11. The Rate of Growth of Bluegill Sunfish in Lakes of Northern Indiana

by

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ABSTRACT

The variation in average length of bluegills after three growing seasons, in natural lakes of northern Indiana under normal conditions, extends over the range of 90 to 160 millimeters, with a mean at 121 millimeters, fork length. Exceptional conditions of crowding or poor food supply may depress rate of growth below the lower limits cited, whereas in depopulated waters the upper limit is exceeded. Male and female bluegills grew at almost exactly the same rate in a few lakes. In several lakes, rates of growth have remained steady, within narrow limits, over periods up to 20 years, while in others there is fairly good evidence of considerable variation in rate of growth. After eliminating the effects of non-random sampling from the data, earlier mortality of faster-growing than of slower-growing fish could not be demonstrated, and it is evidently not commonly a well-marked phenomenon.

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INTRODUCTION

Scales from Indiana bluegills (*Lepomis macrochirus macrochirus* Rafinesque) have been collected over a number of years, for the purpose of age determinations. Nearly twenty years ago a small collection was made and studied by Bolen (1924). Hile (1931) reported on the age of several hundred specimens from a number of lakes, taken 1926 to 1929. Soon afterward a collection of scales of sport fish was started by the late Dr. Will Scott, principally from material sent in by fishermen throughout the state; it was continued during the summer of 1938 by Messrs. A. E. Weyer and D. F. Opdyke. Of the 1,300 fish in their combined collection, about a third were bluegills. Age determinations were made by Dr. Scott and Mr. Weyer, and the last-named prepared in 1938 a manuscript report on their rate of growth in some lakes. From 1939 to 1941 additional scales have been secured. A large number have been collected by employees of the Division of Fish and Game, mostly taken in the course of checking winter ice fishing. Others have been taken in various ways by the Lake and Stream Survey, mostly in summer. Finally, interested fishermen have continued to send in scales from some lakes.

Most of the available scales from northern lakes have been used in the work reported here. Only when the collection from a lake was less than three or four specimens has mention of that lake been omitted. There remain however collections from lakes and streams in other parts of the state, on which reports will be made separately. Two such reports appear in the current volume of this journal (Ricker and Lagler, 1942; Ricker, 1942) .

METHODS

SCALE READING

Scales were mounted in glycerine jelly made according to Dr. Van Oosten's formula, and examined by means of a projector of the type described by Van Oosten, Deason and Jobes (1934) , using a Promar optical

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apparatus. The magnification used was 60 diameters. Distances from the center of the scale nucleus to the various annuli and to the scale's anterior edge were measured with a transparent ruler.

The determination of age from scales of centrarchid fish is now a well-recognized procedure. The work of Bolen (1924) was an early study on the family, and it has been followed by many others. For a discussion of the validity of age determinations of Centrarchidae the reader is referred to the works of, for example, Creaser (1926), Hubbs and Cooper (1935), Hansen (1937), Bennett, Thompson and Parr (1940) , and Hile (1941) .

In general, bluegill scales are not difficult to read, but three points require care. (1) Recognition of the first annulus is sometimes difficult, particularly in slow-growing fish. In such fish the "cutting-over," usual criterion for confirming the presence of an annulus, is sometimes confined to a single circulus. Rarely it is absent in some and present in other scales from the same fish. However, when a number of fish from the same lake are available, a normal range of positions of first year annuli is established, and the anomalous growth picture resulting from ignoring an annulus can quickly be detected. (2) Another danger to accurate age analysis is the presence of accessory checks, breeding checks, or false annuli, as they are variously called. These may or may not occur, and their incidence varies greatly in different lakes. Ordinarily they are less complete than true annuli, particularly on the top and bottom of the scale, where cutting-over is not pronounced, or even absent. On the anterior field however they are not infrequently more conspicuous than the true annuli. Even when perfectly formed, accessory checks can usually be distinguished by their close proximity to an annulus. In two artificial lakes of west-central Indiana, the writer has had trouble with accessory checks suggestive of the extreme conditions found in Fork Lake, Illinois, by Bennett, Thompson and Parr (1940). In fish of known age, these authors found accessory checks which were often indistinguishable from true annuli ; sometimes two of them in a season. In our northern glacial lakes such conditions have not been encountered. (3) In general, readings from fish four years old or more will be less certain than those from younger fish, owing to the crowding of later annuli, and owing to the fact that annulus formation tends to occur later in the year in older fish. The result is that sometimes it is difficult to decide whether or not the current year's annulus is present, in a fish caught in late June or July. However growth in the earlier years of life can be read as accurately on old scales as on younger ones.

Without making the impossible claim of perfect accuracy, the writer is convinced that no serious error is present in the average growth rates presented here, as a result of mistakes in age determination.

LENGTH MEASUREMENTS

The following measures of fish length have been used in this study :

(1) Fisheries standard length : to the end of the vertebral column, as estimated from external form, without dissection.

(2) Length "from the tip of the snout to the edge of the last scales."
(3) Fork length : to the end of the middle rays, or fork, of the tail. The name "total" length often is used for this length, but it applies better to number 5, below.
(4) Natural tip length: to the tip of the tail fin, when spread into an apparently normal position.
(5) Total or extreme tip length: to the tip of the longest lobe of the tail, when squeezed into the position of maximum extension.

Except for number (2), all of the above measurements were taken with the fish's mouth closed, from whichever jaw projected farthest. True standard length, as used by systematists, is measured to the tip of the upper jaw (Hubbs and Lagler, 1941). In bluegills both of the jaws ordinarily rest against the end of a measuring board.

Standard length has here been used only to establish a basis for comparison with the results of other workers. The length to the edge of the scales was used consistently in the work of Hile (1931), and apparently also in the earlier work of Bolen (1924), but has not been used by later Indiana scale collectors. Fork length has been the principal length taken from 1939 to the present by members of the Lake and Stream Survey. Natural tip length was used by Weyer and Opdyke in the summer of 1938, and by most of the employees of the Division of Fish and Game who took scales during the winters of 1940 and 1941. It is also much used by Indiana fishermen, in the writer's experience more so than total length, except when a point of law is involved. However, in view of a general tendency to round to the next higher, instead of the nearest, scale unit, fishermen's measurements have usually been treated as though made to extreme tip.

All of the above five length measurements, and others, are used in scientific literature. *Fisheries standard length* is of long standing and is still widely used, though possibly less so now than formerly. Its principal drawbacks are (1) that when the fish is laid on a rule or measuring board, the scale (unless very broad) is covered at the point where the measurement is to be made ; (2) that the point at which the vertebral column ends is not sharply marked, externally ; and (3) that it departs considerably **from** the popular idea of a fish's length, which includes the tail. *Length to the scale edge* is open to the same objections ; it appears rarely in American scientific literature, but has had a considerable European vogue. *Fork length* is commonly used by some fisheries workers in eastern and in far western U. S. A., and in Canada, but is not common in the middle west. It meets objections (1) and (2) above, and fairly well satisfies (3). The writer agrees with the statement of Merriman (1941), that "in handling live fish . . . measurements of this type are easiest to make and least subject to error," and considers it equally applicable to freshly-killed fish. Standard length is however often preferable for preserved fish, in which the tail may be damaged. The *natural tip length,* which may be taken to be what the man in the street regards as *the* length of a fish, is unfortunately usually the least usable of all lengths, because of the difficulty in deciding what is the normal position of the tail. It is also inferior to standard length in that, as a fish grows older, the tips of the tail tend to wear off, as illustrated by the fact that now one, now the other, of the lobes will be longest. However it is primarily because of the difficulty of deciding what exactly is a normal position for the tail that natural tip length appears seldom, if at all, in American scientific literature, though it has been used in Europe. The use of extreme tip or *total length* has appeared in this country in fairly recent years, and is now common, particularly in the middle western states. It usually corresponds to the popular idea of length fairly well, being, in the larger bluegills, about as much in excess of natural tip length as the latter exceeds fork length. Legal size limits for game fish are generally presumed to be in total length. However it has the drawback of wearing of the tips, mentioned above. Among Indiana bluegills the ratio $\frac{\text{total length}}{\text{standard length}}$ decreases slightly as size increases, though to different degrees in different bodies of water; whereas the ratio $\frac{\text{fork length}}{\text{standard length}}$ appears to remain constant. Another disadvantage of total length is the fact that the tips of the tail are not in the center line of the fish, hence a broad measuring scale is required for convenient working. Also, in fish with deeply forked and widely spread tail fins, measurement of total length involves considerable distortion ; as for example among the mackerels, or, in fresh water, the gizzard shad. Difficulty is sometimes encountered too in measuring the total length of preserved fish, since the fin rays become stiff and do not compress easily to the required position.

Since several length measurements are in common use, any fisheries biologist must be prepared to convert the results obtained by some of his colleagues into his own preferred unit. Under these circumstances choice of what unit to use should be governed almost wholly by what appears most convenient. As suggested above, the writer believes fork length easily stands first in this respect. Fork length is accordingly used in this paper as the principal measure of fish length, and unqualified references to length are understood to be in that unit. The necessary changes from other units have been made by means of conversion factors or graphs. To convert from standard to fork length the factor 1.22 is appropriate ; to convert from scale-edge length to fork length 1.17 has been used. Average factors for conversion from total length are approximately as follows :

Length	Factor
up to 100	0.94
100-149	0.95
150-199	0.96

RELATION BETWEEN LENGTH AND SCALE RADIUS.

There seems to be no consistent relationship between fish length and scale radius in the Centrarchidae, even within a single species. For example, Hile (1941) describes this relationship for rock bass in a Wisconsin lake by means of a curved (logarithmic) line, whereas Beckman (1941a) found a straight one satisfactory in a Michigan lake.

Graphs of anterior scale radius against fish length have been made for the bluegills of several northern Indiana lakes ; two are shown in Figures 1 and 2. The scales in Figure 2 were taken consistently from the middle of the side of the fish, consequently the line makes a somewhat smaller

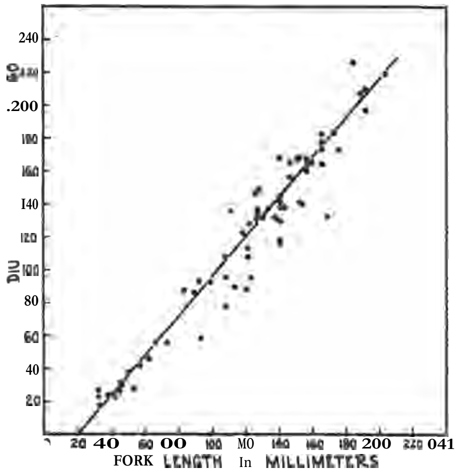

Figure 1. Relation between bluegill length and the anterior radius of the scale, in Winona lake. Scales were taken from the side of the fish, either above or below the lateral line.

angle with the vertical than that of Figure 1, since such scales are about as large as any on the fish. Neither in the examples illustrated, nor in any other, is there any suggestion that the relationship between scale growth and fish growth is anything other than linear. Under these circumstances the method developed by Fraser (1920) for salmon, and used by Beckman (loc. cit.) in Centrarchidae, appears to be the simplest and most accurate one for determining fish length from scale annuli. If the linear relationships of Figures 1 and 2 be produced down to the abcissa of the graph, the length 20 mm. appears to be an appropriate origin. This means that 20 mm. should be subtracted from fish length before calculating growth from measurements. That is,

$$\text{fish length at year } x = 20 + \frac{(\text{scale radius at year } x)\ (\text{total fish length} - 20)}{\text{total scale radius}}$$

Choice of the even value 20 was not wholly accidental, though it seemed as good as any. It simplifies the subtraction and addition necessary in the above calculation to the point where it can accurately be done mentally. As a matter of fact, it would be foolish to use anything but zero or a multiple of 10; the greatest error possible would be 5 millimeters at the origin, say 3 or 4 at the first annulus, grading to 1 or 0 at the last annulus. And since the error would be consistent among all data treated in the same way, comparisons would be practically unaffected.

