VARIATION IN THE NUMBER OF SPINES AND RAYS IN THE FINS OF THE BROOK STICKLEBACK*

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The present study is based on counts of dorsal spines and fin rays in 10 collections of the brook stickleback, *Eucalia inconstans*. The fins examined included the left and right pectoral, the dorsal and anal. Counts also were made on the caudal fin in two collections. The spines and the rays in the fins all showed considerable variation as to number. In order to get a clear picture of this variation counts have been arranged in the form of frequency distributions.

The purposes of this paper are, (1) to show how the distributions in different collections differ from one another and (2) to point out, and then try to explain, the similarity of ray counts in the pectoral fins as a group and in the dorsal and anal fins as another group.

This study represents a side problem of the author's attempt to determine whether geographical races of sticklebacks might not be distinguished on the basis of statistical differences in number of spines and fin rays. That work had been suggested by the paper by Thompson (1931) who compared differences in mean ray number in the Johnny darter with varying water distances separating collections. The work of Hubbs (1922) and others who dealt with the effect of temperature of water during development on number of fin days was not considered at the time the earlier problem was being studied.

This study was carried on under the direction of Professor Charles Zeleny, to whom the author is much indebted for helpful suggestions. The author is also

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Variation in the Number of Dorsal Spines and a Description of an Abnormality in Spine Development

Frequency distributions for dorsal spines are shown in table 1. Thompson (1931), page 280, found a variation of from 3 to 7 spines in the stickleback. In the present study the number of spines was found to vary from 2 to 7 while the number most frequently counted was 5. Among the different collections the percentage of fish having 5 spines varied from 71 per cent in Series I to a maximum of 89 per cent in Series VIII.

In all individuals examined (about 2,200) a count of 2 spines was observed once, 3 spines four times and 7 spines five times. About 98 per cent of the individuals had counts of 4, 5 or 6. Usually 6's were several times more frequent than 4's but with the following exceptions. In Series I and II, no 4's at all were observed, while in Series VIII 4's and 6's were found in equal numbers.

A certain abnormality in dorsal spines was observed a number of times. The spines in the stickleback are not connected with one another by a webbing as in most of our other fishes, but they are nevertheless raised and lowered together. When the spines are lowered each of them fits into a depression and is about flush with the dorsal surface. The abnormality in question was that sometimes an individual spine, which at first appeared to be missing, could be found lying in a folded position covered over by a transparent layer of skin. When the covering was cut through, these spines could be lifted up, showing in some cases that the buried spines were of weaker build. A possible explanation of this abnormality is that the spines were developed in the folded position beneath the skin and remained in that position because the erector muscles possessed by these individual spines were too weak to push them through the skin. Another possible explanation is that they had been secondarily covered over by skin when the musculature was not strong enough to keep them in operation. Spines of this type were included in the counts.

Variation in the fins.—In the original description, Kirtland (1841), gives the number of rays in the dorsal and anal fins as varying between the limits of 9 and 12. In the present study, a still wider range of counts was observed. Rays varied in the dorsal fin from 6 to 12, in the anal fin from 5 to 13, in the pectorals from 4 to 13, and in the caudal from 8 to 14.

In table 2 is shown the frequency with which these different counts were observed. It will be noticed that 10 was the commonest number of rays found in the pectorals, the dorsal and the anal, while 12 was the commonest number found in the caudal.

Some Collection Differences in Frequency Distribution of the Fin Rays

The caudal fin.—Counts of the caudal rays were made on collections V and VI only. These collections were taken only a few rods apart, V in the Franklin Spring trout pond and VI in the stream immediately below the pond. The percentage of the catch having the modal count of 12 rays differed somewhat in these collections; 78 per cent of the pond fish had 12 rays while 88 per cent of the stream fish had 12 rays. In the pond fish, on the other hand, there was a much higher percentage of fish with 13 rays.

The pectoral fins.—In different collections the numbers of individuals with 9 rays and 10 rays were quite variable. The number of individuals with 11 rays also varied but within narrower limits. Among the 10 collections, the percentage of individuals with 9 rays varied from 4 per cent (X) to 31 per cent (VII); those with 10 rays varied from 62 per cent (VII) to 86 per cent (VIII); and those with 11 rays from 0 (II) to 16 per cent (X).

The distribution of low counts was far from uniform, some collections having no counts lower than 8 rays, other collections having rather numerous counts of 5, 6 and 7 rays (IV and V).

