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AGE AND GROWTH OF THE LONG-EARED AND THE GREEN SUNFISHES IN MICHIGAN

This printed report is a new edition of Report 197A with slight alterations and additions covering the green sunfish as well as the long-eared sunfish. It covers the life-history and growth in Michigan of these two species. It is hoped that similar work may be done on other species of sunfishes, and of other inland game species. Considerable material for these further studies has been gathered.

The attention of the Department is called especially to Section IX, pp. 690-694, "Relation of size and growth to the legal limit".

INSTITUTE FOR FISHERIES RESEARCH

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AGE AND GROWTH OF THE LONG-EARED AND THE GREEN SUNFISHES IN MICHIGAN *

CARL L. HUBBS AND GERALD P. COOPER

I. INTRODUCTION

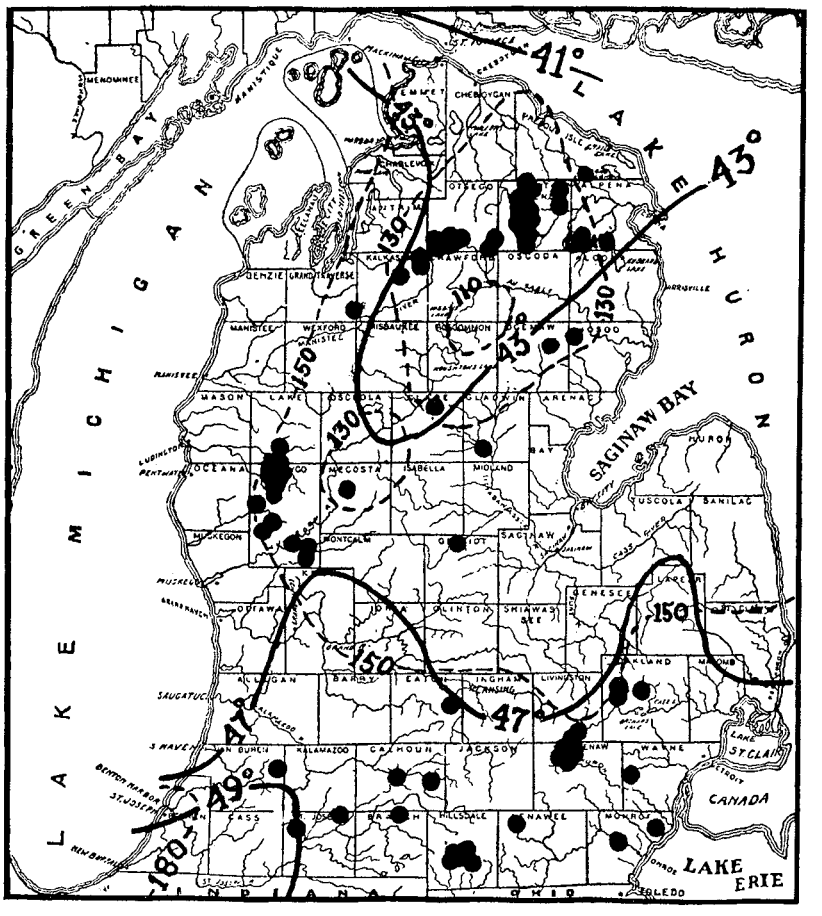
THE investigation reported upon in this paper was undertaken to elucidate several features in the life history in Michigan waters of (1) the dwarfed form of long-eared sunfish, *Xenotis megalotis peltastes*, and (2) the green sunfish, *Apomotis cyanellus*. The study has been based on an examination of the scales of 1,129 specimens of the long-eared sunfish representing 79 collections, all from the Lower Peninsula of Michigan, and of 514 individuals of the green sunfish representing 85 collections. The distribution of these collections is indicated by Maps 46–47.

The methods employed were those now becoming more or less standard in investigations on the life histories of fishes. The scales of all specimens, except most of the yearlings in one large collection of the long-eared sunfish, were mounted in glycerine jelly and were examined by aid of a projecting machine. The age status of this one group of yearlings was so obvious that only a few scale readings were deemed necessary.

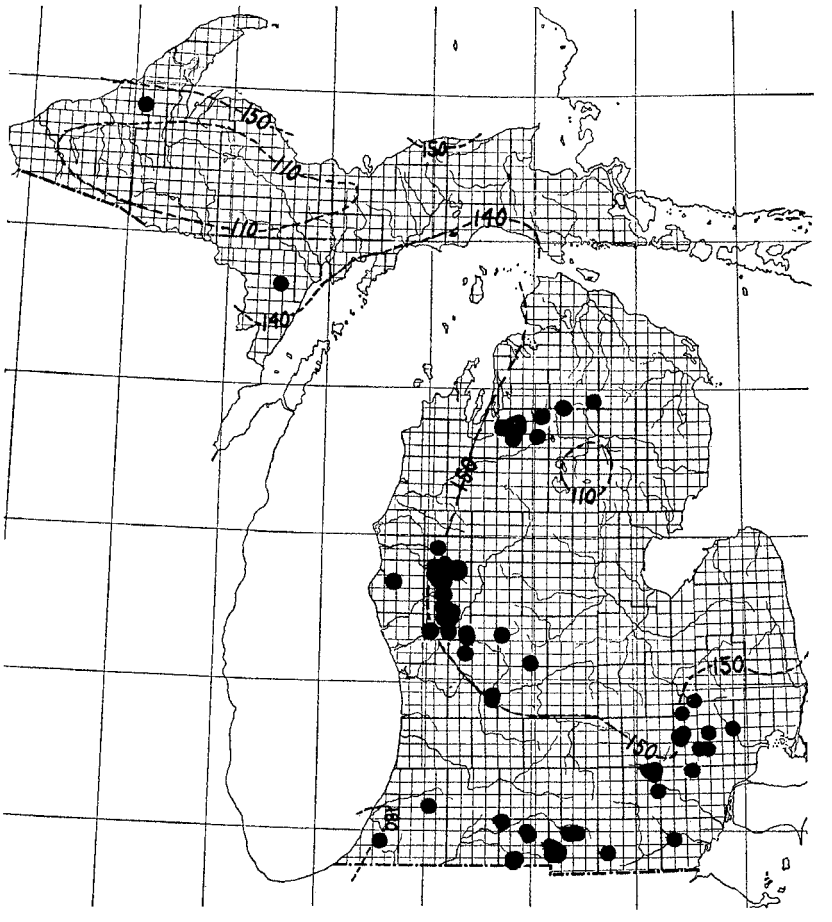
The validity of the scale method for age determination of fishes in the family Centrarchidae, which includes *Xenotis* and *Apomotis*, was demonstrated by Creaser (1926) and has been thoroughly confirmed by the earlier and subsequent researches of Barney and Anson (1923), Potter (1925), Bolen (1924), Wright (1929), Hile (1931), Tester (1932), and Hubbs and Hubbs (1931, 1933). The papers by Creaser and Hile give references to the contributions which introduced and have established the scale method for the determination of the age of fishes in general.

The characteristics of the annulus or winter line on the scales of centrarchid fishes have been adequately indicated by the writers just

* Contribution from the Institute for Fisheries Research, University of Michigan.



MAP 46. Lower Peninsula of Michigan, showing: (1) the mean annual temperatures in degrees Fahrenheit (solid line; after Seeley, 1922, Chart II); (2) the number of days in the growing season — the interval between killing frosts (dashed line; after Seeley, 1922, Chart XIV); and (3) the localities from which the material of long-eared sunfish was obtained. The dividing lines between the northern and southern districts are fixed at 47° F. and at 150 days in the growing season



MAP 47. Outline map of Michigan, showing: (1) average number of days in the growing season (dotted line); and (2) the distribution of Michigan collections of green sunfish

cited, and need not be redescribed. The figures of the scales on Plates CIV–CVIII show that the year marks on the scales of *Xenotis* and *Apomotis* are entirely like those of the other species of this family which have been studied.

II. INCREASED DWARFING TOWARD THE NORTH

In the central parts of the United States the long-eared sunfish (*Xenotis megalotis*) is a species of fair size. Some data on its age and growth in northern Indiana have been published by Hile (1931 : 18, 23, 32, 42, 51). Northward it grades into a dwarfed subspecies, as Forbes and Richardson indicated, for Illinois, in 1909 (p. 255):

> Northward this species grades into a smaller dwarfish variety, probably *Xenotis lythrochloris*, which has been taken only in the clear swift water of the Fox at Ottawa, Lacon, and Algonquin; in the Du Page at Naperville; in the Vermilion at Pontiac and Fairbury; in a small creek in Du Page county; and in Indian creek, La Salle county. These small forms have the ear-flaps red and the scales of the cheek smaller than typical *megalotis*. Their size is alone sufficient to distinguish them, gravid females having been found only 1⅝ inches long, and no specimen exceeding three inches.

The proper name of this northern subspecies seems to be *Xenotis megalotis peltastes* (see Hubbs, 1926 : 72).

In Michigan we likewise find that the long-eared sunfish becomes progressively dwarfed toward the north. The correlation is good between growth and certain climatic features, which change greatly through Michigan. The two climatic gradients selected, from those mapped by Seeley (1922), as having a clear relation to the growth of this sunfish as determined by us, are (1) "the average number of days in the growing season (from last killing frost in spring to first killing frost in autumn)" and (2) "the mean temperature for the year." The distribution of our collections in respect to two divisions in each of these climatic gradients is shown in Map 46. An examination of the figure will make it clear that the groupings of the collections according to the two climatic divisions are identical.

