VARIATION OF VERTEBRAL COUNTS IN SOME OHIO AND MICHIGAN SCULPINS OF THE *COTTUS BAIRDI BAIRDI* GIRARD - *COTTUS BAIRDI KUMLIENI* (HOY) COMPLEX (PISCES, COTTIDAE)

A Thesis

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by

Elizabeth Ann Wydallis, B.S.

The Ohio State University
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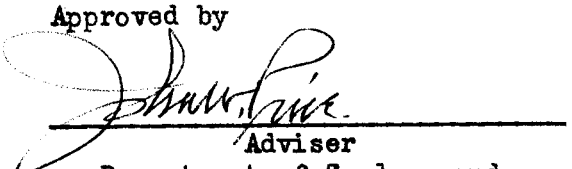
Approved by



Adviser
Department of Zoology and
Entomology

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Elizabeth Ann Wydallis

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INTRODUCTION

Historical Résumé

The earliest recorded observation on variation of vertebral numbers within a group of fishes was made by Günther (1862). He noted that in the Wrasse fishes of the family Labridae twenty-four vertebrae were typical for the tropical species, while the forms of the temperate seas had a larger number with the increase being in the caudal region. In 1863 and 1864, Gill stated that an increase in the number of vertebrae was a normal feature of Acanthopterygian and Malacopterygian families in northern waters. Heincke (1899), one of the pioneers in race investigations in fishes, reported vertebral variations in the herring, Clupea harengus.

David Starr Jordan expressed great interest in this phenomenon from 1886 until his death in 1931. Hubbs (1922) correlated the number of vertebrae with the temperature of the water during embryonic development, and the following year (1923) published his findings on seasonal variation in vertebral counts. In 1926, Hubbs published again on the subject and concluded:

> "The structural consequences of differential rate of development probably comprise a considerable proportion of the characters differentiating local races of fishes."

Clark (1936) reported variation in vertebral numbers among populations of sardines along the Pacific coast. Mottley (1936) discovered that the European species of Salmo have fewer vertebrae than those from western North America but suggested caution in the use of such a character for identifying trout populations. Hart (1937a) pointed out that the female capelin, Mallotus villosus, averages 0.50 vertebra more than

the male. In experimental work with Fundulus heteroclitus, Gabriel (1944) found the vertebral count inversely proportional to the temperture of the water during development and that the progeny of parents with high counts averaged higher counts than the progeny of parents with low counts. Extensive studies on vertebral variation in marine teleostean fishes were conducted by Ford (1937, 1941, 1946). Hubbs and Lagler (1947) used vertebral counts as a key character in the identification of whitefish.

Probably one of the first to employ roentgenography in the study of meristic characters in fish was Gosline (1947). In 1948, he published a paper entitled, "Some Possible Uses of X-rays in Ichthyology and Fishery Research". There he stated that vertebral counts might prove valuable in taxonomic work at the species and race level.

Snyder (1949) considered differences in the mean number of vertebrae significant in separating four species of the family Catostomidae. Tester (1949) did an intensive study of herring populations along the west coast of Vancouver Island and also found significance in mean vertebral counts. Clothier (1950) utilized vertebral counts in the construction of a key to some marine fishes of Southern California. Experimentation on the influence of temperature on the number of vertebrae in fishes was conducted by Tester, and in 1950 he stated:

> "Our experiments have thus produced modifications (comparable to the so-called phenocopies) among offspring of the same parents, which systematists of a generation ago would presumably have taken for separate species, if their origin had been unknown."

Tester and Hiatt (1952) used variation in vertebral number to determine groups or races of anchovies in Hawaiian waters. They also reported a

lack of significant variation between sexes.

One of the more recent studies of note was made by Bailey and Gosline (1955) on the family Percidae. They concluded that average vertebral counts would have taxonomic value for certain groups but their use would be limited in the darters where extensive overlapping of counts occurs. Moffett (1957) followed Clothier's example with the incorporation of vertebral counts into a key to some southern Florida marine fishes.

No extensive work appears to have been done on the Cottidae from the time Girard (1851) published his monograph until Robins (1954) presented his doctoral dissertation on "A Taxonomic Revision of the Cottus bairdi and Cottus carolinae Species Groups in Eastern North America (Pisces, Cottidae)". Robins dealt entirely with such external characters as fin ray counts, lateral line pores, operculomandibular pores, body coloration patterns, and the anal papilla in the male. Except for the kumlieni material and a few scattered stream collections of bairdi, he ignored the Ohio sculpin populations.

