Illinois Academy of Science Transactions, Vol. 47, 1955

ECOLOGICAL FACTORS AFFECTING THE GROWTH OF SMALLMOUTH BASS AND LONGEAR SUNFISH IN JORDAN CREEK

LEONARD DURHAM
Illinois Natural History Survey and Illinois Department of Conservation

Jordan Creek, a small tributary of the Salt Fork of the Vermilion River, in Vermilion County, Ill., has been studied intensively by the Natural History Survey since the summer of 1950. While attention was given to many facets of aquatic ecology, special emphasis has been placed on conditions affecting the game fishes, the most important of which is the smallmouth bass, *Micropterus dolomieu dolomieu* Lacépède.

This paper covers age and growth analyses of smallmouth bass and longear sunfish, *Lepomis megalotis peltastes* Cope, along with possible factors affecting their growth.

Description of Study Area

The study section of Jordan Creek consisted of the lower four miles of the stream. This part of the stream is naturally divided into two contrasting habitat types of about equal lengths—a lower wooded area and an upper open area (Larimore, Pickering, and Durham, 1952).

In addition to the differences in stream bank cover, other contrasting conditions occur. The stream falls an average of 24 feet per mile in the lower area as compared to 9.7 feet per mile in the upper area. The rate of water flow at average levels is 18.6 cubic feet per second in the lower area and 12.9 cubic feet per second in the upper area. Sand and silt are not common in bottoms of the lower area, but there are extensive accumulations of these materials in the long pools of the upper area. The soils adjacent to the stream in the lower area erode easily so little farming is done. The upper area is used extensively for farming.

Temperature Variations

Water temperature exerts a definite influence on the growth rates of fish. Within limits, fish in cold waters usually grow at a slower rate than those in warm waters (Watts and Harvey, 1946).

Water temperatures were taken in Jordan Creek by means of recording thermographs located in the lower regions of each of the two areas of the stream. Their accuracy was checked periodically with a mercury thermometer. Mean daily water temperatures were obtained by averaging temperature readings for two-hour intervals during each day. Table 1 shows the weekly average differences in mean daily temperatures between the upper and lower areas of Jordan Creek during the summer of 1951. Temperature data from the upstream area for the period from July 5 to July 31 were omitted because of inaccuracies resulting from sand deposition upon the thermograph bulb. The sand was deposited by runoff water from rains

TABLE 1.—DIFFERENCES IN WEEKLY AVERAGES OF MEAN DAILY TEMPERATURES BETWEEN THE UPPER AND LOWER AREAS OF JORDAN CREEK, JUNE TO OCTOBER, 1951.

Week	Difference in degrees F.	Week	Difference in degrees F.
June 6–13	+0.8°	Aug. 30–Sept. 5	+2.6°
June 14–20	+1.7°	Sept. 6–12.	+4.5°
June 21–27	+1.1°	Sept. 13–19	+4.2°
June 28–July 4	—0.4° (rain)	Sept. 20–26	+5.6°
July 5–July 31	no data	Sept. 27–Oct. 3	+4.5°
Aug. 1–4	+1.5°	Oct. 4–9	+3.2°
Aug. 9–15	+2.5°	Oct. 10-16	no data
Aug. 16–22	+4.6°	Oct. 17–22	0.0°
Aug. 23–29	+4.6°	Oct. 25–31	—0.5°
			av. +2.5°

+ Upper area higher.
— Upper area lower.

during the week of June 28 to July 4. Mechanical trouble in one thermograph caused the loss of records for the period from October 10 to October 16.

Table 1 shows that, except for the week of June 28 to July 4, the mean daily temperatures in the upper, open area of the stream were higher than the mean daily temperatures of the lower wooded area for all weeks from June 6 to 13 to October 4 to 9 (av. = 2.9°F. higher). After the first or second week in October, the lower area was no longer densely shaded and temperatures in the two areas were more nearly equal.

Cloudy or rainy days often caused the mean daily temperatures of the upper area to drop to a level equal to or below those of the lower area. The lower area usually showed less fluctuation in daily temperatures than the upstream area, not because of the protective shade alone, but also because of the stabilizing effect of several springs that flow into the stream in the lower area. Maximum daily temperatures in the upper area exceeded those of the lower area by as much as 12 degrees, and minimum daily temperatures as much as three degrees lower were also recorded in the upper area. The maximum tem-

TABLE 2.—WEIGHTS IN GRAMS PER SQUARE FOOT OF BOTTOM ORGANISMS TAKEN FROM RIFFLES IN THE UPPER AND LOWER AREAS OF JORDAN CREEK, JUNE TO SEPTEMBER, 1952.

