In no instance have I known of the Shrike attacking so large a bird as the Sparrow Hawk, much less one so well able to defend itself. Whether or not the Hawk had become entangled in the hedge before the attack of the Shrike is not known, but that the Hawk was impaled on the thorns and that the Shrike was striking it with wings and beak is certain.

Material for the Study of the Variation of Etheostoma caprodes Rafinesque and Etheostoma nigrum Rafinesque in Turkey Lake and Tippecanoe Lake.* By W. J. Moenkhaus.

The matter contained in the present paper relates to two species of darters, *Etheostoma caprodes* and *Etheostoma nigrum* from Turkey Lake and Tippecanoe Lake.† The discussion is confined almost wholly to the variation in the dorsal and anal fins. In a few instances the scales in the lateral line and on the nape are also considered. The aim of this paper is to answer the following questions:

1. Do the sexes present any differences in their variations?
2. How do the specimens in Tippecanoe Lake differ from those of Turkey Lake?
3. Is the variation in the two species determinate with the locality; *i. e.*, do both vary in the same direction in the same locality?
4. Do the broods of one season differ from the broods of another season?
5. Are the variations of one fin correlated with the variations in the others?

I. DO THE SEXES PRESENT ANY DIFFERENCES IN THEIR VARIATIONS?

Inasmuch as all the specimens upon which the comparisons are to be made include the two sexes, it will be advisable to first determine just what modifications sex has upon the different structures. The specimens of *Etheostoma caprodes*

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*Contributions from the Zoological Laboratory of the Indiana University under the direction of C. H. Eigenmann, No. 22.

†For the purpose of making a detailed comparison between the faunas of two units of environment, a Biological Station has been established on Turkey Lake, Kosciusko County, Indiana. Five miles from this lake is another lake of different shape and depth—Tippecanoe Lake. The two lakes are on opposite sides of the watershed separating the St. Lawrence from the Mississippi Basin. A physical survey has been made of these lakes, and as far as our means permit, the physical and biological conditions of the two lakes are being studied as two units of environment within which we wish to determine the extent of variation in the non-migratory vertebrates, the kind of variation, whether continuous or discontinuous, the quantitative variation, the direction of variation, and the annual or periodic variation and the effect of selection. The present is one of a series of papers illustrating these points. C. H. E.

and *Etheostoma nigrum* from the lakes show no external marks by which the sexes can be separated. By examining the glands, however, the sexes can readily be distinguished even in individuals only 25 mm. long (about two months old in case of *E. caprodes*).

Below are given a series of tables which contain the counts of the fins for much of the material to be described in the following pages. In all the tables the counts are given for the sexes separately in the first two columns and for the sexes combined in the third column. The first item is the number of specimens examined of each brood. The details of the spinous dorsal, soft dorsal and anal fin follow in the order given. Where it has been possible the broods and ages have also been given separately, so that it is possible to compare not only the sexes with each other, but also the same sex in the two lakes in the different broods and ages and in the two species.

It needs but a glance through these tables to show that the two sexes do not differ materially from each other, and that for all purposes of comparisons that are to be made in this paper the sex may be dropped out of consideration. It seems advisable, however, to consider in brief the details of some of the tables.

In Table I are given the counts for 1,275 specimens of *Etheostoma caprodes* from Tippecanoe Lake. These fall into two broods—that of 1896, 500 in number, taken the same summer (marked '96^6), and that of 1895, 500, taken the same summer (marked '95^5), and the remaining 275 the following summer ('95^6). In the first three columns is given the brood of '95^5, and in the second three columns the brood of '95 after the individuals had attained an age of one year. In the third column is given the brood of '96^6.

Without considering the differences that may exist between the different broods or between the different ages of the same brood, we may notice some things about the two sexes within the same brood or age.

1. In all of the structures the percentages are strikingly similar for any given number of rays or spines.

2. The nature of the variation in both sexes is the same. When this is symmetrical in one sex, we find the same symmetry in the other sex and *vice versa*. This similarity in symmetrical variation in the two sexes is well illustrated in the anal fin of the broods of '96^6. Here the pervailing number of rays is 11, 57.20% having this number in the males and 60.80% in the females. In the males, 20% have 10 and 22% have 12. To correspond to this in the females, 19.20% have 10 and 19.60% have 12. The dorsal rays in the broods of '95^5 show asymmetrical variation very well. Here the prevailing number of rays is 16, 50% having this number in the males and 48.40% in the females. In the males, 39.60% have the

next lower number, 15, while only 4.80% have the next higher number, 17. Similarly, in the females, 42% have 15 and only 5.60% have 17. While therefore the per cent. of specimens possessing a given number of rays may differ slightly in the two sexes, this slight dissimilarity is lost to a very large extent in the much more striking correspondence of the nature of the variation of the two sexes.

3. The males are more variable than the females. Recently the method of using the average deviation of each specimen from the mean as an index of variability, has come into vogue. While this method tells really nothing of the extent of variation from the mean, the symmetry or asymmetry of variation or of instances of great variability, it is of interest in permitting a comparison between two groups of individuals to be expressed numerically, a method more striking to a hasty glance than the parallel columns of the tables. Compared in this way, it is found in Table I that the males have usually a greater index of variability than the females, the only exception in Table I being in the specimens '95[5]. Arranging these indices of variability, we find the variability of the males and females to be to each other as 5073:4680. The means were here calculated to two decimals only, so that a slight error is usually present in the index of variability of the males and females combined, as given in the third series of columns, and the indices of variability of the males and females separately. Averaging the per cents. of specimens having the highest prevailing number in the fins, we find that on an average 1.1 per cent. more females have the prevailing number than males.

Table I.

ETHEOSTOMA CAPRODES FROM TIPPECANOE LAKE.

