Leuciscus Balteatus (Richardson). A Study in Variation. By Carl H. Eigenmann.*

Nowhere else in North America do we find within a limited region such extensive variations among freshwater fishes as on the Pacific Slope. This is true whether we have reference to the extent of variation between the extremes of the same family or to the limits of variation in any given species.

A comparison of the members of the eight families of fishes having representatives on both the Atlantic and the Pacific slopes, show that, on an average, each of these families has four genera and sixteen species on the Pacific slope, and seven genera and thirty-six species on the Atlantic. Yet, although the number of species is more than twice as great on the Atlantic slope, the variation in the number of fin rays among the Pacific slope species is greater in all but two families. I have recently† made a detailed comparison between the members of the different families, and there attributed this great extent of variation to two causes. First: the fauna is of diverse origin; some of the members are of Asiatic, while others are of Atlantic descent. Second: the fauna is new as compared with the Atlantic slope fauna, and has not yet reached a stage of staple equilibrium. It is possible, as suggested to me by President Jordan, that the Pacific slope fauna has retained its primitive characters more nearly than the Atlantic slope fauna, which shows signs of degeneration in its fins and teeth.

This great variation between the members of the same families is not confined to the fin rays. It is equally true of other characters, but can best be demonstrated in characters whose variation can be numerically expressed. The pharyngeal teeth of the Cyprinidæ offer another striking example of these variations among the Pacific slope species. In a number of cases the variations of the Pacific slope species extend along definite and parallel lines. I have pointed out some of these in the paper quoted above. These lines are directed towards an increase of rays and towards a modification of rays into spines.

The following quotations from Gilbert and Evermann's recent work on the Columbia River basin,‡ illustrate the variation among the different specimens of the same species. "The range of variation seems to be very great, and characters which are of undoubted specific value when applied to Atlantic drainage

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* Contributions from the Zoölogical Laboratory of the Indiana University, No. 11.

† Results of explorations in Western Canada and Northwestern United States. Bull. U. S. Fish Comm. for 1894, pp. 101 to 132, plates 5 to 8. June, 1894.

‡ Report of the Commissioner of Fish and Fisheries on Investigations in the Columbia River Basin in regard to the Salmon Fisheries. Washington, 1894. A Report upon Investigations in the Columbia River Basin with Descriptions of Four New Species of Fishes.

species, do not possess any such value for classification of Pacific coast fishes. Each so-called species seems to be in a very unstable state of equilibrium, and not to have yet assumed or been able to retain, with any degree of permanence, any set of specific characters." "The crosswise series of scales [in Agosia nubila (Girard)] varies from 47 to 70 in number; the barbel [a generic character] is present or absent; the pharyngeal teeth vary from 1, 4-4, 0 to 2, 4-4, 1; and the dorsal fin varies much in position and somewhat in size. These characters occur in various combinations, and with some of these are often correlated peculiarities of physiognomy and general appearance, all of which may serve to put a certain stamp upon the individuals from a single stream, or even from one locality in a stream." These observations, especially those contained in the last sentence, accord exactly with the results obtained by me in another fish and confirm my statement which will be further re-enforced by the present paper, that "each locality has a variety which in the aggregate is different from the variety of every other locality."

The remarkable variation of the Pacific slope species, and more especially the variation in the fin rays, was first noted in preparing my account of the specimens collected in the Columbia and Frazer basins.* This variation was most pronounced in the species of the late genus Richardsonius. Of the species of this genus, I had about 250 specimens, collected in the Frazer and Columbia systems, from tide water to an elevation of 2,786 feet. The later explorations of Gilbert and Evermann have increased this number to 825, and these warrant a re-examination of the points stated by me. For all the date concerning the fin rays of the specimens collected by Gilbert and Evermann, I am indebted to them. Their examination of these specimens was made to test certain conclusions reached by me, and their data, therefore, join mine. In counting the anal rays, I counted the rudiments at the beginning of the fin. These were not counted by Gilbert and Evermann, and to bring their data in perfect accord with mine, it is necessary to add two to the number of anal rays. While the number of rudimentary rays is not always two, it is so often that the exceptions would probably not alter the general results.