The only other study of the scale-body relationship in bluegills that has come to our attention is that of Bennett, Thompson and Parr (1940) . Their results, from Fork Lake in Illinois, differ from those above in that their graph is weakly S-shaped rather than straight. Its lower part may not show significant deviation from a straight line with origin at 22 millimeters total length, but the upper deflection could not be reconciled to strict pro-

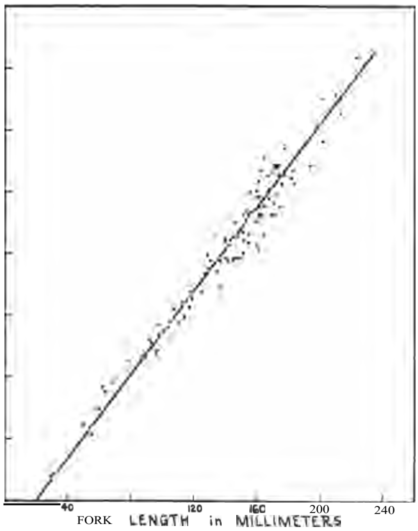

Figure 2. Relation between bluegill length and the anterior scale radius, based on fish from lakes Wawasee, Maxinkuckee and Webster. Scales were taken from a "key" region, 3 to 5 rows below the lateral line and below the middle of the spiny dorsal fin.

portionality. Nor is this because Bennett *et al.* use tip length rather than fork ; change to the latter unit would probably slightly accentuate the drop, rather than eliminate it. Similar deflections are suggested by data from other centrarchids (Hile, 1941; Ricker and Lagler, 1942) , but are lacking in the Indiana bluegill data. They may well occur in some of these waters, where data are insufficient to make a comparison ; but even if it were possible to determine the body-scale relationship for every lake separately, it is a question whether the increase in accuracy would compensate for the work involved. A study should be made of possible seasonal variations in this relationship ; such variations, if present, might reconcile the divergent findings now in the literature.

SAMPLING

The fish used in this study have been taken in four principal ways : from fishermen using hook and line, in traps, in gill nets, and by seining. All of these methods of fishing are *selective;* that is, they do not and cannot catch the different sizes of fish in strict proportion to their abundance in a lake. The general effects of selective sampling may be illustrated by Figure 3, which represents an idealized fish population divided into non-overlapping age groups.

(1) If the sample takes the larger fish of a population, exclusively or principally, then the youngest age-classes in the sample are represented by their faster-growing members, and rates of growth calculated from them will be greater than the class average. Such a sample is illustrated by line B in Figure 3.

(2) Similarly if a sample takes the smaller fish of a population, as represented by line C in Figure 3, then the oldest age-classes included are represented by their slower-growing members, and rates of growth calculated from them will be less than the class average.

(3) If the sample favours an intermediate size range, then the youngest fish present will yield larger growth rates, the oldest smaller growth rates, than the true average for their respective age-classes. This is represented by line D in Figure 3.

In actuality, successive age classes of bluegills overlap in their length range, except usually the first and second, but this strengthens rather

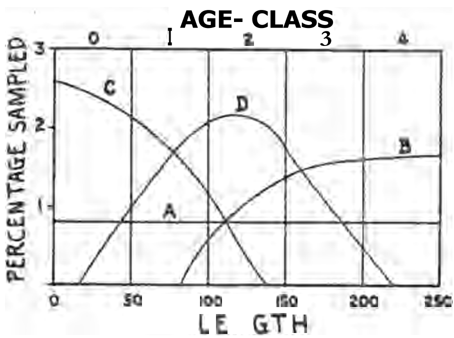

Figure 3. Effects of various sampling procedures upon growth rates calculated from an idealized population. Each age-class is shown as being 50 millimeters in width, and there is no overlapping between adjacent age-classes. Lines A, B, C, D represent the fraction of the total population, of different sizes and ages, taken by different sampling methods.

than alters the conclusions above. In a population of discontinuous age classes, if the limit of effectiveness of a sampling apparatus were to fall in a range of absent sizes, it would be possible for the youngest (or oldest) age class to be perfectly represented in the sample.

The seines used in this study were of ¼-inch square mesh, small enough to take any fish except fingerlings, and even these appeared after they reached 25 to 35 millimeters length. The year-old fish were apparently well sampled by seines in almost every instance, but older groups are, as a rule, represented only by those of slow growth.

The traps used were cylindrical cages of inch mesh chicken fence, 3 or 4 feet long, 2 to 2¼ feet in diameter, with a single funnel about a foot shorter than the trap and having an aperture about 3x4 inches. They caught fish down to 100 mm. long, rarely a little less. Their upper limit of effectiveness was indefinite, and probably more the result of their location than anything else. As a rule they sampled only the faster-growing yearlings, covered the size range of the two-year-old fish most efficiently, and in some instances the next older class appears usable.

The gill net used by Dr. Hile in 1929 was of $1\frac{5}{8}$ inches square mesh ($3\frac{1}{4}$ stretched) ; it captured fish principally in the size range 175 to 225 mm. Accordingly, that age-class whose mean length falls near the middle of this range (though not near the mean length of all fish caught) will be the one whose growth is most worthy of credence. In general, a *characteristic* population growth rate will be considerably less than the *average* growth rate of the fish in a sample from this net, because as a rule the older and larger fish, having typical to slow growth, will be much scarcer than the younger fish, which represent the fast-growing parts of their age-classes.

SAMPLING BY FISHERMEN

Since the majority of the scales used here were obtained from sport fishermen, a more extended examination of their sampling methods is necessary. To begin with, the fisherman is required by law to return to the water any bluegill less than 5 inches in total length, or about $4\frac{3}{4}$ inches (121 millimeters) fork length. If any given age group of fish includes specimens both larger and smaller than this, his catch will contain only the larger specimens ; hence any rate of growth we may calculate from these will be greater than that of the age-group as a whole. The legal limitation is however not the whole of the selection imposed by angling. Some fishermen refuse to keep bluegills as small as 5 inches, particularly if they feel they have a chance of making a good catch of larger ones; so their limit of selection may be an inch or more greater. Others aim at the 5-inch limit, but having no ruler they play safe and reject from say $5\frac{1}{4}$ inches down. Others again may stretch their fish a little. These facts make for some variability between different anglers, as regards size of fish caught, but since fish near the lower limit are suspect in any event, this is perhaps not as important as it might seem.

There is however a much more powerful factor affecting the range of sizes caught by different fishermen, that results from a habit of the fish themselves—the habit, that is, of schooling in groups of restricted size composition. This can be illustrated with data obtained on Shoe Lake in 1941. From available creel census data, the date June 21 was selected at random, and all catches of 5 or more bluegills were enumerated, after eliminating the few fish less than 123 millimeters long. In Table I, considerable differences in the mean length of the various catches appear, some of which must be judged real. For example, the 28 millimeter difference between No. 2 and No. 12 is undoubtedly significant; even though, in selecting extremes from a large number of possible comparisons, much more stringent limits of significance must be used than those appropriate to a unique comparison. We may notice further that the variances of the different catches show great discrepancies ; and also that only two are

TABLE 1

Analysis of variance of length distribution of 12 catches of bluegills taken June 21, 1941, on Shoe Lake. For explanation of the calculation and test of significance, see Snedecor, 1940, section 10.10.

Catch Number	Number of Fish	Mean Length, mm.	Sum of Squares	Mean Square or Variance	Standard Deviation	Standard Error of Mean
1	7	148.7	449	74.9	8.65	3.27
2	30	169.6	2503	86.3	9.29	1.69
3	14	146.2	3893	299.2	17.30	4.62
4	10	155.2	606	67.3	8.20	2.59
5	5	158.0	508	127.0	11.26	5.03
6	13	153.1	1658	138.2	11.75	3.39
7	24	147.6	4122	179.3	13.36	2.79
8	5	147.2	677	169.2	13.01	5.82
9	5	145.0	50	12.5	3.53	1.58
10	6	150.5	2184	436.8	20.96	8.53
11	10	148.0	628	69.8	8.36	2.64
12	32	141.7	3454	111.4	10.55	1.87
Total			20732			
Entire group	161	151.7	35255	220.4	14.84	1.17

Source of Variation	Degrees of freedom	Sum of Squares	Mean Square
Within catches	149	20732	139.2
Between catch means	11	14513	1319.4
Total	160	35255	

$F = \frac{1319.4}{139.2} = 9.47$ n_1 11, n2 149. 1% point 2.44

more variable than the whole 12 together, whereas if the catches were from a homogeneous population we should expect about as many in excess as in defect. The blanket test for homogeneity of the data is made by comparing the sum of the sums of squares within catches with that calculated from the whole, as is done in the analysis of variance at the foot of the table. Here it is demonstrated that the variations between means of the catches is greater than the average variation within catches, to a very significant degree.

A certain contribution to the intra-catch correlation may be made by the fact mentioned earlier, that different fishermen use a different critical length in deciding what fish to keep and what to reject. To test the importance of this effect, the calculations were repeated using only fish of 140 mm. and longer. The variance ratio is now F 7.97, not much less than before and still highly significant. Even if fish up to 149 mm. are rejected, which means omitting about half of the catch of Table I, there is just as significant a correlation within catches, with F 11.6. This indicates that only a part, and much the smaller part, of the observed individuality of the catches is due to differences in selection of a lower size limit. The greater part can most reasonably be ascribed to a tendency for the fish to school in groups of restricted size range; or for different sizes to prefer different habitats. Something may be contributed also by differences in fishing tackle used (size of hook, size of worm, etc.) but our observations indicated that this is of minor importance in these data.

The question now arises, do fish of different sizes frequent different parts of the lake, and if so, which? There is considerable evidence that within limits, there is an increase in size of bluegills with depth, in a lake, in summer, and particularly during the daytime. On this point the information provided by the scarcity of large fish in shore seining may be partially discounted, for the commotion of seining may well prove more disturbing to larger fish. Traps give better evidence, in that, for example in Winona Lake, they rarely caught big bluegills in water a meter deep, but frequently did at two to three meters, the difference being more pronounced in day catches than in night catches. However traps set on or near shallow breeding grounds will often catch big fish, as for example in Shoe Lake. The best evidence is provided by the fishermen's catches, which show a rather consistent increase in size of fish with increasing depth—again excepting catches taken off spawning grounds. To cite only one example from a great many, catches from Hill Lake on August 10, 1941, were as follows:

Age	Number of Fish	Length when Caught	Length at Annulus 1	2	3	4	5
1 Caught in deep water							
II	1	166	52	117			
III	12	192	38	87	154		
IV	3	222	37	89	163	210	
V	2	225	34	76	152	200	220
2 Caught inshore							
II	10	150	39	82			

From such data it follows that growth rates from fishermen's catches must be accepted only with some care. In general, an age class whose mean length is near the middle of the size range sampled will be most likely to be represented by a random sample in the catch. Thus, in the schedule above, the growth of the fish caught inshore agrees fairly well with that of two older age-classes caught in deep water.

The most confusing situation arises when a catch consists almost exclusively of one age-class. In that event there is no internal evidence to indicate whether the fish taken represent principally the larger, smaller, or intermediate length range within the age-class.

A closely-allied question concerns the differences between summer and winter fish. Ice fishing has provided a considerable part of our data, and there is a very general tendency for small bluegills to be scarce in such catches, and large bluegills to be numerous. The ice fishermen themselves seem agreed that winter fish are, as a rule, bigger than summer fish. Beckman (1941b) found no difference in average size of ice fish and summer fish in Michigan, but it is easy to see how this situation could arise. The differences in sizes caught in different parts of a lake, in summer, are sometimes as great or greater than the differences between summer and winter. Thus the sample taken from deep-fishing anglers on Dewart Lake in July averaged more than an inch *longer* than a sample taken through the ice the same spring. If summer fishing were done largely in deep water, in the larger Indiana lakes, it is probable that the size of fish caught would at least equal that of the winter fish. In any event, our winter samples ordinarily cover a wider length and age range than summer samples, and accordingly it is easier to eliminate the effects of selection from them.

Finally it should be noticed that selection of fish by the scale collector is as confusing as selection during the process of catching them. All scales collected by the Survey were taken strictly at random : usually from all catches in sight at the time the lake was visited. The same is true, or nearly so, of the sampling of ice fishermen's catches during the winters of 1940 and 1941. Scales from other sources are, as a rule, from bluegills selected for their large size. On *the whole,* such fish will have had a greater-than-average rate of growth, because each year-class diminishes in numbers as it grows older.

CHANGE IN GROWTH RATE WITH INCREASING AGE

Among fish of many kinds, what is called's Lee's phenomenon is a regular characteristic of calculated growth curves. This consists in a general tendency for fish of a given year-class to have a smaller apparent growth rate in any year of life, the greater is their age when the scale samples are taken. Three types of explanation have been advanced for this phenomenon: (1) that it is the result of inefficient methods of estimating growth from scale markings ; (2) that it results from selective sampling of the population ; (3) that it is a real phenomenon—the older fish are actually recruited more from slow-growing than from fast-growing members of the population.

Discussions of Lee's phenomenon appear in most major works on age determination of fishes, so no review will be given here. It appears that explanation (1) may have applied, at least in part, to some of the earlier work, but recent investigators have for the most part checked scale growth against fish growth in their data, and have devised efficient methods of growth estimation. The other two interpretations of Lee's phenomenon are both possible, in any kind of data. Hence if a real effect of this nature is to be demonstrated, the possibility of its resulting from sampling must first be excluded.

