THESIS

IDENTIFICATION OF BROOK, BROWN, RAINBOW, AND CUTTHROAT TROUT LARVAE

Submitted by

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In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

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COLORADO STATE UNIVERSITY

Fall, 1983

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION

BY ANITA M. MARTINEZ

ENTITLED IDENTIFICATION OF BROOK, BROWN, RAINBOW, AND CUTTHROAT TROUT LARVAE

BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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ABSTRACT OF THESIS

IDENTIFICATION OF BROOK, BROWN, RAINBOW, AND CUTTHROAT TROUT LARVAE

Metalarvae and mesolarvae of Salvelinus fontinalis, Salmo trutta, Salmo gairdneri, and Salmo clarki were analyzed for distinguishing pigmentation patterns, variation in size and abundance of oil globules in the yolk, and morphological and meristic differentiation using percent standard length and multivariate statistical techniques. Laboratory- and hatchery-reared larvae of these species were compared for 48 morphological and meristic characters.

Salmo gairdneri and Salmo clarki differed in position of dorsal fin insertion and adipose fin origin, recorded as percent standard length, and in five characters determined by discriminant function analysis (length of pelvic and adipose fins, length from snout to origin of adipose fin, and depth at origin of dorsal fin and posterior margin of vent). Salmo trutta differed from the other species in having longer pectoral fins, an elongate yolk sac, and unique pigmentation on the mandible, caudal fin, and adipose fin. Salvelinus fontinalis differed from the other species by having numerous minute oil globules in the yolk; a distinctively longer adipose fin; prominent pigmentation on the anterior margin of the mandible, caudal fin, and adipose fin; and a greater number of dorsal and ventral secondary parr marks. Salmo trutta and Salvelinus fontinalis had unilobed preanal

finfolds, while Salmo gairdneri and Salmo clarki had bilobed preanal finfolds. Additional differences between the larvae of these species are discussed.

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I particularly wish to thank Darrel E. Snyder, Director of the Larval Fish Laboratory, for acquiring and assembling most of the study specimens and directing and assisting with the project; Lynn Bjork, whose original illustrations greatly enhanced the quality of this thesis; Steve Culver, for performing the multivariate statistical analysis; and Patrick J. Martinez, whose continued support and encouragement enabled the completion of this project.

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INTRODUCTION

In management of fish or bodies of water and in monitoring impacts of man's activities it is often necessary to study distribution, abundance, and general biology of larval fish. Unfortunately, such investigations can be limited by difficulty in identifying fish larvae. This may occur even in the case of widely distributed salmonids such as brook, brown, rainbow, and cutthroat trout (Salvelinus fontinalis, Salmo trutta, Salmo gairdneri, and Salmo clarki, respectively). Larvae of these species except the cutthroat trout have been described (Crawford 1925, Wales 1941, Knight 1963, Ballard 1973, Lister 1980), but these descriptions are largely incomplete and inadequate for identification purposes. Perhaps the most useful criteria described to date for distinguishing brook, brown, and rainbow trout larvae and juveniles are provided by Bacon (1954), Weisel (1966), Marcinko (1978), and Balon (1980). Cutthroat and rainbow trout larvae, being very similar, are especially difficult to distinguish from one another.

The objectives of this investigation were to provide detailed comparative descriptions of the aforementioned trout larvae and early juveniles, verify diagnostic characters suggested by previous investigators, and determine additional (and perhaps more obvious and consistent) differences for identification purposes. Emphasis was placed on external pigmentation and morphology, including numerous morphometric and meristic characters. Unfortunately, only hatchery- or

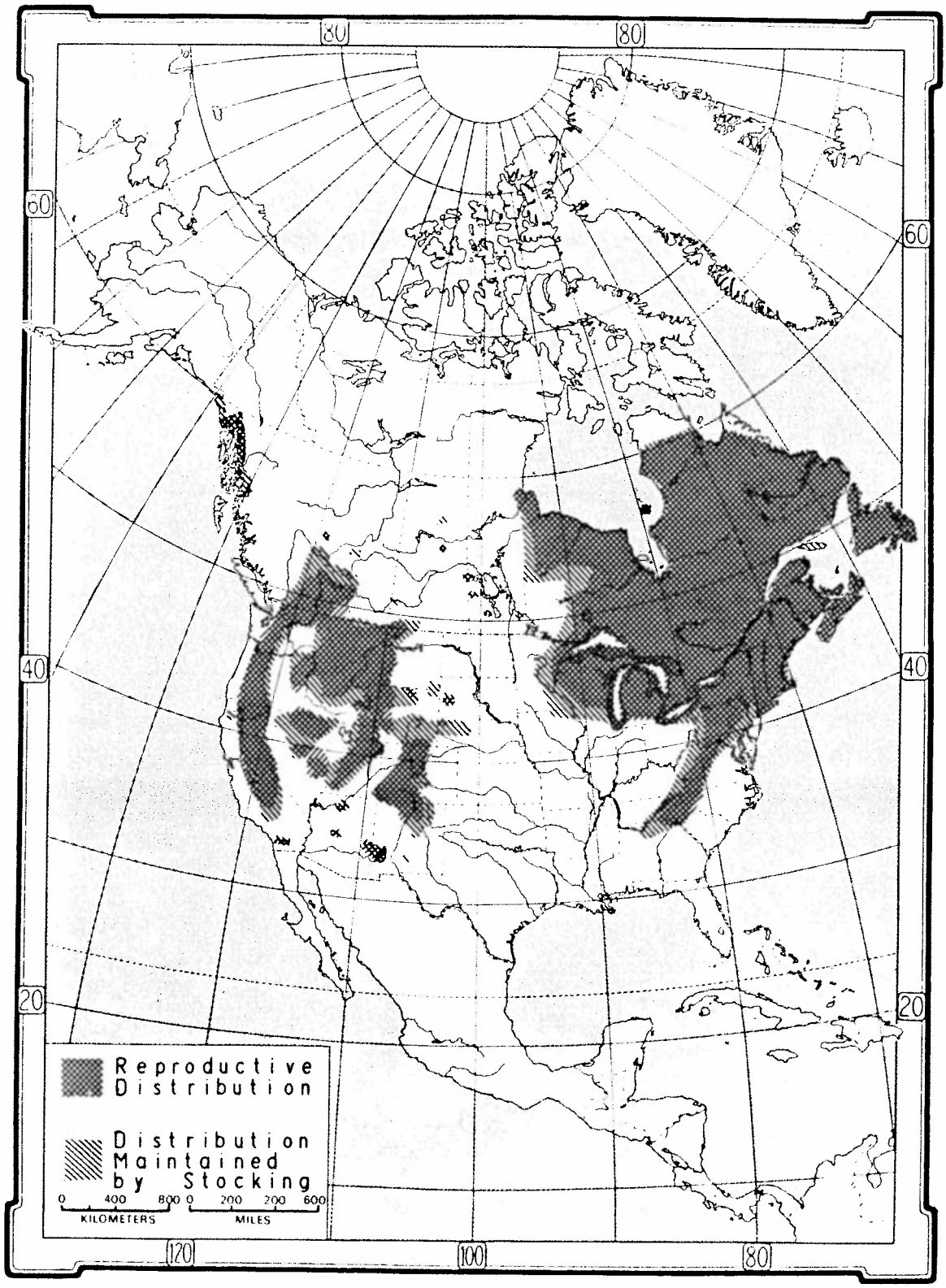
laboratory-reared specimens were available for study; while some characters may differ in naturally-spawned or reared larvae, most diagnostic characters are expected to remain applicable. Reproductive distribution was summarized to document geographic areas in which the larvae of the various species might be encountered.