At the time I began my studies of these forms, they were regarded as two species, forming a peculiar genus, Richardsonius. They were known to inhabit the Columbia river and the streams about Puget Sound. The compressed belly behind the ventral fins was regarded as the character separating them generically from the related forms. It soon became evident that, while some specimens possessed this, if constant, unquestionable generic character, others did not show

* This variation in the same species does not seem to be confined to the fishes. Professor Ritter, Proc. Cal. Acad. Sci., 2d ser. Vol. IV., p. 37, finds the same in *Perophora annectens* a new tunicate described by him.

it at all, and the genus was relegated to the limbo of synonymy. The species *balteatus* and *lateralis* were distinguished as follows:

a. Base of anal, 4¼ in the length; A. 17 or 18; teeth 2, 5-4, 2. Lower jaw slightly projecting beyond the upper. Coloration plain, the sides bright silvery, crimson in males in spring. Scales 13-62-6. *balteatus.*

aa. Base of anal, 5⅓ in the length; A. 14; teeth 2, 5-5, 2. Jaws equal. Blackish above, a dark lateral band; the interspaces and belly pale; crimson in male in summer. Scales 13-55-6. *lateralis.*

No better distinguishing marks could be wished by any systematist. These characters were found to be so bridged, that the extremes could not be specifically sustained and one of them, probably out of deference to the authority of my friends Jordan and Gilbert, from whom the above diagnosis was modified, was retained as a variety of the other. Now I am inclined to regard *lateralis* as a synonym of *balteatus* with Gilbert and Evermann, but I must take exception to the statement attributed to me that I "considered *lateralis* a subspecies of *balteatus* occupying the same brook with its parent form." I found *balteatus* at the lower Frazer to Kamloops, *lateralis* at the headwaters of the Thomson River down to Kamloops. I see no reason why a subspecies should not occupy the same "brook" with its parent form, for some allied species—between which and subspecies there is, after all, but a mental difference—are, even by Gilbert and Evermann, admitted to live side by side (*Agosia falcata* and *umatilla* at Umatilla).

Leuciscus balteatus ascends the tributaries of the Frazer and Columbia as high as the falls will permit. No other species is found in the Frazer system nor in the Columbia basin proper. The specimens from Brown's Gulch were described as different from those of the lower Columbia, but a comparison of large numbers from other localities has shown them to be but one of the numerous local variations. Three other species, *L. hydrophlox*, *lineatus* and *aliciae* are found in the Snake above the falls. The last two belong to a different section of the genus *Leuciscus* and are not closely related to *balteatus*. All three have probably entered the Snake River from the Utah Basin. As far as known the territories of *L. balteatus* and *hydrophlox* do not overlap, unless those specimens of *balteatus* with only 13 or 14 anal rays are in reality *hydrophlox*, and as far as my experience goes, the number of anal rays is the only ready means of distinguishing the two. *L. balteatus* extends up to or near to the first falls of the Snake, *hydrophlox* is found from this point to the headwaters. A comparison of *hydrophlox*, *balteatus* and *gilli*, the specimens from Brown's Gulch, makes it quite certain that they are all modifications of the same form.

Below are given a number of tables which show the variation in several characters. These tables are all from my own specimens.

TABLE OF VARIATION FOR TWENTY-SIX SPECIMENS FROM MISSION.