Bearing in mind the description of selective sampling at the beginning of the last section, examine again the effects of various sampling procedures, as illustrated in Figure 3. A truly random sample would take a fixed fraction of all ages and lengths present, and is represented by the horizontal line A in the diagram. If Lee's phenomenon appeared in such a sample, it would be a reflection of a real characteristic of the population. A sampling procedure favoring small fish is represented by line C. This sample will contain an almost representative group of age 0, will have more of the smaller members of age 1, and only the smallest of age 2. Consequently the sampling procedure introduces Lee's phenomenon into such a sample, regardless of whether it is in the population or not. A sampling procedure favoring large fish is shown by line B. This sample contains only the largest fish of age 1, those of age 2 are too large to be representative, while the age 3 sample is nearly random and the age 4 one is practically so. Hence in this sample Lee's phenomenon will appear in comparisons where 1 and 2 year fish are involved, but will be almost absent from a comparison of ages 3 and 4, unless it is a characteristic of the population itself. Finally, the line D in Figure 3 represents a sampling procedure which captures an intermediate size range most heavily. Here the 0 fish are represented by their largest representatives, and the 4 year fish by their smallest ; a comparison involving either group will produce an "artificial" Lee's phenomenon. A comparison involving the 3 year fish would be similarly though less heavily weighted. Comparing age 1 with age 2, there would still be some tendency for the older fish to have a slower apparent growth than the younger.

Clearly then the necessary condition for making a comparison of the growth rates of different age-classes in the population, is to have a sampling procedure or procedures which catch practically the whole of the length range of at least two age-classes, with equal effectiveness throughout.[1] While this condition may possibly be realized by some of the. sam-

[1] A fairly satisfactory substitute for this requirement occurs where the maximum efficiency of the sampling apparatus coincides with the modal length of the age class being sampled, provided both the efficiency and the length distribution change *symmetrically* on either side of the maximum and modal points (though not necessarily in a quantitatively similar manner). *If* the catching power of a gill net varies nearly symmetrically on either side of a maximum, and *if* length distributions of age classes are close to symmetrical, then any age class whose mean length coincides with the maximum effectiveness of the net should yield *average* growth rates free from bias, though the observed *variability* in length achieved may be considerably less than that in the population. While neither of the above conditions can be critically examined in these data, there is other evidence that they are often fairly well satisfied. Accordingly considerable weight is attached to growth rates computed from a gill

pling procedures employed, it is difficult to prove such a proposition. On the other hand, *absence* of Lee's phenomenon in a sample can usually be considered as evidence that the sampling technique meets these requirements, and also that the phenomenon is absent from the population itself. The principal difficulty here is to accumulate samples large enough that the absence can be confirmed within narrow limits of error. A disturbing factor would be possible variations in rate of growth of different year classes, but such should produce more rapid growth among older fish as often as less rapid growth, hence over a period of years would quickly be detected.

The best opportunity for detecting true differences in growth rate of fish of different ages will perhaps be in comparing intermediate age classes taken by different sampling methods. Some comparisons of this kind are shown in Table II, though none can be proved to fully meet the requirements of random selection. While small differences are evident between older and younger fish, hardly any can be judged significant, and in some cases the older group has the greater apparent rate of growth. Another place where selective sampling appears to be minimized is among the older age classes taken by ice fishermen, and these yield no evidence of a consistent decline in apparent growth rate, among older fish (Table III, below) .

So far, then, there is no satisfying evidence that bluegills of slow growth have a greater expectation of life than have those making more rapid growth. The possibility that an appreciable effect of this kind exists in some lakes cannot be denied either, from these data, but much more extensive information will be necessary before any definite conclusion can be reached regarding the species generally. We can however draw the important conclusion that differential survival, if it exists, is not usually very pronounced, or it would surely show up much more clearly and consistently in the data. This may be considered as indirect evidence that rates of exploitation are for the most part not excessive ; for if they were, the faster-growing fish, having been exposed longer to the fishing effort, would be represented by fewer survivors at greater ages.

PROCEDURE

In view of the numerous pitfalls which lie in the way of accurate interpretation of observed growth rates, two questions must be asked. Is it possible to demonstrate real differences in growth rates between lakes? If so, how can they best be expressed numerically?

Answering the first question, it appears that differences in calculated sizes at a given age are far greater, comparing extremes of the series of

net sample, when the mean length coincides with the size at which the net is presumed to be most efficient. For the 1⅝ inch square mesh net used by Dr. Hile, this is estimated to be close to 200 millimeters—a figure which is of course considerably above the mean length of the fish caught by the net.

TABLE II

Comparisons of rates of growth of fish at different ages, taken from samples which appear most likely to be representative.

Lake	Source of Fish	Season	Year	Age	Number of Fish	[illegible]	Length at Age					
							1	2	3	**4**	**5**	**6**
Irish	Fishermen	winter	1940	IV	31	171	40	79	121	171		
				V	14	195	41	78	118	162		
		summer	1941	**III**	35	143	41	75	112			
Wawasee	Seine	summer	1940	**II**	12	98	42	71				
	Fishermen	winter	1939	V	20	188	37	60	98	139	188	
	Fishermen	winter	1940	VI	18	212	38	62	100	146	191	212
	Fishermen	winter	1941	V	40	195	37	65	102	145	195	
Simonton	Seine	summer	1940	**II**	50	68	36	58				
	Trap	summer	1940	III	36	120	34	61	95			
	Fishermen	summer	1940	**III**	8	163	38	75	122			
Spear	Seine	summer	1939	**I**	12	64	32					
	Fishermen	summer	1940	**III**	35	145	33	66	117			
Shoe	Seine	summer	1939	**II**	12	90	38	60				
	Fishermen	summer	1939	IV	15	154	33	50	86	128		
	Fishermen	summer	1938	IV	25	147	39	67	100	131		
	Fishermen	summer	1941	V	43	153	35	61	84	117		
Winona	Seine	summer	1939	I	15	53	45					
	Trap	summer	1939	**II**	168	117	40	87				
	Fishermen	summer	1940	III	10	138	39	81	115			

the lakes, than are the greatest variations in different samples from a single lake. This is true, even if we include age-classes which there is good reason to consider biased by selective sampling. If such be eliminated, or adjusted as well as possible, the differences between lakes show up more sharply. It seems feasible to arrange the lakes in order of estimated rates of growth, with the stipulation that the order is subject to minor re-arrangements, as new data become available.

What method should be employed in expressing differences in growth numerically is partly a matter of opinion, so some more or less arbitrary selection of procedure must be adopted. In what follows, the size in successive years is estimated, in classes centered at lengths ending in 0 and 5 millimeters, and this is referred to as the "typical" or "characteristic" growth for the lake. Although the relationships discussed above have been used to guide their selection, growth rates estimated in this way are subject to considerable personal whim, and the reader may enjoy checking his own views with the writer's.

RESULTS

The lakes below are listed in alphabetical order. An estimate of the area of each is included, taken from sources of varying accuracy. Many of the larger lakes were surveyed and sounded by Professor W. M. Tucker of Indiana University, working for the Indiana Department of Conservation during the middle 1920's, and his maps include a computation of area. Unfortunately most of them have not been published. Lakes Maxinkuckee and Winona were not surveyed by Tucker, but a good map of the former is published by Evermann and Clark (1920) , and the latter has been surveyed by Dr. Will Scott, his map being published by Wilson (1936). Various other lakes of the Tippecanoe basin were mapped by Scott (1916), and a few unpublished maps of his are available. Areas of two small Kosciusko County lakes were measured from aerial photographs made to a scale of 40 rods to 1 inch. For the lakes of Kosciusko county not treated elsewhere, area has been taken with a planimeter from the soil survey map of Tharp, Fowler, Troth and Beyer (1927) . By checking with lakes of known area, the limits of accuracy of these readings was determined to be from ± 5 acres for the smallest up to ± 25 for those of about 500 acres extent. For most of the other counties no soil surveys have yet been published, and lake areas have been taken from the Indiana Lake Guide (Gutermuth, 1938), or from a simple estimate. (For anyone interested in determining the exact location of any lake, this Guide will prove invaluable.)

Fish caught by anglers are subject to the Indiana legal limit of 5 inches total length, or 121 mm. fork length. Occasionally smaller fish were handled by fishermen at the special request of the Survey, and in all such cases where sublegal fish are included in fishermen's catches, the fact is mentioned below. Such undersized fish were of course returned to the water.

ADAMS LAKE, Lagrange County. (293 acres, Tucker) .

The scales were collected from anglers, who took 4 undersized fish (2 years old) at the request of the Survey.

Fishermen, July 17-August 16, 1940.

Age	Number of Specimens	Length when caught	Length at Successive Annuli 1st	2nd	3rd
II	5	110	37	81	
III	3	167	43	83	137

Estimated characteristic growth

Millimeters	40	80	135
Inches	1.6	3.1	5.3

BASS LAKE, Starke County. (1,350 acres, Tucker).

Dr. Scott's collection included a series taken by a fisherman in 1934, and there are some small ones seined in 1939 by the Lake and Stream Survey.

Fishermen, summer, 1934.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th	8th
III	1	128	42	68	92					
IV	2	137	38	59	82	110				
V	3	142	36	50	72	97	122			
VI	2	153	34	56	73	96	116	130		
VII	1	171	32	55	69	94	128	153		
VIII	1	161	35	54	68	89	114	127	136	151

Seined, June 26-July 1, 1939.

	30	80	50	
II	4	104	33	66

Estimated characteristic growth, 1934.

Millimeters	35	55	75	95	120	130
Inches	1.4	2.2	3.0	3.7	4.7	5.1

The 1934 growth rate is the slowest yet found in any natural lake. The condition of Bass Lake at this time has been described by Ricker and Gottschalk (1941) who ascribe its muddy and vegetationless appearance to an exececssive population of coarse fish. Following removal of many such fish in 1936 and 1937, the lake cleared up, vegetation increased, and bluegills and other sport fish became much more numerous. These growth data are interesting as supplying another particular in which the lake was an inferior habitat for sport fish, during the earlier period. Unfortunately scales from large bluegills have not been obtained in recent years, but the group seined in 1939 suggests a very marked improvement in growth rate. Characteristic growth now is at least 45, 85, for the first two years; that is, in two years the fish now grow as much as they formerly did in three and a half.

BIG LAKE, Noble County. (425 acres, Gutermuth 1938).

The only available information is a series of four large fish sent in by an angler.

Fisherman, July 7, 1937.

Age	Number	Length	1st	2nd	3rd
III	4	200	36	77	147

Estimated characteristic growth

Millimeters	35	75	140
Inche3	1.4	3.0	5.5

The scanty data above provide only a very uncertain estimate of growth in this lake.

BIG BARBEE LAKE, Kosciusko County. (278 acres, Tucker; 262 acres, Scott 1916).

Summer series are available from Dr. Hile's net, and from fishermen canvassed by the Survey.

Gill-net, July 15-29, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th
III	13	184	39	85	146		
IV	6	197	39	78	133	178	
V	1	212	32	55	106	175	205

Fishermen, July 26, 1941.

Age	Number	Length	1st	2nd	3rd	4th
II	14	129	53	90		
III	2	134	38	78	105	
IV	2	166	39	71	112	146

Estimated characteristic growth

Millimeters	40	80	130	175
Inches	1.6	3.1	5.1	6.9

The two series above agree fairly well, and indicate a moderate rate of growth. The 14 two-year-old fish taken in 1941 were from inshore fishermen, who were evidently sampling the larger members of a strong year-class just entering the fishery.

BIG CHAPMAN LAKE, Kosciusko County. (414 acres, Tucker.)

Scales from the four summer fish below were collected by the Survey, and those from ice fishermen by Fish and Game employees.

Ice fishermen, February 12-15, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
IV	1	199	51	113	179	199		
VI	2	212	46	87	126	170	198	211

Fishermen, July 18, 1941.

Age	Number	Length	1st	2nd	3rd	4th
III	3	131	38	64	97	
IV	1	137	35	52	78	105

The slow growth suggested by the summer fish is not borne out by those taken in winter. The former were taken in a small bay at the extreme west end of the lake, which may possibly be sufficiently isolated from the rest to have a distinctive growth rate, though it does not seem probable. Further study will be needed to see whether the two suggested rates can be reconciled, and for the present the lake is omitted from Table 5.

BROWN or MUD LAKE, Steuben County. (25 acres, estimate.)

Employees of the Division of Fish and Game collected a good series of winter scales.

Ice fishermen, February 2-March 1, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	40	169	40	106	169			
IV	7	191	34	80	159	191		
V	12	204	35	81	144	186	204	
VI	1	202	33	59	100	153	177	202

Estimated characteristic growth

Millimeters			35	80	155	190	205
Inches			1.4	3.1	6.1	7.5	8.1

CARR LAKE, Kosciusko County. (76 acres, from aerial photograph.)

A series selected for large size was sent in by a resort owner in 1940, and a small random sample was secured by the Survey in 1941.

Fishermen, June 16, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th
III	11	203	37	108	194				
IV	1	220	44	94	173	216			
VI	1	244	40	91	137	183	213	238	
VII	1	244	42	93	134	185	207	224	244

Fishermen, July 20-August 23, 1941.