DISTRIBUTION

Knowledge of the fish species inhabiting a geographic region or specific drainage often enables researchers to limit the number of potential candidates when identifying collected fish larvae. Figures 1 through 4 are maps of general distribution compiled from the currently scattered and often fragmentary literature. Since fish eggs and larvae are generally collected only in areas or drainages occupied by reproducing populations, they are distinguished on these maps from populations maintained largely by stocking. The maps also include areas converted from inappropriate to suitable trout habitat by man (e.g., below deep release dams and in the hypolimnion of deep reservoirs).

The most comprehensive distribution maps for brook, brown, and rainbow trout were prepared by MacCrimmon and Marshall (1968), MacCrimmon and Campbell (1969), MacCrimmon, Marshall and Gots (1970), and MacCrimmon (1971). These maps are outdated, and I have revised them. Behnke (1979 and 1980) provided most of the information on cutthroat trout distribution. Additional distribution data were obtained through the publications of various state fish and game agencies (Kuhne 1939, LaRivers 1962, Sigler and Miller 1963, Baxter and Simon 1970, Scarola 1973, Clay 1975, and Pflieger 1975) and universities (Cross and Collins 1975, Moyle 1976, Simpson and Wallace 1978, Smith 1979, Wydoski and Whitney 1979, and Werner 1980). More

Figure 1. Distribution of brook trout.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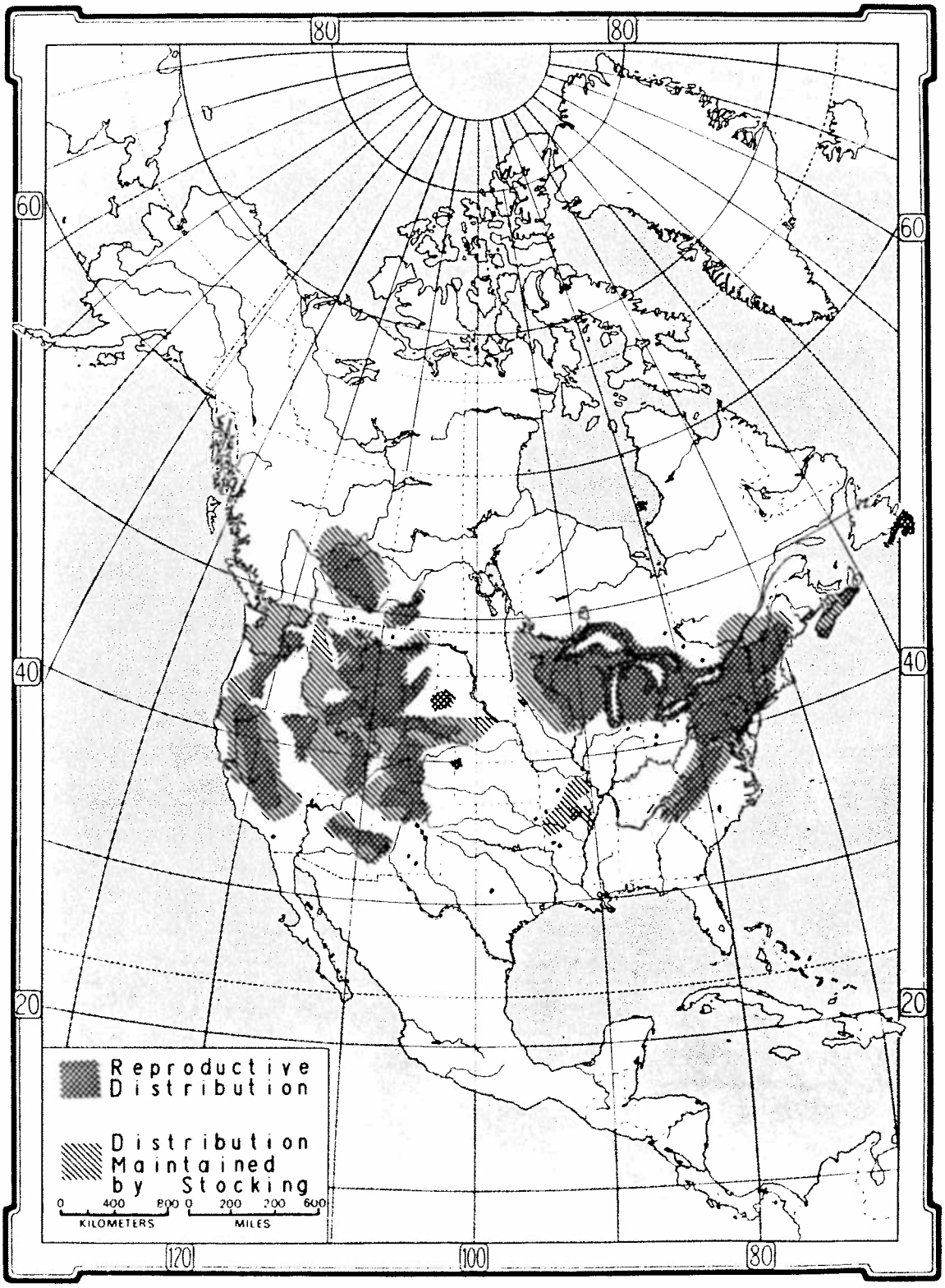
Reproductive Distribution
Distribution Maintained by Stocking
0 400 800
KILOMETERS
0 200 200 600
MILES