Purpose

This present study was undertaken to determine whether there is a significant degree of difference between the average vertebral count of the Central Redfin Sculpin, Cottus bairdi bairdi Girard, and the Northern Redfin Sculpin, Cottus bairdi kumlieni (Hoy), as they occur in Ohio waters. Due to the small numbers of Cottus bairdi kumlieni available in the Ohio collection, the study was extended to include Michigan collections. Since the Cottus bairdi complex displays considerable variation in external morphology from population to population and often

from individual to individual, it was hoped that this investigation would contribute a useful taxonomic tool.

MATERIALS AND METHODS

All Ohio specimens examined were loaned by the Ohio State Museum and were from the collections of the Ohio State Museum and the Ohio State University. Used in this study were 369 specimens of Cottus bairdi bairdi and 17 specimens of Cottus bairdi kumlieni taken from Ohio waters.

The University of Michigan Museum of Zoology supplied the Michigan material. From the Michigan collections, 54 specimens of Cottus bairdi bairdi and 274 specimens of Cottus bairdi kumlieni were used, making the combined totals of 423 bairdi and 291 kumlieni.

A Keleket "Cadet" Portable X-ray Unit was employed. Roentgenographs taken at 10 milliamperes and 40 kilovolts with a distance of 36 inches from the tube aperture to the film plate were satisfactory. The time of the exposure was varied from 2.5 seconds to 8.0 seconds depending upon the size of the specimens, the largest specimens requiring the longest exposure.

All of the roentgenographs were taken on individually wrapped 8 1/2 x 11 inch sheets of Ansco Non-screen X-ray Film. This film was found to be too coarse-grained for successful use with very small specimens. Therefore, no specimens under 30 millimeters in length were used.

A sheet of thin plastic was placed between the fish and the film envelope to protect the film from moisture. To economize on both time and film, the specimens were arranged in rows and nearly touching each other. Strips cut from lead foil were placed between fish from different collections. These furnished clear areas on the developed film where identification data were later written. Careful records were kept

giving the location of each collection on each film sheet. After being developed and properly labeled, the films were cut into strips between specimen rows.

Counting was accomplished by using a binocular dissection microscope and transmitted light in examining the roentgenograph negatives. All counts reported in this paper start with the most anterior vertebra and end with the penultimate, the last vertebra anterior to the urostyle (cf. Figure 1). Each specimen was counted at least twice. Individuals which exhibited abnormalities of the vertebral column were included in the tabulations only when there was no question about the actual number of vertebrae present. In all cases where there was any doubt, the specimens were discarded.

In this study the specimens were treated as population units. No attempt was made to separate groups according to sex or size. The vertebral counts were not divided into abdominal, precaudal and caudal areas.

All Ohio material used was identified by Dr. Milton Trautman, Curator of Vertebrate Collections, the Ohio State Museum. The Ohio kumlieni specimens were also identified by Robins. Unless otherwise indicated, Robins identified the Michigan collections.

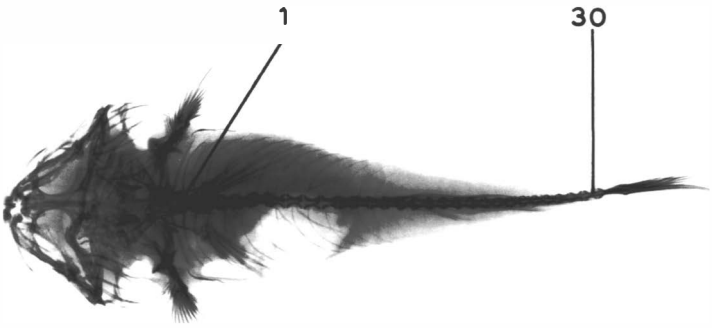

FIGURE 1: X-RAY POSITIVE WITH FIRST AND LAST VERTEBRAE LABELED. (COTTUS B. BAIRDI, O.S.U. 7113).

COTTUS BAIRDI BAIRDI GIRARD, THE CENTRAL REDFIN SCULPIN.

Description

According to Robins the following characters are diagnostic for bairdi: incomplete lateral line with 20 - 24 pores and extending to a point nearer the posterior end than the middle of the dorsal fin base; 11 pores in the operculomandibular canal; upper preopercle spine always present and well developed, second spine reduced to a protuberance, third spine often absent, all three spines present in lake forms; anal papilla in male enlarged as a flat triangular process which reaches to the origin of the anal fin; three well marked dorsolateral bands are regularly present on the body.

Range

Robins gives the following range for the Central Redfin Sculpin:

> "C. b. bairdi occurs from the inlet valley of Cayuga Lake and tributaries of Lake Erie in the Northeast westward through southeastern Michigan, Wisconsin, and southern Minnesota, southward to northern Illinois, central Indiana and the Licking, Big Sandy and New Rivers of Kentucky, West Virginia, Virginia and North Carolina. On the Atlantic slope it occurs from the Patapsco to the Roanoke Rivers. Isolated populations have been found in the Sequatchie and Tennessee Rivers in Tennessee and Alabama, the Niangua River in Missouri and the Upper Missouri River in Montana and Wyoming."