Date	Annelids and insects		Crayfish		Mollusks	
	Upper area	Lower area	Upper area	Lower area	Upper area	Lower area
June 4	0.75	0.83	1.35	2.56	0.06	0.10
July 3	0.53	0.22	1.68	....	0.09	....
Aug. 6	3.45	0.26	1.52	0.84	0.18	....
Sept. 4	0.51	0.25	1.24	0.42	0.40	....

peratures, recorded on August 31, 1951, were 94°F. upstream and 84°F. downstream.

Temperatures for only one season are included in this report. On the basis of field observations and preliminary examination of subsequent data, however, the 1951 temperature data appear to be typical.

Bottom Fauna

Samples of the bottom fauna were taken with a Surber type sampler during each month of each year from the two areas of Jordan Creek. Since crayfish cannot be sampled adequately with this equipment, little importance can be attached to the relative weights of crayfish in the collections. The weights of the annelids and insects are believed to be valid for comparison.

Table 2 shows the average weights, in grams per square foot, of annelids and insects, crayfish, and mollusks collected in the two sections from June 4 to September 4, 1952. In the June 4 collections, the weights from the lower area were slightly higher than those of the upper area in the case of annelids and insects and mollusks and about twice as high in the case of crayfish. After June 4, all of the collections from the upper area of the stream averaged in total weight of bottom invertebrates at least twice those from the lower area.

Few annelids were found in the samples. Caddisfly larvae, stonefly nymphs, beetle larvae and adults, midge larvae, and some mayfly nymphs made up the larger part of the organisms grouped under the heading of "annelids and insects."

Population Density of Fish

Differences in relative numbers of all species of fish present in the two areas of Jordan Creek were noted. Table 3 shows a summary of the numbers of smallmouth bass, longear sunfish, and members of the minnow family collected in each area of the stream.

More bass were collected in the downstream area than in the one above, and the bass from the wooded area weighed a total of twice that of the bass from the upstream area. On the other hand, more longears (al-

Table 3.—Total Numbers and Weights in Pounds of Smallmouth Bass, Longear Sunfish, and Minnows (Cyprinidae) Collected in the Upper and Lower Areas of Jordan Creek in 1950.

Species	Lower area			Upper area			Entire stream	
	No.	Wt. in pounds	Av. wt. fish	No.	Wt. in pounds	Av. wt. fish	No.	Wt. in pounds
Smallmouth bass......	213	48.2	0.23	156	24.1	0.15	369	72.3
Longear sunfish...	448	28.3	0.06	1,567	56.9	0.04	2,015	85.2
Minnows...	9,245	107.0	0.012	23,116	131.6	0.006	32,361	238.6
Totals..	9,906	183.5	....	24,839	212.6	....	34,745	396.1

most four times as many) were collected from the upstream area, and collectively they weighed twice as much as the longears from the downstream area. There were 2.5 times as many minnows upstream as downstream, and the total weight of those from the upstream area was 23 percent more than the total from the downstream area.

Age and Growth of Fish

Age determinations of smallmouth bass and longear sunfish were made from scales collected throughout the summers of 1950 and 1952. After measurements and scales were taken, the fish were returned to the stream. Average growth rates were determined for both species of fish taken from each of the two contrasting areas of the stream; these were then combined to give average growth rates for smallmouth and longears for the entire stream. To justify a comparison of the growth rates of smallmouths or longears from the two areas, it must be assumed that the populations in these areas were distinct and that the individual fish had remained within one or the other of these areas throughout their period of growth. Studies of the movements of marked fish in Jordan Creek in-

Table 4.—Average Lengths for 199 Smallmouth Bass Collected in Jordan Creek in 1950 (117 of these specimens were taken from the lower wooded area and 82 from the upper open area).

