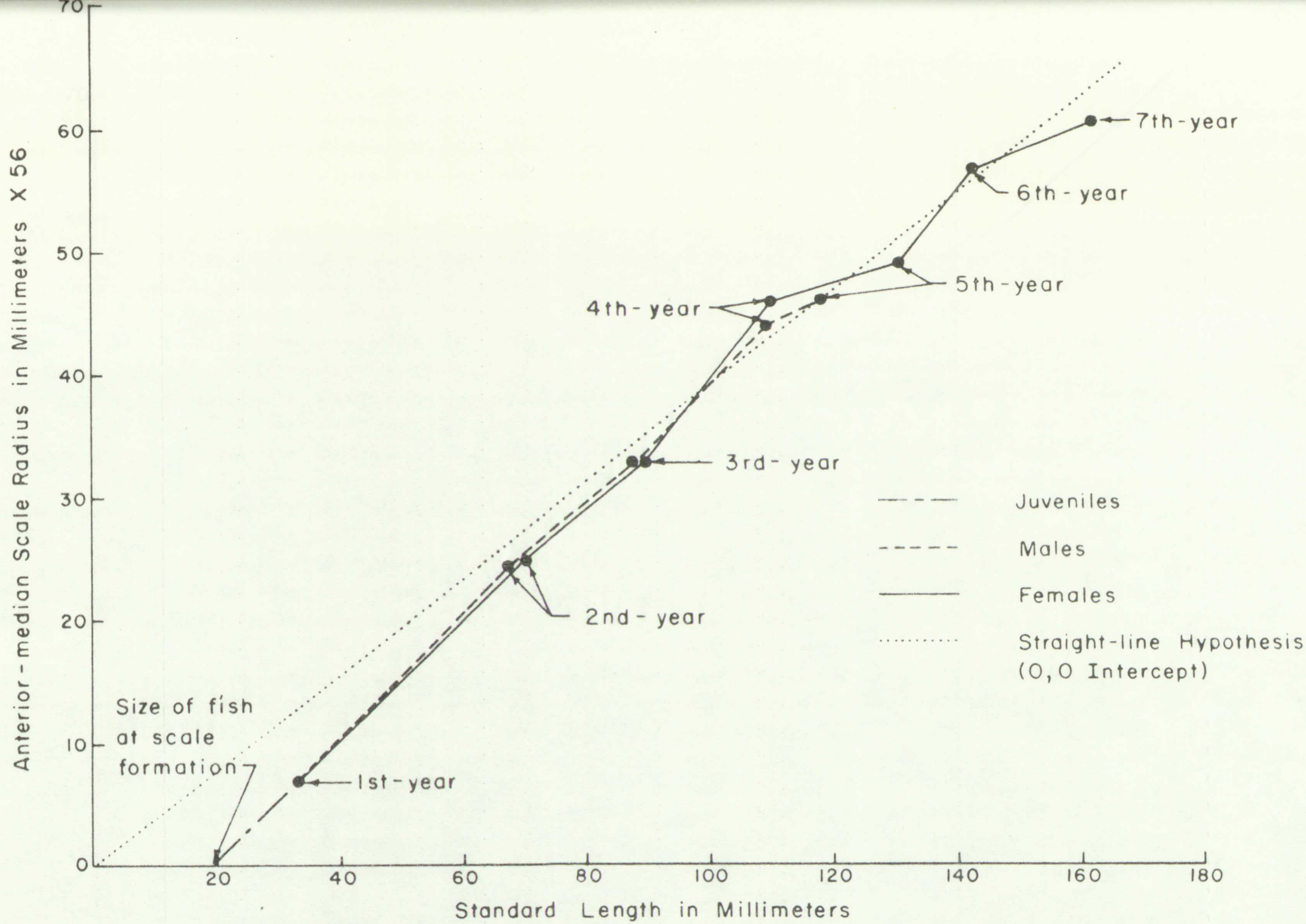


Fig. 50. Average, absolute growth of the anterior edge of the scale compared with average increase in standard length. By year classes. November 1960 collection.