	Brood of 1895 taken in 1895. '95[5].			Brood of 1895 taken in 1896. '96[6].			Brood of 1896 taken in 1896. '96[6].		
	♂	♀	♂ and ♀	♂	♀	♂ and ♀	♂	♀	♂ and ♀
Number of specimens examined	250	250	500	150	125	275	250	250	500
A.—Dorsal Spines—									
Per cent. of specimens having 10 dorsal spines	.....	.....	.....	.....	.....	.....	.....	.40	.20
Per cent. of specimens having 11 dorsal spines	.....	.....	.....	.....	.....	.....	.....	.40	.20
Per cent. of specimens having 12 dorsal spines	1.2	1.6	1.4	.....	.8	.36	.40	.80	.60
Per cent. of specimens having 13 dorsal spines	12.4	16.4	14.4	18.66	15.20	17.06	6.40	6.40	6.40
Per cent. of specimens having 14 dorsal spines	64.	60.4	62.2	54.66	56.00	55.18	61.20	64.40	62.80
Per cent. of specimens having 15 dorsal spines	21.6	20.4	21.0	21.35	26.40	23.59	30.40	27.20	28.80
Per cent. of specimens having 16 dorsal spines	.4	.8	.6	5.33	1.60	3.64	1.20	.40	.80
Per cent. of specimens having 17 dorsal spines	.4	.4	.4	.....	.....	.....	.40	.....	.20
Mean number of dorsal spines	14.08	14.03	14.06	.....	.....	14.05	14.27	14.17	14.22
Average variation $\frac{\Sigma v}{n}$	.4381	.4450	.4396	.....	.....	.....	.5091	.4650	.4888

B.—Dorsal Rays—									
Per cent. of specimens having 10 dorsal spines	.....	.....	.....	.....	.....	.....	.40	.....	.20
Per cent. of specimens having 11 dorsal spines	.....	.....	.....	.....	.....	.....	.....	.....	.....
Per cent. of specimens having 12 dorsal spines	.....	.40	.20	.....	.....	.....	.....	.....	.....
Per cent. of specimens having 13 dorsal spines	.....	.....	.....	.....	.....	.....	.....	.....	.....
Per cent. of specimens having 14 dorsal spines	4.80	3.20	4.00	5.33	6.40	5.81	2.40	.80	1.60
Per cent. of specimens having 15 dorsal spines	39.60	42.00	40.80	50.00	46.40	48.28	27.20	22.40	24.80
Per cent. of specimens having 16 dorsal spines	50.00	48.40	49.20	41.33	42.40	41.74	52.40	58.00	55.20
Per cent. of specimens having 17 dorsal spines	4.80	5.60	5.20	3.33	4.80	3.99	16.00	17.60	16.80
Per cent. of specimens having 18 dorsal spines	.40	.40	.40	.....	.....	.....	1.60	1.20	1.40
Per cent. of specimens having 19 dorsal spines	.....	.....	.....	.....	.....	.....	.....	.....	.....
Per cent. of specimens having 20 dorsal spines	.40	.....	.20	.....	.....	.....	.....	.....	.....
Mean number of dorsal rays	15.58	15.56	15.57	.....	.....	15.44	15.85	15.96	15.90
Average variation	.6110	.6027	.6069	.....	.....	.....	.5960	.4614	.5348
C. Anal.									
a. Spines—									
Per cent. of specimens having 1 spine	.....	.....	.....	.....	2.00	5.60	3.63	.....	.....
Per cent. of specimens having 2 spines	.....	.....	.....	.....	98.00	94.40	96.37	.....	.....
b. Rays—									
Per cent. of specimens having 9 rays	.40	.40	.40	2.66	2.40	2.54	.....	.....	.....
Per cent. of specimens having 10 rays	21.20	23.60	22.40	27.97	29.60	28.68	20.00	19.20	19.60
Per cent. of specimens having 11 rays	58.00	58.00	58.00	51.28	59.20	54.81	57.20	60.80	59.00
Per cent. of specimens having 12 rays	19.60	17.20	18.40	17.98	8.80	13.29	22.00	19.60	20.80
Per cent. of specimens having 13 rays	.80	.80	.80	.....	.....	.....	.80	.40	.60
Mean number of anal rays	10.99	10.94	10.96	.....	.....	10.80	11.04	11.01	11.025
Average variation	.4375	.4287	.4325	.....	.....	.....	.4577	.4020	.4293

TABLE II.

ETHEOSTOMA CAPRODES FROM TURKEY LAKE.

	Brood '93[5].			Brood '94[5].			Brood '95[5].		
	Male.	Female.	Male and Female.	Male.	Female.	Male and Female.	Male.	Female.	Male and Female.
Number of specimens	107	117	224	144	81	225	72	43	115
A.—Dorsal spines.									
Per cent. of specimens having 12 dorsal spines	.....	.....	.....	1.36	.....	0.88	.....	.....	.....
Per cent. of specimens having 13 dorsal spines	4.67	4.23	4.44	9.52	7.40	8.76	2.78	.....	1.74
Per cent. of specimens having 14 dorsal spines	34.58	38.13	37.85	47.60	53.06	49.49	43.03	30.24	38.26
Per cent. of specimens having 15 dorsal spines	50.46	51.70	51.06	34.68	34.55	34.60	47.19	55.80	50.43
Per cent. of specimens having 16 dorsal spines	9.35	5.93	7.55	6.80	3.70	5.69	6.94	9.30	7.83
Per cent. of specimens having 17 dorsal spines	0.93	.....	0.44	0.68	1.23	0.44	.....	4.65	1.74
Mean number of dorsal spines	.....	.....	14.70	.....	.....	14.68	.....	.....	14.69