II	7	136	47	96			
III	3	197	48	95	154		
IV	2	212	32	96	164	200	
V	1	203	28	82	146	189	197

Estimated characteristic growth

Millimeters			40	95	160	200
Inches			1.6	3.7	6.3	7.9

Growth is rapid in Carr Lake, in the second and third years of life particularly.

CENTER LAKE, Kosciusko County. (90 acres, from soil map.)

Dr. Hile's gill-net series, and a single fish collected recently, provide our only information.

Gill-net, July 2, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th
IV	15	183	36	66	113	165	
V	3	190	33	59	97	150	182

Fisherman, August 17, 1941

III	1	122	46	69	88

Estimated characteristic growth

Millimeters		30	55	95	145
Inches		1.2	2.2	3.7	5.7

Since all the fish taken are considerably under the length which is caught most efficiently by the gill net, the characteristic growth rate is estimated considerably below the apparent growth rate.

CLEAR LAKE, Steuben County. (754 acres, Gutermuth, 1938.)

The series below was sent in by an employee of the Division of Fish and game.

Ice fishermen, January 12-29, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
IV	3	187	42	81	134	187					
V	1	220	66	108	154	191	220				
VI	1	224	35	68	125	188	219	244			
VII	6	246	42	74	119	173	211	231	246		
IX	1	256	32	55	105	145	175	219	236	247	256

Estimated characteristic growth

	1st	2nd	3rd	4th	5th	6th	7th
Millimeters	40	75	120	175	210	230	245
Inches	1.6	3.0	4.7	6.9	8.3	9.1	9.7

CLINE LAKE, Lagrange County. (35 acres, Gutermuth, 1938.)

Winter scales were collected by Fish and Game employees.

Fishermen, March 2, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
IV	4	174	39	74	126	174		
V	2	201	38	69	118	174	201	
VI	2	214	35	60	107	158	201	214

Estimated characteristic growth

	1st	2nd	3rd	4th	5th
Millimeters	35	65	115	170	205
Inches	1.4	2.6	4.5	6.7	8.1

The first two years' growth is slow, but there is considerable improvement later, particularly in the fourth year.

CROOKED LAKE, Steuben and Whitley Counties. (802 acres, Tucker.)

Four samples are available, sent in by a Fish and Game employee.

Fishermen, July 28, 1939.

Age	Number	Length	1st	2nd	3rd	4th
III	1	165	39	81	128	
IV	3	203	40	83	130	180

Estimated characteristic growth

	1st	2nd	3rd	4th
Millimeters	40	80	125	175
Inches	1.6	3.1	4.9	6.9

DAN KUHN or EAST BARBEE LAKE, Kosciusko County. (118 acres, Tucker ; 134 acres, Scott, 1916.)

Collections comprise 4 fish taken in Dr. Hile's net, 29 secured from fishermen by the Survey, and 3 taken in winter by Fish and Game employees.

Gill-net, July 31, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	2	194	42	89	146			
VI	2	205	35	56	88	127	164	195

Ice fishermen, February 3-20, 1940.

IV	2	170	36	72	114	170		
VI	1	224	29	52	94	140	187	224

Fishermen, July 26, 1941.

III	18	140	37	71	107	
IV	11	152	36	62	96	129

Estimated characteristic growth

Millimeters	35	70	105	140
Inches	1.4	2.8	4.1	5.5

All three groups above can readily be reconciled to the estimated characteristic rate, if due allowance be made for selection and sampling error.

DEWART LAKE, Kosciusko County. (357 acres, Tucker.)

Scales are available from four collections : Dr. Hile had a series of scales taken in 1929 with his gill-net; a few were present in Dr. Scott's collection, taken by a fisherman, while series were taken randomly from ice fishermen and from summer fishermen by the Survey in 1941.

Gill-net, August 21-22, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	20	181	40	83	134			
IV	23	199	38	77	145	186		
V	1	212	33	60	100	159	185	
VI	1	227	38	57	86	144	192	218

Fishermen, August 24, 1935.

II	1	135	45	82		
III	3	159	35	59	107	
IV	2	207	44	83	138	186

Ice fishermen, March 10, 1941.

III	28	140	40	86	137		
IV	4	186	39	81	134	178	
V	2	194	32	62	113	158	188

Fishermen, July 12, 1941.

III	30	172	43	90	143	
IV	12	191	41	84	134	179

Estimated characteristic growth

Millimeters	40	80	135	180
Inches	1.6	3.1	5.3	7.1

The superiority in length of the 4 year old fish over 3 year old fish, at 3 years of age, is an anomalous feature of Dr. Hile's 1929 data. The difference is almost a significant one, and cannot be explained as the result of selective sampling, which in this instance would favour a difference in the opposite direction.

DREAM or FISH LAKE, Kosciusko County. (17 acres, from aerial photograph.)

Fishermen, July 20, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
II	1	150	53	114				
III	9	173	42	100	149			
IV	1	192	34	85	139	179		
V	1	197	29	50	93	161	192	
VI	1	222	44	83	106	164	207	218

Estimated characteristic growth

Millimeters	35	85	135
Inches	1.4	3.3	5.3

Dream Lake is subject to only a restricted amount of fishing, and the fisherman from whom the above were taken rejected most fish less than 160 mm. (6½ inches).

DULEY LAKE, Noble County. (25 acres, Gutermuth, 1938.)

Dr. Hile's collection of March, 1929, provides our only information about this lake.

Gill-net, March 23, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th	8th
IV	28	188	40	84	140	188				
V	14	192	38	78	130	168	192			
VI	7	205	35	66	107	163	190	205		
VIII	1	205	29	63	101	156	173	187	198	205

Estimated characteristic growth

Millimeters	35	75	115	165	190
inches	1.4	3.0	4.5	6.5	7.5

FOX LAKE, Steuben County. (175 acres, Gutermuth, 1938.)

Three fish, evidently selected for large size, were sampled and scales sent in by the game warden.

Fishermen, October 20-21, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th
III	1	220	40	86	151		
V	2	256	36	80	159	224	243

Estimated characteristic growth

Millimeters	35	80	150	220
Inches	1.4	3.1	5.9	8.7

The above is of course a very uncertain estimate of growth.

GAGE LAKE, Steuben County. (327 acres, Tucker.)

Scales were collected by the Survey.

Fishermen, July 19, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th
II	8	120	47	89			
III	18	148	41	75	118		
IV	1	156	34	47	77	123	
V	1	203	37	60	94	145	192

Estimated characteristic growth

Millimeters	40	75	120
inches	1.6	3.0	4.7

GOOSE LAKE, Kosciusko County. (28 acres, from soil map.)

Fishermen, July 20, 1941.

Age	Number	Length	1st	2nd	3rd	4th
III	27	157	35	72	124	
IV	2	185	36	69	120	178

Estimated characteristic growth

Millimeters	35	70	125	180
Inches	1.4	2.8	4.9	7.1

It is difficult to estimate in which direction, if any, selection affects these data, but since the fish were taken from a number of fishermen, none of whom had small fish, there is a good chance they are representative.

GORDY LAKE, Noble County. (25 acres, Gutermuth, 1938.)

Dr. Hile took a good sample in his gill-net.

Gill-net, July 23, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
IV	10	194	37	81	134	181		
V	7	197	32	71	123	174	195	
VI	5	217	33	62	109	167	199	213

Estimated characteristic growth

Millimeters	35	70	120	170	195
Inches	1.4	2.8	4.7	6.7	7.7

HIGH LAKE, Noble County. (320 acres, Gutermuth, 1938.)

Four samples were sent in by a fisherman.

Fisherman, July 13-15, 1939.

Age	Number	Length	1st	2nd	3rd	4th	5th
III	1	146	42	72	115		
V	3	201	38	67	99	139	182

Estimated characteristic growth

Millimeters	40	70	100	140
Inches	1.6	2.8	3.9	5.5

HILL LAKE, Kosciusko County. (65 acres, from soil map.)

Scales were taken by the Survey from anglers fishing in deep and in shallow water, as described earlier. The figures below include two under-sized fish in age 2.

Fishermen, August 10, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th
11	15	129	39	83			
III	12	192	38	87	154		
IV	3	222	37	89	163	210	
V	1	227	34	74	151	204	221

Estimated characteristic growth

Millimeters	35	85	150	210
Inches	L4	3.3	5.9	8.3

HOWARD LAKE, Steuben County. (76 acres, Gutermuth, 1938.)

Employees of the Division of Fish and Game collected scales in 1940.

Ice fishermen, early 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
IV	3	130	43	79	107	130		
V	1	171	35	57	94	132	171	
VI	2	164	35	68	92	114	136	164

Estimated characteristic growth

	1st	2nd	3rd	4th	5th
Millimeters	35	65	95	120	140
Inches	1.4	2.6	3.7	4.7	5.5

HYNDMAN LAKE, Noble County. (15 acres, Gutermuth, 1938.)

Dr. Hile's net took a good series in the summer of 1929.

Gill-net, August 12-13, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	[redacted]	185	41	83	141			
IV	19	192	40	82	133	176		
V	1	205	35	53	106	159	191	
VI	2	214	36	63	102	161	190	206

Estimated characteristic growth

	1st	2nd	3rd	4th
Millimeters	35	75	125	170
Inches	1.4	3.0	4.9	6.7

INDIAN VILLAGE LAKE, Noble County. (10.4 acres, computed from the map of Scott, 1931.)

Dr. Hile fished this little lake on two occasions.

Gill-net, March 23, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th	8th
IV	12	188	41	88	143	187				
V	6	193	39	72	126	169	193			
VI	6	202	37	66	104	159	186	202		
VII	2	204	32	58	102	144	182	196	206	
VIII	1	215	38	66	98	149	177	199	208	215

Gill-net, July 21, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	[redacted]	195	46	107	165			
IV	7	193	42	88	142	182		
V	1	187	35	68	122	165	183	
VI	1	219	43	85	120	174	194	209

Estimated characteristic growth

	1st	2nd	3rd	4th	5th
Millimeters	35	70	125	164	190
Inches	1.4	2.8	4.9	6.5	7.5

IRISH LAKE, Kosciusko County. (143 acres, Tucker; 154 acres, Scott, 1916.)

The winter series was taken by Fish and Game employees, the summer series by the Survey.

Ice fishermen, February 4-6, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th
III	10	145	47	89	145				
IV	31	171	40	79	121	171			
V	14	195	41	78	118	162	195		
VI	12	196	39	67	107	132	166	196	
VII	2	220	45	91	134	162	176	196	220

Fishermen, July 14-27, 1941.

Age	Number	Length	1st	2nd	3rd	4th
III	35	143	41	75	112	
IV	3	160	37	69	100	134

Estimated characteristic growth

Millimeters	40	75	120	160	180
Inches	1.6	3.0	4.7	6.3	7.1

There is unusual discrepancy between the 5- and 6-year-old fish above, in growth in later years of life.

JAMES LAKE, (including SNOW LAKE), Steuben County. (1,318 acres, Tucker; a modification of this map is published by Scott, 1931.)

Our information is derived from a series seined from the middle basin of the lake, by the Survey.

Seined, June 15, 1939.

Age	Number	Length	1st	2nd	3rd
	72	52	41		
II	33	89	39	71	
III	11	123	38	64	99

Estimated characteristic growth

Millimeters	40	75	120
Inches	1.6	3.0	4.7

Considering that the older groups here include only their smaller representatives, the typical growth rate can hardly be less than that indicated, but the last figure is very uncertain.

LIME LAKE, off Gage Lake, Steuben County. (30 acres, Gutermuth, 1938.)

Scales were collected by the Survey.

Fishermen, July 19, 1940.

Age	Number	Length	1st	2nd	3rd	4th
III	5	145	46	80	116	
IV	1	162	42	77	113	141

Estimated characteristic growth

Millimeters	45	80	115
Inches	1.8	3.1	4.5

LITTLE BARBEE LAKE, Kosciusko County. (68 acres, Tucker; 66 acres, Scott, 1916.)

Dr. Hile's gill-net took 13 specimens, to which 5 have been added in recent years, 3 collected by Division of Fish and Game employees, and 2 by the Survey.

Gill-net, June 17-30, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th
III	10	184	46	94	147		
IV	3	187	40	75	138	171	

Ice fishermen, February 9, 1940.

IV	1	199	32	62	124	199	
V	2	202	34	68	113	162	202

Fishermen, July 27, 1941.

II	1	130	52	94	
III	1	132	34	68	103

Estimated characteristic growth

Millimeters	35	70	115
Inches	1.4	2.8	4.5

Growth is slow in Little Barbee, being significantly less than in Big Barbee and (probably) Irish Lakes, both of which are joined to it by rather short channels. Evidently the populations are reasonably distinct.

LITTLE CHAPMAN LAKE, Kosciusko County. (120 acres, Tucker.)