Number.	Length in MM.	Dorsal.	Anal.	Scales.	Teeth.*	Depth.	Position of Dorsal.	Sex.	Remarks.
1	140	13½	18½	12-59-6		3½	(†)	Female.	Keel scarcely evident.
2	120	12½	21½	11-53-5	‡2, 5-4, 1	3⅗	(§)	Male.	Median keel scarcely evid't
3	110	13½	19½	12-60-6	2, 5-4, 2	3⅔	( )	Male.	Median keel moderate.
4	105	12½	20½	12-58-6	2, 5-4, 2	3¼	( )	Female.	Median keel well developed
5	100	12½	19½	11-57-6	2, 4-4, 2	3⅗	(†)	Male.	Keel typical.
6	102	12½	18½	12-60-6	2, 5-4, 2	3½	(§)	Male.	Keel moderate.
7	91	11½	20½	12-57-5	2, 4-3, 1	3⅔	( )	Female.	Keel evident.
8	92	11½	19½	12-58-6	2, 5-4, 1	3⅘	( )		Keel distinct.
9	88	12½	19½	12-61-6	2, 5-4, 2	3	( )	Male.	Keel well developed.
10	92	12½	21½	12-63-6	2, 5-4, 1	3	(§)	Female.	Keel typical.
11	102	12½	20½	11-62-6	2, 5-4, 2	3⅗	(§)	Male.	Keel well developed.
12	87	12½	20½	13-59-6	1, 5-4, 2	3⅗	(†)	Male.	Keel moderate.
13	86	12½	20½	11-59-7	2, 5-4, 1	3¼	( )	Male.	Keel well developed. (*tanus*
14	83	12½	20½	12-61-7	2, 5-4, 1	3½	(†)	Male.	Keel no more than in *mon-*
15	80	11½	19½	12-61-6	2, 5-4, 1	3⅗	(†)	Male.	Keel distinct.
16	95	12½	18	13-59-7	2, 5-4, 2	3½	( )	Male.	Keel evident.
17	90	12½	17½	13-58-7	2, 5-4, 2	3	(†)	(?)	Keel moderate.
18	80	11½	17½	11-60-7	2, 5-4, 2	3½	(†)	Male.	Keel typical.
19	77	12½	17½	57	2, 5-4, 2	3⅘	(†)	(?)	Keel well developed.
20	87	12½	16½	13-61-7	2, 5-3, 2	3	(§)		Keel well developed.
21	81	12½	22½	12-58-7	2, 5-4, 2	3⅗	( )	Female.	Keel moderate.
22	80	13½	21½	61	2, 5 ?	3⅘	( )	Female.	Keel moderate.
23	74	11½	16½	. . . . .	2, 5-4, 2			. . . . . .	Keel moderate.
24	60	13½	24½	. . . . .	2, 5-4, 2	3¼	(†)	. . . . .	Keel evident.
25	68	13½	24½	. . . . .	. .	.		.	
26	64	12½	23½		. . . . . .	. . . . .		. . . . .	

* I have frequently observed that the largest individuals among the minnows usually have abnormal numbers of teeth.

† Equidistant from base of middle caudal rays and a point above middle of pupil.

‡ Anterior tooth of main row on left side is large, dagger-shaped, and remote from the others, and points inward.

§ Equidistant from base of middle caudal rays and upper angle of preoperele.

Equidistant from base of middle caudal rays and posterior margin of eye.

TABLE OF VARIATION FOR EIGHT SPECIMENS FROM SICAMOUS.

Number.	Length in MM.	Dorsal.	Anal.	Scales.	Teeth.	Depth.	Position of Dorsal.	Remarks.
1	82	12½	19½	11-60-6	2, 4-3, 1	4	(*)	
2	92	12½	16½	11-62-6	2, 5-4, 2		(*)	Keel indistinct.
3	90	12½	14½	14-62-7	2, 5-4, 2	3⅗	(†)	
4	87	12½	17½	12-60-5	2, 5-4	4		
5	85	12½	16½	10-62-5	2, 5-5, 3	4⅕	(‡)	
6	80	12½	18½	11-60-6	2, 5-4, 1	4¼	(*)	
7	85	12½	16½	11-59-5	2, 5-4, 2	4	(†)	
8	77	12½	17½	11-61	2, 5-4, 1	1⅗	(*)	

* Equidistant from base of middle caudal rays and upper angle of preopercle.

† Equidistant from base of middle caudal rays and a point above middle of pupil.

‡ Equidistant from base of middle caudal rays and occiput.

TABLE OF VARIATION FOR EIGHTEEN SPECIMENS FROM THE COLUMBIA AT GOLDEN.