B.—Dorsal rays.									
Per cent. of specimens having 12 dorsal rays	.....	.....	.....	0.68	.....	0.44	1.39	.....	0.87
Per cent. of specimens having 13 dorsal rays	.....	1.69	0.89	2.04	4.94	3.07	2.78	.....	1.74
Per cent. of specimens having 14 dorsal rays	27.08	18.63	22.64	31.96	27.14	30.22	44.42	37.20	41.74
Per cent. of specimens having 15 dorsal rays	57.91	58.44	58.16	55.08	45.65	51.68	49.97	53.48	51.30
Per cent. of specimens having 16 dorsal rays	14.98	16.94	15.98	8.84	22.20	13.58	1.39	9.30	4.35
Per cent. of specimens having 17 dorsal rays	.....	3.38	1.77	1.36	.....	0.88	.....	.....	.....
Per cent. of specimens having 18 dorsal rays	.....	0.85	0.44	.....	.....	.....	.....	.....	.....
Mean number of dorsal rays	.....	.....	14.95	.....	.....	14.97	.....	.....	14.57
C.—Anal rays.									
Per cent. of specimens having 7 anal rays	.....	.....	.....	.....	.....	.....	1.39	.....	0.87
Per cent. of specimens having 8 anal rays	.....	.....	.....	0.68	.....	0.44	.....	.....	.....
Per cent. of specimens having 9 anal rays	.....	0.85	0.44	2.72	.....	1.75	4.16	6.98	5.22
Per cent. of specimens having 10 anal rays	23.35	21.17	22.20	27.88	39.49	31 97	38.86	32.55	36.53
Per cent. of specimens having 11 anal rays	58.84	55.90	57.28	51.68	51.83	57.73	49.97	53.48	51.30
Per cent. of specimens having 12 anal rays	17.75	20.33	19.09	16.32	8.64	13.58	4.16	6.98	5.22
Per cent. of specimens having 13 anal rays	.....	1.69	0.89	.....	.....	.....	1.39	.....	0.87
Mean number of anal rays	.....	.....	11.02	.....	.....	10.86	.....	.....	10.56

Table II contains the counts for 564 specimens of *Etheostoma caprodes* from Turkey Lake. These fall into three different broods, those of '93[5], '94[5] and '95[5], all three broods having been taken during the summer of '95, so that they also represent three different ages. The same can be said of the specimens in this table that was said about the specimens in Table I. The number of specimens in each case here is much smaller than in the other table, and, as a consequence, the per cents in the two sexes do not agree quite so perfectly.

Table III.

ETHEOSTOMA NIGRUM FROM TIPPECANOE LAKE.

	♂	♀	♂ and ♀
Number of specimens	250	250	500
A.—Dorsal spines.			
Per cent. of specimens having 7 dorsal spines	1.20	2.40	1.80
Per cent. of specimens having 8 dorsal spines	15.60	15.20	15.40
Per cent. of specimens having 9 dorsal spines	62.80	56.80	59.80
Per cent. of specimens having 10 dorsal spines	19.20	24.80	22.00
Per cent. of specimens having 11 dorsal spines	1.20	0.80	1.00
Average number of dorsal spines	9.03	9.06	9.04
Average variation	.23016	.26288	.....
B.—Dorsal rays.			
Per cent. of specimens having 11 dorsal rays	2.00	2.00	2.00
Per cent. of specimens having 12 dorsal rays	35.60	40.80	38.30
Per cent. of specimens having 13 dorsal rays	55.20	48.00	51.60
Per cent. of specimens having 14 dorsal rays	7.20	8.80	8.00
Per cent. of specimens having 15 dorsal rays	.....	0.40	0.20
Average number of dorsal rays	12.71	12.64	12.67
Average variation	.53992	.59584	.....
C.—Anal rays.			
Per cent. of specimens having 7 anal rays	0.40	0.80	0.60
Per cent. of specimens having 8 anal rays	8.80	13.60	11.20
Per cent. of specimens having 9 anal rays	66.40	56.80	61.60
Per cent. of specimens having 10 anal rays	22.80	28.40	25.60
Per cent. of specimens having 11 anal rays	1.60	0.40	1.00
Average number of anal rays	9.16	9.15	9.15
Average variation	.43792	.50336	.....

Table III contains the counts for 500 specimens of *Etheostoma nigrum* from Tippecanoe Lake. The females of this group of individuals are more variable than the males in all structures. This difference in variability is most pronounced in the anal fin. In the males 66.40 per cent. of the specimens have the prevailing number of rays, 9, as compared to 56.80 per cent. in the females. This leaves 33.60 per cent. of the specimens varying from this number in the males compared to 43.20 per cent. in the females. This difference is less pronounced in the other two fins, but from its constancy in all three of the fins it certainly must be taken as a sexual difference.

The average variability of each individual from the mean of the group is given under each column. Averaging these averages we have the average deviation of the male to the female as .40266 : .4540.

II. HOW DO THE SPECIMENS IN TIPPECANOE LAKE DIFFER FROM THOSE IN TURKEY LAKE?

In a previous article* I described a number of local varieties of color patterns that were found in this species. Later I gave a more detailed comparison of this species as it occurs in Turkey Lake and Tippecanoe Lake. The number of specimens involved were 600 from Turkey Lake and 300 from Tippecanoe Lake. Comparisons were made upon the dorsal and anal fins, the scale in the lateral line and on the nape and upon the color pattern. The following facts were observed:

1. *Coloration.*—The color-pattern of Turkey Lake specimens is, on the whole, of a more blotched character than that of Tippecanoe Lake specimens, and shows a slighter affinity to the simple, primitive coloration characteristic of the Wabash River forms.

