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Department of Biology

January 31, 1974

Michael Dombeck
Route 2, Box 287
Stevens Point, Wisconsin 54481

Dear Mike,

This is to officially inform you that your graduate committee consists of G. C. Becker, Chairman; F. A. Copes and D. D. Post. R. Wood of Education will be an outside reader but not a committee member. It is my preference that at the time of your thesis defense that some time be donated to the course work aspect of comprehensive examinations. Please check with G. C. Becker for his approval of such an oral examination.

Good luck in the remainder of your degree.

Sincerely,

V. A. Thiesfeld

V. A. Thiesfeld, Chairman
Department of Biology

VAT:sn

cc: G. C. Becker
F. A. Copes
D. D. Post
R. Wood

PROPOSAL FOR BIOLOGY 799 RESEARCH

The meristic characteristics of fishes are the countable and serially repeated characteristics. Meristic characters are of interest to both the fishery biologist and systematic ichthyologist. Variation in meristic characters is utilized in the classification of fishes (Hubbs, 1934; Lagler, et. al., 1962; and Buchanan, 1973). The variation in mean meristic counts aids the fishery biologist in determining races, subpopulations, and populations of fish (Heuts, 1949; Mchugh, 1954; and Vladykov, 1960).

Ichthyologists once thought that significant meristic differences between populations of fish were due to genetic differences between populations. The thought then followed that differences in meristic characters between populations were probably due to environmental effects on gene action unless a genetic basis for the differences could be demonstrated experimentally. It is now believed, especially for fish with disjunct populations, that morphological clines are due to environmental modification of gene action coupled with actual genetic difference (Barlow, 1961 and Fowler, 1970).

MATERIALS, METHODS, AND INTERPRETATIONS

I propose to enumerate the following meristic characters; vertebrae, dorsal fin spines and rays, anal fin spines and rays, pectoral rays, body bars, and lateral line scales. Three regional populations of the rainbow darter, Etheostoma caeruleum will be analyzed. Approxmately 100 specimens from each of the following areas will be examined; Great Lakes Drainage Basin of Wisconsin, Mississippi River Drainage Basin of Wisconsin, and the Mississippi River Drainage Basin of Arkansas. Two or more subpopulations will be included in each of the three regional areas.

I have collected specimens of Etheostoma caeruleum from Northwestern Arkansas. Museum specimens will be used representing the Mississippi River Drainage Basin of Wisconsin. If museum specimens of E. caeruleum from the Great Lakes Drainage Basin of Wisconsin can not be acquired they will be collected.

Meristic characters will be enumerated with the aid of a binocular microscope. X-ray photography will also be used to expedite the enumeration of certain characters.

Results of meristic counts will be graphed traditionally and statistically analyzed by analysis of variance utilizing the IBM, Fortran IV computer.

If significant differences are found I hope to try to correlate the differences with possible environmental difference and/or allopatry and evolutionary trends due to a north-south and/or east-west clines. Should homogeniety be found a stable species will be affirmed.

OBJECTIVES

1. To affirm homogeniety or heterogeniety due to regional meristic variation in Etheostoma caeruleum.
2. To affirm homogeniety or heterogeniety due to local meristic variation in Etheostoma caeruleum
3. To attempt to determine possible causes of variation should they exist.
4. To become a more critical, comprenhesive, and efficient researcher.
5. To become a more competent biologist.
6. To produce a publishable thesis.

Approved:

George C. Becker
Professor of Biology

LITERATURE CITED

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MERISTIC VARIATION OF THE RAINBOW DARTER,

ETHEOSTOMA CAERULEUM, (STORER)

BY

MICHAEL PAUL DOMBECK

A thesis submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE IN TEACHING
(Biology)

at the

University of Wisconsin-Stevens Point

May 1974

Approved:

George C. Becker, Ph.D.

Frederick A. Copes, Ph.D.

Douglas D. Post, Ph.D.

ACKNOWLEDGMENTS

I wish to express my appreciation to Dr. George C. Becker for his suggestions and assistance throughout this study and for his guidance in the preparation of this thesis. I wish to thank Dr. Frederick C. Copes and Dr. Fred Hilpert for their guidance in the statistical analysis involved in this study. Special thanks are due to Dr. Douglas D. Post and the Biology Staff at the University of Wisconsin-Stevens Point for their advice and encouragement throughout the course of this study. I wish to thank Fran Komarmy for the typing of this manuscript and her helpful suggestions.

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INTRODUCTION

Many species, subspecies, races, and populations of fishes are described on the basis of anatomical features. The meristic characters of fishes are the countable and serially repeated characters such as: vertebrae, fin rays, fin spines, and scales. Variation in meristic characters is utilized in the classification of fishes (Schmidt, 1917; Hubbs, 1934; Schaffer, 1952; Mc Hugh, 1954; Vladykov, 1954; Bailey and Gosline, 1955; Weisel, 1961; Lagler, et. al., 1962; Buchanan, 1973; and Wallace, 1973). The variation in mean meristic counts aids the fishery biologist in determining races, populations, and subpopulations of fishes (Heuts, 1949; Mc Hugh, 1954; Vladykov, 1960; and Bryan, 1969).

Interest in the study of meristic variation followed the appreciation of racial studies. Racial studies are useful to the fishery biologist and ichthyologist in determining life histories, migrations and movements, feeding habits, and ranges of populations of fishes.

Ichthyologists once thought that significant meristic differences between populations of fish were due to genetic differences between populations. The thought then followed that differences in the numbers of meristic elements between populations were probably due to environmental effects on gene action unless a genetic basis for the differences could be demonstrated experimentally (Tåning, 1952). It is now believed, especially for fishes with disjunct populations, that morphological clines are due to environmental modification of gene action coupled with actual genetic differences (Barlow, 1961 and Fowler, 1970).

The rainbow darter, Etheostoma caeruleum (Storer), is a wide ranging species and was first recognized as a species by Storer in 1848 (Knapp, 1964). It is found in parts of the Mississippi River system to Northern Alabama, in the Ohio River system, and parts of the Great Lakes drainage basin of the United States and Canada. Populations of the rainbow darter are also found in the upper St. Lawrence and Ottawa River systems of Quebec (Hubbs and Lagler, 1958).

The rainbow darter commonly inhabits cool, clear water streams, preferring the fast-flowing waters of stony or gravelly riffles (Scott, 1967).

The objective of this study is to determine the homogeneity or heterogeneity of eight populations of the rainbow darter, Etheostoma caeruleum, from four different geographic regions. This study is based on the analysis of ten meristic elements of 340 rainbow darters ranging from Arkansas to Ontario.

This investigation, carried out with the cooperation of the University of Wisconsin-Stevens Point under the direction of Dr. George C. Becker, Professor of Biology, involves four phases:

1. Procurement of specimens of Etheostoma caeruleum (Storer).
2. Laboratory analysis involving x-raying specimens and the counting of meristic elements.
3. The statistical analysis of meristic characters.
4. The interpretation of results.

Most of the literature survey was done at the University of Arkansas and University of Wisconsin-Madison libraries.

Origin of Samples

Eight collections of the rainbow darter were obtained from four different geographic regions (Table 1). All collections will be referred to by sample number (Table 1) in the following discussion and analysis.

Samples one and two were obtained by conventional seining using a 10 foot nylon seine with ¼ inch mesh. The seine was placed in the chute of a riffle while the rubble and gravel were kicked and disturbed upstream. The current then carried the specimens into the seine. This method seemed to be very effective for collecting all small fishes inhabiting the riffle areas.

Specimens were fixed in 10% formalin solution for 10 days and permanently preserved in 40% isopropyl alcohol.

I took samples one and two in October and September of 1973, respectively, from the White River drainage of Northwestern Arkansas. Sample one was taken from the East Fork of the White River located approximately 15 miles from the site of sample two which was taken from the West Fork of the White River. The East and West forks of the White River flow together to form the White River which is the major drainage system of the Boston Mountain range. The White River flows into the Mississippi River.

The Wisconsin River samples, three and four, were obtained from the University of Wisconsin-Stevens Point, Museum of Natural History. Samples three and four were taken from the Plover and

TABLE 1

ORIGIN OF SAMPLES

Sample Number	River	Drainage	State or Province	County	Description
1	East Fork White	White River	Arkansas	Washington	T15N:R28W:Sec. 17
2	West Fork White	White River	Arkansas	Washington	T15N:R30W:Sec. 16
3	Plover	Wisconsin R.	Wisconsin	Marathon	T27N:R9E:Sec. 14
4	New Wood	Wisconsin R.	Wisconsin	Lincoln	T32N:R5E:Sec. 24
5	Neenah	Fox River	Wisconsin	Adams	T16N:R7E:Sec. 26
6	Fox	Fox River	Wisconsin	Columbia	T12N:R10E:Sec. 4
7	Grand	Thames River	Ontario	Oxford	43°29' N Latitude 80°24' W Longitude
8	Thames	Thames River	Ontario	Oxford	43°03' N Latitude 81°00' W Longitude

New Wood rivers, respectively, both of which are tributaries of the Wisconsin River. The Wisconsin River flows into the Mississippi River.

Samples 5, 6, 7, and 8 were obtained from the University of Michigan, Museum of Zoology, with the cooperation of Dr. Reeve Bailey. Catalog numbers of collections are listed in Table 2.

Difficulty in obtaining specimens from the Great Lakes drainage basin of Wisconsin was experienced resulting in smaller numbers of specimens per sample (Table 2).

Sample five was taken from a small tributary of Neenah Creek which flows into the Fox River. Sample six was taken from the old channel below Park Lake Dam which is part of the Fox River. The Fox River flows into Lake Winnebago then into Lake Michigan.

Sample seven was taken from the Grand River, a tributary of the Thames River, near Breslau, Ontario. Sample eight was taken from the Thames River near Thamesford, Ontario. The Thames River flows into the St. Lawrence Seaway between Lakes Huron and Erie.

Detailed geographic descriptions of samples five through eight were determined by the author (Table 1) from information given by the collectors. Map 1 shows the general geographic locations of the collection sites.

A total of 340 rainbow darters, representing four major drainage systems, was examined with respect to 10 meristic characters (see page 10).

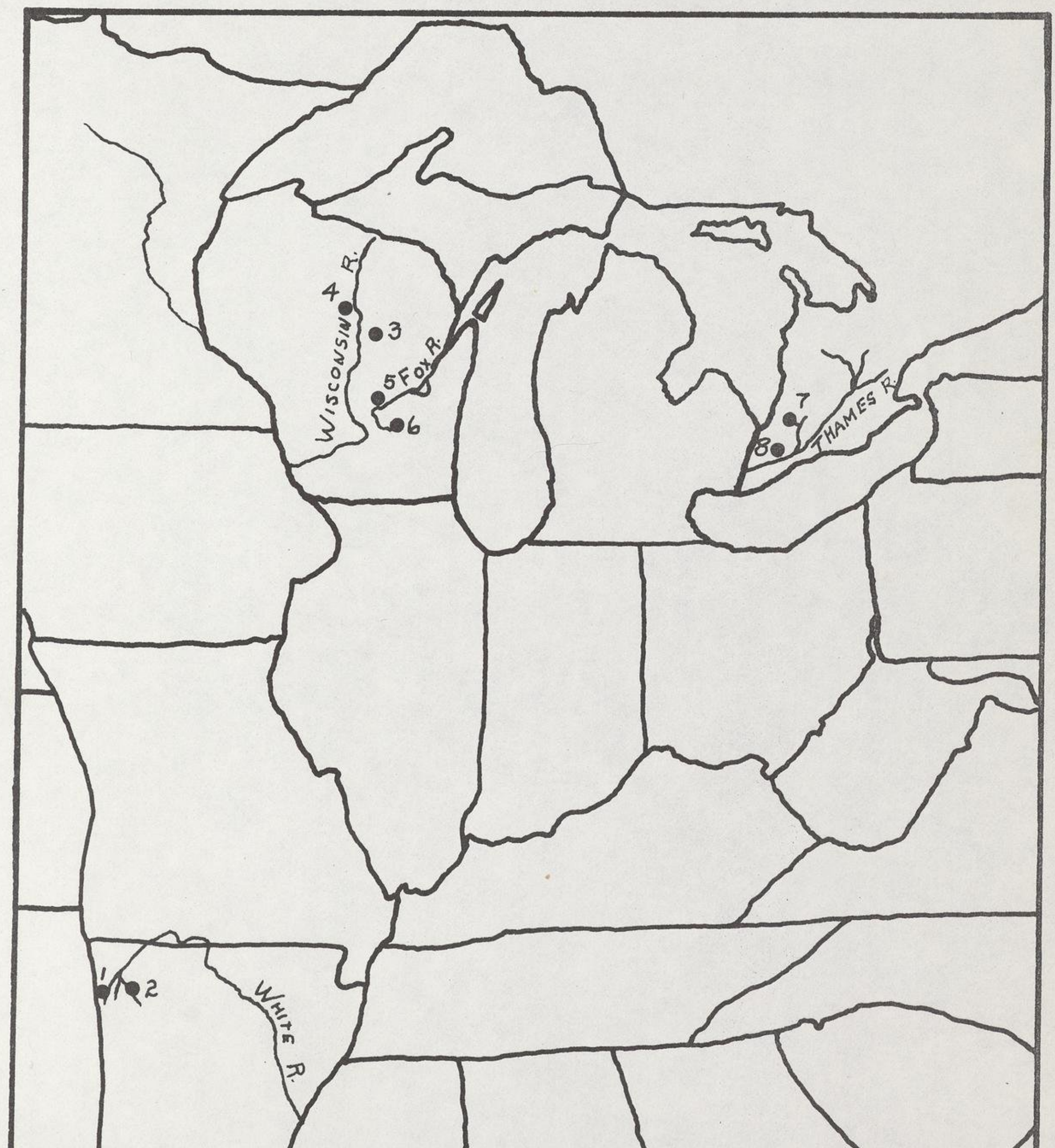
TABLE 2

SAMPLE DATA

Sample Number	Number of Specimens	Date Collected	Catalog Number
1	59	16:IX:1973	---
2	47	7:X:1973	---
3	46	26:VI:1958	UWSP 1144
4	53	7:IX:1973	UWSP 4335
5	18	21:VIII:1925	UMMZ 73531
6	29	22:VII:1925	UMMZ 73581
7	49	27:V:1928	UMMZ 85607
8	39	2:VIII:1927	UMMZ 89033

MAP 1

SAMPLE SITES



X-ray Photography

X-ray photography was utilized in determining the numbers of vertebrae in the rainbow darter. The use of vertebral numbers as a taxonomic character has been restricted because the necessary dissecting resulted in severe damage to museum specimens (Bailey and Gosline, 1955). The x-ray simplifies vertebral counting, makes more characters available for classification, and avoids specimen damage (Gosline, 1948).