Trautman (1957) reported populations of bairdi from 46 of Ohio's 88 counties. The distribution forms a broad, north-south diagonal band across the center of the state with scattered populations in the northwest corner in Williams, Fulton, and Defiance Counties.

Ohio Collections

Material from 29 counties was available (cf. Figure 2). Vertebral counts were made from 369 specimens representing lake, river and creek

populations. No consistent differences in number of vertebrae were noted among these three ecological groupings.

Table I shows the frequency distribution and means of the Ohio bairdi populations studied. The actual number of vertebrae in individuals ranged from 26 in a single specimen from Erie County to 32 in specimens from Champaign, Logan, Ottawa and Portage Counties. The arithmetical mean for the entire Ohio group was 30.40 vertebrae and the sample variance was 0.485. By counties, the lowest mean count was 28.75 based upon 4 specimens from Carroll County in the east-central part of the state. Vinton County in southern Ohio had the highest mean for the state with 31.00 vertebrae, also based upon four specimens. Adams, Butler and Jefferson Counties had mean counts of 31.00, but only one specimen was available from each.

Michigan Collections

Three collections of Michigan bairdi from three counties and representing creek and lake habitats were used (cf. Figure 2). Collection UMMZ 116840 carried a label marked kumlieni, but Robins identified the lot as bairdi in his dissertation. It was, therefore, included with the bairdi material in this study. The other two collections were from southern Michigan and well within the range assigned to bairdi.

The results of the vertebral counts for these 54 specimens are given in Table II. A mean of 30.66 and a variance of 0.339 were calculated. The lowest count recorded was 29 vertebrae for one sculpin from Lenawee County. The high count of 32 vertebrae was found in two of the three populations.

TABLE I

FREQUENCY DISTRIBUTION OF VERTEBRAL COUNTS

IN OHIO SPECIMENS OF COTTUS BAIRDI BAIRDI GIRARD

COUNTY	NUMBER OF VERTEBRAE									NO.	MEAN
	26	27	28	29	30	31	32	33	34		
ADAMS						1				1	31.00
ASHLAND					7	4				11	30.36
AUGLAIZE					2					2	30.00
BUTLER						1				1	31.00
CARROLL			2	1	1					4	28.75
CHAMPAIGN				3	29	21	1			54	30.37
COLUMBIANA					5					5	30.00
DARKE					3	1				4	30.25
ERIE	1			1	7	2				11	29.72
FRANKLIN					3	1				4	30.25
FULTON					3	2				5	30.40
GREEN					3	1				4	30.25
HOCKING				1	7	2				10	30.10
HOLMES					4	3				7	30.42
JEFFERSON						1				1	31.00
KNOX					2					2	30.00
LOGAN				3	28	28	2			61	30.33
LORAIN				1	7	5				13	30.30
MORROW					6	6				12	30.50
OTTAWA					18	33	7			58	30.81
PIKE					3	1				4	30.25
PORTAGE					2	12	1			15	30.93
PREBLE					7	8				15	30.53
RICHLAND				2	18	9				29	30.24
SENACA				1	6	6				13	30.38
STARK				3	13					16	29.81
TUSCARAWAS				2						2	29.00
VINTON						4				4	31.00
WILLIAMS					1					1	30.00
TOTALS	1	-	2	18	185	152	11	-	-	369	30.40

TABLE II

FREQUENCY DISTRIBUTION OF VERTEBRAL COUNTS

IN MICHIGAN SPECIMENS OF COTTUS BAIRDI BAIRDI GIRARD

COUNTY	NUMBER OF VERTEBRAE									NO.	MEAN
	26	27	28	29	30	31	32	33	34		
LENAWEE				1	3	11	1			16	30.75
ST. CLAIR					2	1				3	30.33
WASHTENAW					13	21	1			35	30.65
TOTALS	-	-	-	1	18	33	2	—	—	54	30.66

COTTUS BAIRDI KUMLIENI (HOY), THE NORTHERN REDFIN SCULPIN

Description

Diagnostic characters are listed by Robins for this subspecies as the following: incomplete lateral line with 13 to 18 pores; 10 pores in the operculomandibular canal; upper preopercular spine well developed, second and third spines not noticeable externally; anal papilla in male enlarged as a flat, triangular process tapering to a rounded, terminal filament which often exceeds the length of the first anal ray; dark anterior saddle marking never present; strongly contrasting ventrolateral mottling which is best developed as an irregular series of small dark blotches on the sides above the anal fin.