Number.	Length in MM.	Dorsal.	Anal	Scales.	Teeth.	Depth.	Head.	Position of Dorsal.	Sex.	Remarks.
1	115	12½	15½	12-63-6	2, 5-4, 1	3½	4½	(*)	Female.	Keel nil.
2	104	11½	16½	10-61 ?	2, 5-4, 1	4	4	(†)	Female.	Keel evident.
3	103	11½	18½	10 55-5	2, 5-4, 2	4	4	(*)	Female.	Keel evident.
4	103	11½	17½	12-59-?	2, 4-5, 2	4½	4⅔	(*)	Male.	Keel evident.
5	95	12½	15½	56	1, 5-4, 1	4	4	(‡)	Female.	Keel well marked.
6	92	11½	15½	. . .		4½	4	(§)	(?	Keel well developed.
7	91	12½	17½	57	2, 4-3, 2	3½	4⅗	(‡)	. . . .	Keel nil.
8	85	11½	14½	. . . . .	. . . .	4	4½	(‡)		Keel well developed.
9	85	12½	16½	. . .	. . . .	4½	4⅔	(§)	. . .	Keel scarcely evident.
10	82	11½	16½	. . . . .	.	4	4½	(*)	.	Keel evident.
11	83	11½	16½	. .	. .	3⅚	4	(‡)		
12	77	11	15½	.		4½	4½	(‡)	. . . .	Keel evident.
13	73	12½	15½	.	. . .	4		(‡)	. .	Keel well developed
14	72	10½	15½	. . . . .	. . .	4	.	(‡)	.	Keel moderate.
15	68	11½	16½	. . . . .		4		(*)	. . . .	Keel well developed.
16	67	12½	17½	. . .	. .	3½	. . .	(†)	. . . . .	Keel well developed.
17	65	12½	15½	.	. . . .	4		(§)		Keel strong.
18	62	11½	17½		. .	4½		. . .	. . . .	Keel strong.

* Equidistant from base of middle caudal rays and occiput (beginning of scaled region).
† Dorsal nearer base of middle caudal rays than occiput.
‡ Equidistant from base of middle caudal rays and upper angle of preopercle.
§ Equidistant from base of middle caudal rays and posterior margin of eye.

From these tables it will be noticed that the number of dorsal rays is quite constant, being from 10 to 13. The variation in the anal is enormous, but this I shall treat in detail. The scales are seen to vary from 10 to 14 above the lateral line; from 55 to 63 along the lateral line, and from 5 to 7 below the lateral line. There is nothing unusual in these variations, they are surpassed or equalled by other members of the same family. The variation in the teeth is great. With one exception, there are two teeth in the lesser row of the left side. The major row on the left side contains 4 or 5 teeth in the proportion of 1 to 6. In the right side 3, 4 and 5 teeth were found in 4, 30, and 2 specimens respectively. In the lesser row of the right side 13 specimens had one tooth, 20 had 2 teeth and 1 had 3. This last specimen with dental formula 2, 5–5, 3, exceeds, the dental formula of all the 175 Atlantic slope species of this family. Among these dental formulæ we find variations, the extremes of which have been taken as generic characters. The different combinations of teeth and the number of specimens having each number are as follows: One with 1, 5–4, 1; one with 1, 5–4, 2; two with 2, 4–3, 1; one with 2, 4–3, 2; one with 2, 4–4, 2; one with 2, 4–5, 2; one with 2, 5–3, 2; eleven with 2, 5–4, 1; sixteen with 2, 5–4, 2; one with 2, 5–5, 3. The usual or nominal formula is 2, 5–4, 1 or 2. The variation through ten different combinations is exceptional.

The proportions, while varying considerably, do not show any wider fluctuations than usual. The position of the dorsal, on the other hand, varies from midway from base of the middle caudal rays, and from a point behind to a point above the middle of the eye.

In the development of the keel behind the ventral fins we find again a great fluctuation in specimens from the same locality. In some, the keel is very sharp; in others it is entirely absent, and between these forms, we have all shades of variation. If uniform, it would be of generic value.

Now, as to the variation of the anal rays. The lowest number recorded is 13 (after adding 2 to Gilbert and Evermann's lowest number), and the highest is 24. This gives a total variation of 12 rays. This would be a large variation for any fish, but becomes phenomenal when it is considered that the variation in the number of anal rays of the 175 Atlantic slope species extends only from 6 to 14, a total variation of but 9 for 175 species as compared with the variation of 12 for a single species. The high number of rays reached is also phenomenal, for, leaving out of consideration the two rudimentary spines, the highest number of anal rays, 22, is ten more than the number found in any other Pacific Cyprinoid, and eight more than the number found in any Atlantic species. The average number of rays is seventeen. The variation to lower numbers extends through 4 rays to 13. The variation to higher numbers is much greater, extending through 7 rays to 24. Not only is the extent of variation greater towards higher numbers, but the number of specimens varying in that direction is much greater. Of 825 specimens but 22.3 per cent. have the average number of rays. This is the largest per cent. for any given number of rays. Thirty-four per cent. of all the specimens have fewer than the average number of rays, while 42.9 per cent. have more than the average number. A more striking illustration of determinate variation could not be wished.