Figure 2. Distribution of brown trout.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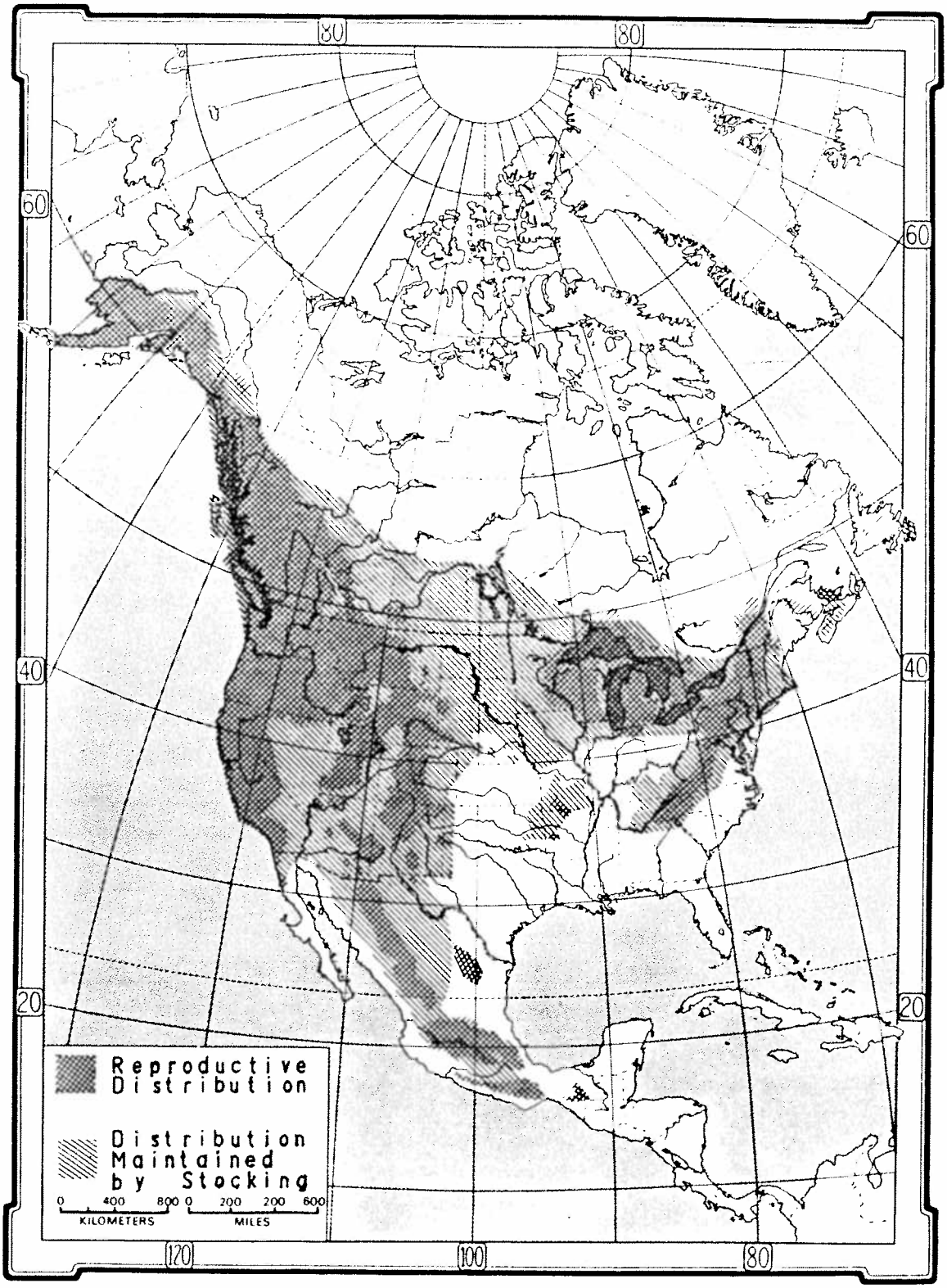
Reproductive Distribution
Distribution Maintained by Stocking
0 400 800
KILOMETERS
0 200 200 600
MILES