Specimens in samples 1 thru 4 were x-rayed by the author. The techniques were developed by a trial and error procedure. The five variables involved in x-ray photography are: exposure time, distance from x-ray source to film, kilovoltage, milliamperage, and film type (Bartlett and Haedrich, 1966). The x-ray unit which was used, thanks to the University of Arkansas, Department of Physics, is a Westinghouse 150 KV Industrial Unit no. 57-986 (see Table 3).

The x-ray film was loaded into a black lightproof cartridge in a darkroom. Cellophane was placed over the cartridge to prevent moisture damage to the film. Each specimen was numbered and several specimens were placed in series on the cartridge using lead numbers to identify each sample. Specimens were x-rayed in size groups to obtain best results. The basic photography and development procedure followed is given in Table 3. Developmental time varied and was dependent on sight determination as the negatives were processed.

Samples 5 thru 8 were x-rayed with the assistance of

Ronald Rigans and Gary Bisping, of the X-ray Technology staff at St. Michael's Hospital, Stevens Point, Wisconsin, who suggested the use of soft tissue technique to obtain greater detail on small specimens. Numbered specimens were placed on cellophane in series on the x-ray cartridge. Lead numbers were used to identify each sample. Specimens were placed into size groups for the photography procedure. Table 4 lists details of x-ray photography and development procedure used for samples 5 through 8. The soft tissue x-ray procedure is far superior to normal procedure (Table 3) in obtaining detail for observation of vertebrae and other characters.

All x-ray negatives were properly labeled and stored in large envelopes for future use.

Meristic Elements Enumerated

The meristic elements counted were: vertebrae, dorsal spines, dorsal rays, anal spines, anal rays, pectoral rays, pelvic rays, pored lateral line scales, lateral line scales, and oblique body bars. Counting techniques for all meristic elements excluding vertebrae and oblique body bars were taken from Hubbs and Lagler (1958).

The counting of vertebrae was accomplished by transmitting light through a frosted glass plate through the x-ray negative. A convex lens was used to aid the counting of vertebrae of small specimens. The first vertebra is shorter than the following vertebrae but possesses a well developed neural spine (Lagler, et. al., 1962). The urostylar vertebra was not included in the

TABLE 3

X-ray photography and development procedure

for samples 1, 2, 3, 4.

Unit: Westinghouse 150KV Industrial Unit No. 57-986

Location: Department of Physics University of Arkansas,

Fayetteville, Arkansas

Film: Kodak RP14 medical x-ray film (10x12")

Exposure: 35KV
7MA
5 Seconds
32 Inch Height

Development: At 70°F

Developer	4 minutes
Stop Bath	20 seconds
Fixer	4 minutes
Photoflow wash	2 minutes

TABLE 4

X-ray photography and development procedure

for samples 5, 6, 7, 8.

Unit: General Electric 300 MA Medical X-ray Unit

Location: St. Michael's Hospital, Stevens Point, Wisconsin

Film: Kodak RP/M-X-O Mat Mammography Film

Exposure: 100MA
5KV
40 Seconds
40 Inch Height

Development: Kodak M-6-M Automatic Developer

vertebral counts. Fused vertebrae were observed in two specimens
which were rejected. Vertebrae were counted twice at two different times, if disagreement resulted a third and fourth count was taken. If differences could not be clearly resolved the specimen was rejected. Approximately 10% of the specimens photographed were discarded due to disagreement in vertebral numbers.

All remaining meristic counts were taken twice at two separate occasions. Recounts were made to resolve any differences. If differences remained in question the specimen was discarded.

Analysis of Data

Statistical methods were used to compare meristic counts between the eight samples of the rainbow darter. Mean, standard deviation, and standard error were calculated (Steel and Torrie, 1960). Single factor analysis of variance (Snedecor, 1956 and Steel and Torrie, 1960) was used to compare meristic numbers. All tests were made at the 5% and 1% levels of significance.

Where significant differences were noted by analysis of variance the Scheffee Multiple-Comparison Test (Scheffee, 1959) was used to determine significant differences between all means of each meristic element. The problem here is to determine whether the mean number of meristic elements at each locality differs from all others. When no significant difference is pointed out by analysis of variance, no further analysis is necessary (Snedecor, 1956). Eberhardt (1968) suggests the Scheffee test as a statistical basis for multiple comparison of means. The Scheffee test conveniently ranks the means in numerical sequence and determines where significant differences occur. All differences in the comparison of the means were determined to the 5% level of significance.

Single factor analysis of variance was performed on all meristic elements of the eight samples utilized in this study. Where significant differences were found the Scheffee test was used to obtain a comparison of the means.

Since the eight samples utilized represent four drainage basins, two samples from each drainage basin were pooled in search of differences between specimens from the different drainages (Table 1 and Map 1). Statistically the accuracy of pooled data is reduced (Hubbs and Perlmutter, 1942). However, in a study such as this one geographic comparisons are necessary.

A graphic presentation of mean meristic counts is also utilized to aid in visualizing the results (Hubbs and Hubbs, 1953). The graphic method of presenting data accompanied by statistical analysis yields an almost ideal presentation of meristic data (Rothschild, 1963).

The use of the IBM Fortran IV computer and the advice and assistance of Dr. Fred Hilpert, of the University of Wisconsin-Stevens Point, Data Processing Center, made the statistical analysis of the data presented in this study much less time consuming.

RESULTS

Vertebrae

The vertebral numbers of the rainbow darters in this study ranged from 33 to 37 with sample means ranging from 35.12 to 36.22 (Table 5). Specimens having lowest mean numbers of vertebrae came from the East and West Forks of the White River while the highest mean number of vertebrae was observed in specimens from Neenah Creek (Figure 1).

Analysis of variance points out a significant difference in numbers of vertebrae between the eight samples of the rainbow darter studied (Table 13, p. 54). A summary table of the single factor analysis of variance is given in Appendix 1. The Scheffee Multiple - Comparison Test shows samples 1, 2, and 8 are significantly different from all other samples considered (Figure 3).

In comparing mean vertebral numbers from the four drainage systems studied the highest mean number of vertebrae was observed in specimens from the Fox River drainage while the lowest mean number of vertebrae was observed in the White River drainage of Arkansas (Table 5 and Figure 2). Analysis of variance indicates significantly different numbers of vertebrae between the eight rainbow darter samples from the four drainage systems considered. The Scheffee Multiple-Comparison Test Shows the White River drainage samples have significantly fewer vertebrae than samples from the Fox, Wisconsin, or Thames River drainages (Figure 3). The Fox River drainage samples exhibited a significantly greater number of vertebrae than samples from the White and Thames River drainages.

FIGURE 1

GEOGRAPHIC VARIATION IN NUMBER OF VERTEBRAE OF THE RAINBOW DARTER

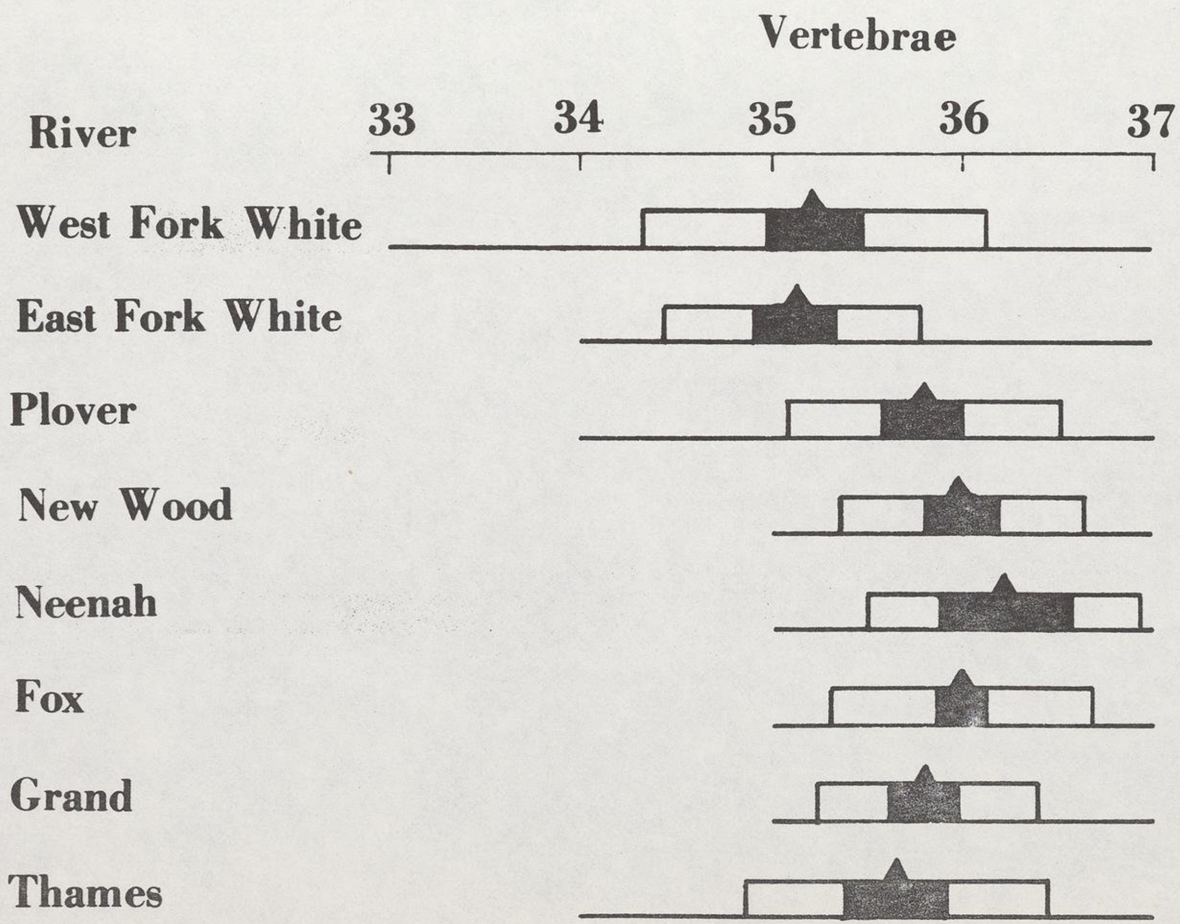


FIGURE 2

GEOGRAPHIC VARIATION IN NUMBER OF VERTEBRAE OF THE RAINBOW DARTER

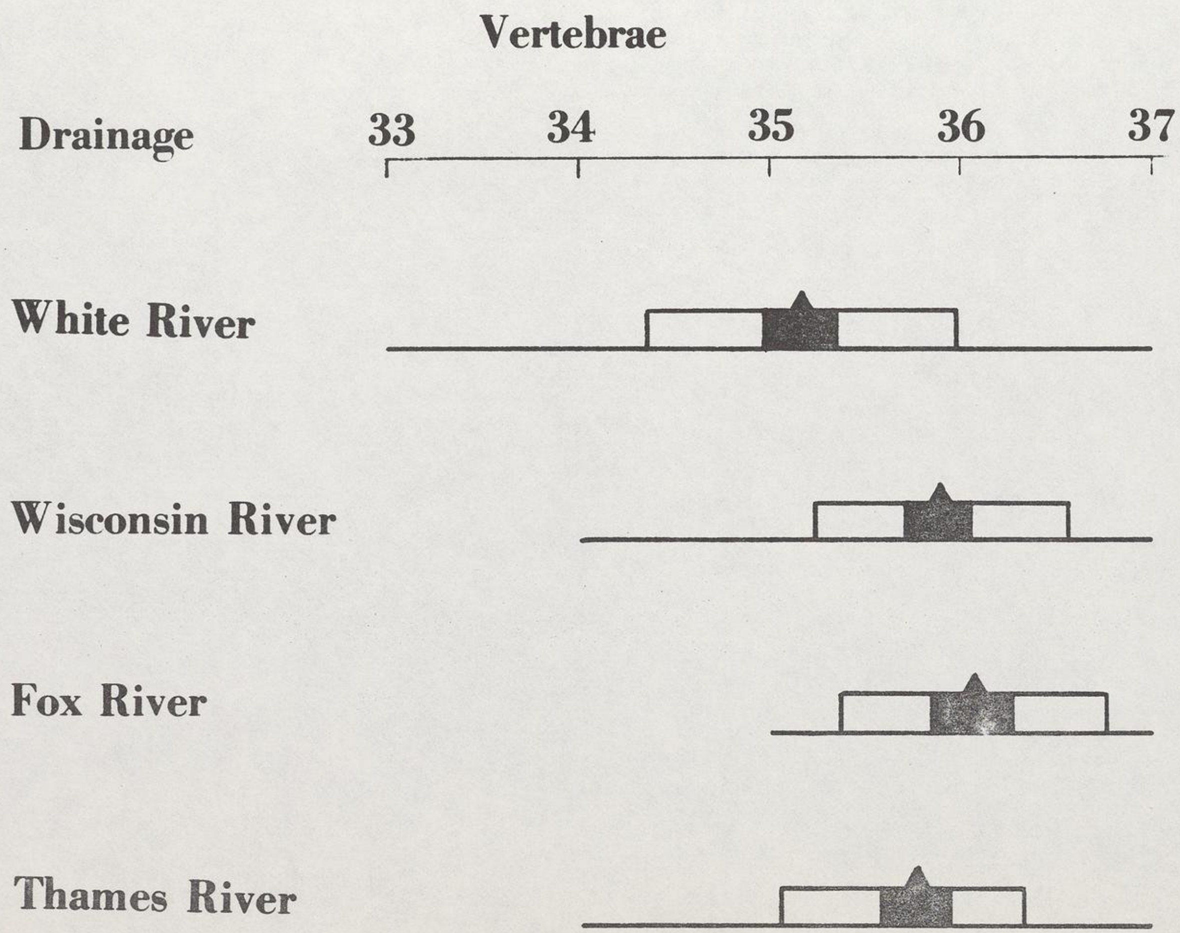


FIGURE 3

Results of the Scheffee test on mean vertebral numbers of the rainbow darter

Sample Number	River	Sample Mean	Significance *	
2	East Fork White	35.12	│	
1	West Fork White	35.22	│	
8	Thames	35.66	│	
3	Plover	35.80		│
7	Grand	35.81		│
4	New Wood	36.00		│
6	Fox	36.00		│
5	Neenah	36.22		│
1 & 2	White	35.17		
7 & 8	Thames	35.75	│	
3 & 4	Wisconsin	35.90	│	│
5 & 6	Fox	36.08		│

* All means indicated by the same line are not significantly different.