Figure 1 graphically represents the variation of the species as shown by the 825 specimens examined. The total hight of the vertical lines represents the greatest possible number, 100 per cent., that could have the given number of anal rays indicated at the bottom of the lines. The curve shows the actual per cent. of specimens having each particular number of rays. Were the variation promiscuous the curve would be symmetrical. The symmetry shows the inherent tendency to a higher number of rays in this fish. It may be well to bear in mind that no other species has a higher number of rays—that no other species joins this curve on the right—while at least one, probably two, related species living in the head-waters of the Snake River have fewer rays, *i. e.*, joins this curve on the left. The curve of *Leuciscus hydrophlox* will not only join this curve, but overlap it, showing that in the number of anal rays *L. belteatus* and *L. hydrophlox* intergrade.

To facilitate the study of the local variations I give below all the data concerning the 825 specimens of this fish. The first column gives the name of the stream and locality; the second column gives the elevation of the locality; the third, the number of specimens collected at the given place; the fourth, the extent of variation in the anal rays in the specimens from the locality, and the succeeding columns, the number of specimens having the particular number of anal rays indicated at the head of the columns. The figures below the column representing the average number of rays for the specimens of the locality are in italics.

DETAILS OF THE VARIATIONS IN THE ANAL RAYS.

Locality.	Elevation.	Number of Specimens.	Variation.	Number of Anal Rays.											
				13	14	15	16	17	18	19	20	21	22	23	24
Payette River, Payette.	2,150	151	9			3	25	29	*27*	28	25	12	3	2	
Boise River, Caldwell	2,372	99	9		2	4	11	17	*29*	19	10	5	3		
Frazer River, Mission	1	79	9				2	7	13	*25*	18	8	2	2	2
Little Spokane River, Dart's Mill	1,850	70	5	1	11	*30*	19	6							
Small Creek, at Sand P't, Idaho	2,100	67	6			2	19	*36*	3	6	1				
Shuswap Lake, Sicamous	1,300	58	6		1	3	13	*28*	8	5					
Lake Washington, Seattle	1	47	7		1	16	*11*	13	4	1	1				
Umatilla River, Pendleton	1,070	26	5		1	5	*10*	9	1						
Grand Ronde, La Grand	2,786	23	4		2	6	*11*	4							
Umatilla River, Umatilla	300	22	6					2	6	*3*	4	6	1		
Colville River, Meyers' Falls	1,200	21	7			7	*5*	6	2			1			
Columbia River, Golden, B. C.	2,550	18	5		1	7	*8*	1	1						
Clear Water River, Lewiston	750	16	4						3	5	*4*	4			
Griffin Lake	1,990	14	4		3	*7*	3	1							
Brown Gulch, Silver Bow	5,344	14	4			2	*10*	1	1						
Skookumchuck River, Chehalis	204	13	6			2		1	*7*	2	1				
Spokane River, Spokane	1,910	11	5		1	1	*5*	1	3						
Hangman Creek, Spokane	1,910	11	4			2	2	*7*	2						
Flathead Lake	3,100	11	4			1	1	*6*	3						
Snake River, Payette	2,150	10	5						1	1	*4*	3	1		
Natches River, North Yakima	1,078	8	5		1		3	*1*	3						
Pend d'Oreille River, Newport	2,000	8	3				*5*	1	2						
Walla Walla River, Wallula	326	6	4						2	*2*		2			
Post Creek, Flat Head Lake	3,100	6	3					*4*	1	1					
Potlatch Creek, Lewiston	1,200	4	3						1	*1*	2				
Newaukum River, Chehalis	204	3	2					[illegible]	1						
Columbia River, Pasco	375	3	3							1	*1*	1			
Thompson River	1,178	4	3					1	1		1		1		
Columbia River, Revelstoke	1,475	1	1			*1*									

After a detailed examination of the specimens collected by myself I found that every locality has a variety peculiar to itself. The number of localities has been trebled by the explorations of Gilbert and Evermann, and the number of specimens raised from 250 to 825, and their detailed examination of these specimens bears out the above statement for every locality examined by them. Unfortunately they allowed themselves to be side-tracked by minor issues, and did not mention this fact of local variation except in connection with another species.