The data are summarized in Tables I and II and in Figure 57. It seems clear that *Xenotis megalotis peltastes* shows a dwarfing toward the north in Michigan, and that this dwarfing is correlated with a decrease in the mean length of the "growing season" (between killing frosts) and in the mean temperature of the year.

As for the long-eared sunfish, we find for *Apomotis* in Michigan that a good correlation holds between growth rate and two climatic

TABLE I

SIZE FREQUENCY DISTRIBUTION OF LONG-EARED SUNFISH OF EACH AGE GROUP IN MICHIGAN, ARRANGED ACCORDING TO LENGTH OF GROWING SEASON

Standard length in millimeters, by groups of five

Summer of life	Growing season in days	Mean temp.	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–99	100–104	105–109	110–114	Total
2d....	110–150*	41–47°F.	14	187	158	12	..	...	...	..	..	..	..	..	..	..	..	..	..	..	..	371
	110–150†	41–47°F.	..	9	38	48	20	3	1	..	..	..	..	..	..	..	..	..	..	..	..	119
	150–180	47–49°F.	1	2	2	6	22	20	2	1	1	2	..	..	..	..	..	..	..	..	..	59
3d....	110–150	41–47°F.	..	...	5	14	34	41	35	25	15	1	8	2	..	..	..	..	..	..	..	180
	150–180	47–49°F.	..	...	...	..	8	32	34	17	15	18	11	4	2	1	..	..	..	..	..	142
4th...	110–150	41–47°F.	..	...	...	..	8	9	21	20	11	12	4	2	1	..	..	..	..	..	..	88
	150–180	47–49°F.	..	...	...	..	..	...	...	3	2	7	7	7	6	2	1	..	..	..	..	35
5th...	110–150	41–47°F.	..	...	...	..	..	...	12	21	24	17	8	1	..	..	..	..	..	..	..	83
	150–180	47–49°F.	..	...	...	..	..	...	...	..	1	5	7	3	5	3	2	1	1	..	..	28
6th...	110–150	41–47°F.	..	...	...	..	..	2	4	1	3	1	..	1	1	..	..	..	..	1	..	14
	150–180	47–49°F.	..	...	...	..	..	...	...	..	..	..	..	..	..	..	..	..	..	..	1	1
7th...	110–150	41–47°F.	..	...	...	..	..	...	...	..	..	..	..	1	1	..	1	..	..	1	..	4
	150–180	47–49°F.	..	...	...	..	..	...	...	..	..	..	..	..	..	..	..	1	..	..	1	2
8th...	110–150	41–47°F.	..	...	...	..	..	...	...	..	..	..	..	1	1	..	..	..	..	..	..	2
	150–180	47–49°F.	..	...	...	..	..	...	...	..	..	..	..	..	..	..	..	..	..	..	..	....
9th...	110–150	41–47°F.	..	...	...	..	..	...	...	..	..	..	..	..	..	..	..	..	..	..	..	....
	150–180	47–49°F.	..	...	...	..	..	...	...	..	..	..	..	..	..	..	..	..	..	..	..	....
10th..	110–150	41–47°F.	..	...	...	..	..	...	...	..	..	..	1	..	..	..	..	..	..	..	..	1
	150–180	47–49°F.	..	...	...	..	..	...	...	..	..	..	..	..	..	..	..	..	..	..	..	....
All ages	110–150	41–47°F.	14	196	201	74	62	55	73	67	53	31	21	8	4	..	1	..	..	2	..	862
	150–180	47–49°F.	1	2	2	6	30	52	36	21	19	32	25	14	13	6	3	2	1	..	2	267
Total	.....	.....	15	198	203	80	92	107	109	88	72	63	46	22	17	6	4	2	1	2	2	1,129

* The yearlings of one collection from Ross Lake, Gladwin County, collected June 26. In this collection only a few fish were older than yearlings.

† Miscellaneous localities and dates, as for all other rows.

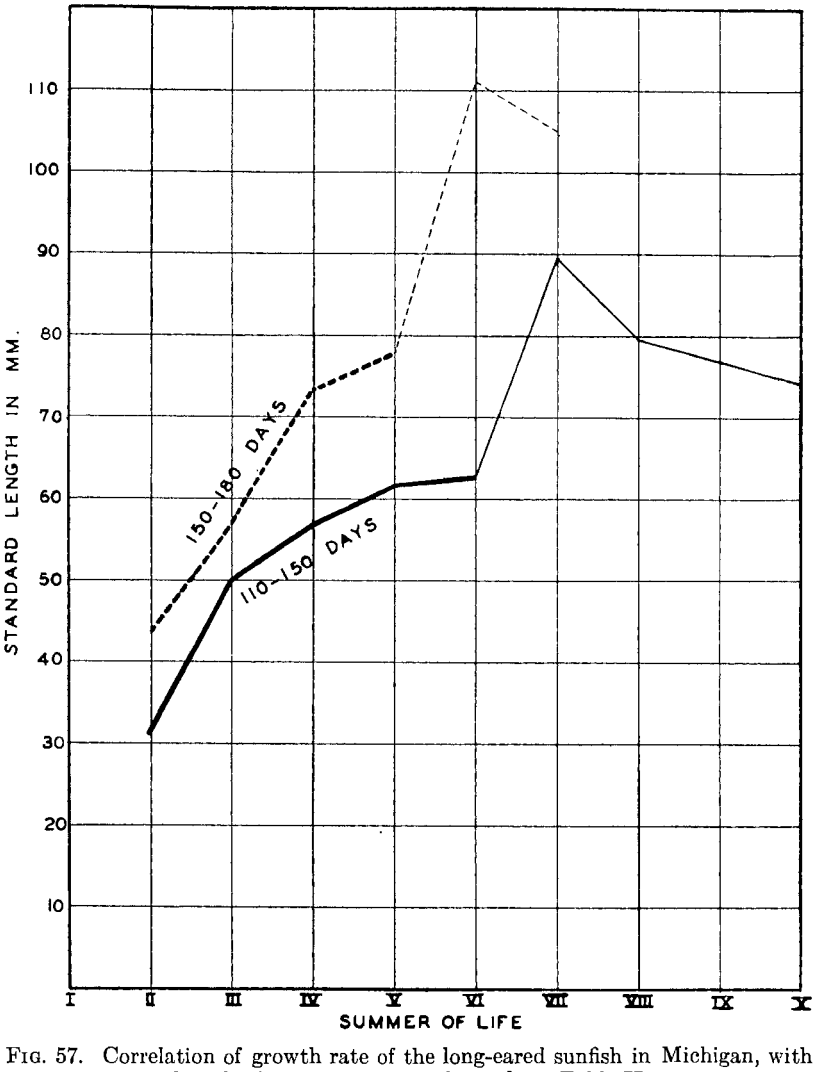


FIG. 57. Correlation of growth rate of the long-eared sunfish in Michigan, with length of growing season. Data from Table II

TABLE II

AVERAGE SIZE (STANDARD LENGTH IN MM.) FOR LONG-EARED SUNFISH OF EACH AGE GROUP IN MICHIGAN, ARRANGED ACCORDING TO LENGTH OF GROWING SEASON AND MEAN ANNUAL TEMPERATURE

The inferior figure appended to each average represents the number of specimens on which the average is based.

Growing season in days	Mean temp.	Summer of life								
		2d	3d	4th	5th	6th	7th	8th	9th	10th
110–150	41–47° F.	31.0_{490}	49.9_{180}	56.7_{88}	61.5_{83}	62.5_{14}	89.3_{4}	79.5_{2}	..	74.0_{1}
150–180	47–49° F.	43.5_{59}	56.6_{142}	73.2_{35}	77.7_{28}	111.0_{1}	105.0_{2}	..	..	..

TABLE III

AVERAGE SIZE (STANDARD LENGTH IN MM.) FOR GREEN SUNFISH OF EACH AGE GROUP IN MICHIGAN, ARRANGED ACCORDING TO LENGTH OF GROWING SEASON

The inferior figure appended to each average represents the number of specimens on which the average is based.

Growing season in days	Summer of life							
	1st	2d	3d	4th	5th	6th	7th	8th
110–150	19.8_{80}	44.0_{129}	59.8_{57}	80.8_{22}	91.7_{11}	114.3_{3}	114.4_{5}	158.0_{1}
150–180	11.0_{6}	40.8_{45}	65.6_{83}	89.2_{45}	118.3_{7}	127.5_{13}	146.5_{6}	145.0_{1}

TABLE IV

NUMBER OF SPECIMENS OF GREEN SUNFISH COLLECTED BEFORE JULY 11 AND AFTER JULY 10 FOR THE TWO CLIMATIC DISTRICTS OF EACH AGE GROUPING

Date of collection	Growing season in days	Summer of life							
		1st	2d	3d	4th	5th	6th	7th	8th
Before July 11	110–150	2	4	6	..	1	..	..	..
	150–180	6	31	31	35	3	11	5	1
After July 10	110–150	78	125	51	22	10	3	5	1
	150–180	..	14	51	10	2	1	1	..

gradients indicated by Seeley, "the average number of days in the growing season" and "the mean temperature for the year." The distribution of our collections of the green sunfish with respect to length of growing season is shown in Map 47. A change from this basis of classification to the mean temperature basis, with groupings of 39° to 47° F. and of 47° to 50° F., would involve the transference of only nine specimens, in their second and third summers, representing three collections, and would in no way modify the conclusions. A study of Table III and Figure 58 reveals a decreased growth rate in the northern part of the state. The circumstance that the northern fish in the first and second summers were larger than the southern fish of the same age groups, though inconsistent with our general conclusion, is easily explained. A separate tabulation of the number of specimens collected before July 11 and after July 10, for the two climatic districts in each age grouping (Table IV), shows that the majority of the northern fish (with a 110–150-day growing season) were collected after July 10, and that the majority of the southern fish (150–180-day season) were taken before July 11. Thus the fish from the northern area had lived through a longer portion of the last growing season than had the fish of the same age group from the southern area. By the third and fourth summers the difference in size effected by climatic factors is more than sufficient to counterbalance the effect of this fortuitous difference in time of capture.