TABLE 5

Vertebral numbers of the rainbow darter

Sample Number	River	33	34	35	36	37	n	$\bar{x}$	s
1	West Fork White	1	13	20	22	3	59	35.22 $\pm$.24	.90
2	East Fork White		7	28	11	1	47	35.12 $\pm$.20	.67
3	Plover		2	11	27	6	46	35.80 $\pm$.10	.71
4	New Wood			11	31	11	53	36.00 $\pm$.18	.64
5	Neenah			3	8	7	18	36.22 $\pm$.34	.71
6	Fox			7	15	7	29	36.00 $\pm$.26	.69
7	Grand			14	30	5	39	35.81 $\pm$.16	.59
8	Thames		3	12	19	5	39	35.66 $\pm$.26	.79
1 & 2	White						106	35.17 $\pm$.16	.81
3 & 4	Wisconsin						99	35.90 $\pm$.14	.68
5 & 6	Fox						47	36.08 $\pm$.20	.70
7 & 8	Thames						88	35.75 $\pm$.14	.69

No significant difference in vertebral numbers was pointed out between the Thames and Wisconsin River drainages or between the Wisconsin and Fox River drainages.

Dorsal Spines

The dorsal spine numbers of the rainbow darters in this study ranged from eight to 13 with sample means ranging from 9.69 on specimens from the Thames River to 10.05 on Neenah Creek specimens (Table 6 and Figure 4).

Variance analysis points out no significant difference in dorsal spine numbers between the eight samples included in this study.

The interdrainage comparison of the dorsal spine numbers of the rainbow darters in this study indicates the Fox River drainage has the lowest mean number of dorsal spines, 9.95, while the highest mean number of dorsal spines, 10.05, was found on specimens from the Thames River drainage (Table 6 and Figure 5).

Analysis of variance points out no significant difference in dorsal spine numbers between the rainbow darters from the four drainage basins sampled (Table 13, p. 54).

Dorsal Rays

The dorsal ray numbers of the rainbow darters in this study ranged from 10 to 15 with the sample from Neenah Creek having the lowest mean number of 12.24 while the highest mean number of dorsal rays, 13.72, was observed in the East Fork of the White River sample (Table 7 and Figure 6).

Analysis of variance shows a significant difference in dorsal

FIGURE 4

GEOGRAPHIC VARIATION IN DORSAL SPINE NUMBERS OF THE RAINBOW DARTER

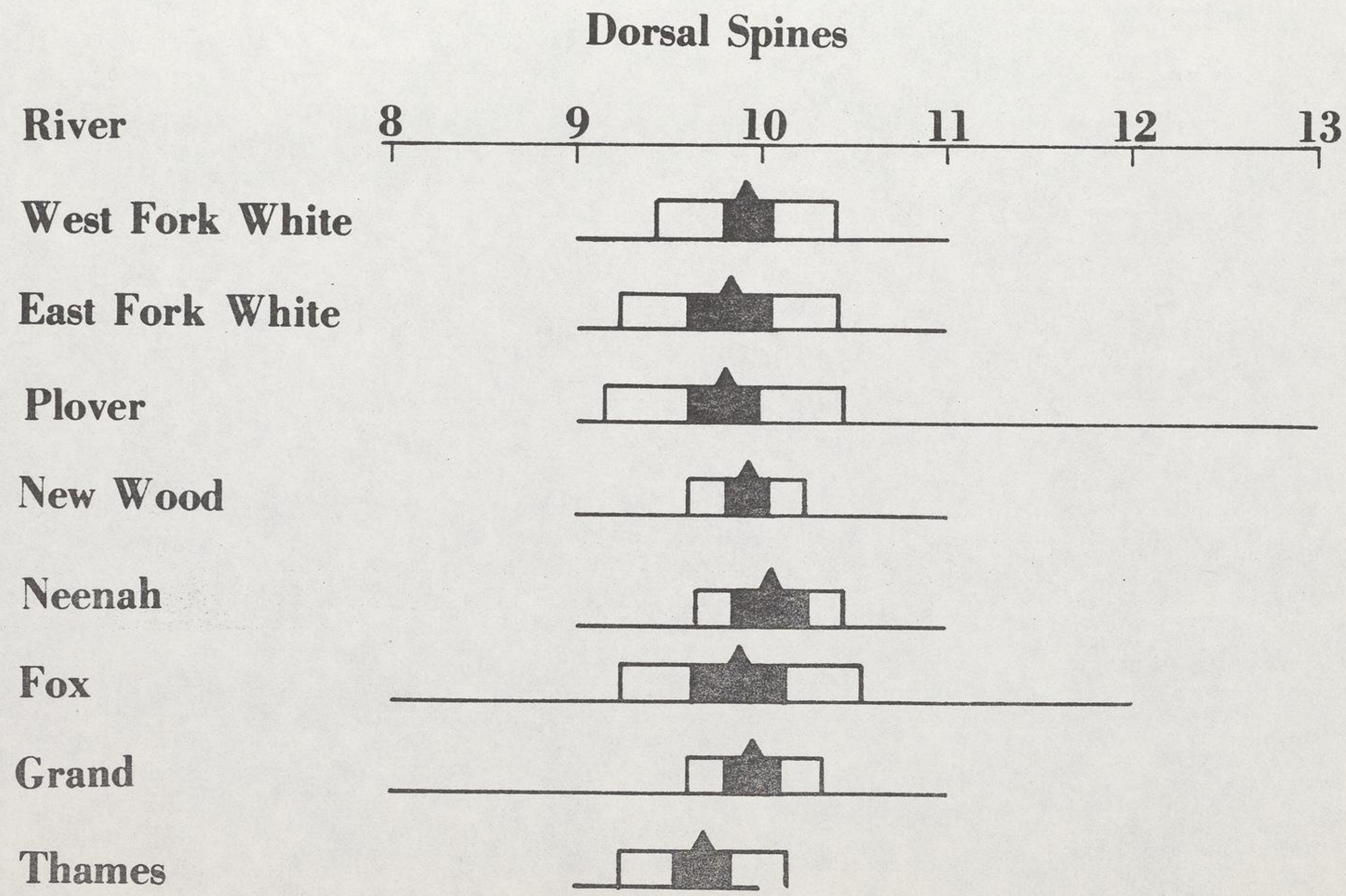


FIGURE 5

GEOGRAPHIC VARIATION IN DORSAL SPINE NUMBERS OF THE RAINBOW DARTER

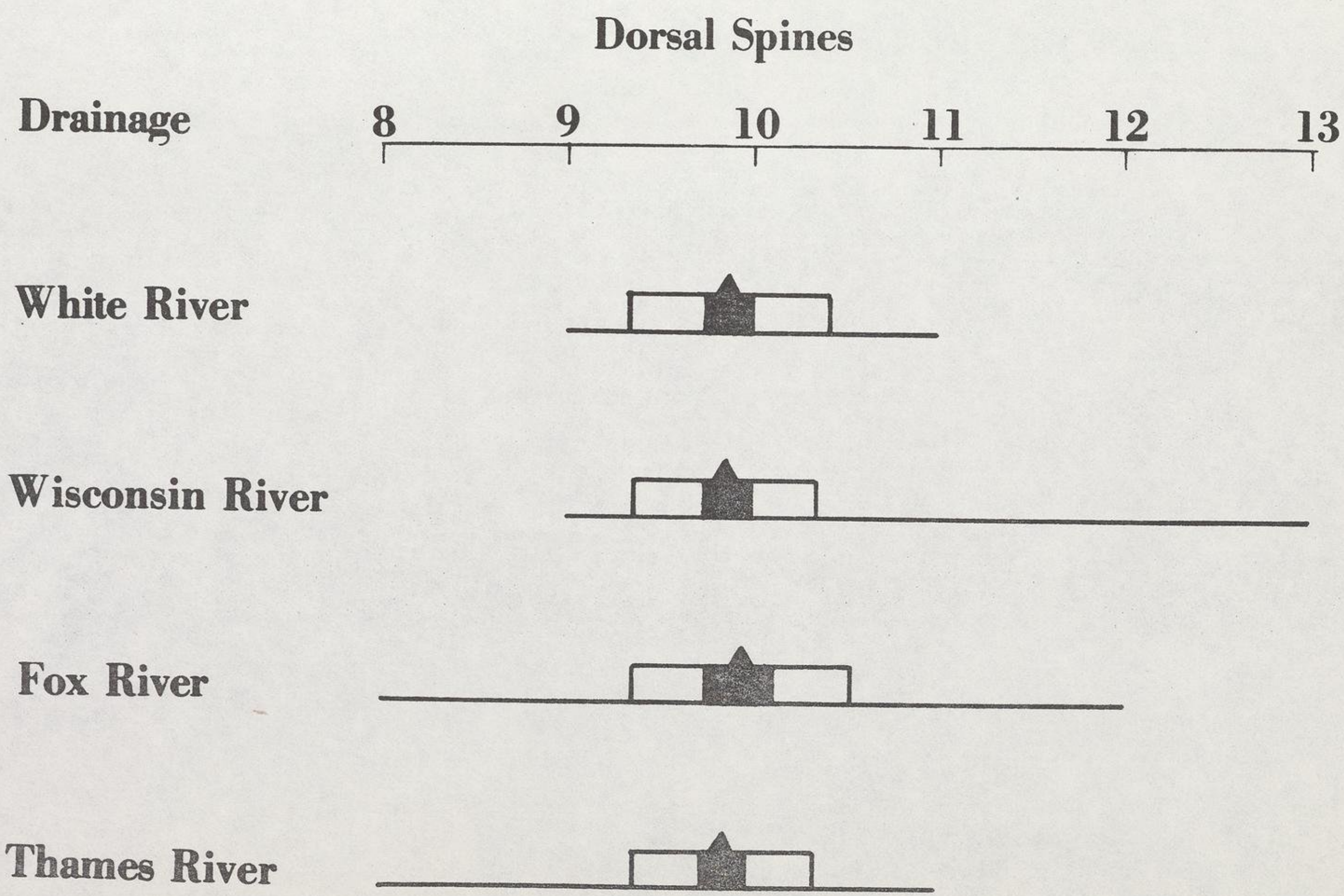


TABLE 6

Dorsal spine numbers of the rainbow darter

Sample Number	River	8	9	10	11	12	13	n	x̄	s
1	West Fork White		10	44	5			59	9.91 ±.12	.49
2	East Fork White		13	29	5			47	9.82 ±.18	.59
3	Plover		11	34			1	46	9.80 ±.18	.64
4	New Wood		5	47	1			53	9.92 ±.08	.32
5	Neenah		1	15	2			18	10.05 ±.18	.40
6	Fox	1	4	22	1			29	9.89 ±.24	.66
7	Grand	1	1	45				49	9.97 ±.10	.37
8	Thames		12	27				39	9.69 ±.14	.46
1 & 2	White							106	9.87 ±.10	.54
3 & 4	Wisconsin							99	9.86 ±.10	.50
5 & 6	Fox							47	9.95 ±.16	.58
7 & 8	Thames							88	9.85 ±.10	.48

ray numbers. The Scheffee test shows that samples 3, 4, 7, and 8 have significantly fewer dorsal rays then the remaining samples (Figure 8).

The comparison of mean dorsal ray numbers between drainage basins shows the White River drainage rainbow darters having 13.69 dorsal rays followed by 13.14 dorsal rays on the Fox River drainage specimens, 12.36 on the Thames River drainage specimens, and 12.26 on the Wisconsin River drainage specimens (Table 7 and Figure 7).

Analysis of variance indicates a significant difference in dorsal ray numbers between the rainbow darters in this study (Table 13, p. 54). The Scheffee Mulitple-Comparison Test indicates no significant difference in dorsal ray numbers between the Thames and Wisconsin River drainages while significant differences exist between the remaining drainages (Figure 8).

<u>Anal Spines</u>

All rainbow darters examined in this study possessed two anal spines.

<u>Anal Rays</u>

The anal ray numbers of the rainbow darters in this study ranged from five to eight. The lowest mean number of anal rays, 6.76, was observed in the Thames River sample while the highest mean number of anal rays, 7.04, was observed on the East Fork of the White River sample (Table 8 and Figure 9).