I collected at three localities in the Fraser basin. At Mission, B. C., I obtained seventy-nine specimens in water which is affected by the high tides. At Sicamous, at an elevation of 1,300 feet, I collected fifty-eight specimens. In Griffin Lake, at an elevation of 1,900 feet, I secured fourteen specimens. Four others were secured at Kamloops, but these are too few to aid us in our study.

The variation for these localities is represented by the three curves of figure two. The vertical lines stand for fin rays to total height of the figure for 100%. The various heights of these curves represent the per cent. of specimens having the given number of rays. The variation is seen to be much the greatest at Mission, a fact which is largely to be attributed to the greater number of specimens secured at this place. The variation from the normal, which is nineteen rays, to a higher number of rays, is as great as the entire variation for the next locality. At Sicamous a much larger per cent. has the normal number of rays, but the normal number has been decreased to seventeen The curve for Griffin Lake is interesting, because the normal number of rays has again been decreased by two. In other words, the higher the altitude the fewer the number of rays and the narrower the limit of variation.* Moreover, the curves are not symmetrical for any of the three localities, but in the aggregate the more gradual slope is on the side of an increase in the number of rays, a condition which, considering the general variation of rays on the Pacific Slope, seems to indicate that the number of rays of this species in the Frazer system is increasing, and that the increase is progressing from lower to higher altitudes.

A glance at the remaining curves will be sufficient to show that no two curves are alike, that the per cent. of specimens having a given number of rays differs with each locality. Naturally the curves constructed from a large number of specimens represent the true conditions better than the curves constructed from

* In their recent paper Gilbert and Evermann have raised this specific statement, which occurs in my paper quoted above, into the dignity of a "theory" and "generalization," which it was never intended to be, and their arguments against it as a "theory" and "generalization" are, therefore, not appropriate.

but a few. The extent of the variation varies largely with the number of specimens examined; that is, the probability of securing extremes becomes greater with an increase in the number of specimens collected.

The greatest extent of variation for any locality as far as known is through nine rays. This has been found only when over seventy specimens have been compared. It decreases to about five rays with ten specimens. The total variation for the species has not been found at any one place.

The question of variation with elevation is an interesting one, and may be taken up in some detail.

In the following table *all* the localities are grouped according to their average number of rays:

Average Number of Rays.	Number of Localities.	Localities, With Their Elevations.
15	3	Little Spokane River, 1,850; Griffin Lake, 1,990; Revelstoke on the Columbia, 1,475.
16	8	Lake Washington, 1; Umatilla River, Pendleton, 1,070; Spokane River, 1,910; Colville River, Meyers Falls, 1,200; Columbia River, Golden, 2,550; Grande Ronde River, La Grande, 2,786; Silver Bow, Brown's Gulch, 5,344; Pend d'Oreille River, Newport, 2,000.
17	7	Newaucum River, Chehalis, 204; Natchess River, North Yakima, 1,078; Sicamous, 1,300; Hangman Creek, Spokane, 1,910; Small Creek, 2,100; Post Creek, 3,100; Flat Head Lake, 3,100.
18	3	Payette River, 2,150; Boise River, Caldwell, 2,372; Skookumchuck River, Chehalis, 204.
19	5	Mission, 1; Umatilla, 300; Walla Walla River, 326; Potlatch Creek, 1,200; Kamloops, 1,158.
20	3	Clear Water, Lewiston, 750; Snake River, Payette, 2,150; Columbia River, Pasco, 375.

The lowest average, 15, is found in but three localities, the lowest of which is at an elevation of 1,475 feet. This last is of no value since only one specimen was obtained, and the chances are against an average specimen if only one is taken.

The second average is found all the way from tide water to an elevation of 5,344 feet. It is, however, notable that only one of the localities, Lake Washington, which does not belong to one of the two large water systems, is at a low elevation. The lowest of the other seven, all of which belong to the Columbian system, is at an elevation of 1,070 feet.

The third average, which is also the general average for all the specimens, is found in seven localities, the lowest of which is at an elevation of 204, the highest at 3,100. All but the first, which, again, does not belong to one of the large river systems, are at an elevation above 1,0 0 feet.