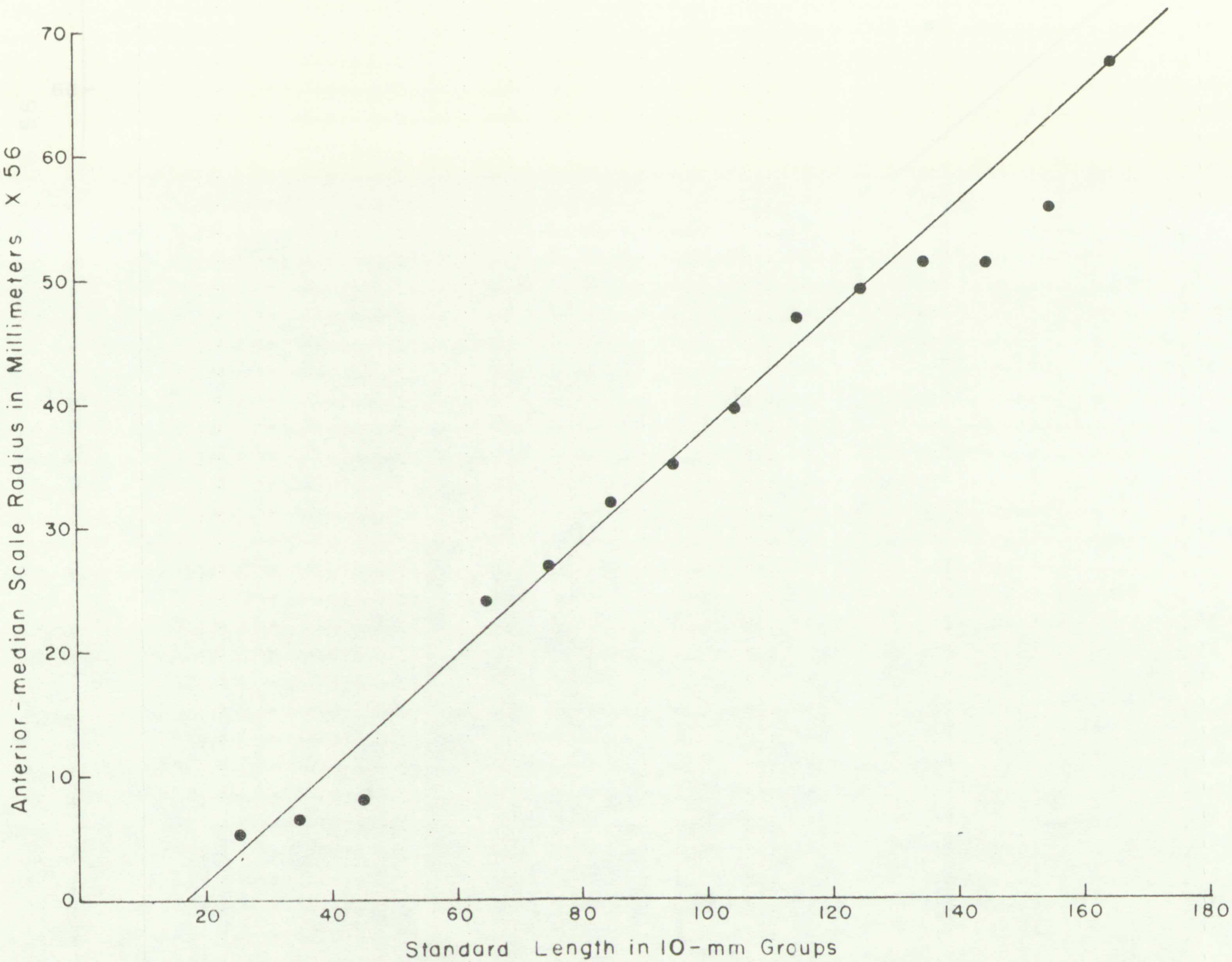


Fig. 51. Average, absolute growth at the anterior edge of the scale compared with average, absolute increase in standard length. By 10-mm groups. November 1960 collection.