Variance analysis points out a significant difference in anal ray numbers between the rainbow darters in this study (Table 13, p. 54).

FIGURE 6

GEOGRAPHIC VARIATION IN DORSAL RAY NUMBERS OF THE RAINBOW DARTER

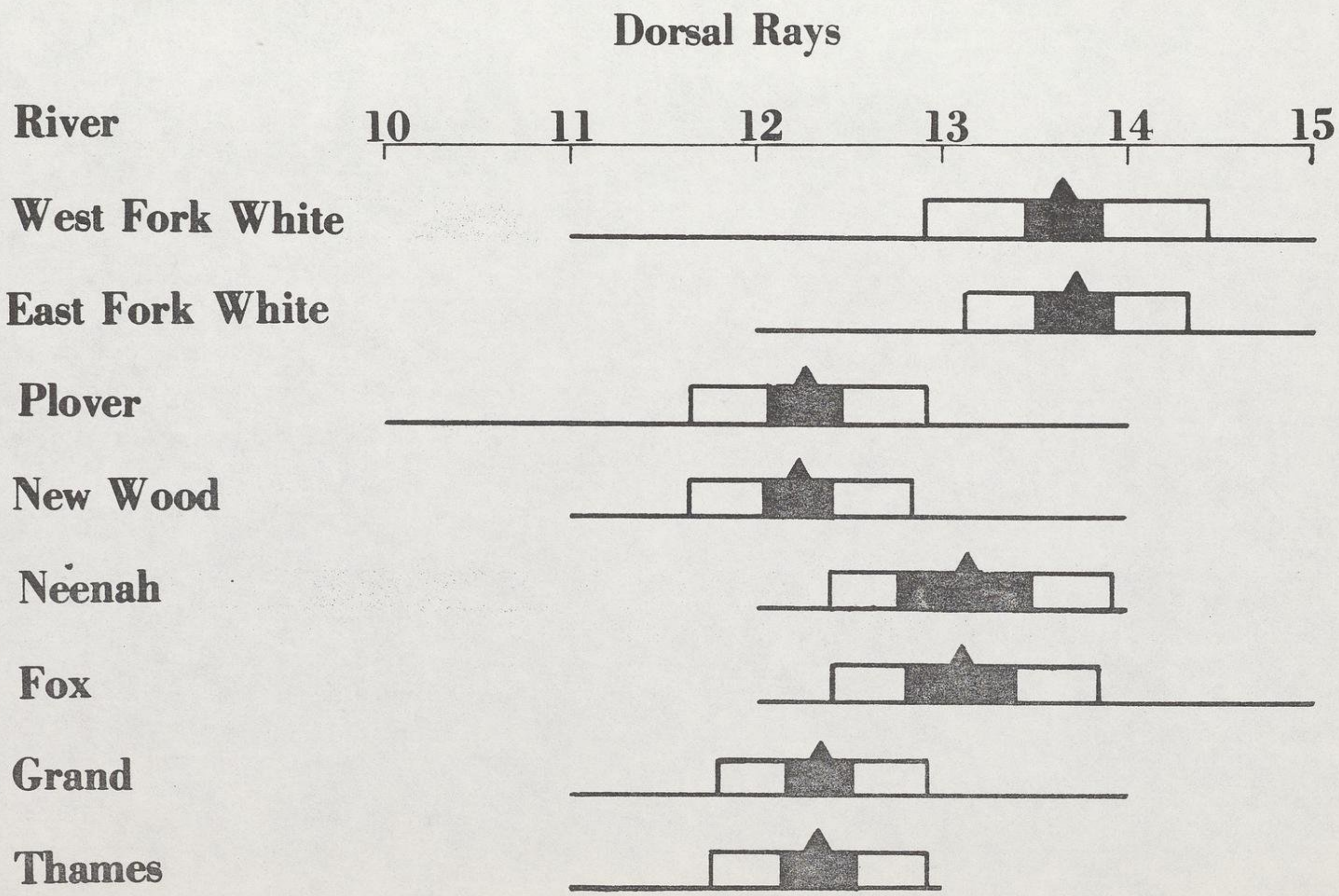


FIGURE 7

GEOGRAPHIC VARIATION IN DORSAL RAY NUMBERS OF THE RAINBOW DARTER

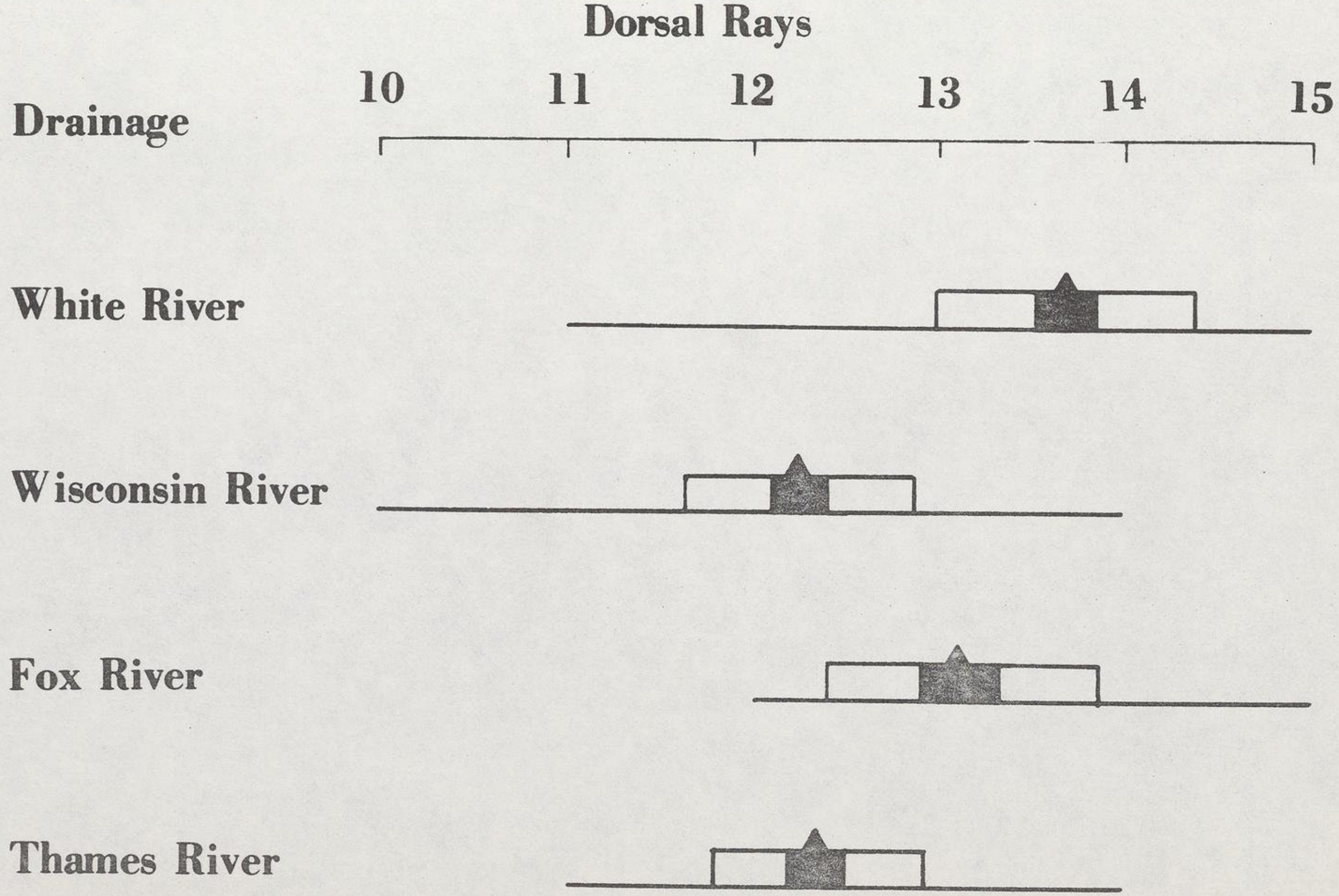


FIGURE 8

Results of the Scheffee test on mean dorsal ray numbers on the rainbow darter

Sample Number	River	Sample Mean	Significance
4	New Wood	12.24	
3	Plover	12.28	
8	Thames	12.35	
7	Grand	12.36	
6	Fox	13.13	
5	Neenah	13.16	
2	East Fork White	13.67	
1	West Fork White	13.72	
3 & 4	Wisconsin	12.26	
7 & 8	Thames	12.36	
5 & 6	Fox	13.14	
1 & 2	White	13.69	

TABLE 7

Dorsal rays on the rainbow darter

Sample Number	River	10	11	12	13	14	15	n	$\bar{x}$	s
1	West Fork White		1	3	15	35	5	59	13.67 ±.20	.76
2	East Fork White			1	14	29	3	47	13.72 ±.18	.60
3	Plover	1		32	11	2		46	12.18 ±.18	.64
4	New Wood		3	36	12	2		53	12.24 ±.16	.61
5	Neenah			4	7	7		18	13.16 ±.36	.76
6	Fox			5	16	7	1	29	13.13 ±.26	.72
7	Grand			30	17	1		49	12.36 ±.16	.56
8	Thames			21	16			39	12.35 ±.18	.57
1 & 2	White							106	13.69 ±.14	.70
3 & 4	Wisconsin							99	12.26 ±.12	.62
5 & 6	Fox							47	13.14 ±.22	.74
7 & 8	Thames							88	12.36 ±.12	.56

The Scheffee Multiple-Comparison Test shows no significant difference in the mean numbers of anal rays between the eight samples included in this study (Figure 11).

In comparing anal ray numbers of the rainbow darters in this study between drainages sampled variance analysis points out a significant difference in mean numbers of anal rays (Table 13, p. 54). The rainbow darters from the Thames River drainage samples had the lowest mean number of anal rays, 6.82, while the Fox River drainage specimens had the greatest mean anal ray number, 6.96 (Table 8 and Figure 10). The Scheffee Multiple-Comparison Test indicates a significantly higher mean number of anal rays on specimens from the Fox River drainage and no significant differences between the remaining drainages (Figure 11).

Pectoral Rays

No significant difference between right and left pectoral rays on the rainbow darters in this study was found. The highest mean number of pectoral rays, 13.33, was observed in the Neenah Creek sample and the lowest mean pectoral ray number, 12.58, was observed on the Grand River sample. Pectoral ray counts ranged from 11 to 14 on the rainbow darters in this study (Table 9 and Figure 12).

Analysis of variance indicates a significant difference in pectoral ray numbers between the rainbow darters in this study (Table 13, p. 54). The Scheffee Multiple-Comparison Test indicates no significant difference in mean pectoral ray numbers between