Year	Number of fish	Calculated length at each annulus						Av. length (inches)
		1	2	3	4	5	6	
		Lower wooded area						
1944	2	3.4	6.4	9.6	11.3	12.8	13.6	14.0
1945	7	3.3	6.0	8.4	10.7	12.2	......	13.2
1946	8	3.6	6.5	9.1	11.2	......	......	12.2
1947	40	3.3	6.5	9.3	......	......	......	10.7
1948	7	3.9	7.5	......	......	......	......	9.2
1949	53	3.4	......	......	......	......	......	5.9
Weighted averages	....	3.4	6.6	9.2	11.0	12.3	13.6	
		Upper open area						
1944	1	3.9	7.1	10.2	12.6	14.0	14.9	15.4
1945	1	3.7	7.1	9.4	11.3	12.8	......	13.3
1946	3	3.0	5.9	9.2	11.3	......	......	12.0
1947	15	3.5	7.9	10.9	......	......	......	12.0
1948	0	......	......	......	......	......	......	......
1949	62	3.4	......	......	......	......	......	7.0
Weighted averages	....	3.4	7.5	10.5	11.5	13.4	14.9	
Weighted averages for all fish	....	3.4	6.8	9.5	11.1	12.5	14.0	

TABLE 5.—AVERAGE LENGTHS FOR 240 SMALLMOUTH BASS COLLECTED IN JORDAN CREEK IN 1952 (171 of these specimens were taken from the lower wooded area and 71 from the upper open area).

Year	Number	Calculated length at each annulus						Av. length (inches)
		1	2	3	4	5	6	
		Lower wooded area						
1946	7	3.5	7.0	9.4	11.2	12.5	*	13.9
1947	17	3.5	6.5	9.3	11.4	12.9	....	13.2
1948	5	3.1	6.0	8.9	11.2	....	....	12.5
1949	35	3.3	6.3	9.4	....	....	....	10.4
1950	91	3.1	6.1	....	....	....	....	8.1
1951	16	3.4	....	....	....	....	....	5.7
1952	0	....	....	....	....	....	....	....
Weighted averages	....	3.2	6.2	9.3	11.3	12.8	....	....
		Upper open area						
1946	1	3.6	6.7	10.6	12.7	13.4	13.9	14.3
1947	8	3.7	7.0	9.8	11.5	12.8	....	13.7
1948	2	3.1	6.5	8.4	*	....	....	11.0
1949	18	3.3	6.8	10.1	....	....	....	11.7
1950	40	3.2	6.4	....	....	....	....	8.8
1951	0	....	....	....	....	....	....	....
1952	2	....	....	....	....	....	....	3.2
Weighted averages	....	3.3	6.6	9.9	11.6	12.9	13.9	....
Weighted averages for all fish	....	3.3	6.3	9.5	11.4	12.8	13.9	....

* Annulus not formed when this collection was taken.

dicate that most of the bass and sunfish remain in about the same locations during successive growing seasons (Larimore, 1952, and unpublished data).

SMALLMOUTH BASS

Growth calculations were made from scales of 439 smallmouth bass, of which 199 were collected in 1950 and 240 in 1952. The body length-scale length relationship was determined and a correction factor of 1.1 inches was used in calculating the growth by means of a nomograph and manila strips (Carlander and Smith, 1944).

Tables 4 and 5 show the average calculated total lengths in inches of the smallmouth bass sampled in 1950 and 1952, respectively. The average growth rate of bass in the upper area of Jordan Creek was almost identical to the average growth rate of bass in the lower area during the first year of life. In succeeding years, however, growth of bass in the upper area was faster than bass growth in

TABLE 6.—AVERAGE LENGTHS FOR 400 LONGEAR SUNFISH COLLECTED IN JORDAN CREEK IN 1950 (260 of these specimens were taken from the lower wooded area and 140 from the upper open area).

Year	Number of fish	Calculated length at each annulus						Av. length (inches)
		1	2	3	4	5	6	
			Lower wooded area					
1944	6	1.0	1.9	2.9	3.9	4.6	5.1	5.4
1945	37	1.1	2.2	3.2	4.1	4.8	....	5.2
1946	116	1.0	2.1	3.2	4.2	....	....	4.7
1947	38	1.2	2.5	3.8	....	....	....	4.4
1948	24	1.1	2.3	....	....	....	....	3.4
1949	39	1.2	....	....	....	....	....	2.4
Weighted averages	....	1.1	2.2	3.3	4.2	4.7	5.1	....
			Upper open area					
1944	1	1.2	2.3	3.1	3.9	5.1	5.5	5.9
1945	9	1.2	2.4	3.7	4.6	5.2	....	5.6
1946	18	1.2	2.2	3.4	4.4	....	....	5.0
1947	29	1.1	2.3	3.2	....	....	....	4.0
1948	40	1.1	2.4	....	....	....	....	3.5
1949	43	1.3	....	....	....	....	....	2.6
Weighted averages	....	1.2	2.3	3.4	4.4	5.2	5.5	....
Weighted averages for all fish	....	1.1	2.2	3.3	4.2	4.8	5.2	....

the lower area. This was also true of each individual year-class except the 1946 year-class shown in table 1 and the 1948 year-class shown in table 2.