In all 10 collections it was found that 9's, 10's and 11's together comprised about 95 per cent of the counts. But the proportion of individuals with 9 rays to

TABLE 1—FREQUENCY DISTRIBUTIONS OF DORSAL SPINE COUNTS. THE TABLE SHOWS NUMBERS (IN PARENTHESES) AND PERCENTAGES OF INDIVIDUALS HAVING DIFFERENT NUMBERS OF DORSAL SPINES.

Collection number, location and date	Number of individuals	Number of Dorsal Spines					
		2	3	4	5	6	7
I. Spring 2 mi. N. of Evansville, Wis., Dec. 29, 1931	212				(151) 71.2	(59) 27.8	(2) 0.9
II. Allen's Creek 2 mi. N. W. of Evansville, Wis., Dec. 29, 1931	35		(1) 2.8		(29) 82.8	(5) 14.3	
III. Spring-fed creek at Evansville, Wis., June 17, 1932	59			(1) 1.7	(46) 77.7	(11) 18.6	(1) 1.7
IV. Franklin Spring Pond 9 mi. N. W. of Rockford, Illinois, Nov. 10 and Dec. 29, 1931	433			(10) 2.3	(370) 85.4	(52) 12.0	(1) 0.2
V. Franklin Spring Pond, Nov. 25, 1932	172			(5) 2.9	(140) 81.4	(26) 15.1	(1) 0.6
VI. Creek just below Franklin Spring Pond, Nov. 25, 1932	131			(2) 1.5	(110) 84.0	(19) 14.5	
VII. Spring connecting with south branch of Kent Creek 5 mi. W. of Rockford, Ill., Dec. 30, 1931	137	(1) 0.7	(2) 1.5	(7) 5.1	(105) 76.6	(22) 16.0	
VIII. Buffalo Creek 6 mi. N. of Sterling, Ill., Apr. 10, 1931	675			(36) 5.3	(602) 89.2	(37) 5.5	
IX. Oxbows along North Branch of Nippersink Creek, Richmond, Ill., May 22, 1932	352			(12) 3.4	(299) 84.9	(41) 11.6	
X. Dredge ditch 2 mi. S. of Harrison, May 3, 1927	81		(1) 1.2	(1) 1.2	(69) 84.9	(10) 12.3	

those with 11 rays was variable. Fins with 9 rays were 9 times as numerous as 11 rays in collection I, while 11 rays were more numerous than 9 rays in collection X.

For comparisons of distribution of pectoral counts in collections taken at points close together, the reader is referred to collections I and II, taken 2 miles apart on the same day at Evansville, Wis., and to collections V and VI, taken only a few rods apart on the same day at Franklin Spring. Differences of 10 per cent in the frequency with which counts of 9 and 10 appear will be noticed in these two comparisons.

Collections IV and V were made a year apart at Franklin Spring trout pond. The distribution of counts was considerably alike, although the collection made the second year had fewer pectorals with 10 rays, more with 9 rays, and many more with 8 rays.

The dorsal and anal fins.—These fins showed less variation in percentage of fish with 10 rays than were found in the pectoral fins. For the anal fins the smallest number counted with 10 rays was 47 per cent found in collection VII and the largest number was 63 per cent observed in collection VIII. A similar range was found in the dorsal fin.

As in the pectoral fins, the counts of 9 and 11 rays varied as to which number occurred most frequently. While in several collections 9's and 11's were found in nearly equal numbers, in collection VII, 11's were five times as numerous as 9's in the dorsal fin and 7 times as numerous as 9's in the anal fin.

Within the respective localities, the three collections from Evansville and the three collections from Franklin Spring show a number of fairly noticeable differences, particularly in numbers of individuals with 9, 10 and 11 rays. The two collections from the pond proper at Franklin Spring were not very much different, although rather large differences were found in the pectoral counts.