2. *Lateral Line.*—The specimens of Turkey Lake have on an average two more scales in the lateral line. The average number for Turkey Lake is 89.46 for the left side, 89.74 for the right side; for Tippecanoe Lake, 87.69 for the left side, 87.45 for the right side.

3. *Squamation of Nape.*—In Turkey Lake the nape is usually naked; in Tippecanoe Lake the nape is usually scaled. (See Table V.)

4. *Dorsal and Anal Fin.*—Decided differences are found in the dorsal fins. The data have been incorporated in the tables below, and these differences will be given then. The anal fin is slightly larger in the Tippecanoe Lake specimens.

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*The variation of *Etheostoma caprodes* Rafinesque in Turkey Lake and Tippecanoe Lake Proc. Ind. Acad. Sci. No. V, 1895, pp. 278-296.

I have since examined the fins of 250 more specimens of *Etheostoma caprodes* from Turkey Lake and 1,175 more specimens from Tippecanoe Lake. The data for these are combined with those previously described and given in the tables below. In addition, the nape and fins of 500 specimens of *Etheostoma nigrum* from Tippecanoe Lake and 100 specimens from Turkey Lake have been examined. The sex has been determined in most of this material, so that a comparison of the proportion of the sexes in the two lakes can be made.

a. ETHEOSTOMA CAPRODES.

1. Proportion of Sexes.—The proportion of the sexes in the two lakes will be found in Table IV. In all the broods, excepting the broods of '93[5], of both lakes, the males are in the majority. In Turkey Lake this majority is greater than in Tippecanoe Lake. In the latter the mean per cent. of males is 55.44 and the females 44.56. In Turkey Lake the mean per cent. of males is 63.96 and of females 36.04. The broods of '93[5] are not included in the latter because this group contains many females of preceding broods that have survived the males or outdone them in growth. Thus all of the larger specimens of this group are females. One can be quite sure when he meets an exceptionally large and aged-looking specimen that it is a female. The broods of '93[5], determined solely by the size of the specimens, ought therefore to show an abnormal per cent. of females and should not be taken to determine the true proportion of the sexes.

TABLE IV.

NUMBER OF SPECIMENS.	Tippecanoe Lake.		Turkey Lake.	
	Male.	Female.	Male.	Female.
882 specimens, brood '96[6]	58.48	41.52	.....	.....
543 specimens, brood '95[5]	52.48	47.	.....	.....
280 specimens, brood '95[6]	55.35	44.65	.....	.....
115 specimens, brood '95[5]	.....	.....	62.60	37.40
222 specimens, brood '94[5]	.....	.....	65.32	34.68
228 specimens, brood '93[5]	.....	.....	45.62	54.38

2. Squamation of Nape.—Table V represents the data for the squamation of the nape of 600 specimens from Turkey Lake and 300 specimens from Tippecanoe Lake. Eighty-eight per cent. have the nape naked in Turkey Lake and only 19 per cent. from Tippecanoe Lake. Twenty-eight per cent. from the latter lake have scales over the entire nape.

TABLE V.

	From Turkey Lake.	From Tippecanoe Lake.
Per cent. of specimens having no scales on nape..	88.00	19.32
Per cent. of specimens having few scales on nape...	8.00	23.87
Per cent. of specimens having several scales on nape	4.00	28.32
Per cent. of specimens having nape thinly scaled...	0.20	16.67
Per cent. of specimens having nape closely scaled..	.....	11.74

In Tables VI, VII and VIII are given the counts for the anal, spinous dorsal and soft dorsal fins, respectively. The per cents. are based on 1,475 specimens of all ages from Tippecanoe Lake and 850 of all ages from Turkey Lake.

C. Anal Rays.—From Table VI, it will be seen that the anal fin is somewhat larger in Tippecanoe Lake than in Turkey Lake. This is shown by the decrease in the per cent. of specimens having the prevailing number, 11, and the increase in the per cent. of specimens having the next lower number, 10, in the Turkey Lake specimens. The mean number of rays is 10.76 for Turkey Lake and 10.97 for Tippecanoe Lake.

TABLE VI.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 7 anal rays... ...	.....	0.12
Per cent. of specimens having 8 anal rays.....	.....	0.23
Per cent. of specimens having 9 anal rays.....	0.75	1.76
Per cent. of specimens having 10 anal rays.....	21.92	31.87
Per cent. of specimens having 11 anal rays.....	58.23	53.40
Per cent. of specimens having 12 anal rays.....	19.66	12.23
Per cent of specimens having 13 anal rays.....	0.48	0.35
Mean number of rays	10.97	10.76

3. Dorsal Spines.—The dorsal spines in the Tippecanoe Lake specimens vary from 10 to 17. The prevailing number is 14, 61.44 per cent. having this number. The variation is slightly greater toward a higher number than toward a lower number of spines. In Turkey Lake specimens the spines vary from 12 to 18. The prevailing numbers are 14 and 15, 42.57 per cent. and 43.48 per cent. respectively having this number. From these the variation is symmetrical in both directions. The mean is 14.20 for Tippecanoe Lake and 14.56 for Turkey Lake.