Legal size of ten inches is reached in the third or fourth year of life in Jordan Creek. This rate of growth compares well with average rates of growth for smallmouths from other waters reported by various investigators (Carlander, 1950). The oldest bass taken in Jordan Creek were in their seventh year but most of the fish disappeared before reaching that age. The longest bass taken measured 15.4 inches in total length. Sixty-eight native legal-length bass were captured in the four-mile section of stream in 1950 and 73 in 1952. Seventeen legal-length bass were taken in the upper, open area in 1950. In 1952, the number of legal-length bass taken in that area increased to 35.

LONGEAR SUNFISH

Age determinations were made from the scales of 400 longear sunfish collected in 1950 and from 415 collected in 1952. The body length-scale length relationship was determined and a correction factor of 0.25 inches was used in calculating the growth with a nomograph and manila strips.

Tables 6 and 7 show the average calculated total lengths in inches for the longear sunfish sampled in 1950 and 1952, respectively. In the 1950 collections, the average growth rate of 140 longears from the upper, open area was slightly greater than the average growth rate of 260 longears from the lower, wooded area. In the 1952 collections, the average growth rates of 213 longears from the upper area and 202 longears from the lower area were almost identical.

Few longear sunfish of desirable sizes (6 inches or longer) were taken in the stream. The oldest were in their seventh or eighth year and the majority of these were taken from the lower area of the stream.

A comparison of the rate of growth of longears from Jordan Creek with growth of those from Michigan and Indiana reported by Hubbs and Cooper (1935) and Hile (1931) shows that longears from Jordan

TABLE 7.—AVERAGE LENGTHS FOR 415 LONGEAR SUNFISH COLLECTED IN JORDAN CREEK IN 1952 (202 of these specimens were taken from the lower wooded area and 213 from the upper open area).

Year	Number of fish	Calculated length at each annulus							Av. length (inches)
		1	2	3	4	5	6	7	
		Lower wooded area							
1945	5	1.2	2.1	3.1	3.8	4.4	4.8	5.2	5.2
1946	19	1.2	2.4	3.5	4.3	4.9	5.3	...	5.7
1947	26	1.2	2.4	3.6	4.4	5.0	...	...	5.1
1948	32	1.2	2.5	3.6	4.5	...	...	...	4.9
1949	24	1.2	2.5	3.7	...	...	...	...	4.2
1950	32	1.0	2.4	...	...	...	...	...	3.2
1951	63	1.1	...	...	...	...	...	...	2.4
1952	1	...	...	...	...	...	...	...	2.1
Weighted averages	....	1.1	2.4	3.6	4.4	4.9	5.2	5.2	...
		Upper open area							
1945	0	...	...	...	...	...	...	...	...
1946	2	1.5	2.6	3.8	4.8	5.3	5.7	...	5.7
1947	12	1.2	2.4	3.5	4.2	4.8	...	...	4.9
1948	39	1.2	2.4	4.0	4.6	...	...	...	4.8
1949	40	1.2	2.5	3.7	...	...	...	...	4.3
1950	95	1.0	2.4	...	...	...	...	...	3.1
1951	23	1.0	...	...	...	...	...	...	2.6
1952	2	...	...	...	...	...	...	...	2.0
Weighted averages	....	1.1	2.4	3.6	4.6	4.9	5.7	...	...
Weighted averages for all fish	....	1.1	2.4	3.6	4.4	4.9	5.3	5.2	...

Creek grow more slowly during the first two or three years of life but faster in succeeding years. This increase in annual increment for longears belonging to the age groups IV to VII is sufficient to cause these fish from Jordan Creek to exceed in length and weight longears of comparable ages from Michigan and Indiana.