Figure 3. Distribution of rainbow trout.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Reproductive Distribution
Distribution Maintained by Stocking
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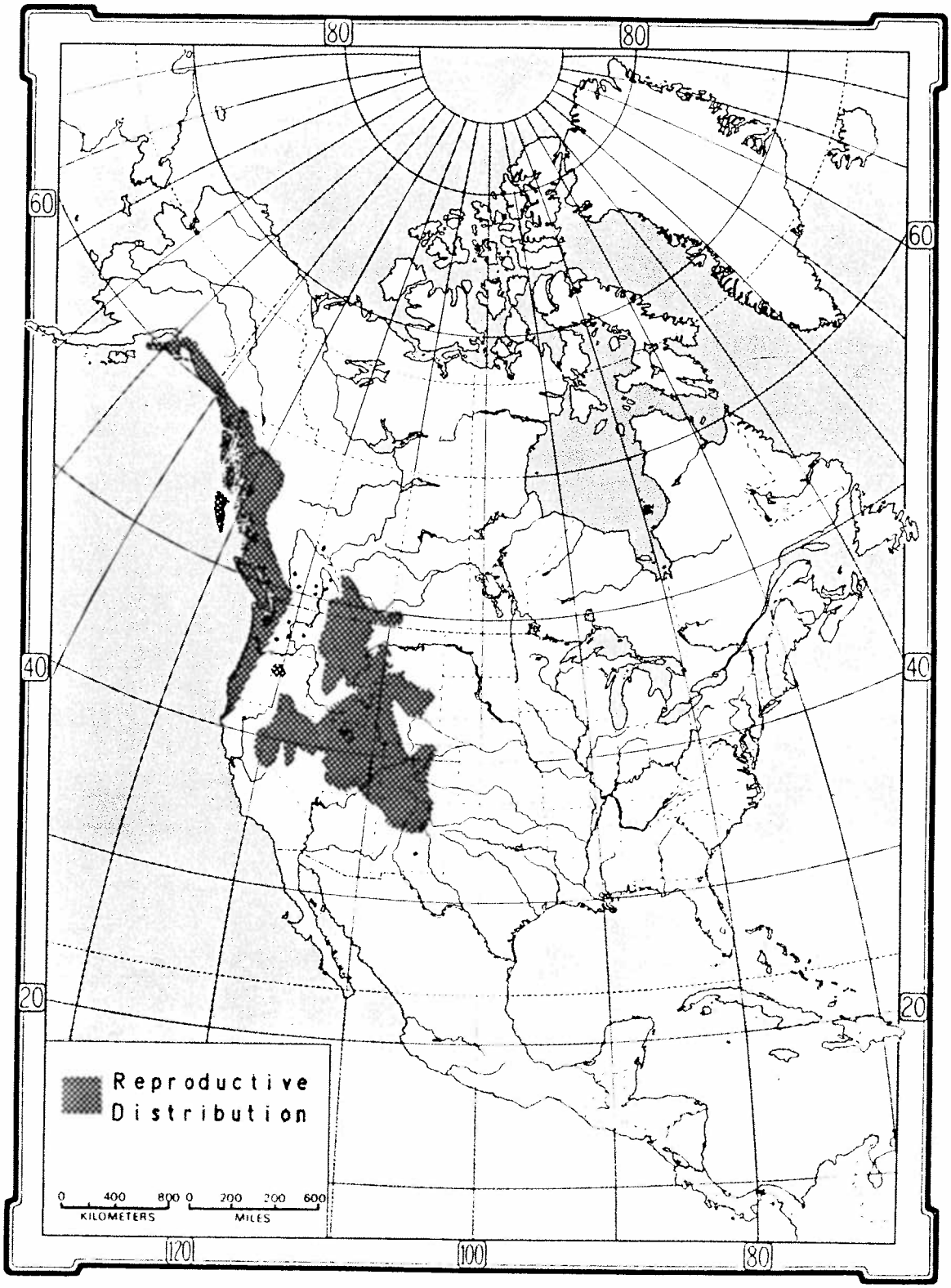
KILOMETERS
0 200 200 600
MILES

Figure 4. Distribution of cutthroat trout.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Reproductive Distribution
0 400 800
KILOMETERS
0 200 400 600
MILES

general distributional maps by Scott and Crossman (1973), Eddy and Underhill (1974), and Lee et al. (1980) were also consulted.

SPECIMENS EXAMINED

Approximately 50 hatchery- and laboratory-reared specimens, from recently hatched to early juvenile stages, were examined for each of the four species. All were obtained between 1976 and 1982 and were preserved in 3% buffered formalin (Farris 1963). The brook, brown, and cutthroat series were raised at approximately 12 C from fertilization or an eyed developmental stage, and the rainbow series was raised at 15-17 C from an eyed egg stage (Table 1). The brown and cutthroat (greenback subspecies S. c. stomias) trout originated from Colorado brood stock in Delaney Butte Lake and Island Lake, respectively. The brook trout came from California's Mount Whitney Hatchery, where they were incubated at 6-9 C to an eyed stage prior to shipment to the Bellvue Hatchery. The rainbow trout (Tasmanian strain) were obtained from Colorado's Rifle Falls Hatchery; they were then transferred as eyed eggs to Colorado State University, where they were raised. Two juvenile rainbow trout (Arlee strain) were also examined. These originated from brood fish at Colorado's Crystal River Hatchery and were raised at the Bellvue Hatchery. Table 1 includes dates of collection and ages at the apparent onset of specific stages or phases of development for each trout species studied.

Table 1. Dates of collection and ages in days (in parentheses) of brook, brown, rainbow and cutthroat trouts examined at the apparent onset of specific stages of phases of development.