Two summer series are available, taken by gill-net in 1929 and from fishermen by the Survey, in 1941.

Gill-net, July 6-8, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th
III	8	184	44	98	159		
IV	15	197	42	86	144	187	
V	2	203	38	68	113	175	198

Fishermen, July 18, 1941.

Age	Number	Length	1st	2nd	3rd
II	2	130	40	92	
III	25	150	39	73	115

Estimated characteristic growth, 1929

	1st	2nd	3rd
Millimeters	40	80	140
Inches	1.6	3.1	5.5

Estimated characteristic growth, 1941

	1st	2nd	3rd
Millimeters	40	75	120
Inches	1.6	3.0	4.7

The discrepancy between apparent growth rates in 1929 and 1941 is considerable, and probably cannot be referred to selective sampling. The two could only be reconciled by assuming the 1941 fishermen to be exploiting a school consisting of a small slow-growing minority of age-group 3. It seems more likely, however, that these 3-year fish are more representative, and have really grown unusually slowly, perhaps because unusually numerous.

MANITOU LAKE, Fulton County. (713 acres, Tucker; 806 acres, Scott, 1916.)

The 11 fish available were sent to Dr. Scott by a fisherman.

Fisherman, August 11-23, 1936.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
IV	7	173	47	82	111	150		
V	3	195	51	89	123	151	181	
VI	1	220	43	77	123	169	192	212

Estimated characteristic growth

	1st	2nd	3rd	4th	5th
Millimeters	45	80	115	150	180
Inches	1.8	3.1	4.5	5.9	7.1

LAKE MAXINKUCKEE, Marshall County. (1,854 acres, Evermann and Clark, 1920.)

Three summer series and two winter series are available, all from fishermen's catches. Those of the summer of 1940 were taken by the Survey. The remainder were taken by other employees of the Division of Fish and Game, or sent by the fishermen themselves.

Ice Fishermen, January 21 - February 2, 1938.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	1	150	44	94	150			
IV	9	188	39	74	133	188		
V	6	206	42	76	129	185	206	
VI	2	228	37	81	116	184	215	228

Fishermen, September 5, 1938.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	2	174	35	63	108			
IV	7	218	38	73	128	182		
V	1	207	36	60	102	169	194	
VI	2	244	34	64	104	163	205	225

Ice fishermen, March 1-4, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
IV	1	183	45	96	134	183		
V	10	226	38	76	126	189	226	
VI	4	232	38	72	125	172	221	232

Fishermen, July 12 - August 3, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
II	4	134	53	96				
III	19	154	39	70	118			
IV	2	214	39	68	112	180		
V	3	233	40	73	115	176	220	

Fishermen, August 18 - September 20, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	3	208	48	87	139			
IV	2	220	40	80	120	188		
V	4	238	36	70	118	187	224	
VI	3	236	36	65	106	171	215	228

Estimated characteristic growth

	1st	2nd	3rd	4th	5th	6th
Millimeters	40	75	125	185	220	230
Inches	1.6	3.0	4.9	7.3	8.7	9.1

The interesting feature of growth in Maxinkuckee is the rapid increase in length in the third and fourth years of life.

O'BLENNIS LAKE, Fulton County. (5 acres, Gutermuth, 1938.)
Five samples were sent in by a fisherman to Dr. Scott.

Fisherman, August 23, 1936.

Age	Number	Length	1st	2nd	3rd	4th
III	1	175	39	70	133	
IV	4	199	41	70	133	178

Estimated characteristic growth

	1st	2nd	3rd	4th
Millimeters	35	65	125	165
Inches	1.4	2.6	4.9	6.5

These fish are almost certainly stringently selected for large size, hence are more likely to represent the faster-growing members of their age classes.

PALESTINE LAKE, Kosciusko County. (290 acres, from soil map.)
Scales were collected by Fish and Game employees.

• Fishermen, January 27, 1940.

Age	Number	Length	1st	2nd	3rd	4th
IV	4	145	37	71	110	145

Estimated characteristic growth

	1st	2nd	3rd	4th
Millimeters	35	65	100	130
Inches	1.4	2.6	3.9	5.1

The characteristic growth above is based on the probability these bluegills represent the larger members of their year-class, since they are small for ice-caught fish.

PRETTY LAKE, Marshall County. (80 acres, Gutermuth, 1938.)
Scales were collected by Fish and Game employees.

Ice fishermen, March 11-14, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
IV	2	195	37	76	134	195		
V	2	210	46	82	138	196	210	
VI	4	229	42	66	107	174	218	229

Estimated characteristic growth

	1st	2nd	3rd	4th	5th
Millimeters	40	70	125	185	215
Inches	1.6	2.8	4.9	7.3	8.5

RIDINGER LAKE, Kosciusko County. (130 acres, Scott, 1916.)

Three specimens were taken in Dr. Hile's gill-net, and two have been sent in by a fisherman.

Gill-net, June 20, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
IV	2	193	38	74	132	188		
VI	1	196	40	61	98	132	174	189

Fishermen, July 7, 1939.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
V	1	220	30	47	97	127	182	
VI	1	220	31	59	90	151	192	210

Estimated characteristic growth

Millimeters			35	60	100	135
Inches			1.4	2.4	3.9	5.3

ROUND LAKE, Elkhart County. (30 acres, Gutermuth, 1938.)

Fishermen sent in scales taken after the lake had been closed to fishing for two years.

Fishermen, June 17, 1939.

Age	Number	Length	1st	2nd	3rd	4th
II	1	177	68	121		
III	8	183	53	117	174	
IV	1	171	46	104	139	164

Estimated characteristic growth

Millimeters			50	115	175
Inches			2.0	4.5	6.9

Round Lake bluegills exhibit the fastest rate of growth of any in the series. The explanation lies in the fact that early in 1936 its fish were severely reduced by "winter kill", or suffocation under the ice. The brood of the following summer, which was three years old in 1939, grew up in an uncrowded world and consequently made very rapid growth—they averaged 7.2 inches long when caught in 1939.

ROUND LAKE, Whitley County. (131 acres, Tucker.)

A winter series of scales was collected by employees of the Division of Fish and Game.

Ice fishermen, January 31 - March 6 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
III	3	143	47	95	143						
IV	15	155	42	71	108	154					
V	8	195	44	78	118	159	195				
VI	3	216	49	84	125	170	198	216			
VII	14	226	41	71	104	148	186	213	226		
VIII	8	227	42	68	97	130	177	200	219	227	
IX	1	224	34	65	92	127	161	193	206	219	224

Estimated characteristic growth

Millimeters			45	75	115	150	185	210	220	225	
Inches			1.8	3.0	4.5	5.9	7.3	8.3	8.7	8.9	

The figures for growth of older fish depend on the assumption that the stock is being fairly evenly sampled right up to the largest sizes present.

ROYER LAKE, Lagrange County. (125 acres, Gutermuth, 1938.)

The series was taken by employees of the Division of Fish and Game.

Fishermen, March 1-5, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th
III	9	157	42	89	157				
IV	11	194	36	78	136	194			
V	7	199	32	73	127	179	199		
VI	2	201	44	72	111	152	193	201	
VII	2	231	36	74	127	193	216	226	231

Estimated characteristic growth

Millimeters			35	75	125	180	200		
Inches			1.4	3.0	4.9	7.1	7.9		

SAWMILL or MABEE LAKE, Kosciusko County. (27 acres, Tucker ; 21 acres, Scott, 1916.)

The survey collected the July scales below, which includes a sublegal specimen taken by request.

Fishermen, July 14-24, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
II	1	118	49	90				
III	42	133	43	76	107			
IV	9	156	37	69	101	136		
Ice Fishermen, January 31, 1940.								
VI	1	174	34	51	77	108	140	174

Estimated characteristic growth							
Millimeters			35	70	100	140	
Inches			1.4	2.8	3.9	5.5	

SECRIST or PLEW LAKE, Kosciusko County. (99 acres, Tucker ; 103 acres, Scott, 1916.)

Scales were collected by employees of the Division of Fish and Game.

Ice fishermen, February 3, 1940.

Age	Number	Length	1st	2nd	3rd	4th
IV	6	177	40	78	118	177
Estimated characteristic growth						
Millimeters			40	75	115	175
Inches			1.6	3.0	4.5	6.9

SHOE LAKE, Kosciusko County. (42 acres, Wilson MS; 38.5 acres, Scott, unpublished ; 39.5 acres, Tucker.)

Fishermen and seine, July 13-22, 1938.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
II	[redacted]	103	40	82				
III	[redacted]	132	40	67	106			
IV	25	147	39	67	100	131		
V	2	173	34	65	106	142	164	
Seined, July 12, 1939.								
1	3	66	40					
II	[redacted]	79	40	60				
III	[redacted]	92	32	50	69			
V	2	166	34	50	74	112	147	
Seined, August 18, 1939.								
	20	63	39					
II	[redacted]	101	37	60				
Fishermen, July 5 - August 3, 1939.								
III	[redacted]	136	36	64	102			
IV	15	154	33	50	86	128		
V	1	175	33	54	84	116	146	
Fishermen, June 15 - 21, 1941.								
III	[redacted]	132	43	77	118			
IV	26	140	41	64	93	130		
V	43	153	35	61	84	117	147	
VI	8	166	36	60	87	118	145	164
Estimated characteristic growth								
Millimeters			40	60	90	120	145	
Inches			1.6	2.4	3.5	4.7	5.7	

The slow growth of Shoe Lake fish is principally the result of a slow-down in the second and third years of life.

SILVER LAKE, Kosciusko County. (94 acres, Scott, 1916.)

Fairly good series were taken by Dr. Hile in 1929, and by the Survey in 1941.

Gill-nets, August 10-17, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th
III	1	118	46	96	163		
IV	13	194	45	95	156	184	
V	1	214	44	91	149	184	205

Fishermen, July 20, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th
II	9	139	53	92			
III	40	167	45	88	127		
V	4	184	34	65	115	151	170

Estimated characteristic growth, 1929

Millimeters	45	90	150	180
Inches	1.8	3.5	5.9	7.1

Estimated characteristic growth, 1941

Millimeters	45	90	130
Inches	1.8	3.5	5.1

In both series growth is rapid for two years, but length at 3 years is much less in 1941 than in 1929. The difference is probably significant, though a reconciliation is perhaps not impossible.

SILVER LAKE, Steuben County. (375 acres, Gutermuth, 1938.)

A small series was collected by employees of the Division of Fish and Game.

Fishermen, August 1-11, 1939.

Age	Number	Length	1st	2nd	3rd	4th
III	3	167	36	76	129	
IV	1	158	29	45	76	122

Estimated characteristic growth

Millimeters	35	70	125
Inches	1.4	2.8	4.9

SIMONTON LAKE, Elkhart County. (260 acres, Gutermuth, 1938.)

Scales were collected by the Survey in seines, in traps, and from fishermen.

Seined, June 27, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
	1	57	41					
II	50	68	36	58				
III	3	110	30	57	93			

Trapped, July 12-15, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
II	4	110	40	80				
III	36	120	34	61	95			
IV	6	137	32	59	98	122		
V	1	160	41	73	99	134	152	

Fishermen, June 27, July 22, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	8	163	38	75	122			
IV	4	172	38	82	125	163		
V	2	201	35	68	112	162	194	
VI	1	213	38	75	126	173	190	207

Estimated characteristic growth

Millimeters	35	65	115	160
Inches	1.4	2.6	4.5	6.3

SPEAR LAKE, Kosciusko County. (40 acres, Wilson, unpublished.)

The winter series was taken by Fish and Game employees, the others by the Survey.

Fishermen, July 7-24, 1939.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
II	3	129	42	97				
III	6	151	31	64	121			
IV	1	186	30	52	109	171		

Seined, August 23, 1939.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
	12	64	32					

Ice fishermen, January 21 - February 15, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	2	162	42	100	162			
V	2	209	41	80	133	179	209	
VI	2	218	33	68	122	174	204	218

Fishermen, July 4-21, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
II	2	126	44	93				
III	35	145	33	66	117			

Estimated characteristic growth

Millimeters	35	75	125
Inches	1.4	3.0	4.9

SYLVAN LAKE, Noble County. (630 acres, Tucker.)

The winter series below was collected by Fish and Game employees. Those of the summer of 1941 were taken by the Survey, partly from fishermen, partly from fish that had died from causes imperfectly understood. As there was little difference in growth calculated from the two kinds of fish, the data are amalgamated.

Ice fishermen, February 11 - March 2, 1939.

Age	Number	Length	1st	2nd	3rd	4th	5th
II	2	156	69	156			
III	47	176	46	107	176		
IV	4	197	42	99	156	197	
V	1	262	43	127	193	246	262

Fishermen, July 22 August 9, 1941.