III. CORRELATION BETWEEN THE GROWTH OF THE FIRST AND OF THE SECOND YEAR

Some authors have indicated[1] a tendency toward "growth compensation" in several fishes, that is, an adjustment leading toward reduced variation in size with increasing age. This would involve a negative correlation between early growth and later growth. We find no evidence that this tendency holds for the growth of the long-eared sunfish in Michigan over the first two years of life (the period for which our data are adequate). A positive correlation exists between the growth of the first year and that of the second year for each sex in single collections (see Table V).

In computing the first year's growth from fish two years old (in

[1] Three such indications were referred to or given by Hubbs, *Ecology*, 2:275. 1921.

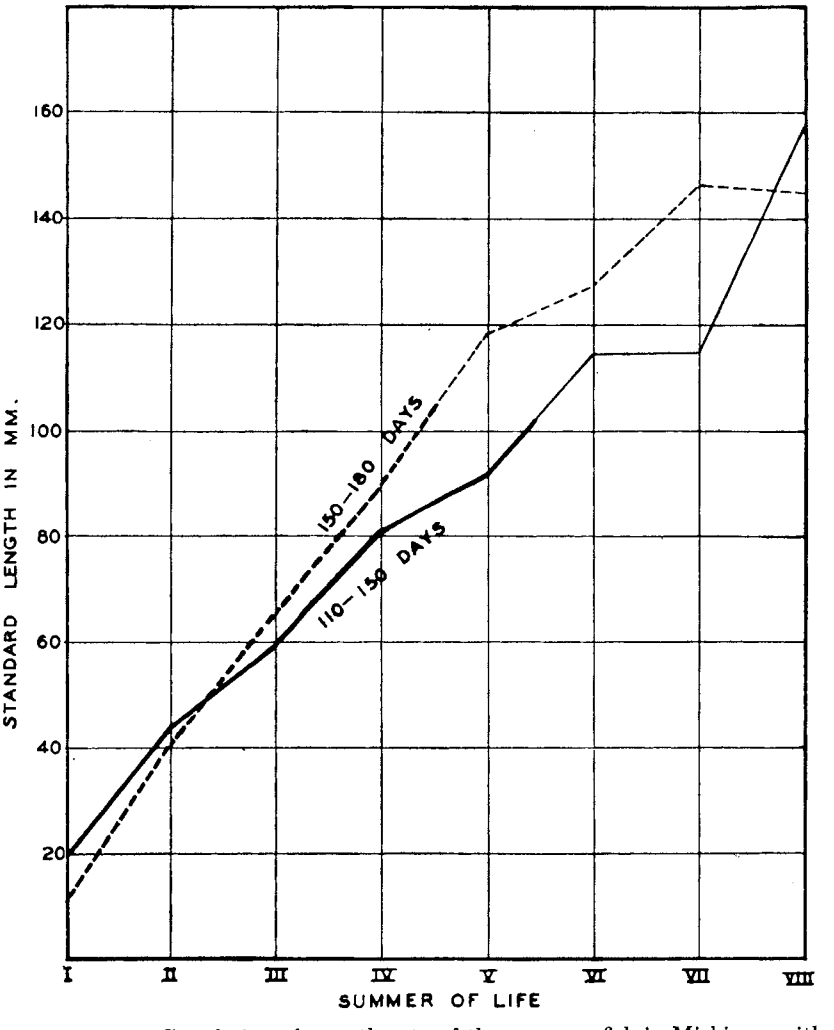


FIG. 58. Correlation of growth rate of the green sunfish in Michigan, with length of growing season. Data from Table III

TABLE V

CORRELATION BETWEEN GROWTH OF FIRST YEAR AND OF SECOND YEAR IN SUNFISHES IN MICHIGAN

Species	Growing season in days	Locality	Sex	No. of specimens	Coefficient of correlation (r)	Probable error of r (PE_r)	$\frac{r}{PE_r}$
Xenotis megalotis	110–130	Tomahawk Lake, Montmorency Co.	Male Female	12 12	+0.63 −0.42	0.12 0.16	5 3 −
Do.	do.	Bass Lake, Kalkaska Co.	Male Female	32 18	+0.54 +0.60	0.08 0.10	6 6
Do.	150–180	Huron River, Washtenaw Co.	Male ..	22 ..	+0.40	0.12	3 + ..
Do.	do.	Wilson Lake, Hillsdale Co.	Male Female	48 20	+0.76 +0.52	0.04 0.11	19 5
Eupomotis gibbosus	do.	Crystal Lake, Oceana Co.	Male Female	90 96	+0.46 +0.47	0.06 0.05	8 9
Eupomotis × *Helioperca*	do.	do.	Male Female	67 16	+0.41 +0.54	0.03 0.12	14 4.5
Helioperca incisor	do.	do.	Male Female	92 91	+0.90 +0.79	0.01 0.03	90 26

third summer), the method of computation adopted by Hubbs and Hubbs (1933 : 619–623) was employed. The scale measurements were made of the anterior embedded field along the median axis.

The data used by Hubbs and Hubbs in the paper just cited show a similar positive correlation between the growth of the first year and that of the second year (up to the time of capture of the yearling fish on October 25) for two other species of sunfish and for the hybrids between them. These data are included in Table V.

The positive correlation between the growth of the first and of the second year in sunfishes means of course that those individuals of one sex at one locality which grow more than the average during the first year usually grow more than the average during the second year as well, whereas those which grow less during their first year usually grow poorly in their second year also. This naturally leads to an increased dispersion in size with age — a phenomenon well shown in the size frequency graphs for separated age groups in sunfishes (Creaser, 1926, Fig. 4; Hubbs and Hubbs, 1933, Figs. 69–70).

The positive correlation between the growth of the first and of the second year at one locality may be due to any one of four reasons:

(1) The individuals which attain a greater growth during their first year, owing to early hatching or any other factor, may possess such a competitive advantage over the slowly growing fish of the same age that they obtain more food during the second year. In rearing sunfish in aquaria it was obvious that the larger fish became the masters, obtaining food first and worrying the smaller individuals in combat, at times to the point of death.

(2) Some fish may select and inhabit through both years ecological niches particularly conducive to rapid growth, or the reverse.

(3) The rate of growth in the first year may in some physiological way similarly affect the growth of the second year.

(4) There may be genetic differences in growth potential between different individuals.

IV. DIFFERENTIAL GROWTH OF THE SEXES

It is a very general belief, as Van Cleave and Markus (1929 : 534) have indicated, that female fishes grow somewhat larger and presumably faster than the males. There is, indeed, a very considerable body of evidence to indicate that the growth of the sexes is either very similar, or that the females grow faster than the males. The general circumstance that very large specimens of many species are usually females is explainable in part as due to the greater growth of the females, but also in part as the consequence of the greater viability of the females.

The long-eared sunfish forms a conspicuous exception to this apparently general rule that the female fish grow faster than the males of the same species. Tables VI–VII and Figure 59 give adequate evidence that the males in this species grow faster than do the females. A small difference is already apparent among yearling fish (that is, those in their second year), and becomes accentuated in the mature fish. When the differential growth starts is uncertain. It becomes apparent a year before first spawning. It is rather doubtful, however, whether there is any significant difference in the average size of the sexes at the end of their first season's growth, that is, in their first winter (Table VIII). For all the sexed specimens of long-eared sunfish from Michigan in our collection (605 males and 491

TABLE VI

AVERAGE SIZE OF THE SEXES OF LONG-EARED SUNFISH OF EACH AGE GROUP, FOR EACH OF THE CLIMATIC DISTRICTS IN MICHIGAN

The inferior figure appended to each average represents the number of specimens on which the average is based.

Growing season	Mean temp.	Sex	Summer of life								
			2d	3d*	4th	5th	6th	7th	8th	9th	10th
110–150 days	41–47°F.	Female	30.5_{233}	47.2_{66}	54.7_{47}	59.2_{52}	54.8_{6}	93.0_{2}	82.0_{1}	..	74.0_{1}
		Male	31.3_{233}	51.6_{113}	59.1_{41}	65.3_{31}	68.3_{8}	85.5_{2}	77.0_{1}	..	..
150–180 days	47–49°F.	Female	43.4_{19}	51.5_{34}	70.0_{18}	69.6_{13}	..	99.0_{1}	..	..	..
		Male	46.6_{32}	58.2_{108}	75.2_{19}	84.7_{15}	110.0_{1}	110.0_{1}	..	..	..

* Usual age at first maturity.

TABLE VII

DEVIATION OF THE STANDARD LENGTH OF INDIVIDUAL MALE SPECIMENS OF LONG-EARED SUNFISH FROM THE MEAN LENGTH OF FEMALES OF THE SAME AGE GROUP IN THE SAME COLLECTION IN MICHIGAN

Only those age groups in any one collection which contain at least four females were used. Measurements and computations are expressed to the nearest millimeter.