	Brook 1977	Brown 1976-1977	Rainbow 1977	Cutthroat 1977
Rearing Temperatures	12 C	12 C	15-17 C	12 C
Fertilized	20 January	15 October	5 January	23 June
Eyes Pigmented	17 February (29)	15 November (33)	23 January (19)	8-22 July (16-30)
Hatched	19 February (31)	15 November (33)	27-31 January (23-27)	8-22 July (16-30)
Protolarvae[1]	24 February-3 March (36-43)	None	None	8 July (16)
Mesolarvae	24 February-7 March (36-47)	15-22 November (33-40)	27-31 January (23-27)	8-26 July (16-34)
Metalarvae	3 March-27 April (43-98)	27 November-10 January (45-89)[4]	27 January->30 March (23-85)	26 July-20 September (34->90)[4]
Juveniles	25 April-19 May (96->120)[4]	≥5 January[2] (>83)[4]	≥21 January[3] (>91)[4]	No Data

[1] Premature hatching.
[2] Two juveniles collected 5 January 1982, fertilized 15 October 1981; origin - Delaney Butte Lake.
[3] Two juveniles collected 21 January 1982, fertilized 23 October 1981; origin - Crystal River Hatchery.
[4] No data beyond stated age.

METHODS

Equipment

Specimens were examined and measured under a variable-magnification dissecting microscope with a 10-mm eyepiece reticle, 0.5X objective lens, polarizing filters and transmitted and/or reflected lighting as needed. Magnification was initially set at approximately 5X or 10X, depending on whether the eyepiece was to be calibrated as a 10-mm or 20-mm scale. The scale in the reticle was then calibrated against a stage micrometer positioned in the plane of focus by adjusting the magnification. The polarizing filters were of limited value in counting myomeres of these relatively large and thick-bodied larvae, but they were useful in illuminating fin rays and pterygiophores.

Morphometrics

Analysis of 35 specific length measurements illustrated in Figures 5 through 7 was included in this study (Table 2). Lengths were measured from the anterior margin of the snout to a specific structure or point along imaginary lines parallel to the longitudinal axis of the body (Figs. 5a and 5b). The distance between any two points of reference was simply determined by subtraction (e.g., length of the base of the fin is the measurement to the fin's insertion minus the measurement to its origin). Fin length was measured as the maximum

Table 2. Taxonomic characters examined (x) and analyzed (s-% standard length, d-discriminant function analysis, p-principal component analysis) for 1) protolarvae, 2) mesolarvae, 3) metalarvae, and 4) juveniles of brook, brown, rainbow, and cutthroat trout. Asterisk indicates useful methods for segregating the trouts when using the coinciding character.

Morphometric and Meristic Characters		Life Phases			
Abbreviations		1	2	3	4
Lengths					
AS to:	Anterior margin of snout to:				
AE	Anterior margin of eye	x	d,s	s	x
PE	Posterior margin of eye	x	d,s	d,s	x
OP1	Origin of pectoral fin(s)	x	d,s	d,s	x
OP2	Origin of pelvic fin(s)	x	d,s	d*,p*,s	x
PY	Posterior margin of yolk	x	d,s*	s*	
IY	Insertion of yolk	x	s*	s	
OPAF	Origin of preanal finfold				
	First lobe	x	d*,p,s*	s*	
	Second lobe			x	
ODF	Origin dorsal finfold	x	s*	s*	
OD	Origin of dorsal fin		s*	d*,p*,s*	x
ID	Insertion of dorsal fin		s*	d,s*	x
OAD	Origin of adipose fin			d*,p*,s*	x
PV	Posterior margin of vent	x	d*,p,s,	d,s	x
OA	Origin of anal fin		x	d	x
IA	Insertion of anal fin		x	d,s	x
PHP	Posterior margin of hypural plates	x	x	x	x
AFC	Anterior margin of fork of caudal fin			s	x
PC	Posterior margin of caudal fin	x	d,s	s	x
Max. Y	Maximum yolk	x	d*,p	x	
D	Dorsal fin		x	d*	x
A	Anal fin		s	d*,p*	x
P1	Pectoral fin(s)	x	d	s*	x
P2	Pelvic fin(s)		s	d*,p*,s	x
AD	Adipose fin			d*,p*,s*	x
Depths at:					
BPE	Behind posterior margin of eye	x	x	x	x
OP1	Origin of pectoral fin(s)		d*	d*,p*	x
OD	Origin of dorsal fin		x	d*,p*	x
BPV	Behind posterior margin of vent	x	d	d*,p*	x
AMPM	Anterior margin of most posterior myomere	x	d*,p	d*,p*	x
Max. Y	Maximum yolk	x	d*,p	x	
Widths at:					
BPE	Behind posterior margin of eye	x	d*,p	d*,p*	x
OP1	Origin of pectoral fin(s)	x	d*,p	d	x
OD	Origin of dorsal fin			x	x
BPV	Behind posterior margin of vent	x	d*,p	x	x
AMPM	Anterior margin of most posterior myomere		d	x	x
Max. Y	Maximum yolk	x	x	x	

Table 2. Continued.

Morphometric and Meristic Characters		Life Phases			
Abbreviations		1	2	3	4
Myomeres to:					
PY	Posterior margin of yolk		x	x	x
OPAF	Origin of preanal finfold		x	x	x
OP2	Origin of pelvic fin(s)		x	x	x
ODF	Origin of dorsal finfold		x	x	x
OD	Origin of dorsal fin		x	x	x
PV	Posterior margin of vent		x	x	x
total	Total myomeres		x	x	x
Fin Ray Number					
C	Caudal fin principal rays	x	x	d	x
	Dorsal secondary rays		x	d*,p*	x
	Ventral secondary rays		x	d	x
D	Dorsal fin principal rays	x	x	d*,p*	x
	Secondary rays		x	d	x
A	Anal fin principal rays		x	d*,p*	x
	Secondary rays		x	d*,p*	x
P1	Pectoral fin rays		x	x	x
P2	Pelvic fin rays		x	d*,p*	x

Figure 5a. Length measurements for morphometric analysis of salmonid larvae and early juveniles. All were measured from the anterior margin of the snout to a specific point of reference on all developmental stages in which the referenced structure exist.