FIGURE 9

GEOGRAPHIC VARIATION IN ANAL RAY NUMBERS OF THE RAINBOW DARTER

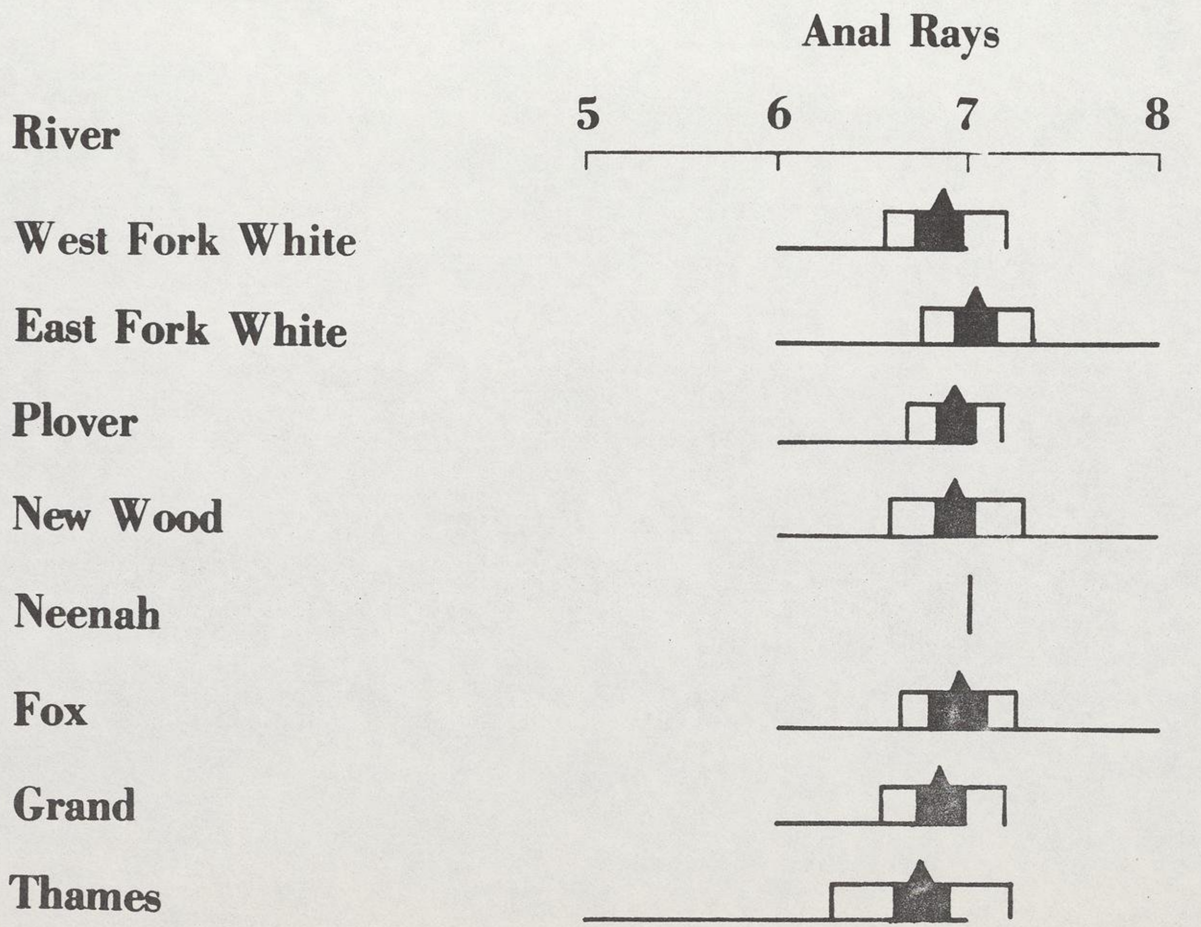


FIGURE 10

GEOGRAPHIC VARIATION IN ANAL RAY NUMBERS OF THE RAINBOW DARTER

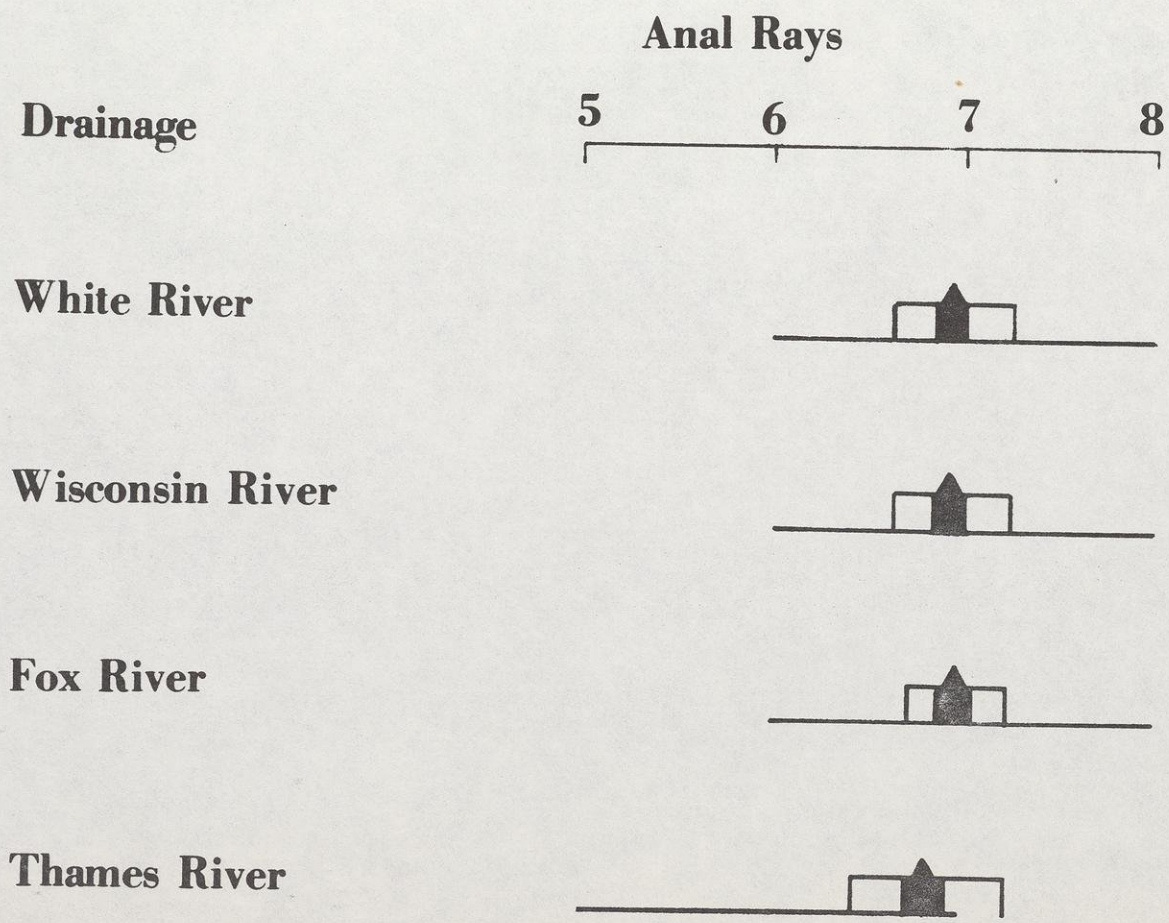


FIGURE 11

Results of the Scheffee test on mean anal ray number of the rainbow darter

Sample Number	River	Sample Mean	Significance
8	Thames	6.76	|
7	Grand	6.87	|
1	West Fork White	6.88	|
3	Plover	6.93	|
4	New Wood	6.94	|
6	Fox	6.96	|
5	Neenah	7.00	|
2	East Fork White	7.04	|
7 & 8	Thames	6.82	|
3 & 4	Wisconsin	6.93	|
1 & 2	White	6.95	|
5 & 6	Fox	6.97	

TABLE 8

Anal rays of the rainbow darter

Sample Number	River	5	6	7	8	n	$\bar{x}$	s
1	West Fork White		7	52		59	6.88 $\pm$.08	.32
2	East Fork White		1	43	3	47	7.04 $\pm$.08	.28
3	Plover		3	43		46	6.93 $\pm$.08	.24
4	New Wood		5	46	2	53	6.94 $\pm$.10	.35
5	Neenah			18		18	7.00 $\pm$.00	.00
6	Fox		2	26	1	29	6.96 $\pm$.12	.31
7	Grand		6	43		49	6.87 $\pm$.08	.32
8	Thames	1	7	31		39	6.76 $\pm$.16	.47
1 & 2	White					106	6.95 $\pm$.06	.31
3 & 4	Wisconsin					99	6.93 $\pm$.06	.31
5 & 6	Fox					47	6.97 $\pm$.08	.25
7 & 8	Thames					88	6.82 $\pm$.08	.40

FIGURE 12

GEOGRAPHIC VARIATION IN PECTORAL RAY NUMBERS OF THE RAINBOW DARTER

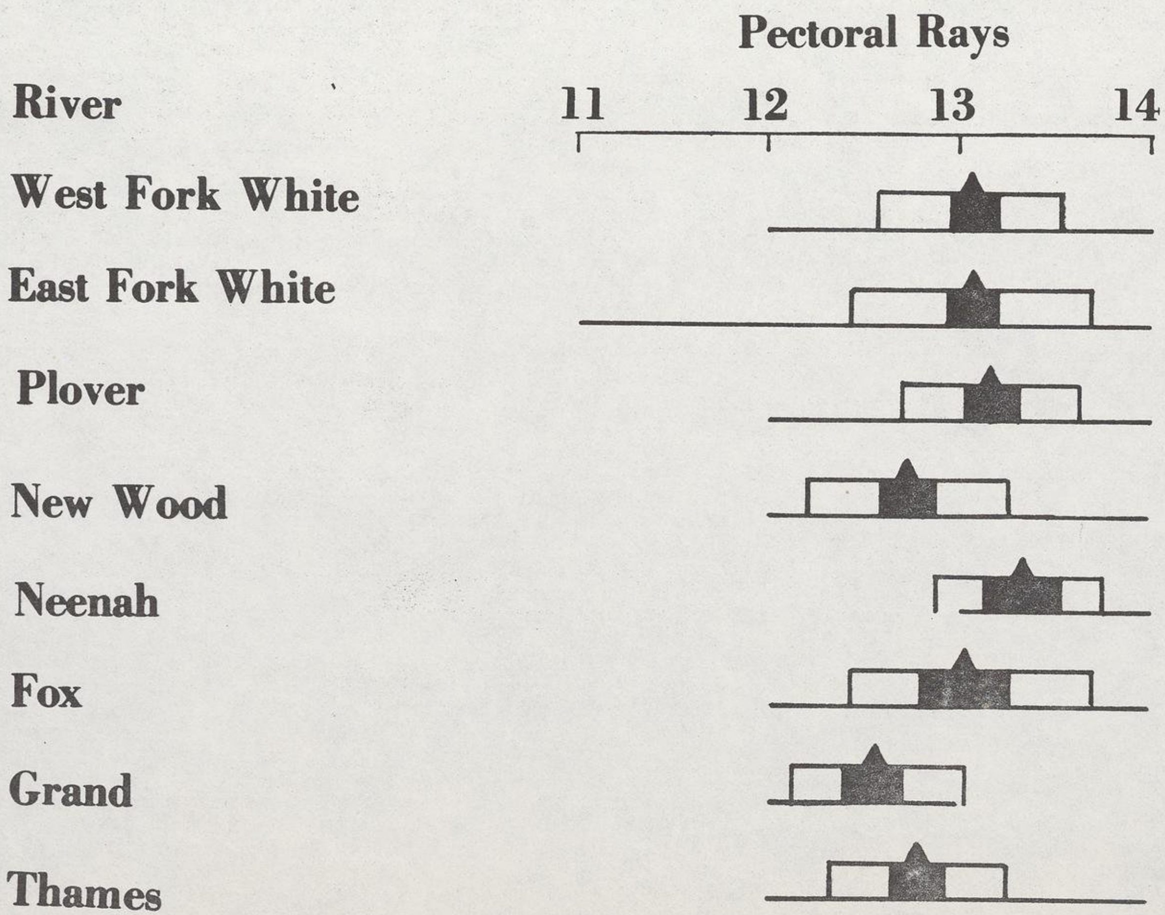


FIGURE 13

GEOGRAPHIC VARIATION IN PECTORAL RAY NUMBERS OF THE RAINBOW DARTER

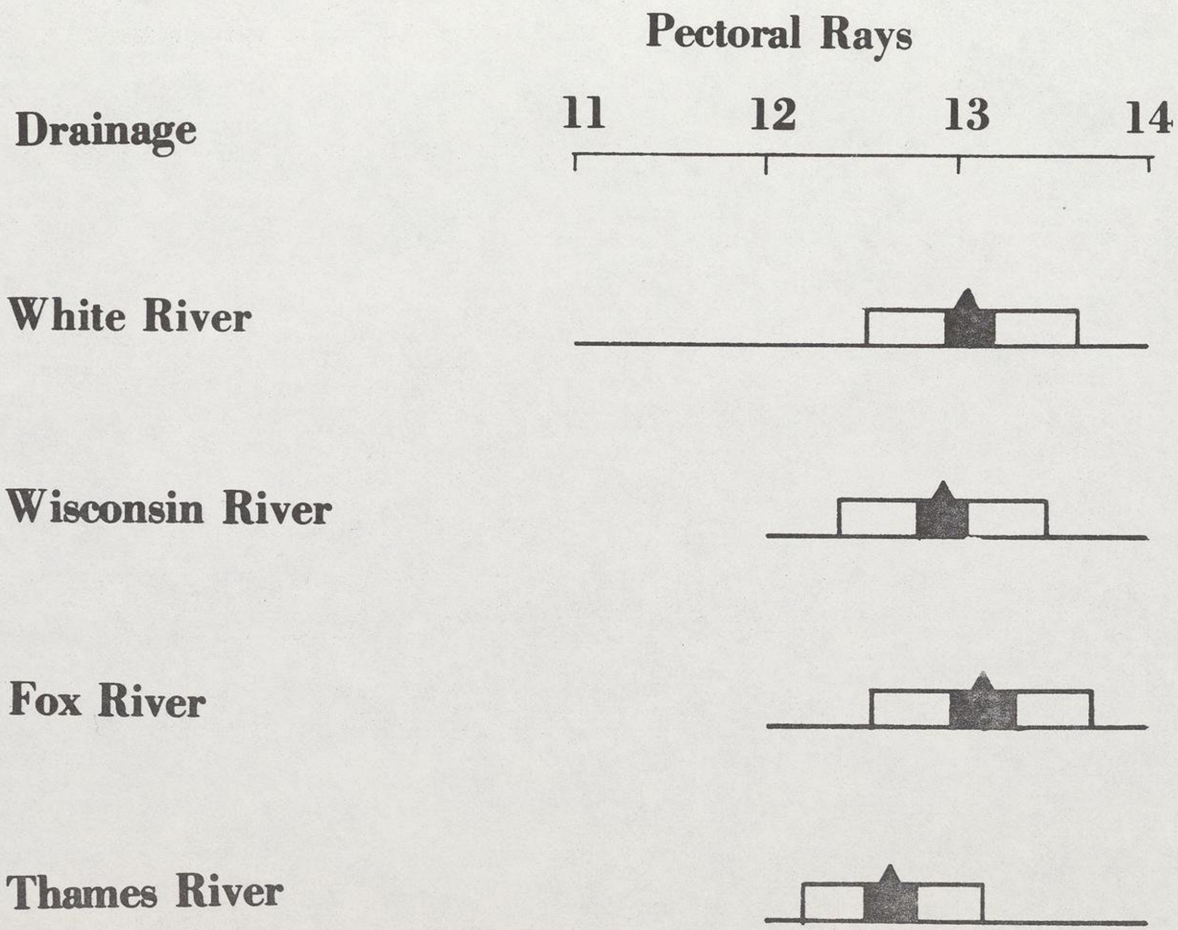


FIGURE 14

Results of the Scheffee test on mean pectoral ray numbers on the rainbow darter

Sample Number	River	Sample Mean	Significance
7	Grand	12.58	
4	New Wood	12.73	
8	Thames	12.79	
6	Fox	13.03	
1	West Fork White	13.06	
2	East Fork White	13.07	
3	Plover	13.16	
5	Neenah	13.33	
7 & 8	Thames	12.67	
3 & 4	Wisconsin	12.93	
1 & 2	White	13.07	
5 & 6	Fox	13.14	

TABLE 9

Pectoral rays of the rainbow darter

Sample Number	River	11	12	13	14	n	$\bar{x}$	s
1	West Fork White		5	41	13	59	13.06 ±.12	.48
2	East Fork White	1	5	30	11	47	13.07 ±.18	.63
3	Plover		4	28	14	46	13.16 ±.14	.46
4	New Wood		20	28	5	53	12.73 ±.14	.53
5	Neenah			11	7	18	13.33 ±.20	.44
6	Fox		6	15	8	29	13.03 ±.22	.61
7	Grand		24	25		49	12.58 ±.12	.45
8	Thames		12	25	2	39	12.79 ±.14	.46
1 & 2	White					106	13.07 ±.10	.55
3 & 4	Wisconsin					99	12.93 ±.10	.54
5 & 6	Fox					47	13.14 ±.16	.57
7 & 8	Thames					88	12.67 ±.10	.47

samples; 4, 7, 8; 1, 2, 4, 8; 1, 2, 6, 8; and 1, 2, 3, 5, 6
(Figure 14).