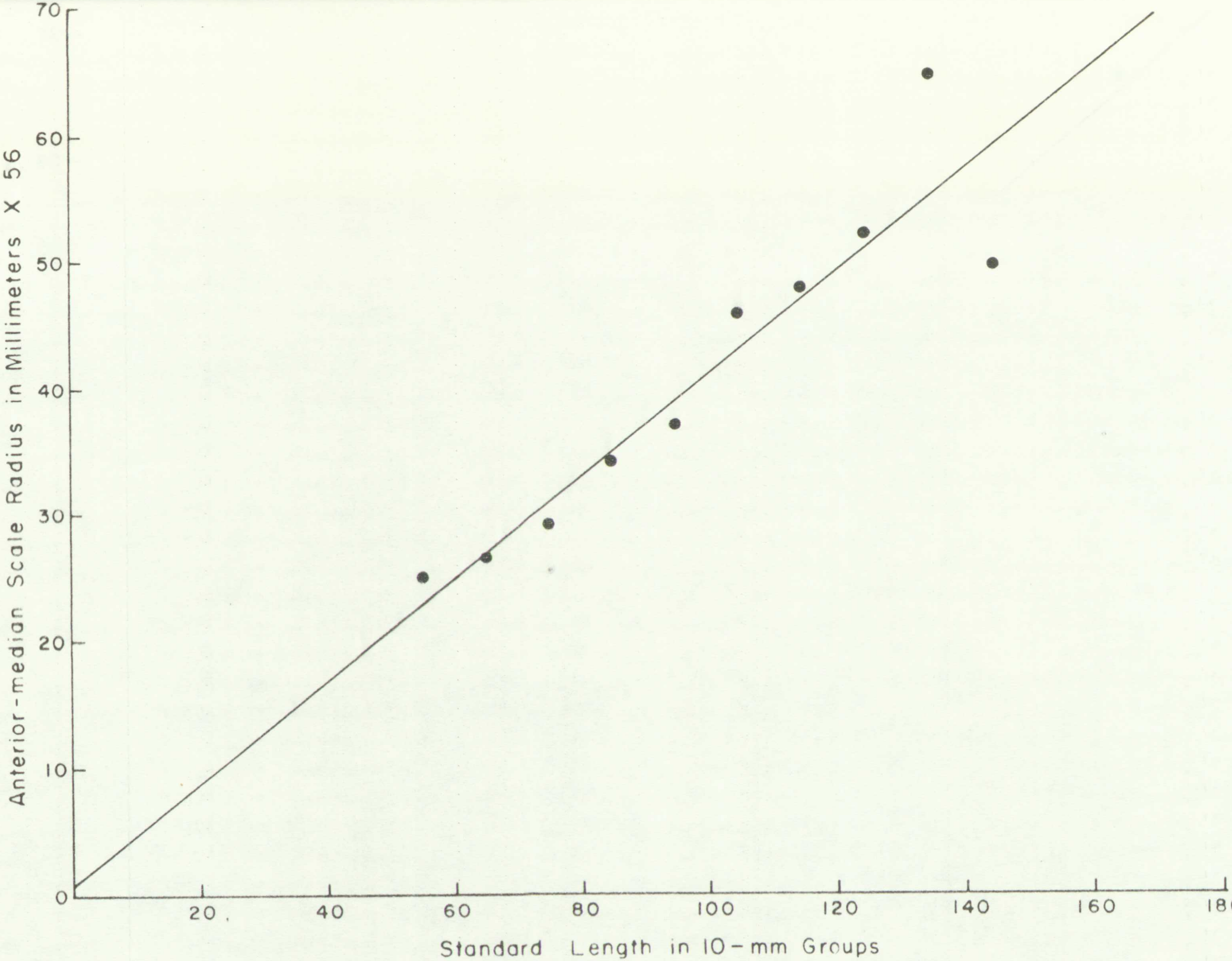


Fig. 52. Average, absolute growth at the anterior edge of scale compared with average, absolute increase in standard length. By 10-mm groups. May 1961 collection.