Range

According to Robins, the Northern Redfin Sculpin occupies the following range:

> "C. b. kumlieni occurs from Labrador and tributaries of the St. Lawrence River in the Northeast westward through the tributaries of Hudson Bay to at least the Lake Winnipeg Region. To the south it ranges as far as the Finger Lakes in New York, Lake Erie, to the approximate latitude of Green Bay and Big Sable Point in Lake Michigan and through the tributaries of Lake Superior in the west. Specimens from central and southern Lake Michigan are designated as intergrades ..."

In Ohio, kumlieni has been taken only along the Lake Erie shore of Ashtabula County.

Ohio Collections

Only 17 specimens of Cottus bairdi kumlieni from Ohio waters were available for study. These were taken in three collections made during the winter months from the shore of Lake Erie, Ashtabula County (cf. Figure 2). The frequency distribution of vertebral counts for these

specimens is given in Table III. The mean count is 31.88 and the sample variance is 0.360.

Michigan Collections

The Michigan specimens of Cottus bairdi kumlieni numbered 274 individuals collected from eight counties. Populations from Lake Huron, Lake Superior and inland streams were represented (cf. Figure 2).

All collections except two, UMMZ 70492 and UMMZ 164248, had been identified as kumlieni by Robins. The museum jar labels for UMMZ 70492 and UMMZ 164248 listed those collections as bairdi. However, the vertebral counts were found to run exceptionally high (mean 32.07 and mean 32.45) when compared to the counts made from other bairdi material. A check on the external morphology favored kumlieni, but this was not as conclusive as desired. Since collection UMMZ 70492 was taken from the Au Sable River from which Robins lists another collection (UMMZ 65733) as kumlieni, it was considered reasonable to include the vertebral counts of collection UMMZ 70492 with the kumlieni data. Collection UMMZ 164248 from the Pine River, Chippewa County, was obtained well within the range Robins assigned to kumlieni, and, on that basis, was also included with kumlieni in this investigation.

As is shown in Table IV, the vertebral counts for the Michigan kumlieni ranged from 30 to 34 with a mean value of 31.86. A variance of 0.476 was calculated.

TABLE III

FREQUENCY DISTRIBUTION OF VERTEBRAL COUNTS

IN OHIO SPECIMENS OF COTTUS BAIRDI KUMLIENI (HOY)

COUNTY	NUMBER OF VERTEBRAE									NO.	MEAN
	26	27	28	29	30	31	32	33	34		
ASHTABULA	-	-	-	-	-	4	11	2	-	17	31.88

TABLE IV

FREQUENCY DISTRIBUTION OF VERTEBRAL COUNTS

IN MICHIGAN SPECIMENS OF COTTUS BAIRDI KUMLIENI (HOY)

COUNTY	NUMBER OF VERTEBRAE									NO.	MEAN
	26	27	28	29	30	31	32	33	34		
CHEBOYGAN						2	1			3	31.33
CHIPPEWA						2	8	12		22	32.45
IOSCO						2	5	7		14	32.07
MENOMINEE					2	25	29	7	1	64	31.88
LAKE						9	36	2		47	31.85
MARQUETTE						32	21	4		57	31.50
OSCODA						4	47	12		63	32.11
ST.MARYS RIVER						3	1			4	31.25
TOTALS	-	-	-	-	2	79	148	44	1	274	31.96

STATISTICAL ANALYSIS OF DATA COLLECTED

The "Students t-Test" for the comparison of mean values was used (Ostle, 1954:98;451). Three hypotheses were tested.

Hypothesis I: the mean of the Ohio *bairdi* sample equals the mean of the Michigan *bairdi* sample (30.40 = 30.66). Result of t-Test: t = 2.98; therefore, if the means are equal, the means of the two groups could be expected to vary by 0.26 about 23 per cent of the time. The hypothesis was accepted.

Table V shows the frequency distribution of the combined vertebral counts for the Ohio and Michigan *bairdi*. A variance of 0.473 and a mean of 30.43 were calculated.

Hypothesis II: the mean of the Ohio *kumlieni* sample equals the mean of the Michigan *kumlieni* sample (31.88 = 31.86). Result of t-Test: t = 0.13; therefore, if the means are equal, the means of the two groups could be expected to vary by 0.02 at least fifty per cent of the time. The hypothesis was accepted.

The frequency distribution of the combined vertebral counts for the Ohio and Michigan *kumlieni* is given in Table VI. For these combined data a mean of 31.86 and a variance of 0.360 were calculated.

Hypothesis III: the mean of the combined *bairdi* data equals the mean of the combined *kumlieni* data (30.43 = 31.86). Result of t-Test: t = 28.03; therefore, if the means are equal, the means of the two groups could be expected to vary by 1.43 less than five per cent of the time. The hypothesis was rejected.