TABLE VII.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 10 dorsal spines...	.069	.....
Per cent. of specimens having 11 dorsal spines...	.069	.....
Per cent. of specimens having 12 dorsal spines...	0.82	0.23
Per cent. of specimens having 13 dorsal spines...	11.85	5.17
Per cent. of specimens having 14 dorsal spines...	61.44	42.57
Per cent. of specimens having 15 dorsal spines...	25.21	43.48
Per cent. of specimens having 16 dorsal spines...	1.30	7.29
Per cent. of specimens having 17 dorsal spines...	0.27	0.94
Per cent. of specimens having 18 dorsal spines...	.....	0.23
Mean number of rays.....	14.20	14.56

4. Dorsal Rays.—The dorsal rays vary from 10 to 20 in Tippecanoe Lake. The prevailing number of rays is 16, 51.03 per cent. having this number. There is a tendency to vary toward a lower number of rays. Thus, 35.55 per cent. have 15 and only 10.74 per cent. have 17. In Turkey Lake the soft dorsal varies from 12 to 18 rays. The prevailing number here is 15, with 53.98 per cent. of the specimens having this number. Here, too, the tendency to vary toward a lower number is quite marked, 31.40 per cent. having 14 and only 11.17 per cent. having 16. The mean number of rays is 15.66 for Tippecanoe Lake and 14.80 for Turkey Lake.

TABLE VIII.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 10 dorsal rays.....	0.07	.....
Per cent. of specimens having 11 dorsal rays.....	.....	.....
Per cent. of specimens having 12 dorsal rays.....	0.07	0.23
Per cent. of specimens having 13 dorsal rays.....	.....	1.88
Per cent. of specimens having 14 dorsal rays.....	3.49	31.40
Per cent. of specimens having 15 dorsal rays.....	35.55	53.98
Per cent. of specimens having 16 dorsal rays.....	51.03	11.17
Per cent. of specimens having 17 dorsal rays.....	10.74	1.29
Per cent. of specimens having 18 dorsal rays.....	0.69	0.23
Per cent. of specimens having 19 dorsal rays.....	.....	.....
Per cent. of specimens having 20 dorsal rays.....	0.07	.....
Mean number of rays.....	15.66	14.8

b. ETHEOSTOMA NIGRUM.

1. Squamation of Nape.—The following Table IX, is based on 100 specimens from each of the lakes, and is intended to show the occurrence of scales on the nape in this species. Eighty-five per cent. of the specimens from Turkey Lake have their nape naked, and none have their nape completely scaled. Compared with this, only 50 per cent. of the specimens from Tippecanoe Lake have a naked nape, while four per cent. have their nape completely scaled.

TABLE IX.

	Turkey Lake.	Tippecanoe Lake.
Per cent. of specimens having no scales on nape..	85.00	50.00
Per cent. of specimens having few scales on nape.	13.00	28.00
Per cent. of specimens having several scales on nape	2.00	18.00
Per cent. of specimens having nape thinly scaled .	.....	2.00
Per cent. of specimens having nape closely scaled.	.....	2.00

In Tables X, XI and XII are given the counts of the anal rays, dorsal spines and dorsal rays of *Etheostoma nigrum* from the two lakes. The counts are based on 100 specimens from Turkey Lake and 500 from Tippecanoe Lake.

2. Anal Rays.—Table X. The anal rays vary from 7 to 11 in Tippecanoe Lake, 61.60 per cent. having nine rays. There is a tendency to vary toward an increased number of rays, 25.60 per cent. having 10, and but 11.20 per cent. eight. In Turkey Lake the variation is from eight to ten ; 58 per cent. have nine, 40 per cent. have a smaller number of rays and only two per cent. a greater number. The mean number of anal rays is 9.15 for Tippecanoe Lake and 8.62 for Turkey Lake.

TABLE X.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 6 anal rays	.....	.....
Per cent. of specimens having 7 anal rays	0.60	.....
Per cent. of specimens having 8 anal rays	11.20	40.00
Per cent. of specimens having 9 anal rays	61.60	58.00
Per cent. of specimens having 10 anal rays	25.60	2.00
Per cent. of specimens having 11 anal rays	1.00	.....
Mean number of rays	9.15	8.62

3. Dorsal Spines.—Table XI. The dorsal spines vary from 7 to 11 in Tippecanoe Lake, 59.80 per cent. having nine. The variation from this number is almost symmetrical. In Turkey Lake the variation ranges from 7 to 10. Nine is the prevailing number, 52 per cent. having this number. The variation toward a lower number of spines is much the greater, 39 per cent. having eight, compared to five per cent. having ten. The mean for Tippecanoe Lake is 9.04, and 8.58 for Turkey Lake.

TABLE XI.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 6 dorsal spines...	.....	.....
Per cent. of specimens having 7 dorsal spines...	1.80	4.00
Per cent. of specimens having 8 dorsal spines...	15.40	39.00
Per cent. of specimens having 9 dorsal spines...	59.80	52.00
Per cent. of specimens having 10 dorsal spines...	22.00	5.00
Per cent. of specimens having 11 dorsal spines...	1.00	.....
Mean number of rays.....	9.04	8.58

4. Dorsal Rays.—The Tippecanoe Lake specimens present a range of variation from 11 dorsal rays to 15. The prevailing number is 13, 51.60 per cent. possessing this number, while 38.20 per cent. have 12 and only 8 per cent. have 14. The Turkey Lake specimens vary from 11 to 13. The prevailing number here is 12, 59 per cent. having this number. The variation toward a higher number is greater than toward a lower number. Thus, 36 per cent. have 13 and only 50 per cent. have 11. The mean number of rays is 12.67 for Tippecanoe Lake and 12.31 for Turkey Lake.

TABLE XII.

	Tippecanoe Lake.	Turkey Lake.
Per cent. of specimens having 11 dorsal rays.....	2.00	5.00
Per cent. of specimens having 12 dorsal rays.....	38.20	59.00
Per cent. of specimens having 13 dorsal rays.....	51.60	36.00
Per cent. of specimens having 14 dorsal rays.....	8.00	.....
Per cent. of specimens having 15 dorsal rays.....	0.20	.....
Mean number of rays.....	12.67	12.31

From the foregoing comparison it will be seen that the specimens of Tippecanoe Lake differ in every structure examined from those of Turkey Lake. This is true for both species. In some structures this difference is small, as in the anal fin, and in others it is greater, as in the scales on the nape and the dorsal rays.