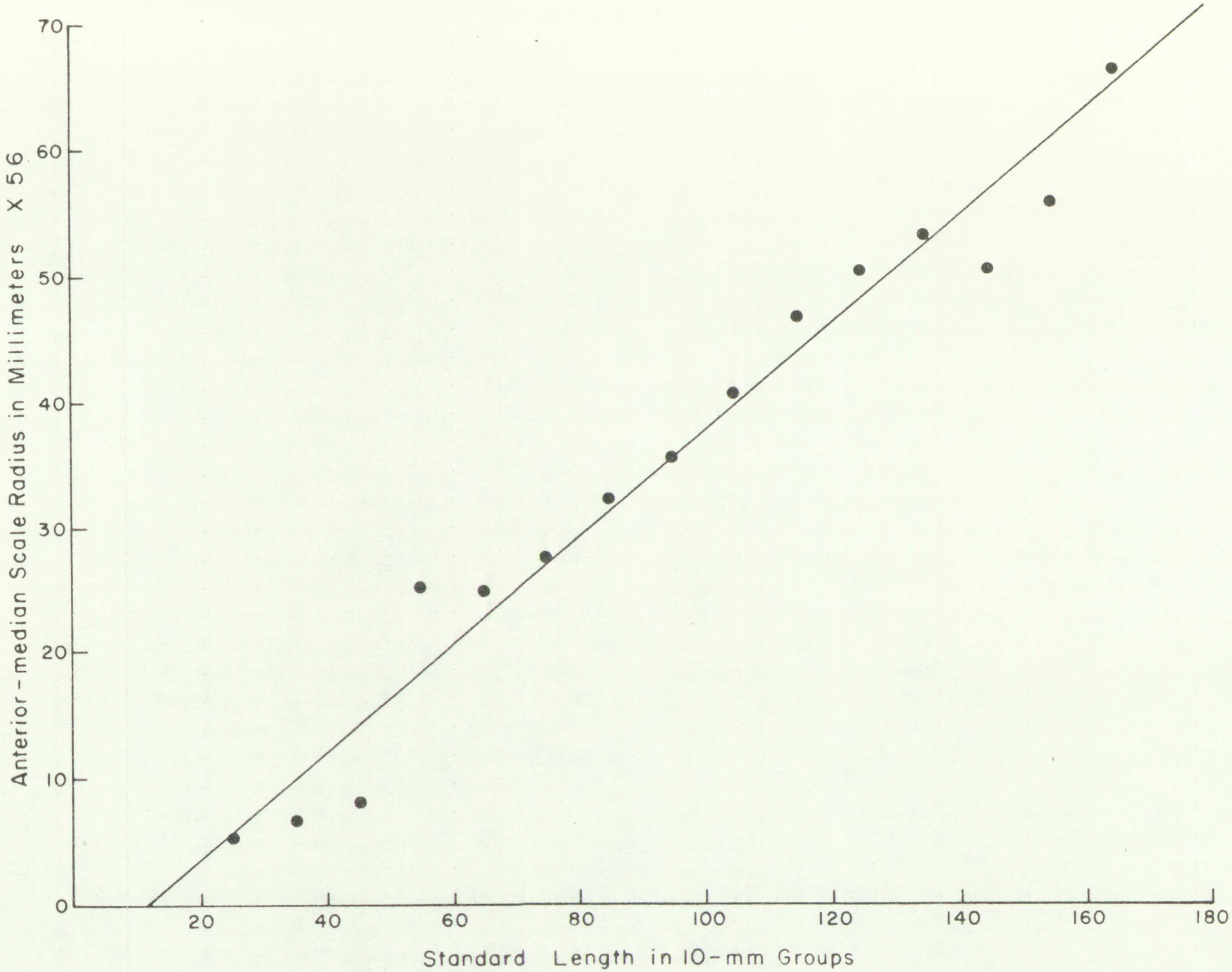


Fig. 53. Average, absolute growth at the anterior margin of the scale compared with average, absolute increase in standard length. By 10-mm groups. November 1960 and May 1961 collections combined.