TABLE V

FREQUENCY DISTRIBUTION OF VERTEBRAL COUNTS

IN ALL SPECIMENS OF COTTUS BAIRDI BAIRDI GIRARD

STATE	NUMBER OF VERTEBRAE									NO.	MEAN
	26	27	28	29	30	31	32	33	34		
OHIO	1	-	2	18	185	152	11	-	-	369	30.40
MICHIGAN	-	-	-	1	18	33	2	-	-	54	30.66
TOTALS	1	-	2	19	203	185	13	-	-	423	30.43

TABLE VI

FREQUENCY DISTRIBUTION OF VERTEBRAL COUNTS

IN ALL SPECIMENS OF COTTUS BAIRDI KUMLIENI (HOY)

STATE	NUMBER OF VERTEBRAE									NO.	MEAN
	26	27	28	29	30	31	32	33	34		
OHIO	-	-	-	-	-	4	11	2	-	17	31.88
MICHIGAN	-	-	-	-	2	79	148	44	1	274	31.86
TOTALS	-	-	-	-	2	83	159	46	1	291	31.86

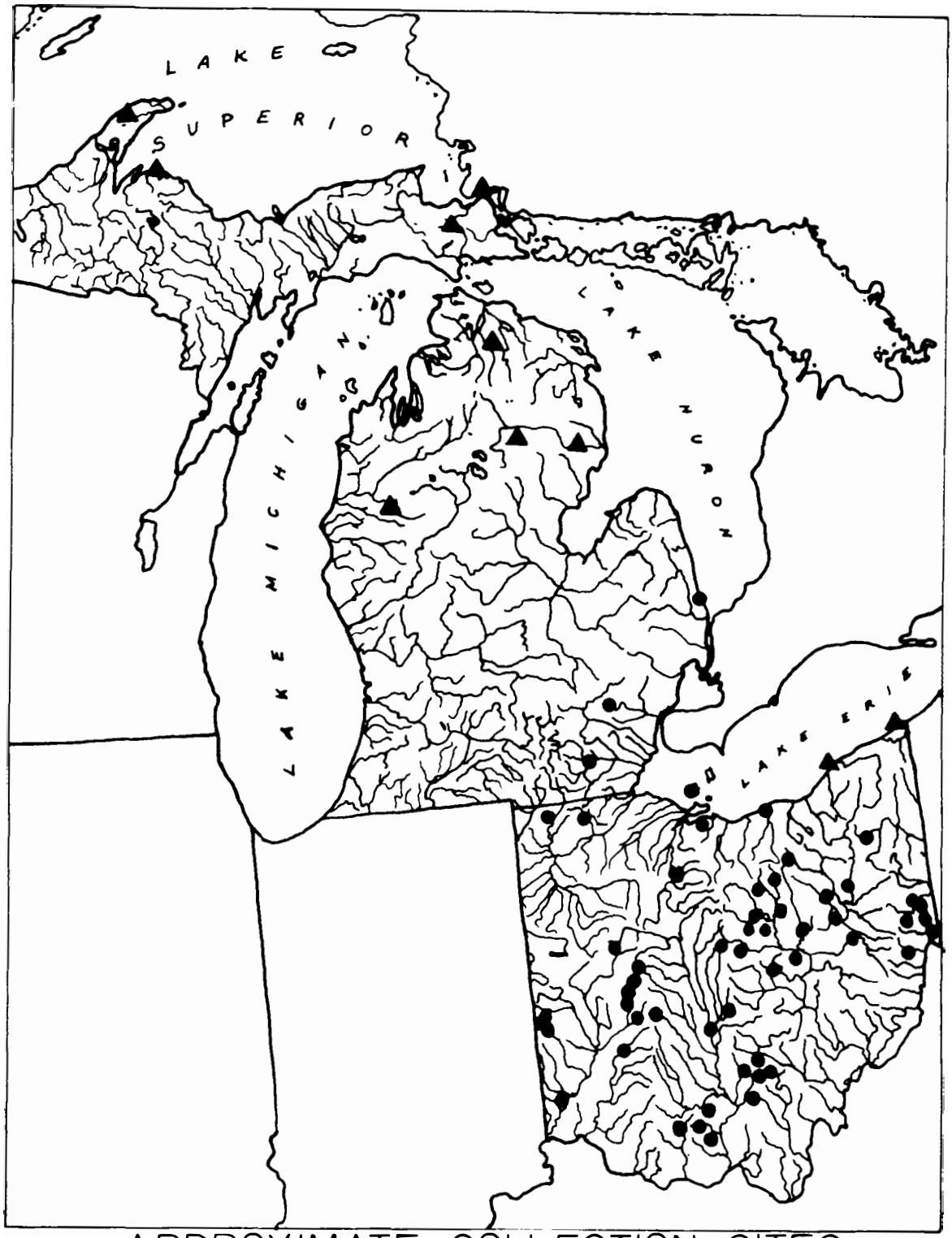

FIG. 2 APPROXIMATE COLLECTION SITES

● COTTUS BAIRDI BAIRDI GIRARD

▲ COTTUS BAIRDI KUMLIENI (HOY)

DISCUSSION

The data gathered from this study reveal a difference in the mean vertebral counts of the subspecies Cottus bairdi bairdi Girard and Cottus bairdi kumlieni (Hoy). The significance of this difference and the factor or factors responsible are open to speculation.