Interdrainage mean pectoral ray numbers ranged from 12.67 on specimens from the Thames River drainage to 13.14 on specimens from the Fox River drainage (Table 9 and Figure 13). The Scheffee Multiple-Comparison Test indicates the only significant difference in mean pectoral ray numbers is between the Thames River drainage samples and the three other drainages sampled (Figure 14).

Pelvic Rays

Six pelvic rays were observed in both the right and left pelvic fins of all rainbow darters in this study.

Pored Lateral Line Scales

Pored lateral line scale numbers ranged from 15 to 35 in the rainbow darters observed in this study. A mean low of 25.75 pored lateral line scales was found in the Fox River sample while a mean high of 28.43 was found in the Plover River sample (Table 10 and Figure 15).

Analysis of variance indicates a significant difference in the numbers of pored lateral line scales between the rainbow darters in this study (Table 13, p. 54). The Scheffee Multiple-Comparison Test indicates that significant differences in mean pored lateral line scale numbers exist between samples 3 and 6 (Figure 17).

The interdrainage mean number of pored lateral line scales ranged from 26.21 in the Fox River drainage to 27.91 in the White River drainage (Table 10 and Figure 16). Analysis of

FIGURE 15

GEOGRAPHIC VARIATION IN PORED LATERAL LINE SCALE NUMBERS OF THE RAINBOW DARTER

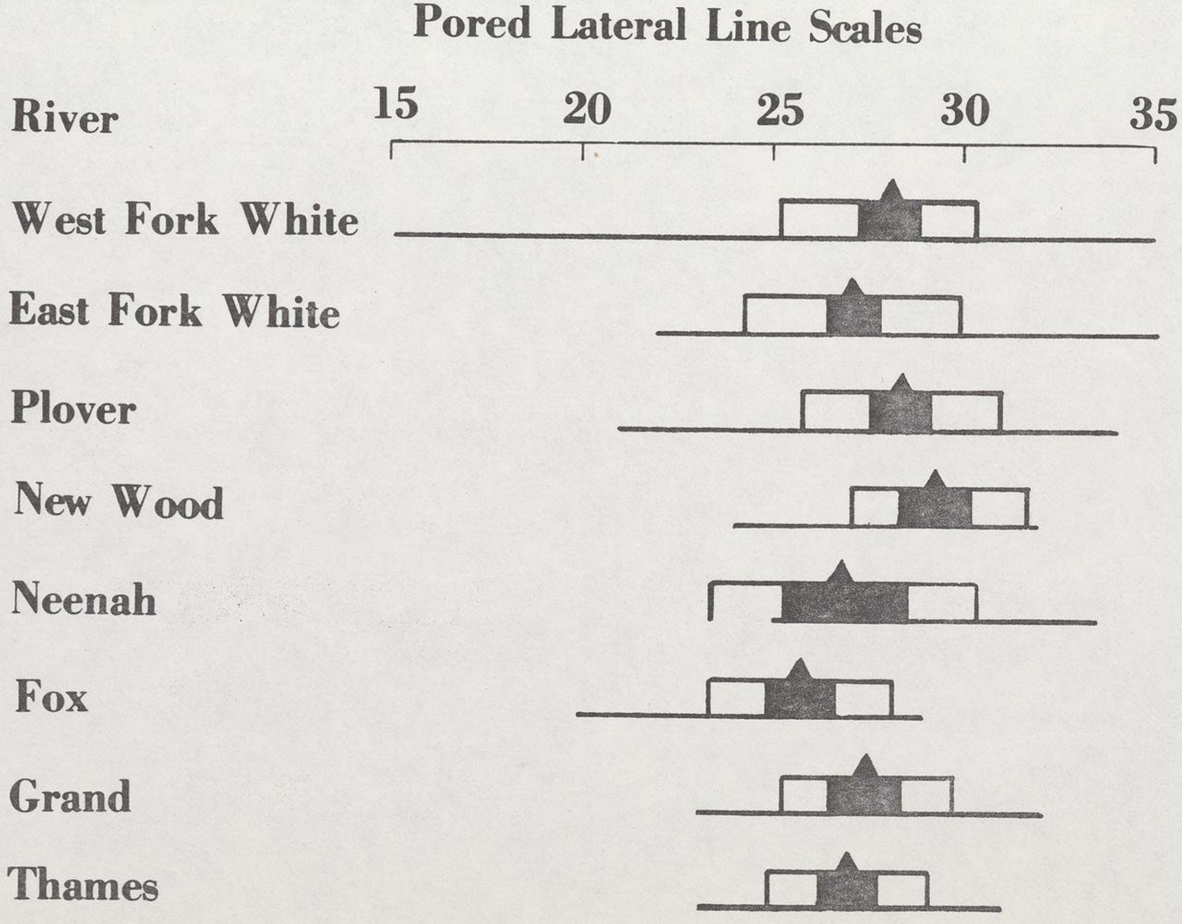


FIGURE 16

GEOGRAPHIC VARIATION IN PORED LATERAL LINE SCALE NUMBERS OF THE RAINBOW DARTER

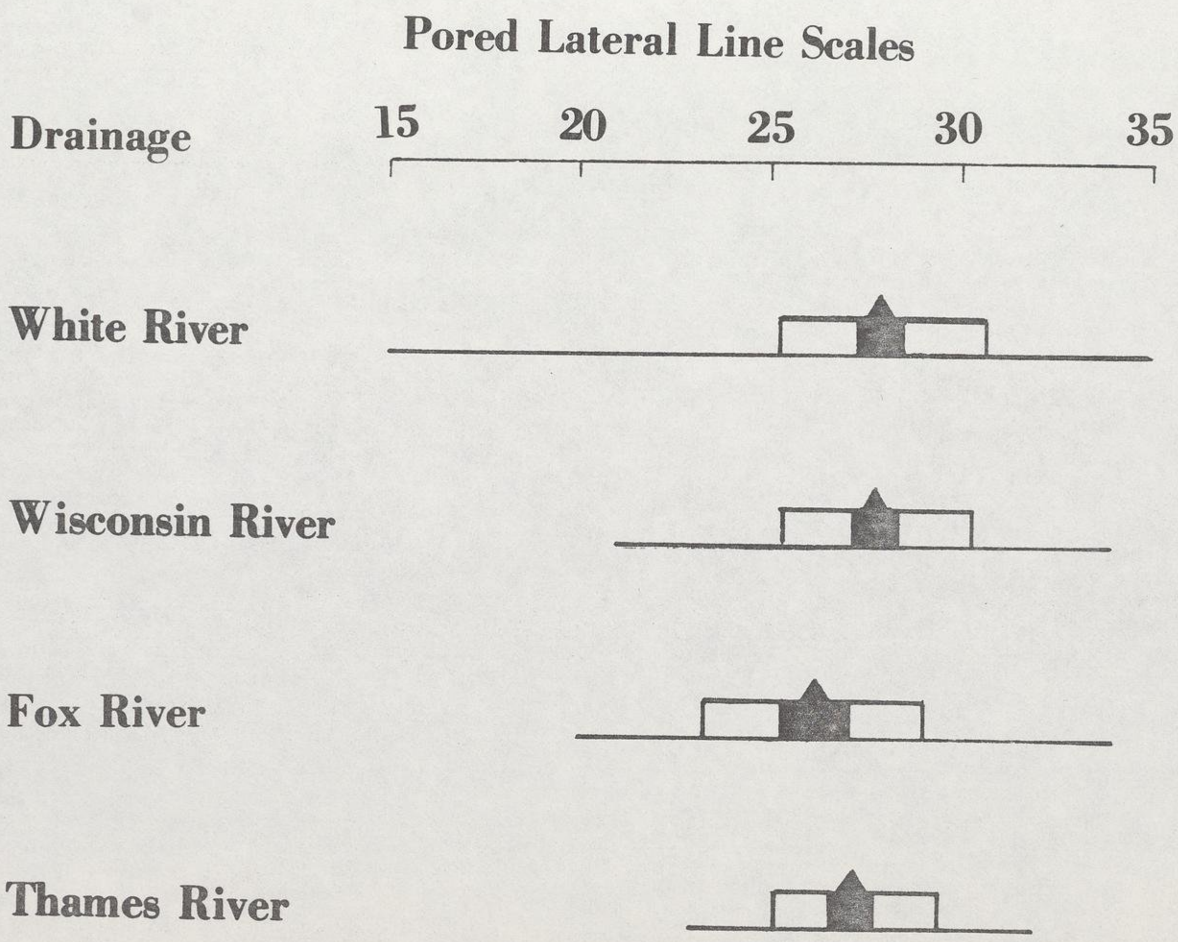


FIGURE 17

Results of the Scheffee test on mean pored lateral line scale numbers on the rainbow darter

Sample Number	River	Sample Mean	Significance
6	Fox	25.75	
5	Neenah	26.94	
8	Thames	27.07	
4	New Wood	27.39	
7	Grand	27.46	
2	East Fork White	27.80	
1	West Fork White	28.00	
3	Plover	28.43	
5 & 6	Fox	26.21	
7 & 8	Thames	27.29	
3 & 4	Wisconsin	27.87	
1 & 2	White	27.91	

TABLE 10

Pored lateral line scales of the rainbow darter

Sample Number	River	15	17	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	n	x̄	s
1	West Fork White			1	1		5	2	7	11	4	11	9	3	1	2	2		59	28.00 ±.70	2.71
2	East Fork White				1	1	6	3	5	6	5	7	5	1	6			1	47	27.80 ±.84	2.87
3	Plover			1	1		1	3	3	4	9	8	7	5	2	1	1		46	28.43 ±.76	2.59
4	New Wood		1				3	2	8	15	9	8	3	2	2				53	29.39 ±.62	2.31
5	Neenah	1						1	5	3	4	2		1		1			18	26.94 ±1.64	3.47
6	Fox			3	1	1	2	4	6	2	9	1							29	25.75 ±.86	2.32
7	Grand						3	5	10	8	5	8	4	2	3				49	27.46 ±.64	2.22
8	Thames						3	2	6	8	6	7	2	2					39	27.07 ±.68	2.10
1 & 2	White																		106	27.91 ±.54	2.78
3 & 4	Wisconsin																		99	27.87 ±.50	2.50
5 & 6	Fox																		47	26.21 ±.84	2.88
7 & 8	Thames																		88	27.29 ±.46	2.18

variance indicates a significant difference in pored lateral line scales on an interdrainage comparison (Table 13, p. 54). The differences in mean pored lateral line scale numbers exists between the Fox River drainage, the White River drainage, and the Wisconsin River drainage (Figure 17).

Lateral Line Scales

Lateral line scale counts on the rainbow darters in this study ranged from 37 to 52 with mean lateral line scale numbers ranging fron 43.28 in the Plover River sample to 46.08 in the West Fork of the White River sample (Table 11 and Figure 18).

Variance analysis indicates a significant difference in numbers of lateral line scales between the eight samples of the rainbow darters in this study (Table 13, p. 54). The Scheffee Multiple-Comparison Test indicates that significant differences in mean lateral line scale numbers exist between sample 3 and 1, 2, 6, 7, 8; and between sample 4 and 1, 7 (Figure 20).