The fourth average ranges from 204 to 2,372 feet.

The fifth average, 19 rays, is found in five localities, three of which are below 1,000 feet, and the highest is at 1,200.

The sixth average, of 20 rays, varies from 375 to 2,150 feet; two of them are at an elevation of less than 1,000 feet.

This grouping does not show any uniform variation with the altitude. It may be emphasized that the lowest average is not found below 1,475 feet, that only one of the seven having an average of 16 rays is found below 1,000 feet, and that but one of the eight having an average of 17 rays is found below 1,000 feet. From the last but three specimens are known. It may be further emphasized that three of the five localities having an average of 19 rays are found below 1,000 feet, and that two of the three having an average of 20 rays are found below 1,000 feet. Generally the lower locality has the larger number of rays, to which there are several notable exceptions, Lake Washington and Snake River at Payette. These facts can be presented in curves for groups of localities.

Taking the specimens from the different groups of localities we obtain the following:

Elevation, Feet.	Number of Localities.	Number of Specimens.	Extent of Variation.	General Average of Anal Rays.
1 to 750	8	189	11	18.4
1,078 to 2,000	12	234	10	16.6
2,001 to 3,100	8	388	10	17.5
5,000 to ——	1	10	. . .	16

Whether we consider the number of localities having a high average of rays or whether we consider the averages of all the specimens from a similar horizon, we find that the largest number of rays is found in the lower horizon. Furthermore, the extent of variation for the 189 specimens from 1 to 750 feet is greater than the variation for 234 and 588 specimens of the higher horizons. The variation for these three horizons is given in the three curves of figure 3.

In the above we have considered the localities regardless of the system to which they belong. Lake Washington and the Newaucum and Skookumchuck rivers belong to separate short water courses. Eliminating these and considering the localities of the Frazer and of the Columbia systems separately we get the conditions described for the Frazer system above and for the Columbia system the following—arranging the localities in the order of elevation:

Locality.	Elevation.	Av. No. of Anal Ray.	Locality.	Elevation.	Av. No. of Anal Ray.
Umatilla	300	19	Haugman Creek	1,910	17
Wallula	326	19	Pend d'Oreille	2,000	16
Pasco	375	20	Small Creek	2,100	17
Lewiston	750	20	Payette	2,150	18
Pendleton	1,070	16	Snake River	2,150	20
Yakima	1,078	17	Caldwell	2,372	18
Colville	1,200	16	Golden	2,550	16
Potlatch	1,200	19	La Grande	2,550	16
Revelstoke	1,475	15	Flat Head	3,100	17
Little Spokane	1,850	15	Brown's Gulch	5,341	16
Spokane	1,910	16			

Only one specimen.

Summarizing this: Below 1,000 feet the averages are 19 and 20; above 1,000 feet only one averages 20, only one reaches 19, two reach 18, four have 17, seven have 16 and two have 15. These figures "are not so unanimous in their indications" of a decrease of rays with an increase of altitude as those for the Frazer system. But the lower locality generally possesses a higher number of rays. Here, where we have data from many widely separated branches, a close variation of rays with altitude is not found. Local issues have modified national tendencies among these fishes in the Columbia system.

Among the locality curves (figures 4 and following) the ideal curve is most nearly approached at Caldwell. The variation from the average is here equally great in both directions, and the curve of the ascending variation is almost identical with the curve of the descending variation. Nearly as ideal conditions are found at Little Spokane, where the extent of variation is much smaller. *A priori* such symmetry or approach to symmetry is to be expected for each locality, but the deviations from it are many and great. The many shoulders and peaks in localities from which but few specimens have been collected, indicate probably nothing so much as the lack of a sufficient number of specimens. When but ten specimens are examined, each specimen, more or less, makes such a vast difference in the character of the curve that the localities with less than twenty specimens may be dismissed without further notice.

Aside from curves, such as that of Little Spokane, where a certain number of rays is the predominant one, we have curves, such as that of the Payette River, where the number of specimens having 16, 17, 18, 19 and 20 rays, is nearly equal. Still another type of curve is represented by the curves for Lake Washington, Colville and Umatilla, in which two numbers predominate, with the intervening numbers in minority. The conditions are most marked at Umatilla, where we have two incipient varieties with 18 and 21 as the predominatin number of rays.