Age	Number	Length	1st	2nd	3rd	4th
II	4	142	52	108		
III	20	160	38	74	129	
IV	2	182	36	68	125	167

Estimated characteristic growth, 1939

Millimeters	45	105	170	200
Inches	1.8	4.1	6.7	7.9

Estimated characteristic growth, 1941

Millimeters	40	75	130
Inches	1.6	3.0	5.1

There appears to be a very significant difference in growth rate, between the 1939 and the 1941 series. At the third annulus the 1939 fish averaged 6.7 inches, the 1941 fish only 5.1.

Sylvan Lake water carries a very heavy load of organic matter, owing to its having a large fraction of sewage in its inlet water. More or less serious mortalities among its fish are reported from time to time, for which the only apparent explanation is asphyxiation. During a long winter a great many fish could die in this way, under the ice, without attracting much attention. If this happened during the hard winter of 1936, then a lake partially emptied of fish would account for the unusually rapid growth of bluegills up to 1939.

SYRACUSE LAKE, Kosciusko County. (564 acres, including extensive marshes; Tucker.)

Dr. Hile took a series from fishermen, and another in a small-meshed seine.

Fishermen, July 3, 1926.

Age	Number	Length	1st	2nd	3rd	4th	5th
III	15	130	38	66	106		
IV	1	144	34	57	90	128	
V	2	203	37	58	108	155	190

Seined, July 8, 1927.

	3	60	43		
II	3	99	42	80	
III	1	138	43	79	107

Estimated characteristic growth, 1926

Millimeters	35	60	95
Inches	1.4	2.4	3.7

Contrary to the usual condition, the seined fish suggest more rapid growth than do the line-caught ones. The latter have grown quite slowly, since the three-year-old fish having an average length of only 130 mm. almost certainly represent the faster-growing members of their year-class. It is possible the seined fish were from a bay or channel not typical of the whole lake, or again this may constitute another example of a secular change in growth rate.

TIPPECANOE LAKE (excluding Oswego Lake), Kosciusko County. (707 acres, Tucker.)

Dr. Hile had a good series from his gill-net, and a few have been taken in recent years.

Gill-net, August 19-20, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	22	185	38	82	137			
IV	6	198	35	69	122	174		
V	2	221	34	69	114	168	208	
VI	2	222	33	60	90	154	196	216

Fishermen, August 15-28, 1938.

III	1	171	45	84	131	
IV	2	183	36	70	104	148

Estimated characteristic growth, 1929.

Millimeters	35	70	120	170
Inches	1.4	2.8	4.7	6.7

WALL LAKE, Lagrange County. (160 acres, Gutermuth, 1938.)

The long winter series below was secured by employees of the Division of Fish and Game.

Ice fishermen, January 21 - March 3, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	30	149	42	89	147			
IV	149	178	40	73	124	178		
V	7	201	35	75	140	182	201	
VI	4	218	43	78	132	190	208	218

Estimated characteristic growth

Millimeters	40	75	130	180	205	215
Inches	1.6	3.0	5.1	7.1	8.1	8.5

LAKE WAWASEE, Kosciusko County. (2,964 acres, Tucker.)

Several series were taken by Dr. Hile from fishermen and in the gill-net, while in recent years scales from ice fishermen have been collected, chiefly by Fish and Game employees. Most of the latter are from the southeast end of the lake, near the hatchery, or from Johnson's bay on the north side. On March 10, 1941, a series was taken by the Survey from ice fishermen at Macy's slip at the extreme west end.

Fishermen, July 15-25, 1926.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
III	63	134	39	69	107						
IV	4	158	35	59	92	134					
V	2	200	36	61	92	140	190				
VI	2	218	40	64	103	148	186	214			

Fishermen, August 8-24, 1926.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
III	9	135	37	65	101						
IV	3	183	36	66	100	148					
V	13	207	38	67	103	147	192				
VI	3	224	32	60	98	149	193	214			
VII	1	238	35	50	80	123	170	217	234		

Seined, July 7-14, 1927.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
	10	56	43								
II	3	89	37	69							

Fly fishermen, June 30, 1928.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
IV	1	219	41	85	134	191					
V	6	197	38	65	99	147	189				
VII	1	238	38	61	102	140	197	226	238		

Gill-net, April 13-25, 1929.

IV	5	186	42	77	127	186					
V	1	195	40	70	106	153	195				
VII	1	231	31	57	91	134	182	220	231		

Gill-net, June 18 - July 5, 1929.

IV	2	180	39	63	108	162					
VI	3	233	37	64	99	145	189	229			

Ice fishermen, February 8 - March 3, 1939.

III	1	146	45	88	146						
IV	11	165	39	74	111	165					
V	20	188	37	60	98	139	188				
VI	2	176	35	57	84	116	148	176			
VII	2	249	40	66	97	132	188	226	249		
VIII	1	224	31	50	75	121	147	185	210	224	

Ice fishermen, February 6-16, 1940.

IV	3	135	38	65	116	168					
V	6	207	36	68	108	162	207				
VI	18	212	38	62	100	146	191	212			
VII	5	215	40	70	107	150	182	200	214		

Fishermen, July 28, 1940.

III	5	144	44	79	118						

Ice fishermen, January 31 - March 7, 1941. Mostly from Johnson's Bay.

III	6	133	50	84	133						
IV	121	173	43	78	118	173					
V	40	195	37	65	102	145	195				
VI	8	221	37	62	103	153	194	221			
VII	15	233	38	63	100	142	193	219	233		
VIII	3	251	44	75	118	165	207	226	240	251	
IX	1	230	40	69	100	132	179	200	216	224	230

Ice fishermen, March 10, 1941. Macy's slip.

III	3	128	44	80	128						
IV	46	167	42	76	114	167					
V	5	197	38	66	106	147	197				
VII	1	223	36	50	89	130	161	198	223		

Seined, August 14, 1940.

II	12	98	42	71							
III	1	118	36	65	94						

Estimated characteristic growth

Millimeters	35	65	100	145	195	220	235
Inches	1.4	2.6	3.9	5.7	7.7	8.7	9.3

Growth on Wawasee is as well known as on any lake. It is a slow growth rate, at least in the first 3 or 4 years of life, and there is no evidence it has changed significantly from 1926 to 1941. The estimate of characteristic growth corresponds closely to the growth of fish of intermediate age in the ice-caught series. A simple average of all fish in the catches examined would give higher figures, but in nearly all cases the fish in the more abundant younger age-classes appear to have been selected for large size.

An interesting feature of the results from Lake Wawasee is the indication that, in spite of its size, growth appears to be uniform throughout the lake. This is best illustrated by comparing the growth of bluegills taken in the winter of 1941 from Johnson's Bay with that of bluegills from Macy's slip, three and a half miles distant by the shortest water route. Not only is the growth rate the same, but the dominance of 4-year-old fish in the catch is apparent at both places.

WEBSTER LAKE, Kosciusko County. (585 acres including the backwater, Tucker.)

Ice fishermen, January 29 - March 26, 1940.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
III	2	154	48	94,	154			
IV	12	172	46	81	131	171		
V	14	200	44	78	119	168	200	
VI	7	203	37	67	104	152	186	203

Seined, July 25, 1940.

	6	58	43		
II	2	72	32	54	
III	1	131	32	59	97

Estimated characteristic growth

	1st	2nd	3rd	4th	5th
Millimeters	45	80	125	170	195
Inches	1.8	3.1	4.9	6.7	7.7

WINONA LAKE, Kosciusko County. (503 acres, Dr. Scott's map published by Wilson, 1936.)

Scales are available from two collections of Dr. Hile's and several made by the Survey in various years.

Seined (?), July 19, 1929.

Age	Number	Length	1st	2nd	3rd	4th	5th	6th
II	6	102	44	75				

Gill-net, July 22 - August 9, 1929.

IV	15	185	46	82	125	165		
V	8	191	36	67	106	145	201	
VI	6	199	34	64	102	143	173	191

Fishermen, June 29 - August 8, 1929.

III	83	137	43	81	114	
IV	1	148	44	80	117	139

Fishermen, June 22, 1938.

III	16	151	46	83	127	
IV	3	165	50	80	118	153

Trap, July 10 - August 2, 1939.

II	168	117	40	87	
III	17	140	36	65	116

Anglers, July 23, 1940.

II	6	129	51	99	
III	10	138	39	81	115

Seine, June 8-27, 1939.

	115	53	45	
II	7	104	41	84

Estimated characteristic growth, 1929 (gill-net)

Millimeters	35	65	100	140
Inches	1.4	2.6	3.9	5.5

Estimated characteristic growth, 1929 (fishermen)

Millimeters	40	75	110
Inches	1.6	3.0	4.3

Estimated characteristic growth, 1938-1940 (fishermen)

Millimeters	45	75	110
Inches	1.8	3.0	4.3

The mean growth rate shows some variability in these data. The 5- and 6-year fish of 1929 give higher figures than the 3- and 4-year fish. In 1939 trap-caught specimens point to possibly 40, 80, which is similar to that from fishermen's catches in 1938 and 1940 and also in 1929. The contrast then is between fish of different ages caught by different methods in 1929, and it is difficult to assess its significance.

LAKE OF THE WOODS, Marshall County. (409 acres, Tucker.)

A series was collected on the lake by the Survey.

Fishermen, August 19-29, 1941.

Age	Number	Length	1st	2nd	3rd	4th	5th
II	16	144	50	89			
III	10	169	44	92	138		
IV	13	177	36	74	118	155	
V	2	162	38	71	110	130	148

Estimated characteristic growth

Millimeters	45	85	130
Inches	1.8	3.3	5.1

DISCUSSION

TIME OF ANNULUS FORMATION

The formation of the new annulus in the bluegills studied occurs at least from February to June, the majority probably being laid down in May. Sometimes current-year's annuli are found on a part of the bluegills taken by ice fishermen. The best examples are found on scales from 19 out of 26 fish taken from Dewart Lake, March 10, 1941. The water temperature under the ice, where the fishing was going on, had reached 5° Centigrade on this occasion, and the fish were actively feeding, as their full stomachs testified. It is possible however that only a small part of the lake's population was affected. On Lake Maxinkuckee one of 15 fish taken March 1-4, 1940, had new growth ; and even on January 23, 1938, one of the 18 bluegills taken from the same lake had a very narrow but clearly indicated annulus. Other possible examples are 2 out of 52 fish taken in February and early March on Round Lake, Whitley County, and 1 of 3 taken on Big Chapman Lake; though the possibility of these being accessory checks cannot be excluded.

On several other lakes fish taken in winter, up to early March, fail to show any new growth. This is true of Lake Wawasee, from which numerous winter scales have been taken in several years, and also of Brown, Royer and Wall Lakes, in Steuben County, to cite only those from which the best series are available.

Dr. Hile collected a series of 40 bluegills from Duley Lake March 23, 1929, which show no new annuli. Four out of 27 caught in Indian Village Lake, April 23, 1929, were considered definitely to have new growth, and it is possible some of the others did too, for it is usually difficult to distinguish a newly-formed annulus before cutting-over appears on the top and bottom of the scale. No new annuli could be detected on 7 specimens from Wawasee, April 13-25, 1929. Unfortunately there are very few scales taken in the period May 1 to June 15, because there is a closed season on fishing then. When the season reopens on June 16 practically all scales have a new annulus, with a variable amount of growth beyond it. The only exceptions encountered are from a very few of the largest fish.

VARIATION IN LENGTH WITHIN AGE-CLASSES

Tabulation of standard deviations for the whole of the data presented above has not been attempted, but a few exploratory calculations have been made. A typical one is shown in Table 3. Consideration of the variation in length within age groups represented in this sample will give a rough idea of the variation to be expected, in this and other lakes. The standard deviation increases with length and about in proportion, for the first 100 millimeters of length achieved. Later, standard deviation increases less rapidly than length, and beyond 200 millimeters it actually

TABLE 3

Mean length (L), and standard deviation in length (s), at successive annuli, of 193 bluegills taken by ice fishermen from Lake Wawasee, January-March, 1941. All standard deviations are calculated using a divisor one less than the number of individuals in the sample.

Age			III	IV	V	VI	VII	VIII
Number			6	121	40	8	15	3
Mean Length			132.8	173.3	194.7	221.0	233.1	251.0
Length and Standard Deviation at Successive Annuli	1	L	50.2	42.6	37.4	47.0	37.9	44.0
		s	3.55	4.80	5.30	5.55	4.68	3.61
	2	L	84.5	77.8	64.8	62.3	62.7	74.7
		s	3.39	8.72	9.10	9.09	7.98	14.17
	3	L	132.8	117.9	102.4	100.6	100.3	117.7
		s	7.48	11.84	14.04	16.30	13.17	8.89
	4	L		173.3	144.9	153.4	142.3	165.3
		s		14.63	15.78	23.36	17.64	21.43
	5	L			194.7	194.5	193.3	207.3
		s			16.44	18.95	18.46	10.82
	6	L				221.0	219.3	226.0
		s				5.61	9.52	3.61
	7	L					233.1	240.0
		s					8.77	2.00
	8	L						251.0
		s						3.47

begins to decrease. Approximate values for the ratio of the two are shown below:

Length	Length / Standard Deviation
35-100	7
125	8
150	9
175	10
200	11
225	25
250	50

These values (except those greater than 11) have been used elsewhere in this paper to estimate standard deviations, standard errors of means.

and hence the probability of significance of differences in mean lengths, in rough fashion.