← LENGTHS FROM SNOUT →

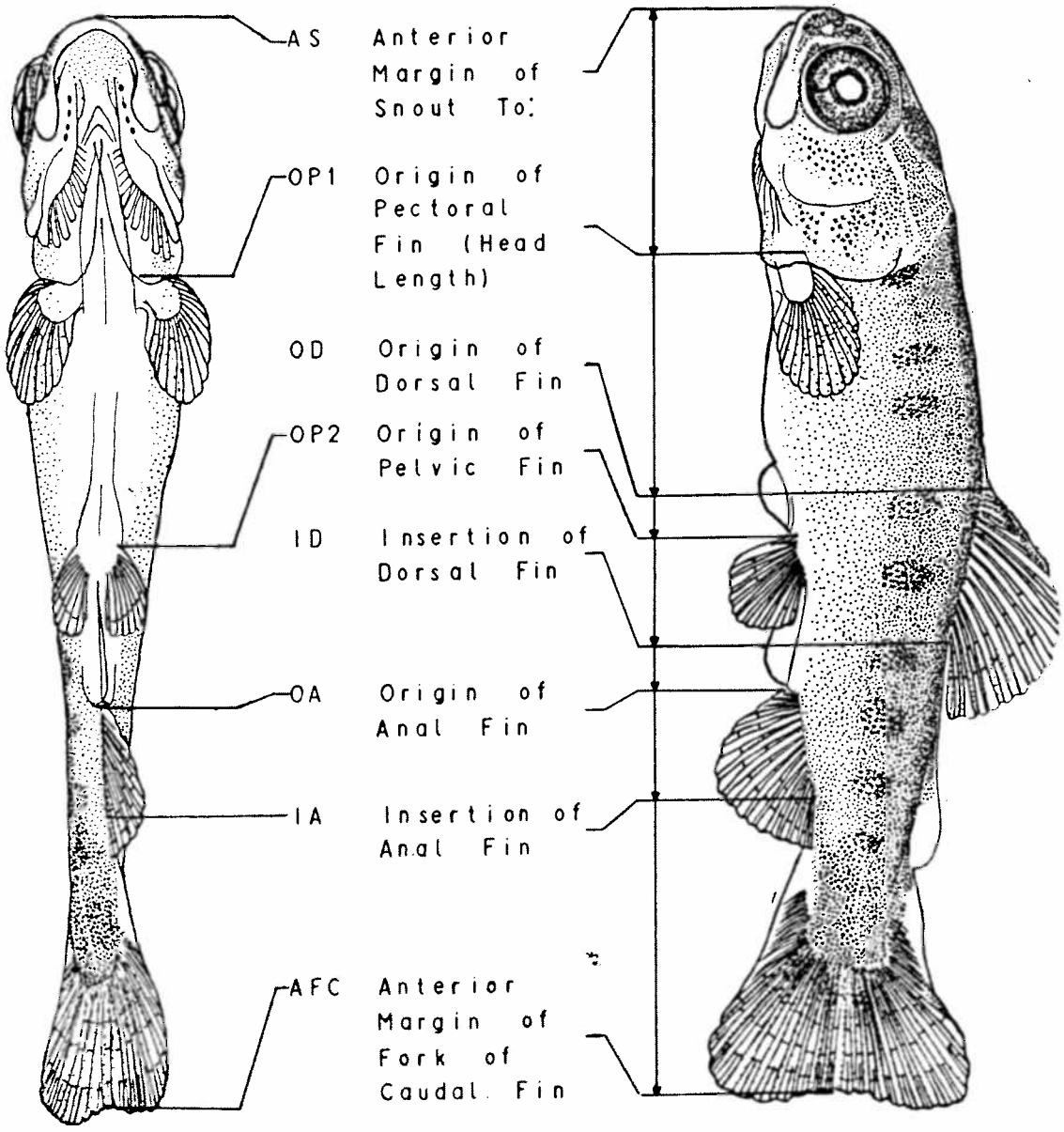


Figure 5b. Length measurements for morphometric analysis of salmonid larvae and early juveniles. All were measured from the anterior margin of the snout to a specific point of reference on all developmental stages in which the referenced structure exist.