Summer of life	Deviation in size of individual males from average size of females in millimeters											
	−13 to −11	−10 to −8	−7 to −5	−4 to −2	−1 to +1	+2 to +4	+5 to +7	+8 to +10	+11 to +13	+14 to +16	+17 to +19	+20 to +22
Second.....	1	..	10	39	90	73	27	2	..	..	..	..
Third.....	..	1	8	11	15	16	15	14	14	5	6	4
Fourth.....	..	..	..	..	1	3	4	2	4	1	2	..
Fifth.....	..	..	..	1	2	1	1	2	4	2	..	..

females) the average size is 48.1 mm. for males and 43.3 mm. for females. This is presumably not due to a greater longevity of the males, because the males seem to be less viable than the females (see section below on sex ratios).

In the green sunfish also the males grow faster than the females (Table IX and Fig. 60). The difference in the size of the sexes in their second summer, as determined by averaging the lengths of all specimens studied, is slight and seemingly not significant. A com-

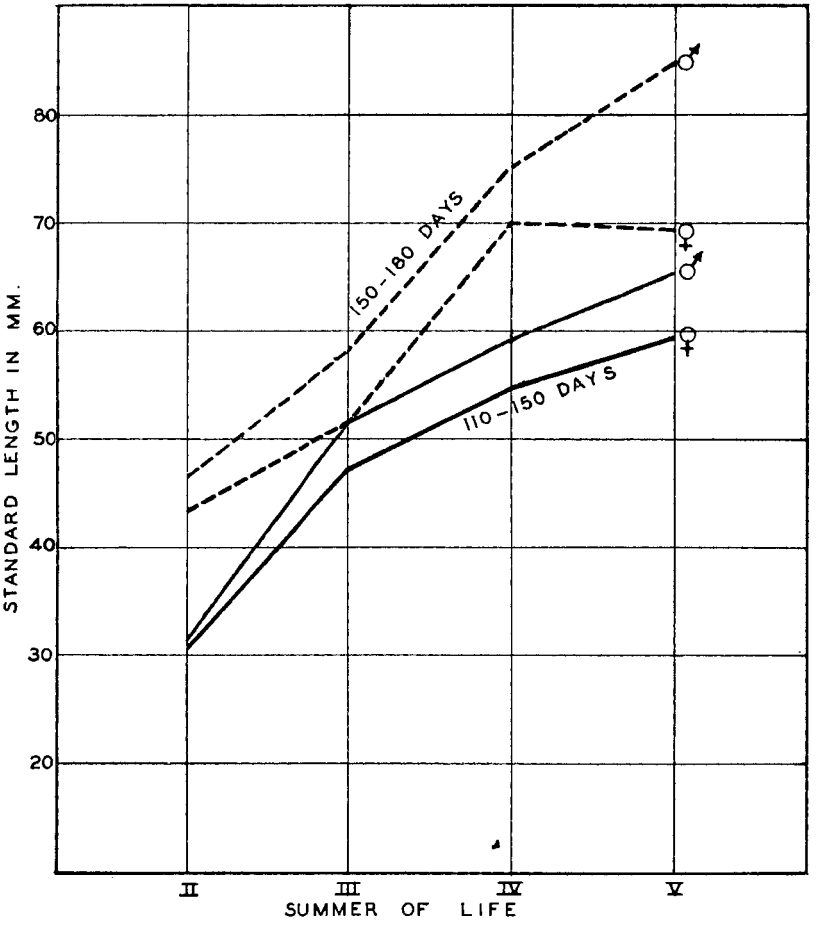


FIG. 59. Growth curves of the two sexes of long-eared sunfish in the two growing-season districts of Michigan. Data from Table VI

parison of the sizes of specimens of each sex within single collections (Table X) shows that the males apparently average somewhat larger than the females even before maturity is attained. The sexual dimorphism in size seems to increase during the third and fourth summers, and probably also throughout the still older year groups, though these are represented by too few specimens to yield certain conclusions.

TABLE VIII

COMPARATIVE SIZE OF SEXES OF LONG-EARED SUNFISH IN THREE COLLECTIONS FROM MICHIGAN, AT THE END OF THEIR FIRST SEASON'S GROWTH, AS COMPUTED FROM FISH IN THEIR THIRD SUMMER

Growing season	Locality	Sex	No. of specimens	Average size
110–130 days	Tomahawk Lake, Montmorency Co.	Female	12	22.6
		Male	12	21.7
110–130 days	Bass Lake, Kalkaska Co.	Female	18	23.7
		Male	32	24.3
150–180 days	Wilson Lake, Hillsdale Co.	Female	20	20.3
		Male	48	20.6

TABLE IX

AVERAGE SIZES OF THE SEXES OF GREEN SUNFISH IN EACH AGE GROUP, ARRANGED ACCORDING TO THE LENGTH OF THE GROWING SEASON

The inferior figure appended to each average represents the number of specimens on which the average is based.

Growing season	Sex	Summer of life						
		2d	3d	4th	5th	6th	7th	8th
110–150 days	Female	44.9_{60}	59.2_{32}	75.6_{8}	83.0_{2}	96.0_{1}	.....	.....
	Male	45.4_{54}	62.0_{22}	83.8_{14}	93.7_{9}	123.5_{2}	114.4_{5}	158.0_{1}
150–180 days	Female	41.7_{26}	59.8_{36}	81.1_{19}	110.3_{3}	126.3_{4}	122.0_{1}	.....
	Male	40.8_{18}	70.0_{47}	95.2_{26}	124.3_{4}	128.1_{9}	151.4_{5}	145.0_{1}

It is probable that the males of at least most species in the family Centrarchidae grow faster than the females. This was suggested by Creaser's data (1926, Fig. 3) for *Eupomotis gibbosus,* and was definitely indicated by Tester (1932 : 215) to hold for *Micropterus dolomieu.* Hubbs and Hubbs (1933 : 622) showed that the males of *Eupomotis gibbosus,* of *Helioperca incisor,* and of hybrids between them grow at about the same rate as the females during their first year of life, but at a faster rate during their second year. Dr. Ralph Hile informs us that the males of *Ambloplites rupestris* grow faster than the females.

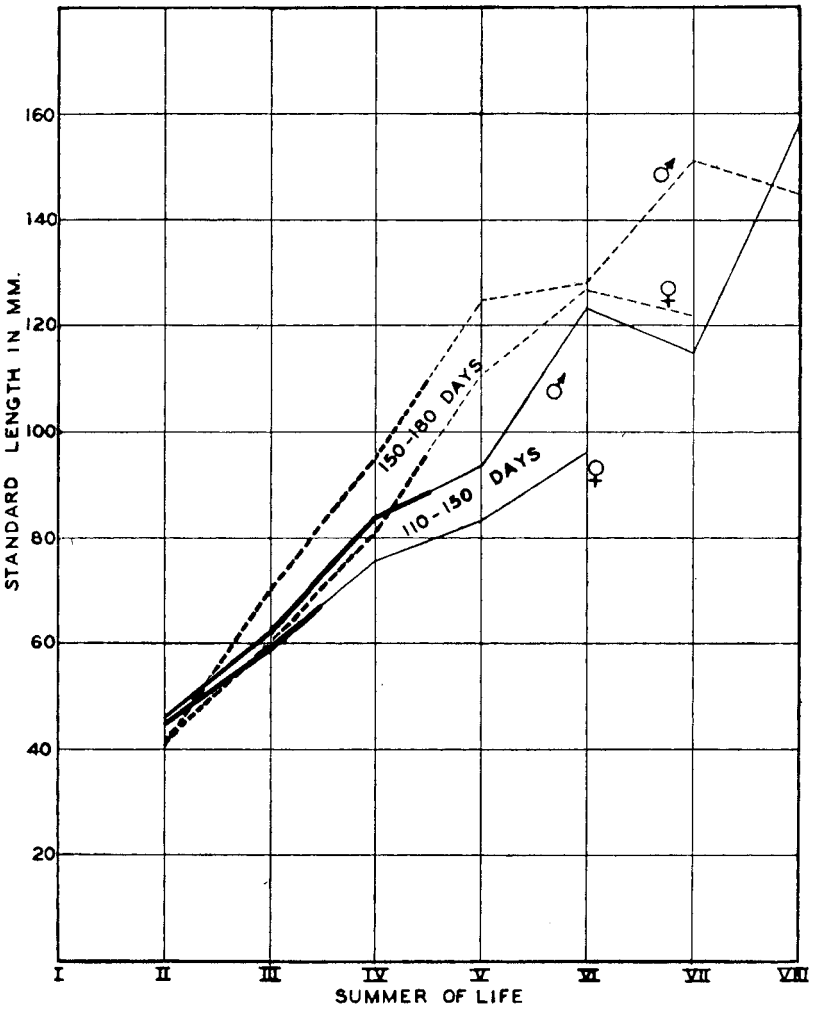


FIG. 60. Growth curves of the two sexes of green sunfish in the two growing-season districts of Michigan. Data from Table IX

TABLE X

DEVIATION OF THE STANDARD LENGTH OF INDIVIDUAL MALE SPECIMENS OF GREEN SUNFISH FROM THE MEAN LENGTH OF FEMALE SPECIMENS OF THE SAME AGE GROUP AND COLLECTION IN MICHIGAN

Only those age groups in any one collection which contain at least four females were used. Measurements and computations are expressed to the nearest millimeter.