The standard deviations cited above are appropriate only when nearly the whole of an age-class is sampled. In Table 3 the age 3 fish are evidently incompletely sampled, accordingly their standard deviations are much less than those of older groups, while their mean lengths are greater than representative values for the age-class as a whole. The same is suggested even for the four-year-old fish, whose standard deviations average a little less than those calculated from the older fish. From 5 to 8 years, there are no significant changes in standard deviations; if anything there is a slight tendency downward, but this cannot be confirmed. In conjunction with stable calculated mean lengths, this constitutes good evidence that the older fish are fairly adequately and evenly sampled through their entire length range, and attests the value of this type of sampling.

Among the oldest three age classes there is a pronounced tendency for variability in length to decrease in the later years of life. The differences show up as very significant, when tested with a table of critical values of the variance ratio (Snedecor, 1940, Table 10.3.) The reason for the decrease appears simple enough. The rate of increase in length declines sharply after a certain length (not a certain age) is reached, in Wawasee about 200 millimeters. Consequently the faster-growing fish are slowed up soonest, at a time when the slower ones are still maintaining fairly rapid growth, and in this way the frequency distribution of lengths is narrowed. So effective is this process, that when an age-class attains a mean length of 225-250 millimeters, it appears to be only about as variable in length as when it averaged 30-60 millimeters long. In the interim it will have been 3 to 4 times as variable. Selective mortality might of course contribute to the same result, but it would almost certainly also produce a shift in the calculated mean lengths at earlier ages —which shift is not apparent in fish 5 years and older.

RATE OF GROWTH OF THE Two SEXES

Comparison of the calculated growth rates of the two sexes, in several lakes, are shown in Table 4. The only place where a significant difference between the sexes occurs, in rate of growth, is in Shoe Lake fish caught during the height of the spawning season. Males outnumber females among such fish ; and in Shoe Lake the females are larger and have grown faster throughout their life than have males of the same age. The difference for either age-class separately (Table 4) is not significant, but taken together they give fairly good evidence of a real effect. It is not known whether Shoe Lake fish exhibit a similar discrepancy at other seasons, but in the light of the information from other lakes this is doubtful. The difference in June could result from average differences between the sexes in size at first maturity, or differences in breeding behavior.

Hubbs and Cooper (1935) have found a larger average apparent rate of growth for male longear and green sunfish than for females, in samples

TABLE 4

Comparison of rates of growth of male and female bluegills

Lake	Source of Fish	Date	Age	No. of Fish	Sex	Length when caught	Length at annulus				
							1	2	3	4	5
Winona	Trap	June-August 1939	II	67	♂	118	39	87			
				79	9	118	41	88			
			III	8	♂	145	37	66	120		
				7	♀	143	37	65	120		
Dewart	Fishermen	March 10, 1941	III	11	♂	140	39	86	136		
				15	♀	143	41	87	140		
	Fishermen	July 12, 1941	III	13		178	44	95	148		
				8	9	173	44	92	147		
			IV	2		193	43	83	131	179	
				9	9	191	41	85	135	180	
Shoe	Fishermen	June 15-21,1941	IV	13	♂	135	41	64	90	125	
				6	9	143	42	66	96	133	
			V	30	♂	150	35	61	83	115	144
				5	9	159	38	67	89	122	153,
Wawasee	Fishermen	March 10, 1941	IV	22		166	42	76	113	166	
				20	9	164	41	74	113	164	
				3		195	36	64	101	141	195
				2	9	200	44	70	113	157	200

taken in various parts of Michigan, and the same is true of some other Centrarchidae. Before concluding that bluegills differ in this respect from related species, it would perhaps be well to reconsider all available data from the point of view of the effects of selective sampling upon apparent rate of growth. For such a reconsideration it would be necessary to have knowledge of how and when the samples were taken, and something of the habits of the fish involved.

STABILITY OF GROWTH RATES

If the rate of growth in a lake were to vary sharply from year to year, or over periods of four or five years, the results of growth studies might have only a limited applicability to problems of fisheries management, however interesting they would be scientifically. Significant variations over longer periods, of the order of 10 years or more, would be less disturbing, but still a factor to be reckoned with.

Examining the data above for short-term variations first, the few comparisons available suggest that rate of growth is rather stable. Compare, for example, the growth of fish taken through the ice in 1939, 1940 and 1941 on Lake Wawasee ; or the growth of summer fish taken in 1938, 1939 and 1941 on Shoe Lake ; or the summer and winter fish taken from Maxinkuckee in 1938, 1940 and 1941. Minor variations, of questionable significance, appear in these series, but at best they amount to no more than about 5 millimeters at 3 years of age. In Winona Lake there appears a difference which may be significant : the contrast between 2- and 3-year-old angler-caught fish with 4- and 5-year-old net-caught fish, in 1929. The latter appear to have grown more slowly—being about 10 millimeters shorter at 3 years. There are two examples of more striking change in growth rate, on Bass and Sylvan Lakes, but the reasons for instability in those instances appear to lie outside the range of normal environmental variations, as discussed earlier.

More comparisons can be made over a longer time interval, thanks to Dr. Hile's scale collections made 1926 to 1929. One of the best of these is a comparison of fish caught by fishermen in Lake Wawasee in 1926 and 1928, with those caught 1939 to 1941. There is no suggestion that the prevailing slow growth has been modified over that period. On other lakes comparisons are usually more difficult, owing to the use of different collecting methods. However, on Dewart Lake a comparison of large fish is possible between 1929 and 1941, and no significant differences appear. The same is true of Big Barbee and Dan Kuhn Lakes, though the samples are small.

Two lakes however give some evidence of change in growth rate. On Little Chapman it appears almost certain that growth rate has decreased in a 12-year interval, the difference amounting to 20 millimeters of length at three years of age. Similarly, on Silver Lake (Kosciusko County) the gill-net used in 1929 caught much faster-growing fish than did fishermen in 1941, the difference again being nearly an inch at 3 years. But for complete assurance regarding the reality of these changes, new samples taken by the same method as Dr. Hile used would be very desirable.

Shoe Lake was not sampled by Dr. Hile, but there is other evidence that growth has been slow there over a long period. Bolen (1924) determined ages of bluegills taken from Winona Lake and from Shoe Lake in 1923; his results are reproduced below, with his "length to the base of the caudal fin" converted to fork length, using the factor 1.17.

	Winona Lake		Shoe Lake	
Age	No.	Ave. length when caught	No.	Ave. length when caught
I	16	69		
II	29	123	30	132
III	7	169	7	163
IV	2	196		
V	1	199	1	178
VI	—			
VII		—	1	181

While it seems to the writer that Bolen was probably overlooking the first annulus on these scales, the interesting feature is the fact he found the Shoe Lake fish to be definitely slower in growth than those of Winona—just as at the present time. (The larger apparent size of Shoe Lake fish at 2 years is referable to the fact that there were many sublegal fish in his Winona series, but his Shoe Lake ones were probably all taken by fishermen). In 1941 several fishermen on Shoe Lake, including one whose fishing experience dated back 50 years, assured the writer that the lake had always produced numerous small bluegills, but none as large as those in many neighboring lakes. A similar statement was published in the early years of the century by Dr. Carl Eigenmann or one of his colleagues at the Indiana University Biological Station, though the exact reference escapes the writer. This may be considered indirect evidence that rate of growth too, has been small over a long period of years.

Summarizing, we may say that in some lakes, including those from which the best samples are available, growth appears to have varied very little over periods up to 20 years. In two lakes there is a strong suggestion that the growth rate has decreased considerably over a 12 year period ; but on this point a critical jury would return the Scottish verdict of "Not Proven."

VARIATIONS IN ABUNDANCE OF AGE-CLASSES

The data of this paper are for the most part not well adapted to showing up variations in abundance of successive age-classes, because collections do not extend, in unbroken line, over more than 3 or 4 years. There are however some suggestions that the fish produced by different spawnings vary considerably in number, in a fashion similar to that demonstrated for rock bass in a Wisconsin lake (Hile, 1941) . Perhaps the best example of a "strong" age-class here is that from the spawning of 1934 in Lake Wawasee, which in three successive years was much more numerous than were adjacent ages, in the catch of the ice fishermen. The spawning of 1937 is apparently another numerous group, in the same lake.

COMPARISON OF GROWTH RATES IN DIFFERENT LAKES

In the glacial lakes studied, extreme variation in size at the third annulus is from 2.9 inches in Bass Lake, in 1934, to 6.9 in Round Lake in 1939 (Table V). If only strictly normal conditions be considered, the range is 3.5 inches in Shoe Lake to 6.3 inches in Carr Lake. This range is more impressive if it be regarded in terms of weight, for at 3 years the average Carr Lake fish would be at least 6 times as heavy as the average Shoe Lake fish. Clearly then great variability exists in growth rates in different lakes. On the other hand, within the middle half of the lakes as arranged in order of growth, average length at 3 years does not vary a great deal—only from say 4.6 to 5.1 inches (115 to 130 millimeters). The mean size achieved at the third annulus is 121.2 millimeters, or $4\frac{3}{4}$ inches, which is the legal size limit.

TABLE V

List of lakes arranged in order of the average length achieved at formation of the third annulus. Except as indicated, growth is estimated principally from scales collected from 1939 to 1941. Asterisks indicate lakes for which the data are scanty, or their interpretation unusually uncertain.

Length at Annuli			Lake	Length at Annuli			Lake
2nd	3rd	4th		2nd	3rd	4th	
50	65	80	Springwood (see Ricker,	75	120	175	Clear
50	75		Gravel Pit 1942)	70	125		Silver* (Steuben Co.)
55	75	95	Bass, 1934	75	125		Spear
60	90	120	Shoe	65	125	165	O'Blennis*
60	95		Syracuse*, 1929	70	125	165	Indian Village, 1929
65	95	120	Howard*	75	125	170	Hyndman, 1929
55	95	145	Center*, 1929	80	125	170	Webster
65	100	130	Palestine*	80	125	175	Crooked*
60	100	135	Ridinger*	70	125	180	Goose
70	100	140	High*	75	125	180	Royer
65	100	140	Winona, 1929 (part)	70	125	185	Pretty*
70	100	140	Sawmill	75	125	185	Maxinkuckee
65	100	145	Wawa see	75	130		Sylvan, 1941
70	105	140	Dan Kuhn	85	130		Lake of the Woods
75	110		Winona, 1939-40, 1929 (part)	90	130		Silver (Kosciusko Co), 1941
70	115		Little Barbee, 1929	80	130	175	Big Barbee
80	115		Lime*	75	130	180	Wall
75	115	150	Round (Whitley Co.)	85	135		Dream
80	115	150	Manitou*	80	135		Adams*
65	115	160	Simonton	80	135	180	Dewart
75	115	165	Duley, 1929	75	140		Big* (Noble Co.)
75	115	175	Secrist*	80	140		Little Chapman, 1929
65	115	170	Cline*	100	145	170	Foots Pond (see Ricker and Lagler, 1942)
65	120	140	Homewood (see Bennet et al., 1941)	90	150	180	Silver (Kosciusko Co.), 1929
75	120		Gage	85	150	210	Hill
75	120		James*	80	150	220	Fox*
75	120		Little Chapman, 1941	80	155	190	Brown
75	120	160	Irish	95	160	200	Carr
70	120	170	Gordy*, 1929	105	170	200	Sylvan, 1939
70	120	170	Tippecanoe, 1929	115	175		Round (Elkhart Co.), 1939

The distribution of lengths at three years is shown in Figure 4. Even considering only lakes in a balanced condition, there is a suggestion of bimodality in the distribution ; its deviation from the "normal" shape shows up as scarcely significant however, when tested by means of the χ^2 test. The standard error in mean length at 3 years is 16.0 millimeters.

It would be extremely instructive to discover that this order and distribution of growth rates was paralleled by an arrangement of the lakes on some other physical or biological basis. Aside from the winter killing in Round and possibly Sylvan lakes, and the peculiar history of Bass Lake, no definite association of this kind can be made. No association between bluegill growth and size of the lake can be established, at any rate up to 4 years of age. Other features, such as average depth, transparency, quantity of vegetation, abundance of bottom food organisms, apparent abundance of predacious or competing fish, and so on, which can be estimated for some of the lakes, also exhibit no obvious relation to growth rate. The writer is completely at a loss to explain why growth is rapid in Carr Lake and slow in Shoe Lake ; or why Maxinkuckee produces larger and faster-growing bluegills than Wawasee. That genetic differences in rate of growth exist between lakes is possible, and should be tested, but at the moment few fisheries biologists are inclined to believe that such are of importance.