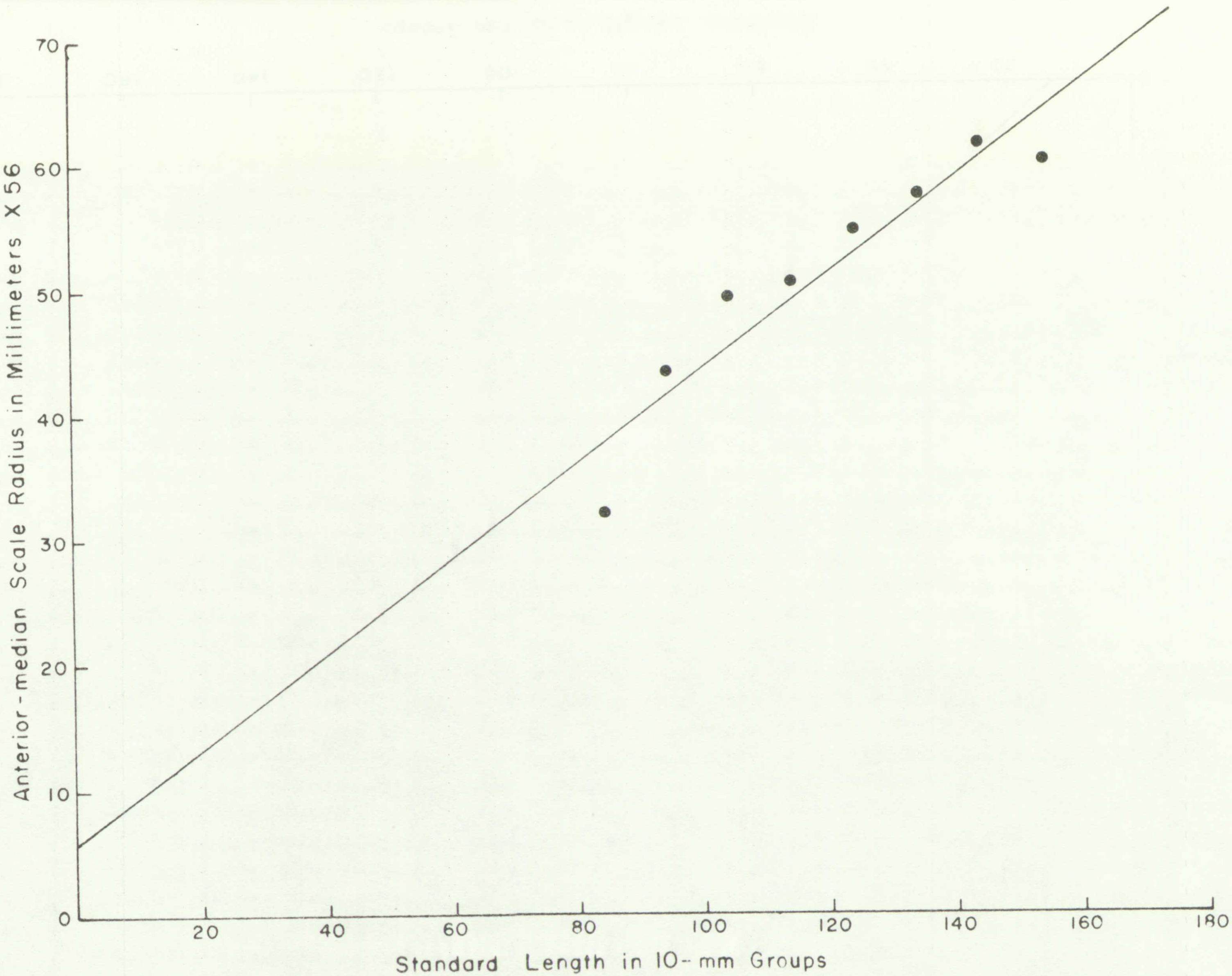
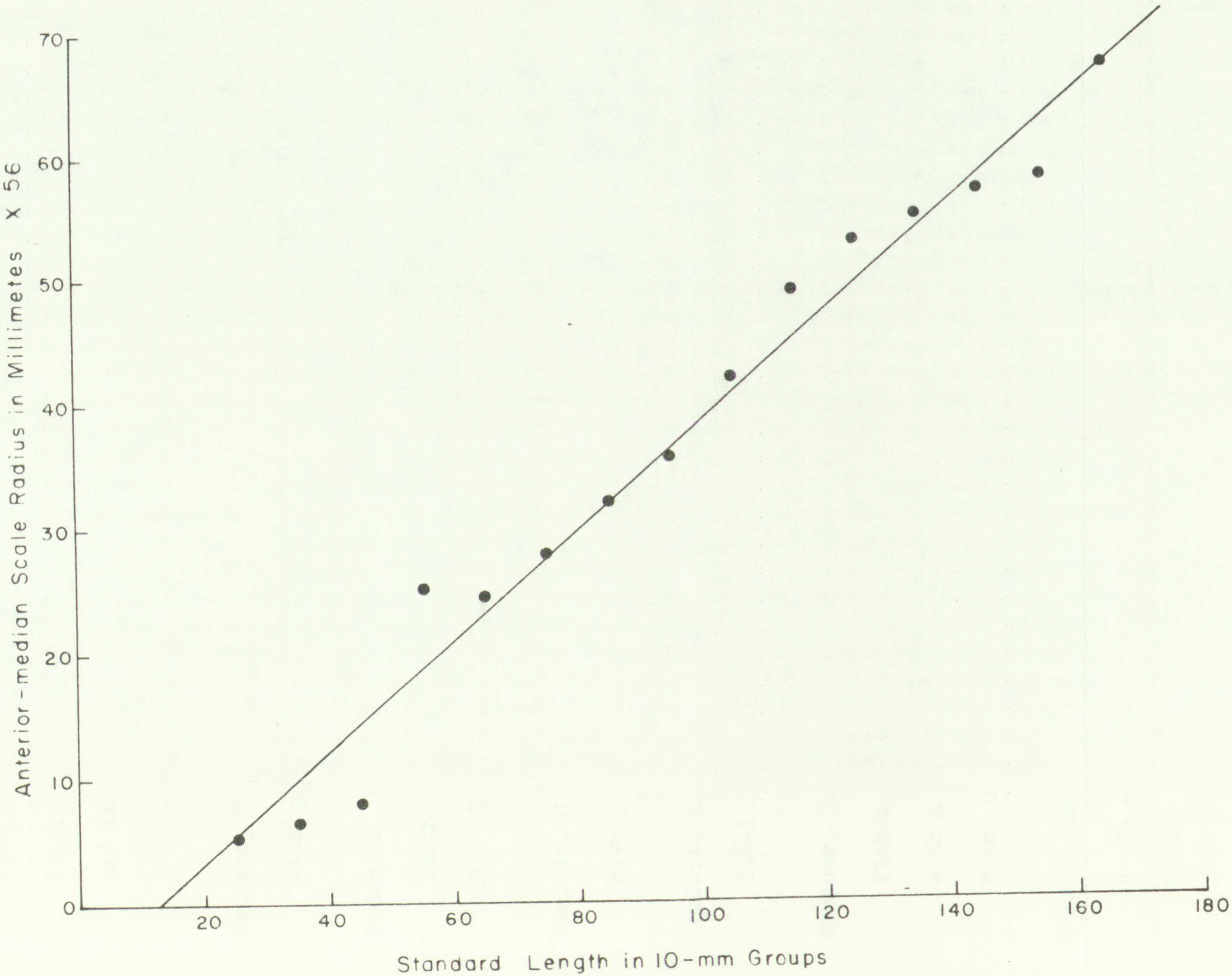


Fig. 54. Average, absolute growth at the anterior margin of the scale compared with average, absolute increase in standard length. By 10-mm groups. May 1949 collection.



of the scale compared with aver-

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