III. IS THE VARIATION IN THE TWO SPECIES DETERMINATE WITH THE LOCALITY?

But of greater importance is the fact that both species are being modified in the same way by the same lake. Thus, with one exception, if a given structure varies in a certain manner in *Etheostoma caprodes* in Tippecanoe Lake, the same structure will show a similar modification in *Etheostoma nigrum* in the same lake. This holds true with one exception.

From tables V and IX, it is seen that both species show a greater per cent. of individuals with a scaled nape in Tippecanoe Lake than in Turkey Lake. For Tippecanoe Lake the percents of specimens with a naked nape are 19.32, and 50 for *Etheostoma caprodes* and *Etheostoma nigrum* respectively, while for Turkey Lake they are 88 and 85 respectively.

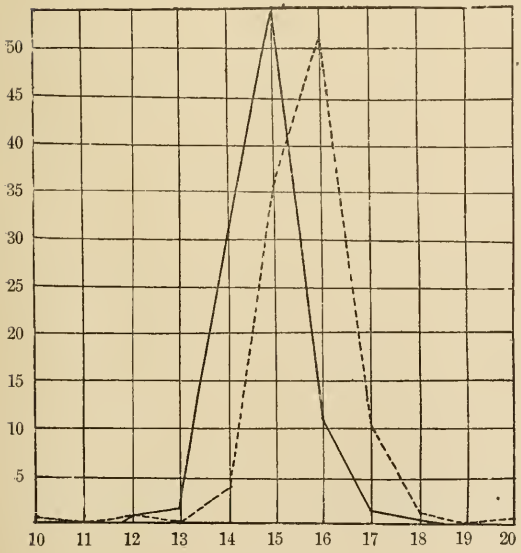

FIG. 1.

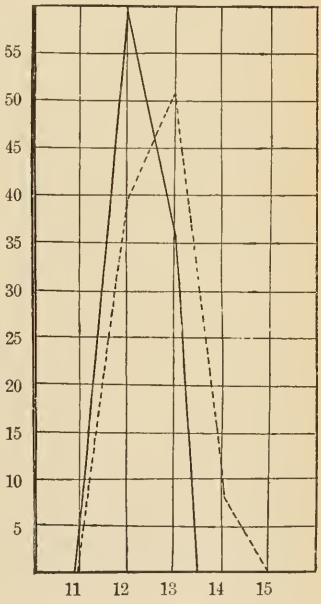

FIG. 2.

In Tippecanoe Lake the anal fin in both species is slightly larger. The *nature* of the variation in the anal fin is quite definite for each lake. Thus from Tables VI and X we find that the variation in Tippecanoe Lake is very nearly symmetrical around the prevailing number, 9, while in Turkey Lake the variation is pronouncedly asymmetrical, a much greater per cent. varying below nine than above.

On the contrary, the dorsal spines of one species show an increase, and of the other a decrease in number. Aside from this exception, however, there is, as in the anal fin, a marked parallelism in the *nature* of the variation in the two species for each lake. Thus in Tippecanoe Lake the variation is nearly symmetrical, while in Turkey Lake it is very asymmetrical. The asymmetry in *Etheostoma caprodes* is due to the difference in the three broods included, yet, as can be seen from Fig. 2, each brood shows this asymmetrical variation in its dorsal spines.

The soft dorsal in both species has one more ray in Tippecanoe Lake than in Turkey Lake. In Figs. 1 and 2 are given the curves for the dorsal rays. In the curves for both species the continuous line is for the Turkey Lake specimens and the broken line for Tippecanoe Lake specimens. From these it will be seen that in Tippecanoe Lake the prevailing number is 16 and 13 for *Etheostoma caprodes* and *Etheostoma nigrum* respectively, and in Turkey Lake it is 15 and 12 respectively. In the dorsal rays, too, the Turkey Lake specimens, in contrast to the Tippecanoe Lake specimens, vary asymmetrically.

The comparison of the two lakes, in so far as these two species are concerned, may be briefly summarized as follows: Tippecanoe Lake is characterized by a greater number of scales on the nape and rays in the anal and soft dorsal. The variations are very nearly symmetrical in Tippecanoe Lake, while in Turkey Lake they are decidedly asymmetrical. The proportion of males to females is greater in Tippecanoe Lake than in Turkey Lake.

This parallelism in the variation of these two species becomes the more interesting when considered in another relation, namely, that one of the species does not thrive equally well in both lakes. *Etheostoma nigrum* is as excessively rare in Turkey Lake as it is abundant in Tippecanoe Lake. One to 50 approximates the ratio. On the other hand, *Etheostoma caprodes* is equally abundant in both lakes. The modifications found in these structures, therefore, can not be attributed to any selective influence, or at best, this influence is so slight as to be largely overcome in its effect by ontogenic influences. Otherwise we could hardly account for the parallel modifications in two nearly related species living side by side, the one thriving, and the other on the point of extermination.

IV. DO THE BROODS OF ONE SEASON DIFFER FROM THE BROODS OF ANOTHER SEASON?

The different broods could be clearly separated only in *Etheostoma caprodes*. A series of 565 specimens from Turkey Lake taken during the summer of '95 were readily separable into three groups on the basis of their size. These three groups represented the broods of '93, '94 and '95. These are the broods contained in Table 1. The comparison of the broods has already been made (Proc. Ind. Acad. Sci. No. 5, pp. 289–96, 1895), but the following points seem worth repeating in this connection.

1. The broods of '93[5] and '95[5] were alike in all the structures examined.

2. The brood of '94[5] differed from the other two broods in having on an average two more scales in the lateral line, and a fewer number of dorsal spines.