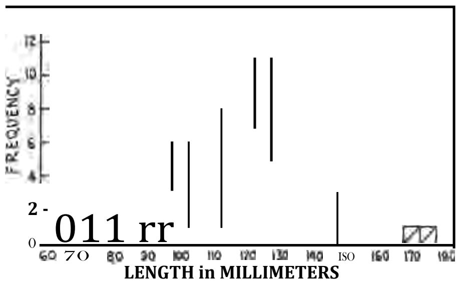

Figure 4. Distribution in northern Indiana lakes of mean lengths of bluegills at completion of the third annulus. Lakes outside the normal range of variation are marked with a cross-bar.

Approaching the problem from another angle, there is one factor which notoriously produces profound effects upon the rate of growth of fish, and that is their population density in relation to food available. This is evident from experiments in stocking ponds with different numbers of young fish (cf. Swingle and Smith, 1941); from the rapid growth rates often obtained in new or poorly stocked lakes (as in Round Lake, above ; cf. also Bennett et al., 1940), and from the stunted growth observed in densely-stocked waters (cf. Beckman, 1941a; Ricker, 1942). That this may be the major factor in controlling growth rate in natural lakes is a reasonable, if not an established, proposition. The density of fish produced, and hence rate of growth, must depend ultimately upon the combined action of various factors of the physical and biological environment, but these appear to be so complex as to defy analysis on the basis of the knowledge available at present.

APPLICATIONS TO FISHERIES MANAGEMENT

Whether or not abundance effectively controls growth now, the known effects of changes in abundance can be used as a basis for predicting the effects of current and proposed fish management practices.

For example, adding young bluegills to a lake from outside sources increases their abundance, and if done on a scale sufficient have an appreciable effect, will tend to decrease the rate of growth of the bluegills in the lake. If growth is moderate or rapid to start with, this decrease may be a small price to pay for the increased number of fish. Accordingly, in the absence of knowledge of survival rates, it can be presumed that stocking young bluegills will be most useful in lakes where their growth rate is rapid. It may be argued that stocking of lakes where growth is slow would at least not be harmful, but this assumption is not above question. Elsewhere in this volume (Ricker, 1942) two artificial lakes are described, where the bluegills grew so slowly that they rarely became legal size by the time they were 5 years old. Consequently a great deal of the productive capacity of these lakes was being devoted to raising fish that would never be of value to anyone. Aside from Bass Lake, such extremely retarded growth has not yet been found in our natural lakes ; but even in them, overabundance may be reducing the poundage of fish removed per annum. Thompson (1941) has determined for largemouth bass an optimum rate of growth--i.e. the one at which body weight increases fastest per unit amount of food consumed. This rate is about 1.3 percent increase per day, for 10-inch bass at 21° Centigrade. There can be little doubt that with bluegills a similar situation exists, where both too slow growth and too rapid growth use up food inefficiently. Consequently it is quite conceivable that an abundance of fish which results in growth rates like those in the first part of Table V may actually reduce the production of fish flesh in the lakes concerned. Any additions to the stock on hand will further decrease both the rate of growth and the efficiency of food utilization, so that heavy stocking of such a lake with bluegills could result in a smaller rather than a larger poundage of bluegills produced. On the other hand, effective stocking of a lake where growth is rapid not only increases the number of fish there, but may also improve the efficiency of food utilization by decreasing rate of growth.

We are unfortunately not able to specify exactly what annual rate of growth would give maximum production. Since food supplies vary seasonally, a population large enough to utilize this week's supply to best advantage may have been too small for last week's, or be too great for next week's. Similarly the length of the growing season and water temperature are important factors, and these may vary from lake to lake. In general, the longer the growing season, the greater will be the optimum per annum rate of growth ; on the other hand, optimum temperature may depend partly on the food available. Bennett, Thompson and Parr (1940) refer to the bluegills of Homewood Lake, Illinois, as "crowded", though their growth to the third annulus is about the average for northern Indiana lakes (see Table V) ; but since the latitude of Homewood Lake is considerably south of the Indiana lakes, the bluegills there are doubtless accurately characterized. Similarly bluegills of Foots Pond, in extreme southern Indiana, had rapid growth to three years as measured by northern standards (Table V), but probably no more than the average for their latitude (Ricker and Lagler, 1942) .

There is need for caution then in interpreting the results of growth studies, but to the writer it seems that the rates prevailing in the first quarter, at least, of the list of Table V should be regarded as probably considerably less than the optimum. The aim of fish management should be to increase these rates of growth, rather than to reduce them by further crowding of the fish.

Methods by which this could be achieved include (1) encouraging valuable predacious fish like bass, (2) relaxation of various restrictions on fishing, (3) actual removal of young bluegills from lakes where growth is slow for transfer to lakes where growth is rapid, and (4) discouragement of less valuable fish which compete with bluegills for available food. Some of these proposals would have far-reaching repercussions ; they could only be adopted after a more careful examination of their various effects, and would require an educational campaign to make them palatable to the public. This is particularly true of the one which gives most promise of producing real results, namely, changes in fishing regulations. Any attempt to provide longer open seasons or smaller size limits on some lakes than on others would encounter much criticism at first, and would make law enforcement more difficult.

In conclusion, a word of warning to those who may wish to interpret the arrangement of lakes in Table V as being a reflection of their excellence as fishing lakes. For one thing, since no account is taken of fish other than bluegills, the arrangement could at best be only one-sided. Apart from that, our observations indicate that there is little association between rate of growth and availability of bluegills to fishermen ; if anything, the correlation is negative. A creel census of Shoe Lake, where growth is slow and the average fish caught is small, indicated that a very satisfactory total weight of bluegills was being taken. Nor will Table V serve to forecast where big bluegills may be had. Some lakes where growth is rapid produce larger-than-average fish, as a rule ; but this is equally true of Maxinkuckee where growth in the first few years is only mediocre, and of Lake Wawasee, where growth is slow. For information concerning where and when to fish, the fisherman must continue to heed his own experience or his friends' advice.

SUMMARY

1. Scale samples of bluegills from 53 natural lakes of northern Indiana have been used to determine age and rate of growth.
2. On several lakes, there is a linear relationship between the anterior scale radius, and the fork length of the fish less 20 millimeters.
3. The selective nature of all sampling procedures introduces considerable difficulties into the task of estimating a characteristic growth rate for any lake. Fish caught by angling in summer are probably

least satisfactory, because the fish school in groups of restricted size composition, and it is impossible to define a mode or range of length which is most efficiently sampled by anglers generally. In winter this is much less serious, and a range of lengths including several age-classes is rather evenly sampled by ice fishermen. A gill net, which catches a narrow but prescribed range of sizes, will often yield good information when appropriate adjustments are made. The results of this paper illustrate very strikingly that accurate estimation of a representative rate of growth from a lake does not consist solely in amassing a large number of scales.

4. Lee's phenomenon of a decrease in apparent growth rate at a given age, when calculated from fish of increasing age, appears ubiquitously in these data as a result of selective sampling. Its presence as a real population characteristic cannot be definitely demonstrated, and it is, at most, of small importance.
5. In several lakes, male and female bluegills grow at the same rate. In one lake where females apparently grew faster than males, the difference may be ascribable to selective sampling resulting from earlier sexual maturity of the males.
6. The scale annulus is laid down from February to June in these lakes, the majority probably in May.
7. On several lakes rates of growth have remained constant within narrow limits over periods of up to 20 years. Two fairly well authenticated instances of decrease in growth rate, in 12 years, were discovered.
8. Pronounced variation in the abundance of successive year-classes is evident on Lake Wawasee, and is suggested on some other lakes.
9. For all lakes under strictly normal conditions the average size achieved at the time the third annulus is laid down is 121 millimeters, or 4% inches. The standard deviation is ± 16.0 millimeters, and the distribution of lengths has some tendency toward bimodality. The range is from 90 to 160 millimeters (3.5 to 6.3 inches).
10. Excessive crowding in artificial lakes, or conditions associated with the presence of numerous coarse fish, have produced growth rates below the range just given. Similarly growth in excess of the upper limit of the normal range has been found in fish living in waters known or presumed to be depopulated.
11. Artificial additions to the stock of bluegills in lakes where growth is slow are unnecessary, and may be undesirable. As far as present knowledge goes, best utilization of hatchery-reared bluegills would be obtained by putting them in lakes where growth is rapid, or at any rate average. At least from a strictly biological point of view, relaxation of restrictions on fishing can be recommended for lakes where growth is unusually slow.

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REFERENCES

Beckman, William C. Increased growth rate of rock bass, *Ambloplites rupestris* (Rafinesque), following reduction in the density of the population. Trans. Amer. Fish. Soc. 70: 143-148. (1940) 1941 (a) .

Beckman, William C. Meet Mr. Bluegill. Michigan Conservation 10(7) : 6-7. June, 1941 (b) .

Bennett, George W., David H. Thompson and Sam A. Parr. Lake Management reports. 4. A second year of fisheries investigations at Fork lake, 1939. Illinois Natural History Surv., Biol. Notes 14, 1-24. 1940.

Bolen, Homer R. The relation of size to age in some common freshwater fishes. Proc. Indiana Acad. Sci. 33: 307-309. (1923)1924.

Creaser, Charles W. The structure and growth of scales of fishes in relation to the interpretation of their life history, with special reference to the sunfish, *Eupomotis gibbosus*. Misc. Publ. Univ. Michigan Mus. Zool. 17: 1-82. 1926.

Evermann, B. W., and H. W. Clark. Lake Maxinkuckee. A physical and biological survey. Vol. 1. Indiana Department of Conservation, Indianapolis, 1920.

Fraser, C. McLean. Growth rate in the Pacific Salmon. Trans. Roy. Soc. Canada (V), III, 13: 163-226. 1920.

Gutermuth, C. R. Where to go in Indiana. Official Indiana lake guide. 56 pp. Indiana Department of Conservation, Indianapolis, 1938.

Hansen, Donald F. The date of annual ring formation in the scales of the white crappie. Trans. Amer. Fish. Soc. 66: 227-236. (1936)1937.

Hile, Ralph. The rate of growth of fishes in Indiana. Investigations of Indiana Lakes 1 (2) : 8-55. 1931.

Hile, Ralph. Age and growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in Nebish lake, Wisconsin. Trans. Wisconsin Acad. Sci. 33: 189-337. 1941.

Hubbs, Carl L., and Gerald P. Cooper. Age and growth of the long-eared and green sunfishes in Michigan. Papers Mich. Acad. Sci. Arts Letters 20: 669-696. 1935.

Hubbs, Carl L., and Karl F. Lagler. Guide to the fishes of the Great Lakes and tributary waters. Cranbrook Inst. Sci. Bull. 18, 1-100, Bloomfield Hills, Mich. 1941.

Merriman, Daniel. Studies on the striped bass *(Roccus saxatilis)* of the Atlantic coast. Fishery Bull. U. S. Fish and Wildlife Service 50: 1-77. 1941.

Ricker, William E. Fish populations of two artificial lakes. Investigations of Indiana Lakes and Streams 2(13) : 255-265. 1942.

Riker, William E., and John Gottschalk. An experiment in removing coarse fish from a lake. Trans. Amer. Fish. Soc. 70: 382-390. (1940)1941.

Ricker, William E., and Karl F. Lagler. The growth of spiny-rayed fishes in Foots Pond, Indiana. Investigations of Indiana Lakes and Streams 2 (5) : 85-97. 1942.

Scott, Will. Report on the lakes of the Tippecanoe basin (Indiana). Indiana Univ. Studies 3 (31) : 1-39. 1916.

Scott Will. The lakes of northeastern Indiana. Investigations of Indiana Lakes 1(3) : 59-144. 1931.

Snedecor, George W. Statistical Methods. Iowa State College Press, Ames. 422 pp. 3rd edition, 1940.

Swingle, Homer S., and E. V. Smith. The management of ponds for the production of game and pan fish. Pp. 218-226 in "A symposium on hydrobiology". University of Wisconsin Press, Madison, 1941.

Tharp, W. E., Earl D. Fowler, L. S. Troth and H. R. Beyer. Soil survey of Kosciusko County, Indiana. Part II. U. S. Dept. Agric., Bureau of Soils, Washington. 1927.

Thompson, David H. The fish production of inland streams and lakes. Pp. 206-217 in "A symposium on hydrobiology", Univesity of Wisconsin Press, Madison, 1941.

Van Oosten, John, H. J. Deason and Frank W. Jobes. A microprojection machine designed for the study of fish scales. Journ. Conseil Expl. Mer 9(2) : 241-248. 1934.

Wilson, Ira T. A study of the sedimentation of Winona lake. Proc. Indiana Acad. Sci. 45: 295-304. (1935) 1936.