Summer of life	Deviation in millimeters																
	−10 to −8	−7 to −5	−4 to −2	−1 to +1	2 to 4	5 to 7	8 to 10	11 to 13	14 to 16	17 to 19	20 to 22	23 to 25	26 to 28	29 to 31	32 to 34	35 to 37	38 to 40
Second ..	4	4	8	5	3	11	4	2	2	1	..	1	..	..	..	..	..
Third ...	1	1	4	2	4	7	5	3	4	2	2	2	..	..	..	..	1
Fourth ..	..	..	1	1	2	..	2	2	1	2	1	2	..	..	1	..	..

The significance of this apparently altered differential growth rate of the sexes is of course a matter of speculation. Our supposition is that the increased growth of the males has been of selectional significance, enabling them the better to ward off enemies from the nests which they guard so pugnaciously.

This hypothesis will of course be very difficult to test. It receives confirmation, however, from the differential growth rate of the sexes in Cyprinidae. In that family most species show no specific nest-building or nest-guarding habits, and in these forms the females reach as large a size as the males or become larger, and probably grow as fast or faster. But there are some notable exceptions, in which the male becomes much larger than the female. These are the very species which build or guard some sort of nest, or perform both functions. This correlation of differential growth rate with breeding habits can hardly be a coincidence, since it involves a considerable number of unrelated genera. The greater growth rate of the male has been indicated in published papers for two cyprinids, for *Hyborhynchus notatus* by Van Cleave and Markus (1929), and for *Semotilus atromaculatus* by Greeley (1930). Hubbs and Creaser observed this phenomenon in 1921, not only for the two species just mentioned, but also for *Nocomis biguttatus* and *Notropis cornutus frontalis*. Males of other American cyprinids which guard the eggs grow larger than the females, notably the other subspecies of *Notropis cornutus*, and *Nocomis micropogon, Leucosomus corporalis, Exoglossum*

maxillingua, Pimephales promelas, and *Campostoma anomalum.* Professor Yuanting T. Chu calls our attention to the fact that the males of an Asiatic cyprinid, *Pseudorasbora parva,* likewise guard the eggs and grow larger than the females.

V. SEX RATIO

Among the second-summer or yearling specimens of the long-eared sunfish, almost all immature, the two sexes are represented in approximately equal numbers. About seven tenths of the fish a year older, in their first usual year of maturity, are males. This aberrant sex ratio is certainly not representative of the actual natural population, but obviously results from the extreme ease of collecting the gregariously breeding males on their nests in shallow water. But by the next year (fourth summer) the sexes in the collections are again approximately equal, suggesting an actual preponderance of the more retiring females. For subsequent years the females in the collections somewhat outnumber the males, and are presumably decidedly more numerous in nature. Of the three oldest fish two are females in their eighth and tenth summers, and one is a male in its eighth summer. The data are given in Table XI.

Data on the sex ratio in *Apomotis cyanellus,* given in Table XII, show an increasing percentage of males among the older fish, thus contrasting with the condition found in *Xenotis.* Since the males of *Apomotis* are not so gregarious in their breeding, collections having an abnormally large number of that sex do not occur. As an apparent consequence the sexes are more evenly represented in the collections of green sunfish. The increasing ratio of males in *Apomotis* with age suggests that the males are more viable than the females. This is contrary to the general rule as well as to the situation found for *Xenotis,* and needs confirmation.

VI. AGE AND SIZE AT MATURITY, AND SUBSEQUENT LIFE HISTORY

Xenotis megalotis in Michigan appears to mature at a definite age rather than at a definite size. In both the southern and northern parts of the state the great majority of individuals mature first at the age of two years, that is, in their third summer. This is true despite the circumstance that the immature yearlings in the south are often as large, usually 40 to 50 mm. in standard length, as the average mature two-year-old fish in the north. In their first summer of

TABLE XI

SEX RATIOS FOR LONG-EARED SUNFISH AS DETERMINED FROM THE MICHIGAN SPECIMENS STUDIED

Summer of life	Usual maturity	No. of males	No. of females	Percentage of males
Second.....	Immature (yearlings)	265	252	51
Third.....	First year of maturity	221	100	69
Fourth.....	Second year of maturity	60	63	49
Fifth to tenth	Subsequent years (mature)	59	76	44

TABLE XII

SEX RATIOS FOR GREEN SUNFISH AS DETERMINED FROM THE MICHIGAN SPECIMENS STUDIED

Summer of life	Maturity	No. of males	No. of females	Percentage of males
Second.....	Almost all immature	72	86	46
Third.....	About 75% mature	69	68	50
Fourth.....	All mature	40	27	60
Fifth to eighth	All mature	36	11	77

maturity the long-eared sunfish in southern Michigan are usually 45 to 75 mm. in standard length (2.0 to 3.5 inches in total length), while those in northern Michigan are usually 35 to 65 mm. in standard length (only 1.5 to 3.0 inches long over all) during this first season of maturity (Tables I and XIV).

There is little variation in the age at maturity of long-eared sunfish in Michigan. Occasional large yearlings at scattered localities are mature, or maturing so as to spawn in their second summer. Similarly a few two-year-old (third-summer) fish are immature, and, in agreement with this, a few fish show no trace of a spawning mark on their scales inside the third winter line.

A considerable percentage of the long-eared sunfish in Michigan which reach maturity live through three years of maturity (Tables I and XIV). About as many four-year-old as three-year-old fish appear in the collections studied. Relatively few, however, live to be older; for both sections of the state there is a sharp drop in numbers between the fifth and the sixth summer of life. Of the 1,129 fish

studied only 6 are in the seventh summer, 2 in their eighth, and 1 in its tenth year (approximately nine years old). All three of the eighth- and tenth-summer fish are from the northern growing district (110–150 days). Of the 24 fish in their sixth to tenth year, 21 (nearly 90 per cent) are from the northern district, although only 64 per cent of the total number of fish studied, yearlings excepted, are from that district.

All the green sunfish in Michigan appear to be mature in their fourth and subsequent summers. Roughly about three fourths of the third-summer fish and a very few of the second-summer fish are mature. In single collections the early spawners within a given year group are the larger individuals of that year group, yet no significant differences in age of maturity are correlated with the differential growth rates of fish from the northern and the southern parts of the state, or with sex. The over-all size at first maturity for both sexes averages slightly over three inches in the southern part of the state, and slightly under three inches in the northern district. Greater longevity in the region of slower growth is indicated by the data; in our collections from the southern and the northern areas the relative numbers of individuals in each summer of life from the first to the eighth, are: 80 : 6, 129 : 45, 57 : 83, 22 : 45, 11 : 7, 3 : 13, 5 : 6, 1 : 1. The ages and sizes of the green sunfish at maturity are indicated in Tables XII and XV.

VII. THE SPAWNING SEASON

Observations of nesting fish, supplemented by the examination of the gonads of preserved specimens, show that the spawning season of the long-eared sunfish in Michigan centers in July, but extends from the latter part of June into early August. Like other distinctly summer spawners, it does not mature the gonads during the fall preceding spawning, as do most of our early spring spawning fishes.

Our observations of the green sunfish indicate a prolonged spawning season for this species in Michigan. This is especially obvious from our data on the size distribution of the young of the year, given in Table XIII. The first two entries in this table definitely indicate June spawning; the sizes of the young of subsequent collections make it clear that spawning extends through July and probably into August, to judge from the growth attained at the time of capture. Gravid females occur in collections made as early as June 25 and as

TABLE XIII

SIZE OF GREEN SUNFISH IN THEIR FIRST SUMMER OF LIFE, IN SINGLE COLLECTIONS FROM MICHIGAN

Growing season in days	Lake	County	Date	Mean length, in mm.	No. of specimens
150–180	Third Sister Lake	Washtenaw	July 1	11.0	6
110–150	Whipple Creek	Newaygo	July 9	31.0	2
Do.	Railroad Lake	Lake	July 18	17.0	1
Do.	Little Log Lake	Kalkaska	August 9	18.0	1
Do.	Highbank Lake	Newaygo	August 24	18.1	34
Do.	Kichners Lake	Menominee	August 30	21.8	29
Do.	Cranberry Lake	Kalkaska	Sept. 11	20.2	5
Do.	Sand Lake	Newaygo	Sept. 17	16.0	1
Do.	Onatoga Lake	Otsego	Sept. 27	23.0	1
Do.	Horseshoe Lake	Otsego and Crawford	Sept. 29	16.7	6

late as July 27. Males in southern Michigan retain running milt as late as September 28. Forbes and Richardson (1909 : 250) indicated spawning of the green sunfish in Illinois as late as August 14.

VIII. THE SPAWNING MARK ON THE SCALES

Several who have worked on the life history of centrarchid fishes have noted "double annuli" which we have thought might reflect checks in growth due to both winter and breeding. Now we feel justified in stating, for the long-eared and the green sunfishes at least, that spawning is usually registered on the scale by a definite mark (Pls. CIV–CVIII). The spawning mark is closely associated with and lies within a winter annulus, usually within each annulus from the third one out to the last one shown on the scale. This spawning mark indicates an abrupt though temporary slackening or cessation of growth during the breeding season.

The spawning mark is most clearly evident across the anterior or concealed field of the scale and in the anterior portion of the lateral fields. Here it is often more conspicuous than the true winter line. It often appears as a definite clear break across the anterior field, caused largely by the straightening out of the ridges (circuli) between the radii. Between a spawning mark and the preceding annulus the ridges are usually strongly curved inward between each two radii,

whereas from the spawning mark outward to the following annulus the ridges are usually straight. This change in the curvature of the ridges tends to leave clear lenticular gaps along the line of the spawning mark.