In his introduction Robins warned:

> "Variation within a species often exceeds or masks the differences between species when meristic counts alone are considered. Particularly this is true, if the species are wide-ranging and show geographic differentiation. In this respect, it is unwise to place little known nominal forms in synonymies or to treat them as conspecific on the basis of similar meristic counts."

Later, he continued:

> "When considered in terms of hundreds of years it seems likely that populations of Cottus are periodically decimated by environmental catastrophes. Populations are then reestablished by relatively few individuals which exhibit only a portion of the variability of the subspecies or species. The populational differences which ensue are not due to new mutations but to segmentation and random fixation of the existing variability . . . Moreover, characters which do seem to be environmentally influenced, such as prickling, show consistant or recognizable differences from area to area on a local basis. Intensive study of Cottus b. bairdi at a populational level would lead to the recognition of almost all populations as racially or subspecifically distinct if such differences were emphasized. To do so would hopelessly burden the nomenclature and confuse the picture of evolution and differentiation within the form."

The mean vertebral counts of the Ohio bairdi populations (cf. Table I) support the above concepts. If one were to compare only the Vinton County data (mean 31.00; 4 specimens) with the Carroll County data (mean 28.75; 4 specimens), an entirely different conclusion would likely be reached than when populations covering the total state range

are studied. If material were available from more areas, presumedly the same could be said about the Michigan bairdi.

The Ohio kumlieni collection is much too small to undergo a detailed analysis. However, the mean does vary considerably from the means of the Ohio and Michigan bairdi and compares favorably with the mean of the Michigan kumlieni.

When the high mean and low mean populations of the Michigan kumlieni are compared (cf. Table IV), the conclusion drawn is likely to be quite different from that of a more extensive study. With this and the Ohio bairdi data in mind, it is suggested that mean vertebral counts may be of taxonomic value in the Cottus bairdi bairdi - Cottus bairdi kumlieni complex only in reasonably large-scale investigations where data from many areas throughout the ranges of the subspecies are available.

Through the years, several factors have been suggested as possible causes for the variation of vertebral counts found in many teleostean fishes. The concept of a south to north increase has been found to apply in certain marine forms but does not appear to be an important factor within either subspecies in this study. Closely allied with changes in latitude are changes in temperature. Several investigators have uncovered positive evidence that the influence of water temperature during embryonic development is expressed in the mean vertebral count of a fish population. Just how great a role microclimate has played in the bairdi and kumlieni populations studied is open to conjecture. McHugh (1954), experimenting with the grunion, reported an inverse relationship between the mean vertebral count and the amount of light during develop-

ment of the embryos. No data on the effects of light intensity on quantitative vertebral development in the Cottus bairdi groups are available at this time. In the absence of experimental evidence, it seems best to agree with Tester (1949) who wrote:

> ". . . each group of young representing the progeny of a spawning taking place at a certain time and place must be considered to have a unique mean count, of which the general numerical value is set by hereditary factors and the exact numerical value is largely determined by environmental conditions pertaining at that time and place."

Robins reported "obvious intergradation" of the bairdi and kumlieni subspecies in southern Lake Michigan. Trautman (1957) suggested that intergradation might be taking place in Lake Erie. No supporting evidence for intergradation has resulted from the X-ray examination of the South Bass Island shore populations. The mean count for this area was 30.81 vertebrae. Several inland stream collections had higher mean counts. An examination of deep water specimens might give more conclusive data. In discussing the intergradation problem, Robins stated,

> "It has been difficult to evaluate single specimens . . . which appear in many samples throughout the southern Great Lakes Region. Are they extremes of the sample or do they indicate that occasional strays of the one form enter the range of the other without interbreeding? It seems that bairdi and kumlieni may interbreed in one area and act as different species in a neighboring locality."

The only known specimens of Ohio kumlieni were collected along the Lake Erie shore of Ashtabula County in winter. This suggests that the Lake Erie form is a deep water fish which enters shallow waters only during the winter months. True bairdi specimens are relatively abundant in the shallow shore waters of Ottawa and Erie Counties and the Bass Islands. No unquestionable hybrids have been identified. Perhaps in

Lake Erie, bairdi and kumlieni are separated by a difference in spawning sites and are behaving as distinct species.

Before any definite taxonomic value can be assigned to vertebral counts in the bairdi - kumlieni complex, there must be an understanding of the environmental plasticity and hereditary limits of this character as it is expressed in this group.