Discussion

A faster rate of growth for smallmouth bass in the upper area of Jordan Creek is not unexpected when warmer water temperatures, more bottom organisms, and greater numbers of minnows occur in that area during the main part of the growing season. These same factors might also be expected to have a similar effect upon the other species of fish in that area. The longear sunfish, however, showed only a slightly faster average rate of growth in the upper area of the stream in the 1950 collections, and an almost identical rate of growth in the two areas of the stream in the 1952 collections.

Obviously several factors controlling growth rates are involved in this situation. Some factors may affect all species in the same way; others may affect one species in a different way from another. The warmer temperatures in the upper area of Jordan Creek might be expected to increase the rate of digestion (and metabolism) for both the smallmouth bass and the longear sunfish in that area. Markus (1933) showed that the rate of digestion of minnows by largemouth bass increased with a rise in water temperature, at least until the water reached about 93°F. (the end point of his experiment). The maximum temperature recorded for the upper area of Jordan Creek was 94°F. and this water temperature held for only a few hours on August 31, 1951.

The greater weight of bottom organisms upstream during the major part of the growing season also may be considered as an asset to fish inhabiting the upstream area. Bottom organisms enter into the food of both smallmouths and longears, either directly or indirectly, as links in the food chains of the aquatic habitat.

The minnow population may affect bass and longears in different ways. Minnows often serve as part of the food of smallmouth bass, whereas it is very doubtful that any significant number of minnows enter into the diet of longears except when the former are very small. It is also possible that longears and many species of minnows compete with one another for food. Thus the minnow population upstream, which was 2½ times greater in number and 23 per cent greater in weight than in the lower area, could partially account for the faster growth rate of the bass and could, by increasing food competition for longears, neutralize the effects of the warmer water temperatures and greater numbers of bottom organisms.

Another important consideration may be the relative numbers of each of the two species of fish in the two areas of the stream. There were less than three-fourths the number and one-half the weight of bass upstream as downstream in 1950. If all other factors are ignored, this smaller population upstream might be used to explain the faster growth for bass. On the other hand, there were almost four times the number and twice the weight of longears in the upstream area compared with the downstream area. Considering only the comparative weights of the two longear populations, a faster growth rate would be expected to occur in the downstream area. Such was not the case; growth of longears was not proportional to population density in the two areas.

Growth of these two species of fish in the two segments of the stream appears to be controlled by an interplay of many factors. The smallmouth bass upstream apparently received benefit from all the factors discussed here and reflected those benefits in their faster growth rate. The longear sunfish upstream may have gained from the warmer temperatures and greater density of bottom fauna, but these gains were perhaps counterbalanced by greater inter- and intra-specific competition for food.

Summary

1. The portion of Jordan Creek which was studied consisted of the lower four miles of the stream. This study area is divided into an unshaded upstream area and a shaded downstream area.

2. The mean daily water temperatures in the upstream area were higher than those in the downstream area during the summer months of 1951. Greater extremes of water temperatures occurred in the upstream area.

3. Samples of the bottom fauna in 1952 revealed that in June there were slightly more annelids, insects, and mollusks in the lower area of the stream than in the upstream area. There were about two times as many crayfish in the lower area as in the upper area, but in July, August, and September, there were always at least twice as many bottom invertebrates in the collections from the upstream area as in those from the downstream area.

4. Smallmouth bass grew faster in the upper open area of the stream than in the lower wooded area. There were 27 percent more bass downstream in 1950, and collectively they weighed twice as much as the bass upstream.

5. Longear sunfish grew at almost the same rate upstream as downstream. There were almost 4 times the number and twice the weight of longears upstream as downstream in 1950.

6. The faster growth rate of bass in the upstream area of Jordan Creek may be the result of warmer temperatures, more bottom organisms, less interspecific crowding, and greater numbers of minnows. Growth of longear sunfish may not reflect the possible advantages of warmer temperatures and more bottom invertebrates because of increased inter- and intra-specific competition in the upstream area.

Acknowledgments

This study is a contribution from a stream research project supported jointly by the Illinois Natural History Survey and the Illinois Department of Conservation. R. Weldon Larimore of the Natural History Survey supervised the project and, along with George W. Bennett of the Survey and William Childers of the Department of Conservation, gave valuable assistance in the preparation of this paper. Quentin Pickering, David W. Menzel, W. Leslie Burger, and James F. Opsahl aided in the field work at various times. Thanks are due Wilbur Stites, now with the Department of Conservation, for first bringing to our attention the possibilities of using Jordan Creek as an experimental stream.

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