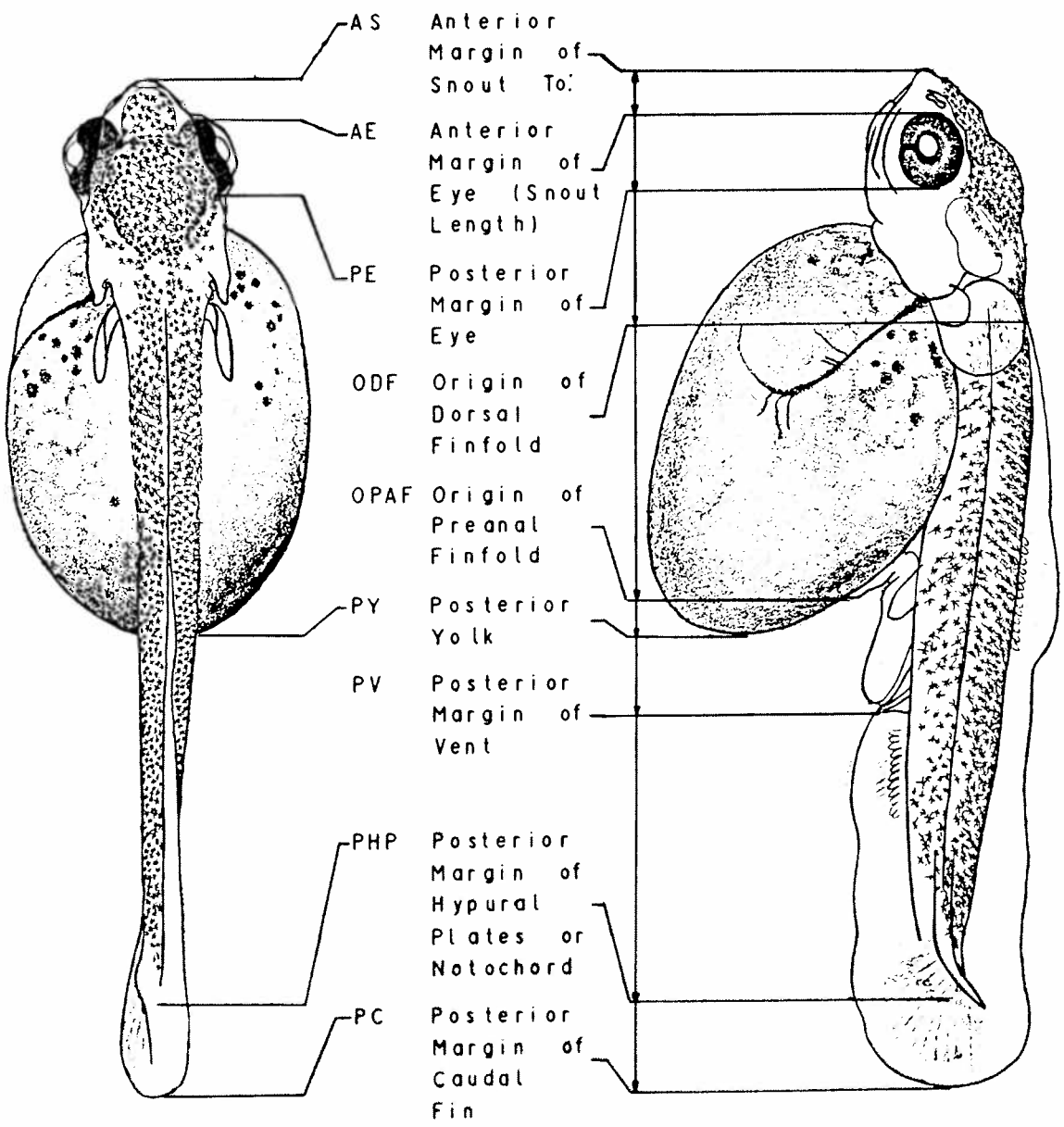

LENGTHS FROM SNOUT
AS Anterior Margin of Snout To:
AE Anterior Margin of Eye (Snout Length)
PE Posterior Margin of Eye
ODF Origin of Dorsal Finfold
OPAF Origin of Preanal Finfold
PY Posterior Yolk
PV Posterior Margin of Vent
PHP Posterior Margin of Hypural Plates or Notochord
PC Posterior Margin of Caudal Fin

Figure 6a. Depth measurements for morphometric analysis of salmonid larvae and early juveniles.