The ridges representing the spring growth out to the spawning check are widely spaced; those representing the fall growth outside the spawning mark are often (though by no means always) more densely crowded, so as to form a dark band across the anterior field of the scale. This dark band of crowded ridges when developed is usually continued around and just back of the anterolateral angles. Rarely the breeding mark may be traced into or even across the posterior or exposed field of the scale, separate from the winter annulus, though usually the two marks merge together in advance of the posterolateral angle. This would seem to indicate that the scale grows chiefly in the anterior direction after the spawning time, thus embedding the scale more deeply into the flesh. Dorsoventral growth of the scale seems to be very slight after spawning, except toward the anterolateral angle, along which the growth is about as great as on the anterior field.

The more complete spawning marks have probably been mistaken occasionally by previous investigators for winter annuli. A thorough understanding of the features of the two marks should make such errors in age determination very rare.

Although as stated above the spawning season of the long-eared sunfish in Michigan centers in July, extending from late June to early August, the spawning mark is usually much nearer the following winter annulus than the preceding one. This suggests that a very rapid spring growth and a more sluggish late summer and fall growth is the rule. The wide spacing of the circuli laid down prior to spawning and the crowding of the post-spawning circuli are in harmony with this view that the growth is slackened in the later part of the season.

The formation of the spawning mark is clearly coincident with breeding. Scales from either species taken in the late spring prior to spawning show the widely spaced ridges characteristic of spring growth, without a trace of a spawning mark near the margin. Scales from male long-eared sunfish taken on their redds in the Huron River, Michigan, on June 28, show little indication of a spawning mark, whereas almost all those taken on their nests in the same river on

July 7 and 9 show a spawning mark forming or completely formed, at or very near the margin of the scale. Autumn-taken fish have scales showing the spawning mark well inside the margin.

IX. RELATION OF SIZE AND GROWTH TO LEGAL LIMIT

The laws of Michigan, as they now stand (March, 1934), list the long-eared sunfish (*Xenotis megalotis peltastes*) and the green sunfish (*Apomotis cyanellus*) as game fishes, and stipulate the legal size limit of these species as six inches.

Not one long-eared sunfish among the 1,129 specimens available for the present research is so large (see Table XIV). It is doubtful whether one long-eared sunfish per thousand mature fish in Michigan is of legal size. Less than 0.5 per cent of our examples are more than 5 inches long. Only 1 in 18 or 19 is more than $3\frac{1}{2}$ inches long. This species is clearly not in need of any protection in the way of a legal size limit. Placing a legal size limit of 6 inches, or of 5 or even of 4 inches, on this species gives it complete or almost complete protection.

Only 4 per cent of the green sunfish specimens studied are of legal size (Table XV). Whether this percentage is representative of the natural fauna or not is debatable, since most collecting is done in shallow water with small seines and is somewhat selective of the smaller fish. However, of the twenty fish of legal size, eleven were collected by Professor T. L. Hankinson in Oakland County, mostly from Walnut Lake. Since his collections included only five specimens under the legal size, he obviously selected for preservation chiefly the larger fish. This compensates more or less for the selectiveness of seining methods for the smaller fish. This selectivity is probably not severe anyway, since the green sunfish is a shoal-loving species. All the legal-sized fish were taken from lakes, 85 per cent from the southern part of the state (150–180-day growing season), and hence only 15 per cent from the northern district (110–150-day growing season). Of the fish studied only one in one hundred from the northern zone is of legal size. If the selected Walnut Lake collections be excluded, only one fish in thirty-two from the southern zone is of legal size.

Protecting these dwarfed sunfishes apparently has no beneficial effects, and may be decidedly harmful to fishing for pan fish in certain inland lakes. They must to a considerable degree compete with the pumpkinseed and bluegill sunfishes for food and for spawning

TABLE XIV

DISTRIBUTION OF SPECIMENS OF LONG-EARED SUNFISH ACCORDING TO TOTAL LENGTH IN INCHES AND TO MATURITY

	Summer of life	Growing season in days	Total length, including caudal fin, in inches															
			0.9–1.1	1.2–1.4	1.5–1.7	1.8–2.0	2.1–2.3	2.4–2.6	2.7–2.9	3.0–3.2	3.3–3.5	3.6–3.8	3.9–4.1	4.2–4.4	4.5–4.7	4.8–5.0	5.1–5.3	5.4–5.6	Total
	2d*	110–150	8	200	213	56	10	2	1	..	..	..	..	..	..	..	..	..	490
		150–180	..	4	2	14	26	9	1	2	1	..	...	..	..	..	..	..	59
Almost all mature	3d	110–150	..	...	10	23	42	52	32	11	8	1	1	..	..	..	..	..	180
		150–180	..	...	...	..	28	48	19	21	19	3	4	..	..	..	..	..	142
	4th	110–150	..	...	...	2	11	19	27	12	13	4	..	..	..	..	..	..	88
		150–180	..	...	...	..	...	...	3	4	11	5	9	3	..	..	..	..	35
	5th	110–150	..	...	...	..	...	8	28	24	20	2	1	..	..	..	..	..	83
		150–180	..	...	...	..	...	...	...	1	12	3	5	5	1	1	..	..	28
	6th	110–150	..	...	...	..	2	4	1	3	1	1	..	1	..	..	..	1	14
		150–180	..	...	...	..	...	...	...	..	..	..	..	..	..	..	1	..	1
	7th	110–150	..	...	...	..	...	...	...	..	..	1	1	1	..	..	1	..	4
		150–180	..	...	...	..	...	...	...	..	..	..	..	..	..	1	1	..	2
	8th	110–150	..	...	...	..	...	...	...	..	..	1	1	..	..	..	..	..	2
		150–180	..	...	...	..	...	...	...	..	..	..	..	..	..	..	..	..	....
	9th	110–150	..	...	...	..	...	...	...	..	..	..	..	..	..	..	..	..	....
		150–180	..	...	...	..	...	...	...	..	..	..	..	..	..	..	..	..	....
	10th	110–150	..	...	...	..	...	...	...	..	..	1	..	..	..	..	..	..	1
		150–180	..	...	...	..	...	...	...	..	..	..	..	..	..	..	..	..	....
	All ages	110–150	8	200	223	81	65	85	89	50	42	11	4	2	..	..	1	1	862
		150–180	..	4	2	14	54	57	23	28	43	11	18	8	1	2	2	..	267
	Total	.....	8	204	225	95	119	142	112	78	85	22	22	10	1	2	3	1	1,129

* Almost all immature.

TABLE XV

DISTRIBUTION OF SPECIMENS OF GREEN SUNFISH ACCORDING TO TOTAL LENGTH IN INCHES AND TO MATURITY

Summer of life	Growing season in days	Total length, including caudal fin, in inches																									
		0.3 to 0.5	0.6 to 0.8	0.9 to 1.1	1.2 to 1.4	1.5 to 1.7	1.8 to 2.0	2.1 to 2.3	2.4 to 2.6	2.7 to 2.9	3.0 to 3.2	3.3 to 3.5	3.6 to 3.8	3.9 to 4.1	4.2 to 4.4	4.5 to 4.7	4.8 to 5.0	5.1 to 5.3	5.4 to 5.6	5.7 to 5.9	6.0 to 6.2	6.3 to 6.5	6.6 to 6.8	6.9 to 7.1	7.2 to 7.4	7.5 to 7.7	Total
First.....	110–150	..	34	28	17	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	80
	150–180	4	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6
Second...	110–150	..	..	..	3	17	38	36	21	5	6	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	129
	150–180	..	..	1	2	12	14	5	4	6	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	45
Third....	110–150	..	..	..	..	..	..	5	13	17	10	6	2	1	1	2	..	..	..	..	..	..	..	..	..	..	57
	150–180	..	..	..	..	..	..	2	13	12	21	13	12	5	3	..	1	..	1	..	..	..	..	..	..	..	83
Fourth...	110–150	..	..	..	..	..	..	..	..	1	2	3	5	3	3	3	1	1	..	..	..	..	..	..	..	..	22
	150–180	..	..	..	..	..	..	..	..	..	..	2	10	6	8	7	7	3	2	..	..	..	..	..	..	..	45
Fifth.....	110–150	..	..	..	..	..	..	..	..	..	..	1	..	2	2	3	1	1	1	..	..	..	..	..	..	..	11
	150–180	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	2	1	..	2	1	..	..	..	..	7
Sixth.....	110–150	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	..	..	..	..	1	..	..	..	3
	150–180	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	3	1	3	3	..	1	1	..	13
Seventh...	110–150	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	2	..	1	..	..	..	..	..	5
	150–180	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	3	2	..	6
Eighth....	110–150	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1
	150–180	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1
All ages ...	110–150	..	34	28	20	18	38	41	34	23	18	13	7	6	6	9	2	5	3	..	1	..	1	..	..	1	308
	150–180	4	2	1	2	12	14	7	17	18	22	15	22	12	11	7	9	5	7	2	5	4	1	4	3	..	206
Total.....	.....	4	36	29	22	30	52	48	51	41	40	28	29	18	17	16	11	10	10	2	6	4	2	4	3	1	514
Maturity		Almost always immature. Less than three inches long.									Mostly mature but below legal size. Three to six inches long.										Always mature and of legal size. Six inches or longer.						
% total population		61%									35%										4%						

grounds. The competition for food between the adults of the long-eared sunfish and the half-grown of the larger species must be rather severe, especially when the long-eared sunfish becomes abundant. The voracious habits of the green sunfish make it an even worse competitor of the bluegill and pumpkinseed. Its large mouth even enables it, when adult, to eat the same kind of food as the larger young or even the half-grown of the larger game fishes. It even tends to be a predator. When it becomes abundant, it must have an effect on the population of the larger species.