Interdrainage mean lateral line scales on the rainbow darters in this study range from 43.55 in the Wisconsin River drainage specimens to 45.75 in the White River drainage specimens (Table 11 and Figure 19). Analysis of variance indicates a significant difference in lateral line scales on the rainbow darter samples studied between drainages (Table 13, p. 54). The Scheffee Multiple-Comparison Test indicates a significant difference in mean lateral line scale numbers on the rainbow darters sampled between the

FIGURE 18

GEOGRAPHIC VARIATION IN LATERAL LINE SCALE NUMBERS OF THE RAINBOW DARTER

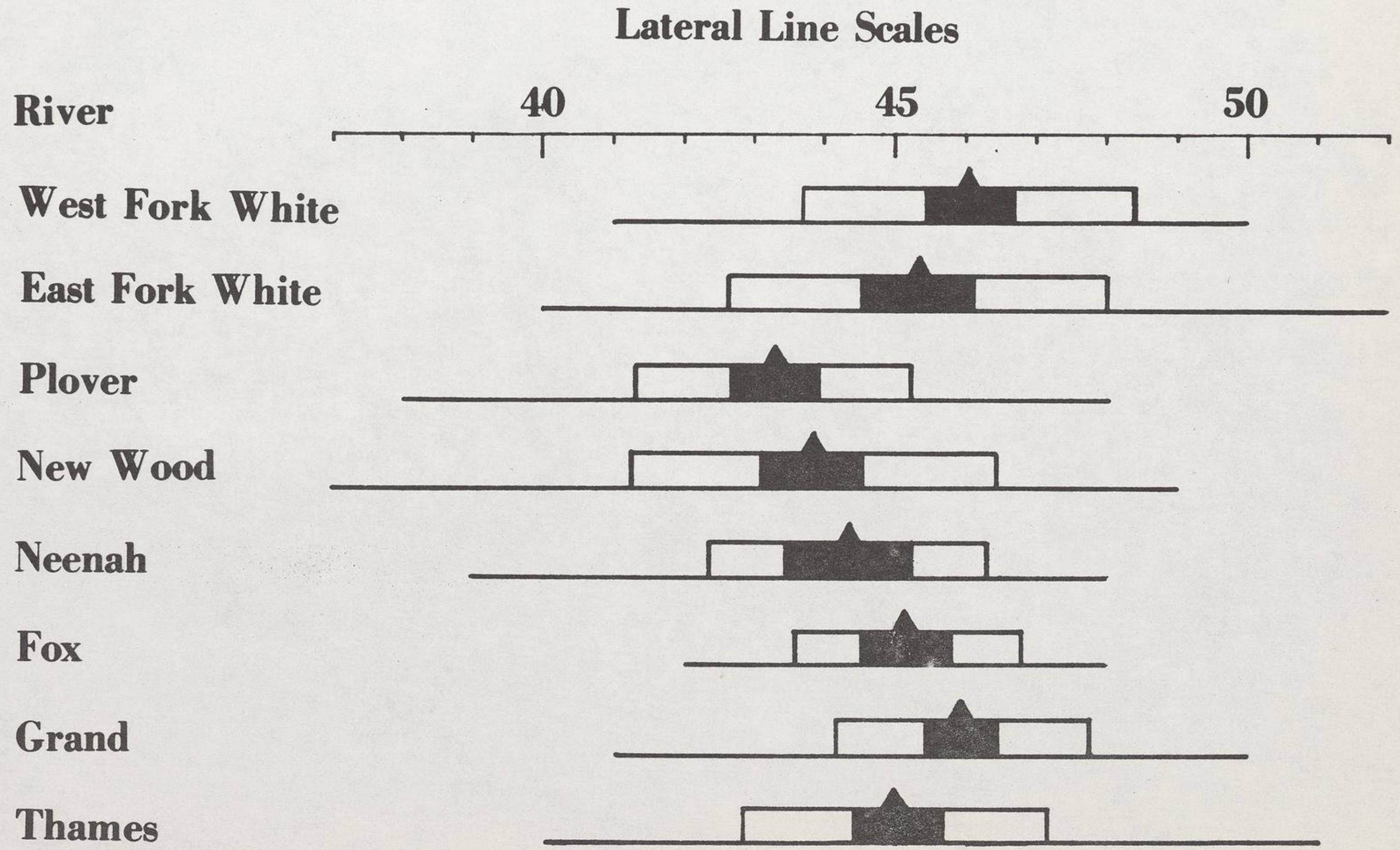


FIGURE 19

GEOGRAPHIC VARIATION IN LATERAL LINE SCALE NUMBERS OF THE RAINBOW DARTER

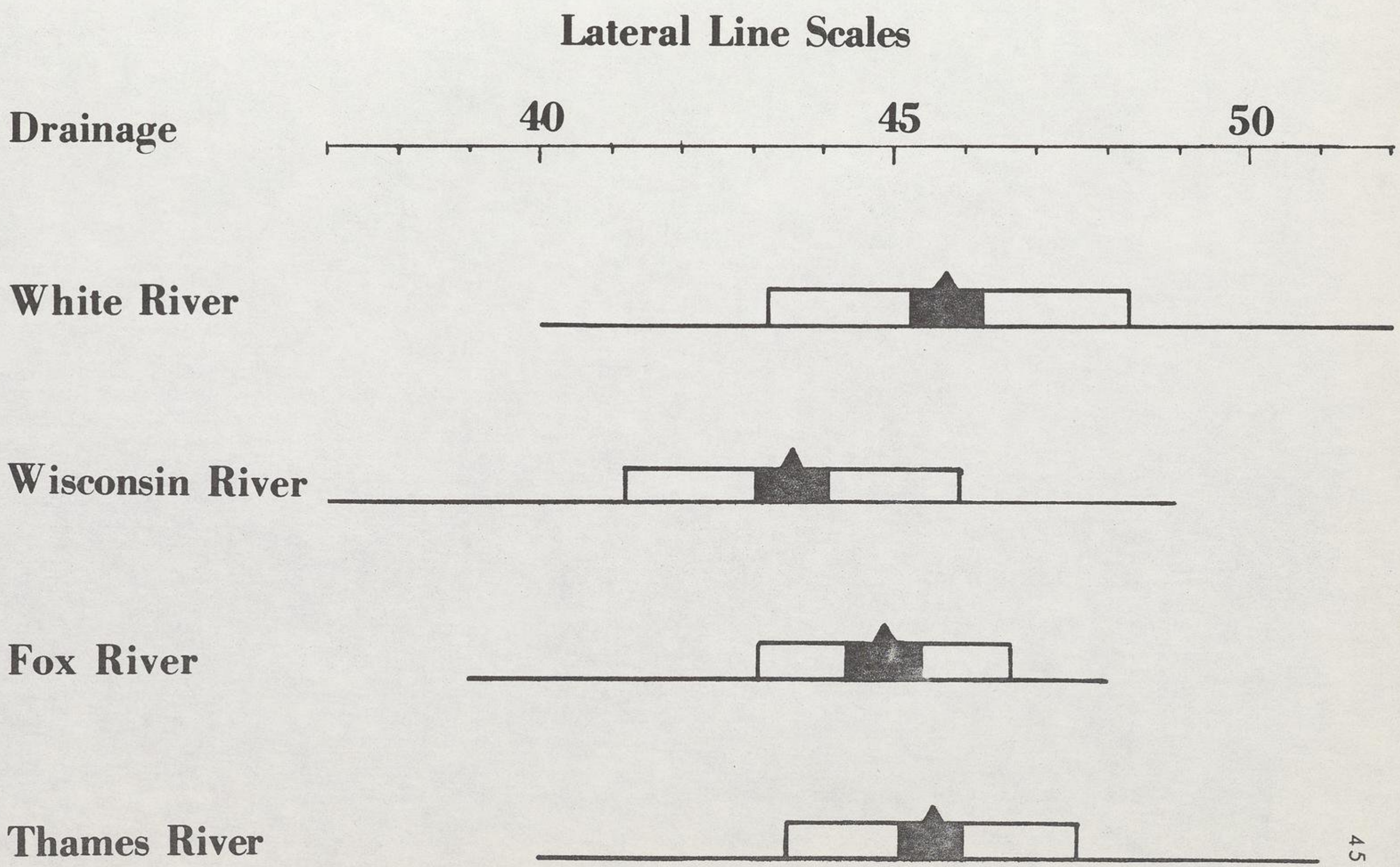


FIGURE 20

Results of the Scheffee test on mean lateral line scale numbers on the rainbow darter

Sample Number	River	Sample Mean	Significance		
3	Plover	43.28	|		
4	New Wood	43.84	|	|	
5	Neenah	44.33	|	|	|
8	Thames	45.00		|	|
6	Fox	45.17		|	|
2	East Fork White	45.34		|	|
7	Grand	45.95			|
1	West Fork White	46.08			|
3 & 4	Wisconsin	43.58			
5 & 6	Fox	44.85	|		
7 & 8	Thames	45.53	|		
1 & 2	White	45.75	|		

TABLE 11

lateral line scales of the rainbow darter

Sample Number	River	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	n	$\bar{x}$	s
1	West Fork White					2	2	6	4	10	7	13	5	4	6			59	46.08 ±.62	2.35
2	East Fork White				1	3	3	5	8	5	5	7	5	1	3		1	47	45.34 ±.78	2.69
3	Plover		1		3	3	11	6	8	8	5		1					46	43.28 ±.58	1.98
4	New Wood	1		2	2	7	2	7	11	8	5	3	3	2				53	43.84 ±.72	2.60
5	Neenah			1			1	3	5	3	3	1	1					18	44.33 ±.92	1.97
6	Fox						1	5	4	6	6	5	2					29	45.17 ±.60	1.62
7	Grand					1		1	9	10	10	8	5	4	1			49	45.95 ±.52	1.80
8	Thames				1	2	1	5	6	9	7	2	5			1		39	45.00 ±.70	2.19
1 & 2	White																	106	45.75 ±.50	2.53
3 & 4	Wisconsin																	99	43.58 ±.48	2.35
5 & 6	Fox																	47	44.85 ±.52	1.80
7 & 8	Thames																	88	45.53 ±.44	2.04

Wisconsin River drainage and the remaining drainages studied (Figure 20).

Oblique Body Bars

Numbers of oblique body bars on the rainbow darters of this study ranged from seven to 13 with means of 9.71 on the Plover River specimens to 10.77 on the Neenah Creek specimens (Table 12 and Figure 21).

Variance analysis indicates a significant difference in oblique body bar numbers between the rainbow darters in this study (Table 13, p. 54). The Scheffee Multiple-Comparison Test indicates that significant differences in mean oblique body bar numbers exist between samples 1,2, 3, 4, 7, 8 and 5, 6; and between samples 1, 2, 5, 6, 8 and 3, 4, 7 (Figure 23).

An interdrainage comparison on mean oblique body bar numbers on the rainbow darters in this study ranged from 9.71 in the Wisconsin River drainage specimens to 10.65 in the Fox River drainage specimens (Table 12 and Figure 22). Variance analysis shows a significant difference in oblique body bar numbers between the rainbow darters in this study (Table 13, p. 54). The Scheffee Multiple-Comparison Test indicates the mean oblique body bar numbers is significantly different between the White and Wisconsin River drainages, between the Fox and Wisconsin River drainages, and between the Fox and Thames River drainages (Figure 23).

Summary

No variation in anal spine numbers and pelvic ray numbers was found among the rainbow darters in this study. Results of