COMPARISON BETWEEN THE RAY COUNTS OF THE PECTORAL FINS AS ONE GROUP, AND THE DORSAL AND ANAL FINS AS ANOTHER GROUP

Examination of the frequency distributions in table 2 will show that counts of 10 rays were more common in the pectoral fins than in dorsal and anal. For

TABLE 2—FREQUENCY DISTRIBUTIONS OF FIN RAY COUNTS. THIS TABLE SHOWS NUMBERS (IN PARENTHESES) AND PERCENTAGES OF INDIVIDUALS HAVING DIFFERENT NUMBERS OF FIN RAYS. THE PLACES AND DATES OF COLLECTIONS ARE SUPPLIED IN TABLE 1

Collection	Fin	Number of individuals	Number of Rays										
			4	5	6	7	8	9	10	11	12	13	14
I	L. Pect.	212		(1) 0.5	(1) 0.5		(1) .5	(28) 13.1	(178) 83.9	(3) 1.4			
	R. Pect.	212				(1) 0.5	(6) 2.8	(27) 12.7	(171) 80.6	(7) 3.3			
Evansville, Wisconsin Spring	Dorsal	212					(1) .5	(35) 16.6	(138) 65.1	(36) 17.0	(2) 0.9		
Dec. 1931	Anal	212					(3) 1.4	(57) 26.8	(115) 54.2	(37) 17.4			
II	L. Pect.	35					(1) 2.8	(7) 20.0	(26) 74.2	(1) 2.8			
	R. Pect.	35			(1) 3.0			(8) 22.8	(26) 74.2				
Evansville, Wisconsin Allen's Creek	Dorsal	35						(3) 8.6	(19) 54.3	(11) 31.4	(2) 5.7		
Dec. 1931	Anal	35						(5) 14.2	(20) 57.1	(9) 25.7	(1) 2.8		
III	L. Pect.	59					(4) 6.8	(14) 23.7	(38) 64.4	(3) 5.1			
	R. Pect.	59						(17) 28.8	(41) 69.5	(1) 1.7			
Evansville, Wisconsin, Spring fed creek	Dorsal	59					(2) 3.4	(12) 20.3	(32) 54.2	(13) 22.0			
May, 1932	Anal	59					(1) 1.7	(16) 27.1	(30) 50.8	(8) 13.6	(4) 6.8		
IV	*L. Pect.	433	(1) 0.2	(2) 0.5	(2) 0.5	(3) 0.7	(4) 0.9	(36) 8.3	(364) 84.0	(20) 4.6	(1) 0.2		
	R. Pect.	433		(2) 0.5		(2) 0.5	(3) 0.7	(33) 7.6	(367) 84.7	(24) 5.5	(2) 0.5		
Franklin Spring Pond	Dorsal	433			(1) 0.2		(6) 1.4	(88) 20.3	(241) 55.7	(91) 21.1	(6) 1.4		
Nov. and Dec. 1931	Anal	433				(1) 0.2	(2) 0.5	(109) 25.2	(239) 55.2	(78) 18.0	(4) 0.9		
V	L. Pect.	173		(1) 0.6	(3) 1.7	(5) 2.9	(15) 8.7	(22) 12.7	(113) 65.3	(11) 6.4	(2) 1.2	(1) 0.6	
	R. Pect.	173				(7) 4.0	(5) 2.9	(24) 13.9	(122) 70.5	(12) 6.9	(3) 1.7		
Franklin Spring Pond	Dorsal	170			(1) 0.6		(2) 1.2	(28) 16.5	(102) 60.0	(32) 18.8	(5) 2.9		
	Anal	172		(1) 0.6			(4) 2.3	(42) 24.4	(95) 55.2	(24) 14.0	(6) 3.5		
Nov. 1932	Caudal	172					(1) 0.6		(2) 1.2	(12) 7.0	(134) 77.9	(18) 10.5	(5) 2.