Both the long-eared and green sunfishes do in fact swarm and dominate in certain inland lakes of the state. In all probability the complete or almost complete protection accorded these species by the law has been conducive to their increase. The larger and better sunfish species have suffered a drain and depletion, while the survival of the dwarf species has been favored.

Another potentially harmful effect of multiplying the numbers of these dwarfed species is the increase in number of interspecific hybrids. Whereas these hybrids are not dwarfed, they are infertile, though they vigorously monopolize the sunfish spawning grounds throughout the warm season (Hubbs and Hubbs, 1931, 1933).

It is true that the long-eared sunfish is not generally distinguished by Michigan anglers from the larger species, but the green sunfish is confused with the warmouth bass (*Chaenobryttus gulosus*) under the name of "mud bass." It is claimed by some that a special size limit on the two species would lead to confusion in the enforcement of the law. Our recommendation, however, is that both be removed from the list of game fish entirely, and that the legal limit for "sunfish" be specified as applying to the pumpkinseed and the bluegill. This would allow cottagers (and their children) to remove the excess of the long-eared and green sunfishes when overabundant, after they have learned the identity of the dwarfed species.

In more southern states both the long-eared and the green sunfish attain a more respectable size, and in places rank as pan fishes of some importance. In the Ozarks the green sunfish readily takes the fly, and has a good reputation as a game fish, though in some isolated ponds and in creeks throughout its range it swarms and becomes dwarfed. The recommendations for a change in the legal status of the long-eared and green sunfishes apply to Michigan only. For the lakes in northern Indiana Hile (1931 : 42) concluded that: "It is

doubtful whether legal size [five inches] is reached [by the long-eared sunfish] before the fourth growing season, and some individuals in the III, IV, and V groups scarcely pass the scrutiny of the law." In Ohio no size limit is stipulated for either the long-eared or the green sunfish (there is a bag limit of twenty per day for all sunfishes combined), even though both species tend to grow larger in that state than in Michigan. Milton B. Trautman informs us that in certain of the smaller Ohio ponds protected from fishing the green sunfish excludes the other species, and becomes so numerous as to be dwarfed.

X. SUMMARY

1. This study was based on the age determination of 1,129 long-eared sunfish (*Xenotis megalotis peltastes*) and of 514 green sunfish (*Apomotis cyanellus*) from Michigan, using the scale methods now becoming standard.

2. These species become more dwarfed toward the north in Michigan, in good correlation with a shortened growing season and lower mean annual temperature.

3. There is no evidence for "growth compensation." In three genera of Centrarchidae, *Xenotis*, *Helioperca*, and *Eupomotis*, a positive correlation exists between the growth of the first and of the second year.

4. In *Xenotis* and *Apomotis*, as in other centrarchids, the male grows faster than the female. This unusual relation may be an adaptation, since larger size would obviously be of advantage to these nest-guarding fishes. In the Cyprinidae likewise the males grow larger than the females in those species in which the male guards the eggs.

5. In *Xenotis* the females apparently live longer than the males, on the average. Our data for the green sunfish indicate, anomalously, that the males are more viable than the females.

6. Attainment of maturity in both species is related to age (usually just two years) rather than to size. Greatest longevity is probably attained in the region of greatest dwarfing. Maximum indicated age for the two species in Michigan is nine years for the long-eared sunfish and seven years for the green sunfish.

7. Both species are summer spawners, nesting from the latter part of June at least into August.

8. A definite spawning mark is usually produced on the scale of

both species, indicating a slackening or cessation of growth during spawning. Spring growth (prior to spawning) appears to be more vigorous than late summer and fall growth.

9. Since the long-eared sunfish very seldom if ever attains its designated legal length of six inches in Michigan, and since relatively few green sunfish exceed that length, these species are obviously not in need of such legal protection. Maintaining them as game fishes favors their increase. They tend to become overly abundant, and probably compete with the better species for food. It is recommended that they be omitted from the list of designated game fishes and that they be exempted from any size or bag limit.

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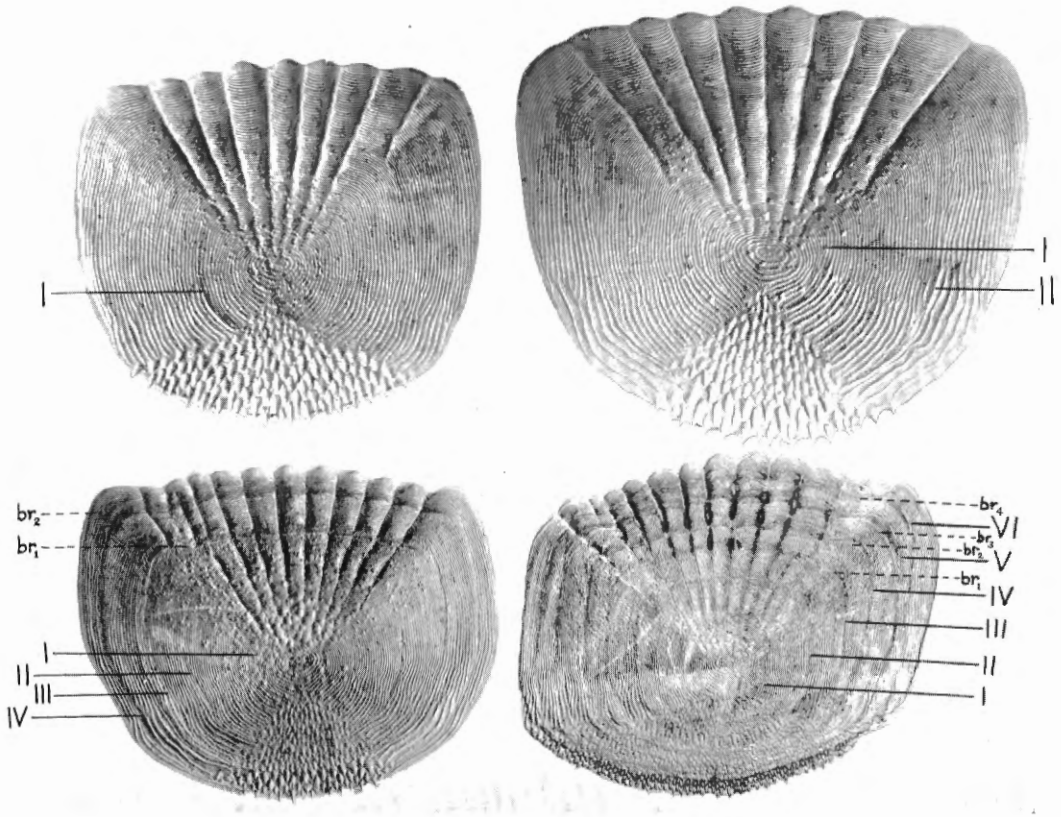
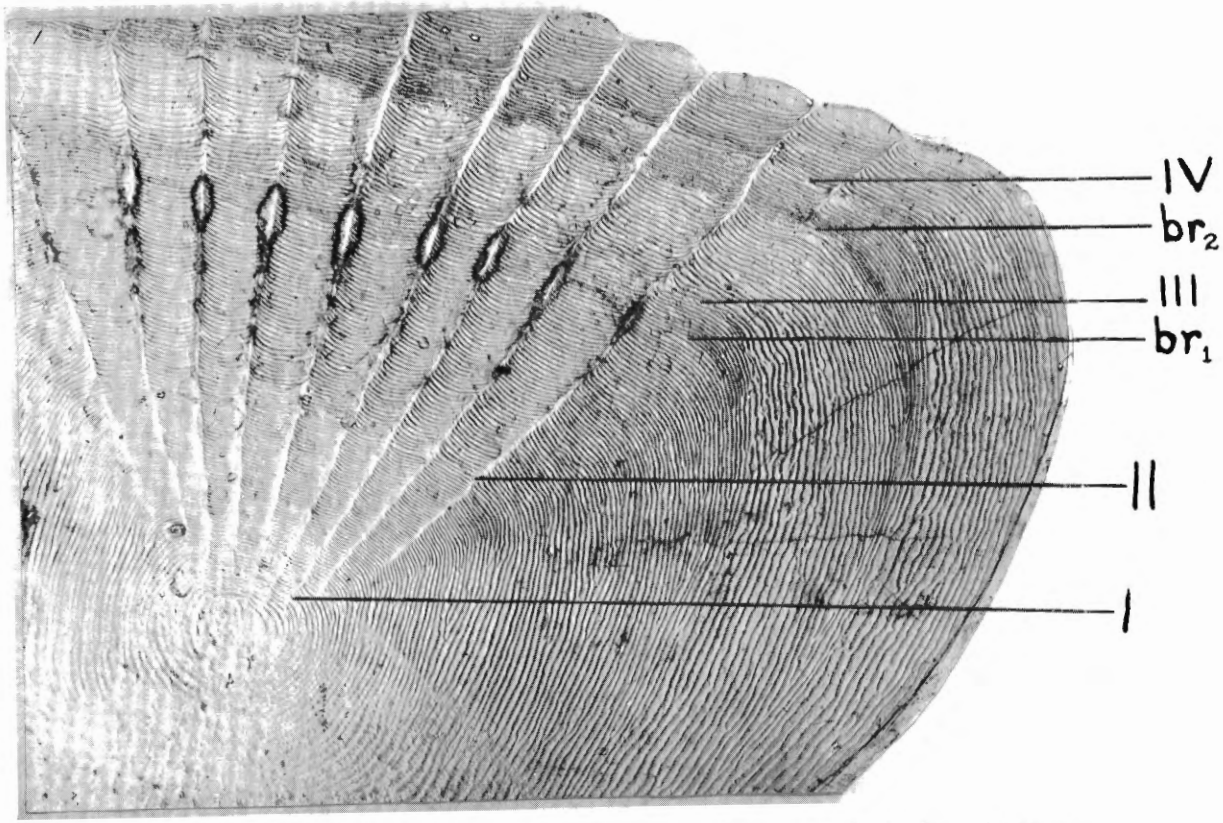
PLATE CIV