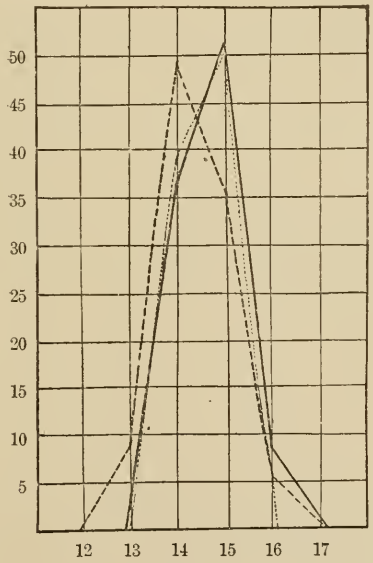

Fig. 3.

In Fig. 3 are given the curves for the dorsal spines of these three broods. The curves are based on the counts for the dorsal spines given in Table I. The continuous line is for the broods of '93[5], the broken line for the broods of '94[5] and the dotted line for the broods of '95[5].

From these it will be noticed that the curves for the broods of '93 and '95 are almost identical, with 15 as the prevailing number of spines, while the brood of '94 stands quite distinct, with 14 as the prevailing number. The mean for the broods of '93 and '95 is 14.65 and 14.69 respectively, and for the brood of '94, 14.39.

A comparison of the fins of 500 specimens, including an equal number of each sex, from Tippecanoe Lake, of the brood of '95, taken the same summer with 500 specimens of both sexes of the brood of '96 taken the same summer, shows them to be almost identical in the anal rays and dorsal spines, as can be seen from the counts given in Table II. Thus, in the anal fin we have 10.96 and 11.02 for the mean in the two broods; 58 and 59 are the percents of specimens having the prevailing number, 11 rays. Around this the variation is symmetrical in both broods, The means for the dorsal spines are 14.06 and 14.22. The per cent. of specimens having the prevailing number, 14, are 62.20 and 62.80. The variation from this number is nearly the same.

These two broods, however, show quite a difference in the dorsal rays, as shown by the mean and by the nature of the variation. The mean number of rays for the brood of '95 is 15.57 and 15.90 for the brood of '96. In Fig. 4 are given the curves for the dorsal rays and Table XIII contains the details of the counts. In the curves the continuous lines represent the brood of '95.

Both broods have 16 as their prevailing number, 49.20 per cent. in the brood of '95 and 55.20 per cent. in the brood of '96 having this number. In the brood of '96 there is an approximation to a symmetrical variation around this number, while in the brood of '95 the number of specimens, 40.80 per cent. having the next lower number, 15, is almost as great as that of 16.

TABLE XIII.

	'95[5].	'96[6].
Per cent. of specimens having 10 dorsal rays	.....	0.20
Per cent. of specimens having 11 dorsal rays	.....	.....
Per cent. of specimens having 12 dorsal rays	0.20	.....
Per cent. of specimens having 13 dorsal rays	.....	.....
Per cent. of specimens having 14 dorsal rays	4.00	1.60
Per cent. of specimens having 15 dorsal rays	40.80	24.80
Per cent. of specimens having 16 dorsal rays	49.20	55.20
Per cent. of specimens having 17 dorsal rays	5.20	16.80
Per cent. of specimens having 18 dorsal rays	0.40	1.40
Per cent. of specimens having 19 dorsal rays	.....	.....
Per cent. of specimens having 20 dorsal rays	0.20	.....

Thus the broods of '94[5] in Turkey Lake differs from the broods of the preceding and succeeding year in the number of scales in the lateral line and in the number of dorsal spines, and the broods of '95[5] in Tippecanoe Lake differ from the broods of '96[6] in the number of dorsal rays. In regard to the former, I have already remarked that "the difference in the dorsal spines may possibly be due to the presence of local races in the lake. While this may possibly be the case, it is not at all probable, because, in the first place, the curve constructed for the dorsal spines of 100 specimens of the brood of '93[5] taken within a distance of 100

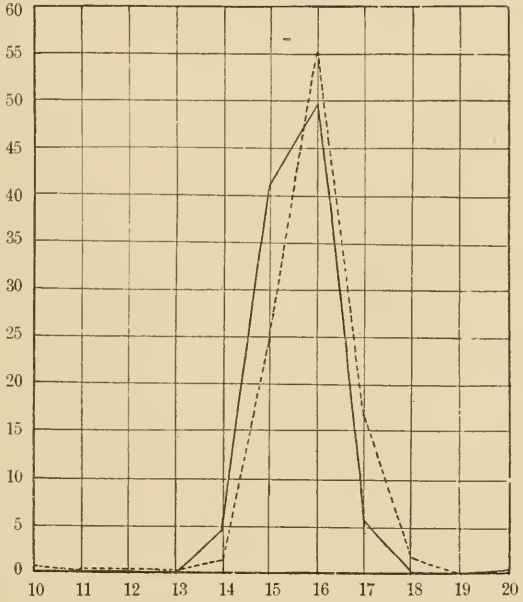

FIG. 4.

yards along the shores where the conditions were undoubtedly uniform, gave a curve identical with that for all the broods of '93[5]. In the second place, the '93[5] and '94[5] specimens are found in about equal abundance together, and since these were promiscuously preserved it is altogether probable that from any given locality, an equal number of each brood was taken."

I have since examined a considerable number of specimens from three distant localities in the lake, and find that they do not present sufficient local differences to account for these occurring in the different broods.

In regard to the broods in Tippecanoe Lake it need but be said that they were of the same age and were collected from the same place in the lakes.