FIGURE 21

GEOGRAPHIC VARIATION IN BODY BAR NUMBERS OF THE RAINBOW DARTER

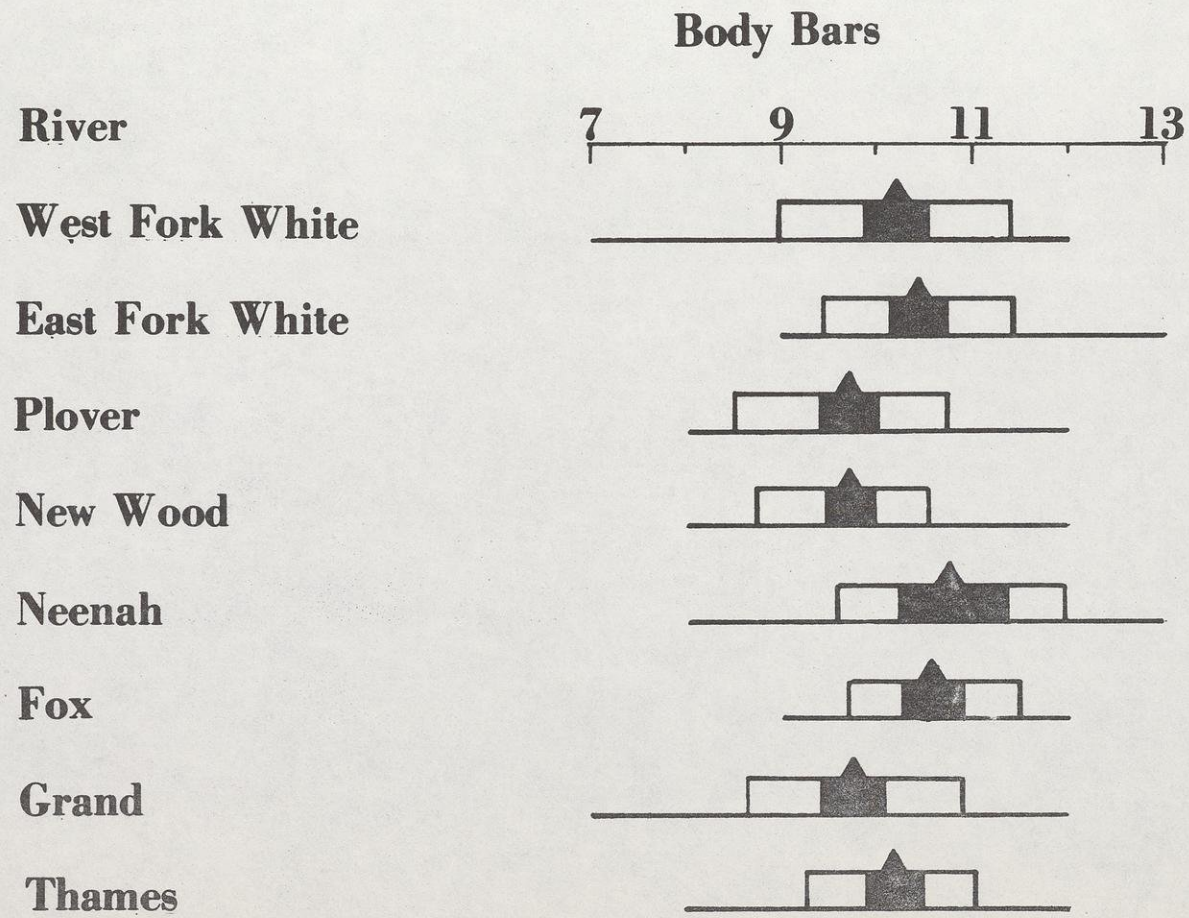


FIGURE 22

GEOGRAPHIC VARIATION IN BODY BAR NUMBERS OF THE RAINBOW DARTER

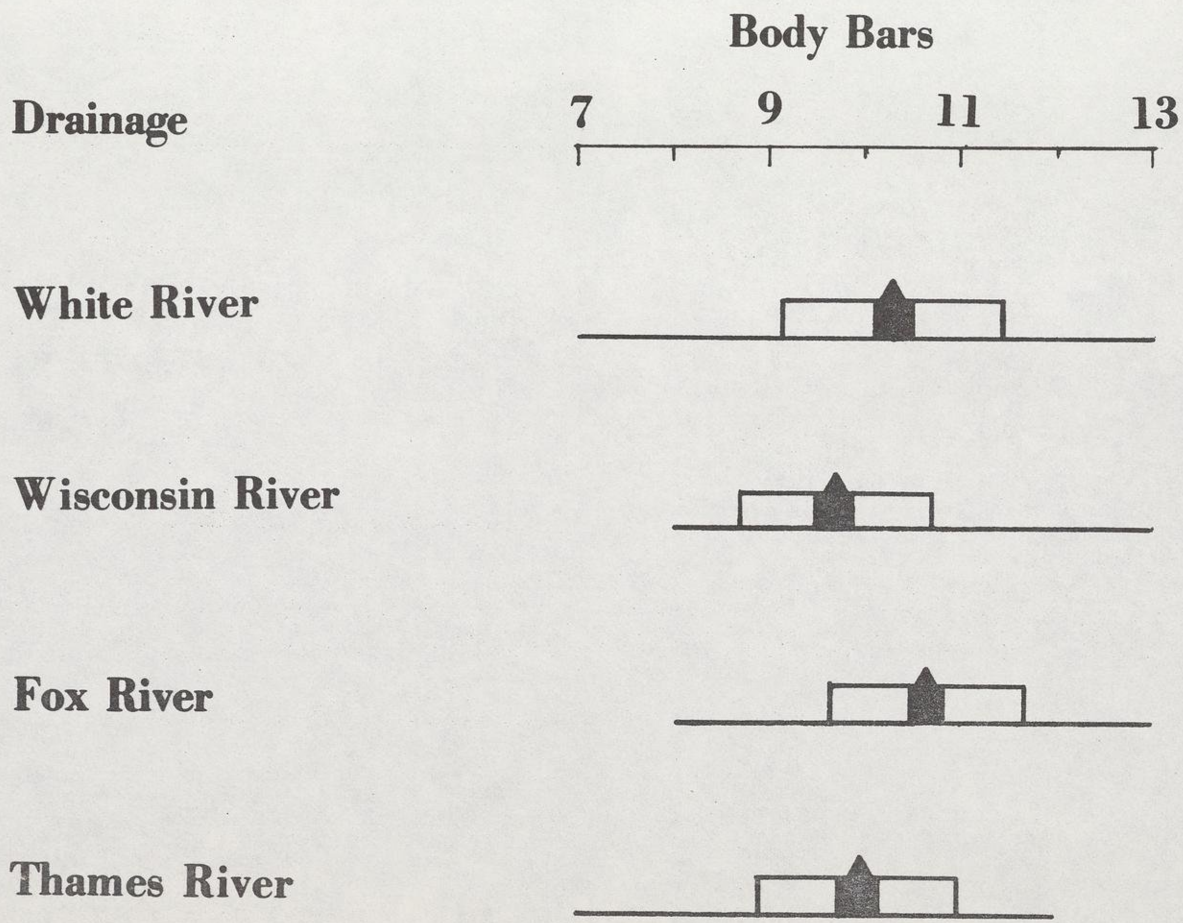


FIGURE 23

Results of the Scheffee test on mean body bar numbers on the rainbow darter

Sample Number	River	Sample Mean	Significance
3	Plover	9.71	
4	New Wood	9.71	
7	Grand	9.73	
8	Thames	10.15	
1	West Fork White	10.20	
2	East Fork White	10.42	
6	Fox	10.58	
5	Neenah	10.77	

3 & 4	Wisconsin	9.71	
7 & 8	Thames	9.92	
1 & 2	White	10.30	
5 & 6	Fox	10.65	

TABLE 12

Body bars of the rainbow darter

Sample Number	River	7	8	9	10	11	12	13	n	x̄	s
1	West Fork White	3	2	8	20	19	7		59	10.20 ±.32	1.21
2	East Fork White			9	17	14	6	1	47	10.42 ±.28	1.00
3	Plover		6	14	15	9	2		46	9.71 ±.30	1.05
4	New Wood		2	24	18	5	4		53	9.71 ±.26	0.95
5	Neenah		1	2	2	9	3	1	18	10.77 ±.56	1.18
6	Fox			3	11	10	5		29	10.58 ±.32	0.89
7	Grand	2	4	13	18	10	2		49	9.73 ±.32	1.12
8	Thames		1	7	18	11	2		39	10.15 ±.28	0.86
1 & 2	White								106	10.30 ±.22	1.13
3 & 4	Wisconsin								99	9.71 ±.20	1.00
5 & 6	Fox								47	10.65 ±.30	1.01
7 & 8	Thames								88	9.92 ±.22	1.03

analysis of variance (Table 13) indicates the most significant differences found in the rainbow darters in this study occur in the dorsal ray numbers and lateral line scale numbers. No significant difference is indicated in dorsal spine numbers of the rainbow darters studied.

The highest mean number of meristic elements on the rainbow darters in this study was observed in specimens from Neenah Creek in three out of seven meristic elements showing significant variation while the highest mean number of meristic elements was observed in specimens from the West Fork of the White River in two out of the seven meristic elements showing significant variation. The lowest mean number of meristic elements was observed in the Plover River specimens in two out of seven meristic elements showing significant differences.

In an interdrainage system comparison the Fox River drainage samples of the rainbow darter in this study had the highest mean number of meristic elements in four out of the seven meristic elements showing significant variation and the White River drainage specimens showed the highest means in three out of seven meristic elements showing significant differences. Both the Wisconsin and White River drainage specimens had the lowest mean meristic element counts in three out of seven meristic elements showing significant differences.

Within drainage samples of the rainbow darter in this study have mean meristic character numbers which lie next to each other in numerical sequence in 16 out of the 42 possible sequences.

TABLE 13

Results of Analysis of Variance +

Character	F-Ratio: Comparison between all 8 samples	F-Ratio: Comparison between drainages (4). Samples combined within drainages
Vertebrae	11.08**	24.50**
Dorsal Spines	1.62	0.45
Dorsal Rays	44.09**	103.97**
Anal Rays	2.55*	3.05*
Pectoral Rays	8.57**	11.47**
Pored Lateral Line Scales	3.45**	5.67**
Lateral Line Scales	9.28**	18.09**
Oblique Body Bars	5.30**	10.71**

* Significant at 5% level

** Significant at 1% level

\+ This table is a summary of Appendix 1

It is evident that significant meristic variations exist between populations of the rainbow darter. These variations exist both on a local level and a regional level. The anal spines and pelvic rays appear to be very constant and only slight variation is noted in the dorsal spine numbers. Yet variation exists in the seven remaining meristic elements studied on the rainbow darter.

Some of the possible causes of meristic variation of the rainbow darter are genetic gradients and environmental gradients such as; temperature, light, dissolved gases, pH, and salinity (Barlow, 1961).

Genetic differences in populations of fish can cause differences in meristic characters. Until the early 1940's it was thought that any meristic differences were determined by genetics. It now has been shown that environment can change meristic elements, and that meristic differences may be due to environmental changes (Barlow, 1961). More work has been done on environmental influences than has been done on genetic influences. Fowler (1970) says, "I know of no genetic experiment demonstrating directly the existence of genes governing a certain range of vertebral numbers." He goes on to state that indirect evidence is all that is available, but some of this is fairly good.

Many authors have noticed a relationship between meristics of parents and of progeny. Gabriel (1944) in his temperature experiments with Fundulus heteroclitus found that offspring of parents with high vertebral counts had high vertebral counts, and offspring of parents with low vertebral counts had low vertebral counts. Schmidt (1919) says the number of dorsal fin rays in new born guppies is high or low depending on the parentage. Different pairs of parents were raised under identical conditions, and the offspring of the different parents had different vertebral means. Strawn (1961) and Eisler (1961) both found that progeny of different parents showed different amounts of variation which was attributed to slight genetic differences. Separate races of one species raised under similar conditions showed differences in meristic characters (Heuts, 1949). Hybrids between these races have intermediate numbers of elements. This would suggest there is some genetic difference between races of the same species and this would partially explain the meristic variation noted in this study.

The literature concerning experiments designed to actually determine what genes effect certain meristic characters is scanty. Barlow (1961) cites Golovenskaya who found a mutant gene in a carp (*Cyprinus* spp.) that could decrease the number of fin rays, scales, and gill rakers. Hubbs (1955) says he found a single gene in *Gambusia affinis* that controls both the number of dorsal fin rays and the number of anal fin rays. Gordon (Barlow, 1961) questions the findings of Hubbs, and thinks it is multifactor inheritance rather than action of a single gene. Fowler (1970) cites Schroeder who studied the inheritance of dorsal fin ray numbers in *Mollienesia* and concluded that it was polygenic inheritance. Much more work must be done in this area to determine the genetic influence on the determination of meristic numbers in fishes.

Barlow (1961) cites Ege who gave information as to selection for a specific vertebral number. One experimental population had low vertebral numbers while a second population had higher vertebral numbers. These populations were mixed and allowed to interbreed. The first few year classes, resulting from crosses between these two populations, showed a slight increase in the number of vertebrae from year to year. Then the mean for each year class started to decrease and stabilized at a lower level. He realized that there had been a gradual change in the genotype of these fish. Obviously something was selecting for the fish that had lower vertebral numbers. No specific factor or factors were postulated as the cause of this natural selection. Bailey and Gosline (1955) found that natural selection can reduce the variability of vertebral numbers in the percid fishes.

Scott (1972) suggests that there may be a genetic basis to meristic variation. Sand lances were collected from 12 places in the Northwest Atlantic. Significant differences were found in dorsal fins, anal fins, and vertebral numbers. The trend was for meristic characters to increase from south to north. Scott (1972) says that part of the variation was due to temperature changes.

McPhail (1963) worked with populations of the ninespine stickleback, *Pungitius pungitius*, all over North America. Dorsal spine counts varied from seven to 12 and gill rakers varied from

10 to 15. No north to south cline was determined for any of the meristic characters studied. He postulated that these variations were due to separation of the populations by glacial actions, causing allopatric forms.

Trying to separate the effects of genetics from the effects of the environment on meristic characters is very difficult. These two factors work together to produce meristic differences. Fowler (1970) says the range of meristic differences is determined genetically but the actual number is determined by the environment. Tåning (1952) says the environment influences the genotype during the phenocritical period and produces various phenotypic expressions. Barlow and Hubbs (Barlow, 1961) agree that a species gene pool can be altered by the environment. They also say that an altered environment can produce adaptive changes in the organism, and these changes through time may become genetically fixed.

Vertebral numbers of the rainbow darters in this study increased to the north. No other distinct latitudinal cline in mean meristic numbers of the rainbow darter is noted.

In some cases greater meristic variation is noted on an intradrainage level compared to the interdrainage level, leading to the conclusion that each meristic element is influenced independent of all others.

A greater number of dorsal rays of the rainbow darter is present in the White River drainage samples. Knapp (1964) suggests the existence of possible subspecies of the rainbow darter from the Ozark drainages due to difference in dorsal ray numbers.

It is suggested that the phenotype of the rainbow darter is influenced by environmental factors, during ontogeny, and its genetic composition. Spatial and time separation can also be postulated as factors causing meristic variation in the rainbow darter.

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APPENDIX 1

Single Factor Analysis of Variance

Comparison Between All 8 Samples

VERTEBRAE

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	7	42.00	6.00	11.08**
Within	332	179.81	0.54	
Total	339	221.81	0.65	

DORSAL SPINES

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	7	2.98	0.43	1.62
Within	332	87.09	0.26	
Total	339	90.06	0.27	

DORSAL RAYS

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	7	135.48	19.35	44.09**
Within	332	145.75	0.44	
Total	339	281.23	0.83	

ANAL RAYS

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	7	1.98	0.28	2.55*
Within	332	36.88	0.11	
Total	339	38.86	0.11	

*Significant at 5% level

**Significant at 1% level

Comparison Between All 8 Samples

PECTORAL RAYS

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	7	16.45	2.35	8.57**
Within	332	91.06	0.27	
Total	339	107.52	0.32	

PORED LATERAL LINE SCALES

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	7	160.44	22.92	3.45**
Within	332	2206.56	6.65	
Total	339	2367.00	6.98	

LATERAL LINE SCALES

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	7	333.38	42.62	9.28**
Within	332	1703.50	5.13	
Total	339	2036.88	6.01	

OBLIQUE BODY BARS

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	7	41.78	5.97	5.30**
Within	332	373.91	1.13	
Total	339	415.70	1.23	

**Significant at 1% level

Comparison Between Drainages (4) Samples Combined Within Drainages

VERTEBRAE

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	3	39.81	13.27	24.50**
Within	336	182.00	0.54	
Total	339	221.81	0.65	

DORSAL SPINES

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	3	0.36	0.12	0.45
Within	336	89.70	0.27	
Total	339	90.06	0.27	

DORSAL RAYS

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	3	135.38	45.13	103.97**
Within	336	145.84	0.43	
Total	339	281.23	0.83	

ANAL RAYS

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	3	1.03	0.34	3.05*
Within	336	37.83	0.11	
Total	339	38.86	0.11	

*Significant at 5% level

**Significant at 1% level

APPENDIX 1 (CONTINUED)

Comparison Between Drainages (4) Samples Combined Within Drainages

PECTORAL RAYS

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	3	9.98	3.33	11.47**
Within	336	97.53	0.29	
Total	339	107.52	0.32	

PORED LATERAL LINE SCALES

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	3	113.97	37.99	5.67**
Within	336	2353.03	6.71	
Total	339	2367.00	6.98	

LATERAL LINE SCALES

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	3	283.25	94.42	18.09**
Within	336	1753.63	5.22	
Total	339	2036.88	6.01	

OBLIQUE BODY BARS

	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Columns	3	36.27	12.09	10.71**
Within	336	379.42	1.13	
Total	339	415.70	1.23	

**Significant at 1% level