I have given at the outset the probable causes which have brought about the great differences between the Pacific slope fishes.

We must look to other causes for the great variation between species of undoubted Atlantic origin and especially the variation in the same species, which reaches its culmination in *Leuciscus balteatus* and *Agosia nubila*. The climatic, altitudinal and geological differences in the different streams and even in the length of the same stream are very great on the Pacific slope. To these different environments we must attribute the conditions set forth in the present paper for *Leuciscus balteatus*. These differences in different localities in the same stream can only become established in non-migratory species. No such differences are to be expected for a migratory species. Isolation for the specimens of any locality when free intermigration is possible, seems strange. An analogous condition is to be found on the Galapagoes Islands. Dr. Baur tells me that islands within plain sight of each other harbor distinct varieties of the same species of birds which could readily intermigrate, but do not.

This raises the question of the sort of influence exerted by the environment. Is it merely selective, or is it directive? Is the variation promiscuous and inherent in the species, or is it determinate and forced in certain directions by the environments? The latter seems to me the better way of reading such conditions as are represented by the many curves which show a greater variation towards an increased number of rays than towards a decrease of rays. Here the variation is not promiscuous, but definitely determinate. See, in this connection, the curve for all the specimens.

The origin of new varieties is admirably illustrated by the curves for Lake Washington and Umatilla. In these, two distinct peaks are found. While no varietal value is claimed for these peaks, isolation of members of such peaks, either physiologically or locally, would tend to establish such incipient varieties as species.

EXPLANATION OF FIGURES.

The vertical lines in all cases stand for a definite number of anal rays. The total height of the figures represents 100 per cent., and the height of the curves at any point, the per cent. of specimens having the particular number of rays in the anal.

Fig. 1. Curve of variation for 217 specimens of *Leuciscus hydrophlox* from the upper Snake, and 825 specimens of *Leuciscus balteatus* from many localities, ranging from 1 to over 5,000 feet. The two series of specimens are combined in the broken line curve.

Fig. 2. Three curves showing the variation of the three localities represented from the Frazer system:

Griffin Lake, 1,900 feet, 17 specimens.

Sicamous, 1,300 feet, 58 specimens.

Mission, 1 foot, 79, specimens.

Fig. 3. Three curves showing the variation:

a, of 234 specimens from 1,000 to 2,000 feet elevation;

b, (broken line) 388 specimens from 2,000 to 3,000 feet elevation;

c, 189 specimens from 1 to 1,000 feet elevation.

Fig. 4. Variation of 99 specimens from Caldwell, 2,372 feet.

Fig. 5. Variation of 23 specimens from La Grande, 2,786 feet.

Fig. 6. Variation of 70 specimens from Little Spokane, 1,850 feet.

Fig. 7. Variation of 79 specimens from Mission, 1 foot.

Fig. 8. Variation of 154 specimens from Payette River, 2,150 feet.

Fig. 9. Variation of 26 specimens from Pendleton, 1,070 feet.

Fig. 10. Variation of 16 specimens from Clear Water, 750 feet.

Fig. 11. Variation of 14 specimens from Brown's Gulch, 5,344 feet.

Fig. 12. Variation of 67 specimens from Small Creek, 2,100 feet.

Fig. 13. Variation of 47 specimens from Lake Washington, 1 foot.

Fig. 14. Variation of 22 specimens from Umatilla, 300 feet.

Fig. 15. Variation of 21 specimens from Colville, 1,200 feet.

Fig. 16. Variation of 18 specimens from Golden, 2,550 feet.

Fig. 17. Variation of 13 specimens from Skookumchuck, 204 feet.

Fig. 18. Variation of 11 specimens from Hangman's Creek, 1,900 feet.

Fig. 19. Variation of 12 specimens from Flat Head Lake, 3,100 feet.

Fig. 20. *Leuciscus balteatus* from Mission, the specimen now in the British Museum.

Fig. 21. *Leuciscus gilli*, from Brown's Gulch.

Fig. 22. *Leuciscus hydrophlox*.

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THE RED-FISH OF THE IDAHO LAKES. BY B. W. EVERMANN AND J. T. SCOVELL.