The only remaining element, it seems, with which to correlate these differences is the season in which the broods were hatched. The characters of broods vary with the varying conditions of the years. Equally great changes are perhaps not uncommonly produced artificially in the laboratory by subjecting organisms to changed conditions during their ontogeny, so that there is nothing unusual in the changes occurring in these broods. But it is interesting to know that in *nature* within areas of such comparative uniformity as one of these small lakes the most uniform environment from year to year possible in this latitude there is a sufficient fluctuation in the seasonal conditions to produce these measurable differences found in these different broods.

V. ARE THE VARIATIONS IN ONE FIN CORRELATED WITH THE VARIATIONS IN THE OTHERS?

Most of the specimens from both lakes were separated into different groups on the basis (1) of the number of rays in the anal fin, and (2) of the number of spines in the dorsal fin. In the former grouping, by finding the average number of elements in the dorsal fins, both separately and combined, for each group, the correlation of the variations in the anal fin with that of the dorsal separate and combined, can be determined. Similarly in the latter grouping (2) the correlation between the two dorsals can be determined.

In the way of an illustration, the data for the broods of '95[5] and '96[6] from Tippecanoe Lake are given in Table XV. The number of specimens in each group occurs in the first column.

It will be observed that in both broods there is a definite correlation between the anal fin and dorsal fins, separately and combined.

When the anal rays increase in number, the dorsal spines, dorsal rays, or both combined, also increase. There are several exceptions to this law, noteworthy in the dorsal spines of the twelve anal-rayed group and the dorsal rays in the eleven anal-rayed group of the brood of '96[6].

In all cases the increase in the dorsal is considerably smaller than the increase in the anal. The correlation is stronger for the two dorsals combined than for them separately, and of the latter, it is the stronger for the dorsal rays. The ratio of increase in the dorsal to the increase in the anal is approximately twelve to two, five to two and four to two in the spinous dorsal, soft dorsal and both combined, respectively.

Table XIV.

ETHEOSTOMA CAPRODES.

	'95[5]				'96[6]			
	Number of Specimens.	Average Number of Dorsal Spines.	Average Number of Dorsal Rays.	Average Number of Dorsal Spines and Dorsal Rays.	Number of Specimens.	Average Number of Dorsal Spines.	Average Number of Dorsal Rays.	Average Number of Dorsal Spines and Rays.
Specimens with 9 anal rays	2	13.50	15.00	28.50	90	.....	.....	.....
Specimens with 10 anal rays	113	13.85	15.31	28.68	98	14.12	15.60	29.82
Specimens with 11 anal rays	298	14.11	15.59	29.34	294	14.24	15.49	30.14
Specimens with 12 anal rays	94	14.15	15.86	30.01	105	14.20	15.90	30.46
Specimens with 13 anal rays	4	14.00	16.50	30.50	3	14.75	16.75	31.33
Specimens with 10 dorsal spines	.....	.....	.....	.....	1	.....	16.00	.....
Specimens with 11 dorsal spines	.....	.....	.....	.....	1	.....	17.00	.....
Specimens with 12 dorsal spines	4	.....	15.50	.....	3	.....	16.33	.....
Specimens with 13 dorsal spines	73	.....	15.63	.....	31	.....	16.03	.....
Specimens with 14 dorsal spines	319	.....	15.58	.....	316	.....	15.91	.....
Specimens with 15 dorsal spines	105	.....	15.51	.....	142	.....	15.84	.....
Specimens with 16 dorsal spines	3	.....	15.33	.....	5	.....	16.20	.....
Specimens with 17 dorsal spines	1	.....	15.00	.....	1	.....	17.00	.....

In Fig. 6 and Table XVI the correlation between the anal and dorsals combined of both broods is represented graphically. Increase in the dorsal and anal elements are represented by distances away from the point of junction of the horizontal and vertical line respectively. The dotted diagonal line represents the condition of perfect correlation between the two fins. The line y is erected at the mean of the dorsal fin and line x at the mean of the anal rays.

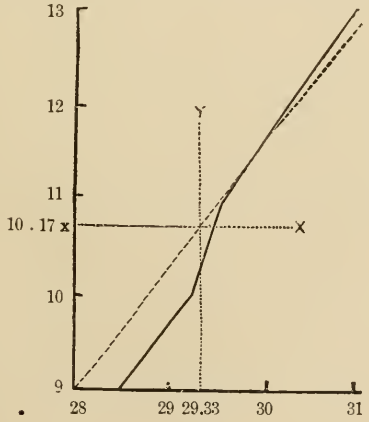

Fig. 6.

TABLE XV.

	Average No. of Dorsal Spines and Rays.
Specimens with 9 anal rays	28.50
Specimens with 10 anal rays	29.20
Specimens with 11 anal rays	29.53
Specimens with 12 anal rays	30.24
Specimens with 13 anal rays	30.85

From the latter half of Table XV the correlation between the spinous and soft dorsals may be obtained. Here it is seen that when the one dorsal increases, the other decreases. This condition shows that within certain limits these two kind of structures are convertible into each other and may replace each other.

SUMMARY.

1. In *Etheostoma caprodes* the males are more variable than the females in the ratio of .507 : .468. In *Etheostoma nigrum* the females are more variable than the males in the ratio of .402: .454.

2. The specimens of both species in Turkey Lake differ from those in Tippecanoe Lake in every structure examined.

3. The variation in the two species is determinate for the lake, that is, both species are modified in the same way by the same lake with but one exception.

4. This difference is not the result of selective influence, but apparently the direct effect of the environment.

5. The successive broods vary with the varying conditions of the year in which they are born.

6. The variations in the fins are correlated as follows:

   a. When the dorsal spines increase in number the dorsal rays decrease in number.

   b. When the anal rays increase the dorsal spines, the dorsal rays and the sum of the elements in the two dorsals increase.