SUMMARY

1. An investigation was conducted of variation in vertebral counts in 423 specimens of Cottus bairdi bairdi Girard and 291 specimens of Cottus bairdi kumlieni (Hoy) from Ohio and Michigan waters.
2. The vertebral counts were made from roentgenograph negatives.
3. The 369 Ohio bairdi specimens had a mean vertebral count of 30.40.
4. The 54 Michigan bairdi specimens had a mean vertebral count of 30.66.
5. The combined 423 bairdi specimens had a mean vertebral count of 30.43.
6. The 17 Ohio kumlieni specimens had a mean vertebral count of 31.88.
7. The 274 Michigan kumlieni specimens had a mean vertebral count of 31.86.
8. The combined 291 kumlieni specimens had a mean vertebral count of 31.86.
9. The data gathered from this study reveal a difference in the mean vertebral counts of the subspecies Cottus bairdi bairdi Girard and Cottus bairdi kumlieni (Hoy).
10. The significance of this difference and the factor or factors causing it are open to speculation.
11. It is suggested that bairdi and kumlieni are behaving as distinct species in Lake Erie.
12. Experimental evidence about the hereditary limits and environmental plasticity of vertebral counts in the bairdi - kumlieni complex is needed.

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APPENDIX

Museum numbers and locality data are given here for all specimens used in this study. Those indicated as OSU are in the Ohio State University collection, and those marked OSM are in the collection of the Ohio State Museum. UMMZ designates collections from the University of Michigan Museum of Zoology.

Cottus bairdi bairdi Girard:

Ohio:

Adams Co. - OSM F424: Near Prebeles, 1928.

Ashland Co. - OSU 540: Clear Fork, Hanover Twp., Sept. 9, 1939; OSU 4-138: Katatowa Cr., Montgomery Twp., June 20, 1939; OSM F176: Clear Fork, Hanover Twp., Sept. 22, 1928; OSU 4-183: Orange Cr., Orange Twp., July 26, 1939.

Auglaize Co. - OSU 4613: Willow Cr., Sec. 10, Clay Twp., July 24, 1941.

Butler Co. - OSM F60-1: Paddy's Run, Morgan Twp., July 26, 1927.

Carroll Co. - OSM F185: Big Sandy Cr. at Minerva, Sept. 23, 1928.

Champaign Co. - OSU 5997: Cedar Run, Cedar Swamp, May 15, 1938; OSU 4787: Buck Cr., Sec. 30, Union Twp., April 18, 1942; OSU 4780: Little Darby Cr., Goshen Twp., April 17, 1942; OSU ? (Nat. Res. Coll. T-39-6A): Macochee Cr., Salem Twp., July 10, 1939.

Columbiana Co. - OSU 4953: Bull Cr., Sec. 29, Unity Twp., May 11, 1942; OSU 5331: Little Bull Cr., Sec. 5, Middleton Twp., May 12, 1942; OSU 651: W. Fk. Lit. Beaver Cr. at mouth, Sec. 2, St. Clair Twp., Sept. 28, 1939; OSU 706: Mid. Fk., Lit. Beaver Cr. at McKinley Crossing, Center Twp., Sept. 28, 1939; OSU 2068: Big Bull Run, Middleton Twp., May 22, 1940.

Darke Co. - OSM F573: Small trib. Whitewater R., Harrison Twp., July 20, 1930.

Erie Co. - OSU 3063: Cold Cr., Margaretta Twp., Sept. 21, 1925; OSU 2026: L. Erie at mouth Vermillion R., Vermillion Twp., Apr. 19, 1940; OSU 2854: Cold Cr., Margaretta Twp., July 28, 1940.

Franklin Co. - OSM F147-1: Plum Run, Jackson Twp., Sept. 6, 1927; Broad St. Dam, Blacklick, Sept. 18, 1945.

Fulton Co. - OSU 3188: Mill Cr., Sec. 36, Gorham Twp., May 16, 1941.

Greene Co. - OSU 6020: Beaver Cr., Sect. 21, Nov. 7, 1938.

Hocking Co. - OSM F191: Salt Cr. Trib., Benton Twp., Oct. 14, 1928; OSM F195: Clear Cr. at mouth, Good Hope Twp., Oct. 14, 1928; OSU 7217: Salt Cr., Salt Cr. Twp., April 9, 1947; OSU 2051: Queer Cr., E. Benton Twp., May 3, 1940.

Holmes Co. - OSM F371: Killbuck Cr. trib., Richland Twp., August 24, 1929; OSU 2211: Killbuck Cr., Oct. 4, 1940.

Jefferson Co. - OSU 6350: Brush Cr., Sec. 36, Saline Twp., May 8, 1944.

Knox Co. - OSM F175: Little Jelloway Cr., Sept. 22, 1928.