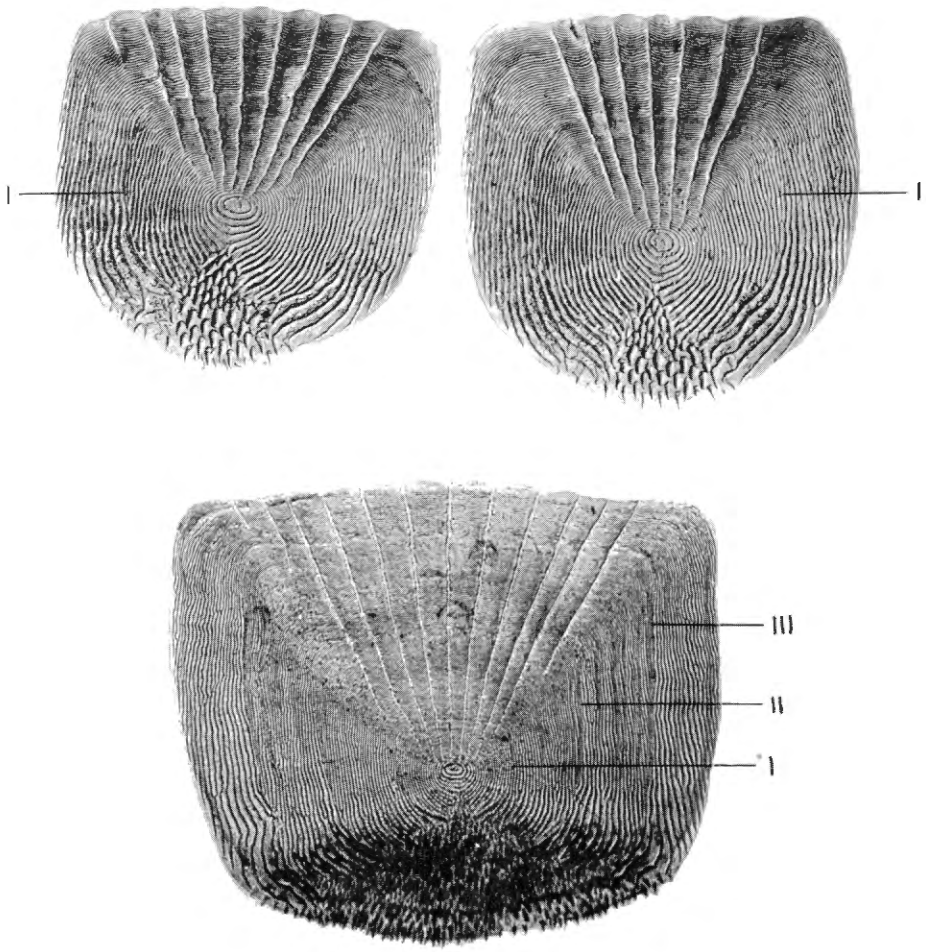
Scales of long-eared sunfish from Michigan, showing respectively 1, 2, 4, and 6 winter marks (annuli). The older scales show in addition 2 and 4 spawning checks (*br*). The older scales are magnified less than the younger two

PLATE CV



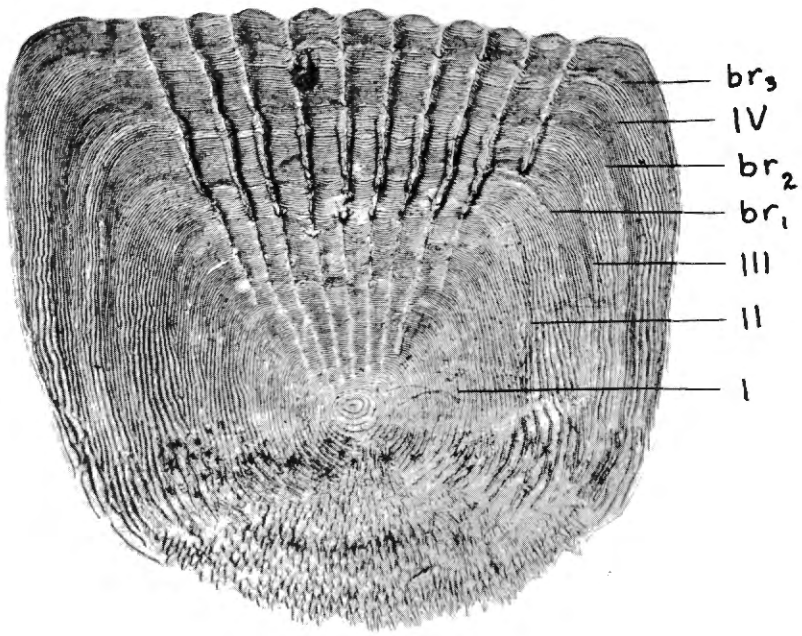
Scale of a four-year-old long-eared sunfish from Michigan, much magnified to show the details of the spawning checks (br_1 and br_2). The Roman numerals, as in the preceding plate, refer to the winter annuli

PLATE CVI



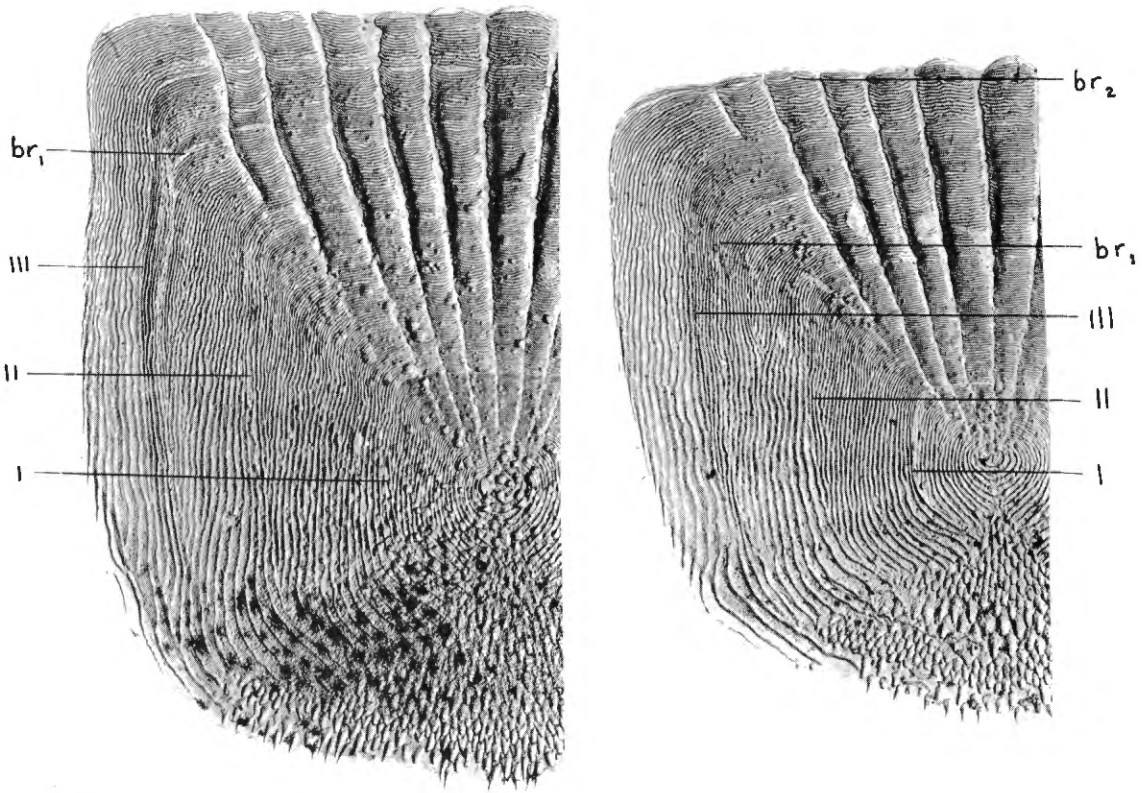
Scales of green sunfish. The two scales showing one winter mark were taken from the same fish, an immature female, standard length of 49 mm., collected in Third Sister Lake, Washtenaw County, on July 1, 1922. The scale showing three winter marks was taken from an adult male, standard length of 92 mm., collected in Long Lake, Hillsdale County, on July 9, 1931

PLATE CVII



Scale of an adult male green sunfish, standard length of 90 mm., collected in Bass Lake, Newaygo County, on August 30, 1926. Four winter marks (I–IV) and three spawning checks (br_1–br_3) are indicated

PLATE CVIII



Sections of green sunfish scales enlarged to show structural details of the spawning check and winter mark. Both fish from which these scales were taken were gravid females (ready to spawn), collected in Long Lake, Hillsdale County, on July 9, 1931. Each scale indicates three winter marks. On one scale the second spawning check had just been formed at the margin, whereas on the other scale the second spawning check had not, as yet, been formed