TABLE 2—Concluded

Collection	Fin	Number of individuals	Number of Rays										
			4	5	6	7	8	9	10	11	12	13	14
VI	L. Pect.	131			(1) 0.7		(3) 2.3	(9) 6.9	(103) 78.6	(14) 10.7	(1) 0.7		
	R. Pect.	131					(3) 2.3	(9) 6.9	(109) 83.2	(9) 6.9		(1) 0.7	
Franklin Spring just below pond	Dorsal	130						(17) 13.1	(72) 55.4	(39) 30.0	(2) 1.5		
	Anal	131				(1) 0.8	(2) 1.5	(15) 11.5	(81) 61.8	(32) 24.4			
Nov. 1932	Caudal	130						(1) 0.8	(2) 1.5	(9) 6.9	(114) 87.7	(2) 1.5	(2) 1.5
VII	L. Pect.	137			(1) 0.7		(3) 2.2	(42) 30.6	(86) 62.6	(5) 3.7			
	R. Pect.	137		(2) 1.5		(1) 0.7	(2) 1.5	(27) 19.7	(99) 72.2	(5) 3.7	(1) 0.7		
Kent Creek	Dorsal	137					(1) 0.7	(9) 6.6	(76) 55.5	(48) 35.0	(3) 2.2		
	Anal	137						(8) 5.8	(64) 46.7	(57) 41.6	(7) 5.1	(1) 0.7	
VIII	L. Pect.	675				(1) 0.1	(1) 0.1	(50) 7.6	(583) 86.3	(40) 5.9			
	R. Pect.	675						(48) 7.1	(572) 84.7	(51) 7.6	(4) 0.6		
Buffalo Creek	Dorsal	675				(1) 0.1	(9) 1.3	(154) 22.8	(441) 65.3	(68) 10.1	(2) 0.3		
	Anal	675					(6) 0.9	(152) 22.5	(423) 62.6	(94) 13.9			
IX	L. Pect.	352					(1) 0.3	(58) 16.4	(286) 81.3	(7) 2.0			
	R. Pect.	352					(1) 0.3	(44) 12.5	(301) 85.5	(6) 1.7			
Nippersink Creek	Dorsal	352					(8) 2.3	(107) 30.4	(191) 54.3	(46) 13.1			
	Anal	352					(6) 1.7	(95) 26.9	(182) 51.7	(66) 18.7	(3) 0.9		
X	L. Pect.	81					(1) 1.2	(5) 6.1	(62) 76.5	(13) 16.0			
	R. Pect.	81						(3) 3.7	(67) 82.7	(10) 12.3	(1) 1.2		
Harrison Ditch	Dorsal	81						(11) 13.6	(40) 49.4	(29) 35.8	(1) 1.2		
	Anal	81					(1) 1.2	(9) 11.1	(44) 54.3	(23) 28.4	(4) 4.9		

example, in collection I 10 rays in these four fins were observed the following number of times:

Left pectoral	178
Right pectoral	171
Dorsal	138
Anal	115

Similarly, in every other collection the pectorals as a group had more counts in the mode than had the dorsal and anal, usually 20-30 per cent more. In most collections the left and right pectorals did not differ with respect to modal counts by more than five per cent. This was also true in the case of occurrence of modal counts in dorsal and anal.

Another way in which these fin pairs differ is in number of low counts and high counts. In the pectoral fins there were more counts of 4, 5, 6 and 7 rays than were found in dorsal and anal, but the dorsal and anal fins showed more counts of 12 rays.

A study of the means for these fins also showed a pairing of values. In 8 of the 10 collections, means for dorsal and anal were higher than for pectorals. In another collection, however, the reverse was true, and in still another the means for all fins were about the same.

Pierson's correlation coefficient (r) has been used here to express the tendency for pectoral fins of individual sticklebacks to have the same number of fin rays on right and left sides. The bilateral arrangement of these fins would seem to suggest the likelihood of rather high correlation. This measurement has also been applied in the case of the dorsal and anal, dorsal and right pectoral and dorsal and left pectoral. The results are shown in the following tabulation. It should be remembered that perfect positive correlation is expressed by $r = +1.0$ and values of r greater than + 0.3 are usually considered significant. These determinations were based on the specimens in all collections combined.

Correlation between ray number in:	*r*
Left pectoral and right pectoral	$+0.327 \pm 0.013$
Dorsal and anal....	$+0.474 \pm 0.012$
Dorsal and left pectoral	$+0.038 \pm 0.020$
Dorsal and right pectoral	$+0.005 \pm 0.020$

Thus there seems to be a definite tendency for left and right pectorals to have the same number of rays, and the same tendency is also found in the case of dorsal and anal, but there was no correlation between ray number in the dorsal with either of the pectoral fins.

It would seem that the most likely explanation of correlation between the pectorals, and also between dorsal and anal would rest on the theory of segmental origin of the fin rays; that is, that each individual ray originates from an individual myotome.* In the stickleback the position of the dorsal fin is directly above the anal which indicates that most of the rays in the two fins probably do originate from the same group of myotomes. In the case of the pectoral fins the origin of the rays, according to the widely accepted "lateral-fold theory" is also in the myotomes, and it would be expected that the rays on right and left fins had usually come from the same segments, but from a different set than those which gave rise to the dorsal and anal. The circumstance that the pectoral fins, the dorsal and the anal all have a mode of 10 rays must be looked upon as accidental.

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