Logan Co. - OSU 4770: Mac-o-chee Cr. at Mac-o-chee Castle, S. W. Monroe Twp., Apr. 6, 1942; OSU 4764: Mad R., N. Monroe Twp., Apr. 6, 1942; OSU 5777: Mad R., N. Monroe Twp., Apr. 26, 1943; OSU 6535: Mad R., Southernmost Twp., March 28, 1945; OSU 6037: Mad R., 1 1/2 miles N. of West Liberty, Liberty Twp., May 6, 1939; OSU 2104: Mad R., SE Liberty Twp., May 30, 1940; OSU 4753: Mad R. at falls, Jefferson Twp., Apr. 6, 1942.

Lorain Co. - OSM F163: Black R., Brighton Twp., Sept. 14, 1928.

Morrow Co. - OSM F255: Alum Cr. trib., Lincoln Twp., May 12, 1929;

OSM F257; Kokosing R. at Chesterville, May 12, 1929; OSU 6588; E. Br. Whetstone Cr., Washington Congress Twp., Aug. 23, 1945.

Ottawa Co. - OSU 8821; Lake Erie, Hatchery Bay, South Bass Is., November 15, 1948; OSU 7126; Lake Erie, Hatchery Intake, South Bass Is., January 15, 1947; OSU 7168; Lake Erie, Squaw Harbor, South Bass Is., March 25, 1947; OSU 7736; Lake Erie, South Bass Is., January 2, 1948; OSU 6737; Fox's Dock, Put-in-Bay Harbor, South Bass Is., February 12, 1946; OSU 7113; Lake Erie, Hatchery Bay, South Bass Is., March 7, 1947; OSU 7107; Lake Erie, Peach Point, Gibralter Is., March 25, 1947.

Pike Co. - OSU 2822; Barn Hollow, Benton Twp., July 18, 1939; OSM F249-11; Camp Cr., Camp Creek Twp., Apr. 21, 1929; OSU 2100; Chenoweth's Fork, Sunfish Twp., May 29, 1940.

Portage Co. - F422; 1928; OSM F180; Sand Cr., Windham Twp., Sept. 28, 1928.

Preble Co. - OSU 4814; E. Fk. Whitewater R., Sec. 30, Jefferson Twp., Apr. 20, 1942; OSU 4801; E. Fk. Whitewater R. at New Paris, E. Jefferson Twp., Apr. 20, 1942.

Richland Co. - OSM F261; Clear Fork at Bellville, May 19, 1929; OSU 2055; Opossum Run, N. Worthington Twp., May 5, 1940; OSU 3114; Opossum Run, Washington Twp., June 9, 1936.

Seneca Co. - OSU 7972; Sugar Cr., July 19, 1948.

Stark Co. - OSU 9254; W. Br. Nimishillen Cr., Aug. 17, 1949; OSU 4259; Pigeon Run Cr., Tuscarawas Twp., Aug. 2, 1941.

Tuscarawas Co. - OSM F395; Sugar Cr., Franklin Twp., Sept. 8, 1929.

Vinton Co. - OSM F309; Middle Branch, Pigeon Cr., Allensville, June

30, 1929.

Williams Co. - OSU 1069: W. Br., St. Joe River, Bridgewater Twp., Oct. 24, 1939.

Michigan:

UMMZ 81559: Mallet Cr., Washtenaw Co., August 10, 1927.

UMMZ 89574: Clear Springs Cr., Lenawee Co., April 5, 1927.

UMMZ 116840: N. of Lakeport, St. Clair Co., August 7, 1937.

Cottus bairdi kumlieni (Hoy):

Ohio:

OSU 5962: Conneaut, in harbor, Ashtabula Co., November 11, 1943.

OSU 6810: Conneaut Hbr., N. E., Conneaut Twp., Ashtabula Co., March 26, 1946.

OSU 6808: Mouth Cowles Cr., N. Geneva Twp., Ashtabula Co., March 25, 1946.

Michigan:

UMMZ 65563: Near Mouth of Big Cr., Oscoda Co., July 22, 1924.

UMMZ 70492: Au Sable R., Iosco Co., September 4, 1924.

UMMZ 81628: Rush Lake, Marquette Co., June 30, 1927.

UMMZ 117613: St. Mary R., opp. Sugar Island, Ontario, August 21, 1930.

UMMZ 126056: Green's Cr., Cheboygan Co., July 17, 1939.

UMMZ 133369: Eliza Cr., Keweenaw Co., August 3, 1926.

UMMZ 164130: Pine R. above Lincoln Bridge, T20N, R 12W, Sec. 13, Lake Co., Sept. 4, 1952.

UMMZ 164248: Pine R., T45N., R 5W., Sec. 33, Chippewa Co., July 10, 1952.