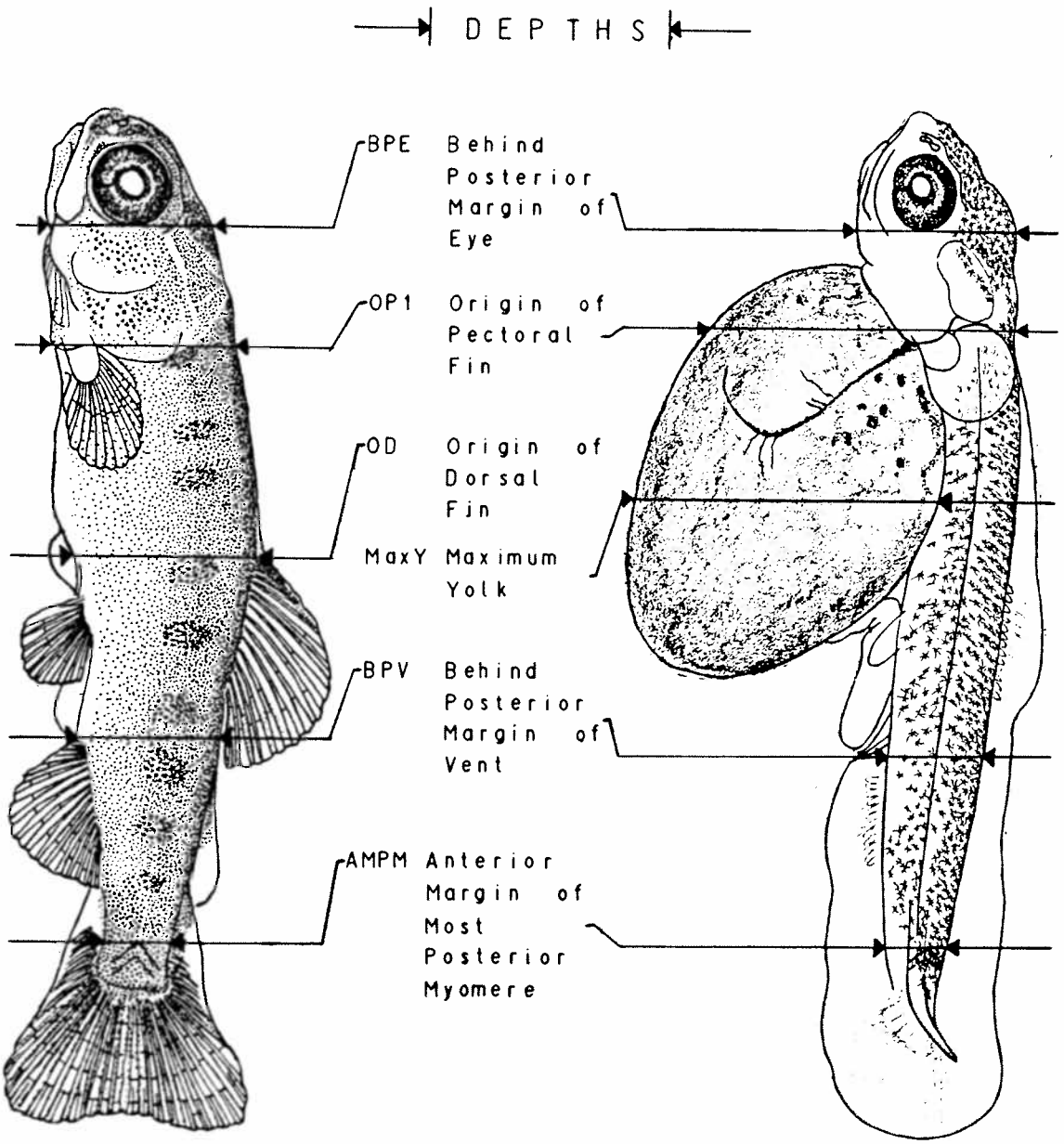

DEPTHS
BPE Behind Posterior Margin of Eye
OP1 Origin of Pectoral Fin
OD Origin of Dorsal Fin
MaxY Maximum Yolk
BPV Behind Posterior Margin of Vent
AMPM Anterior Margin of Most Posterior Myomere

Figure 6b. Width measurements for morphometric anlaysis of salmonid larvae and early juveniles.

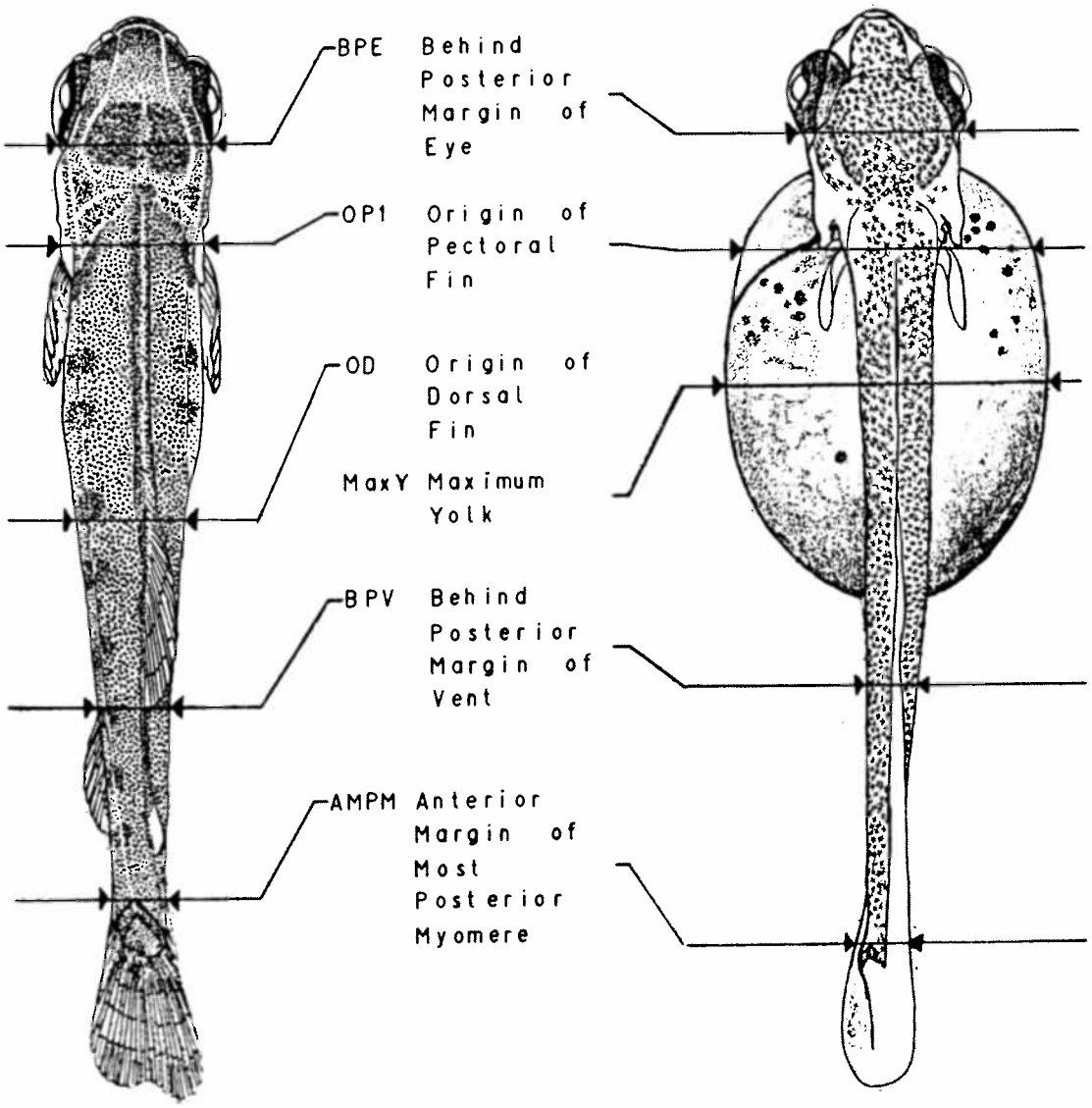
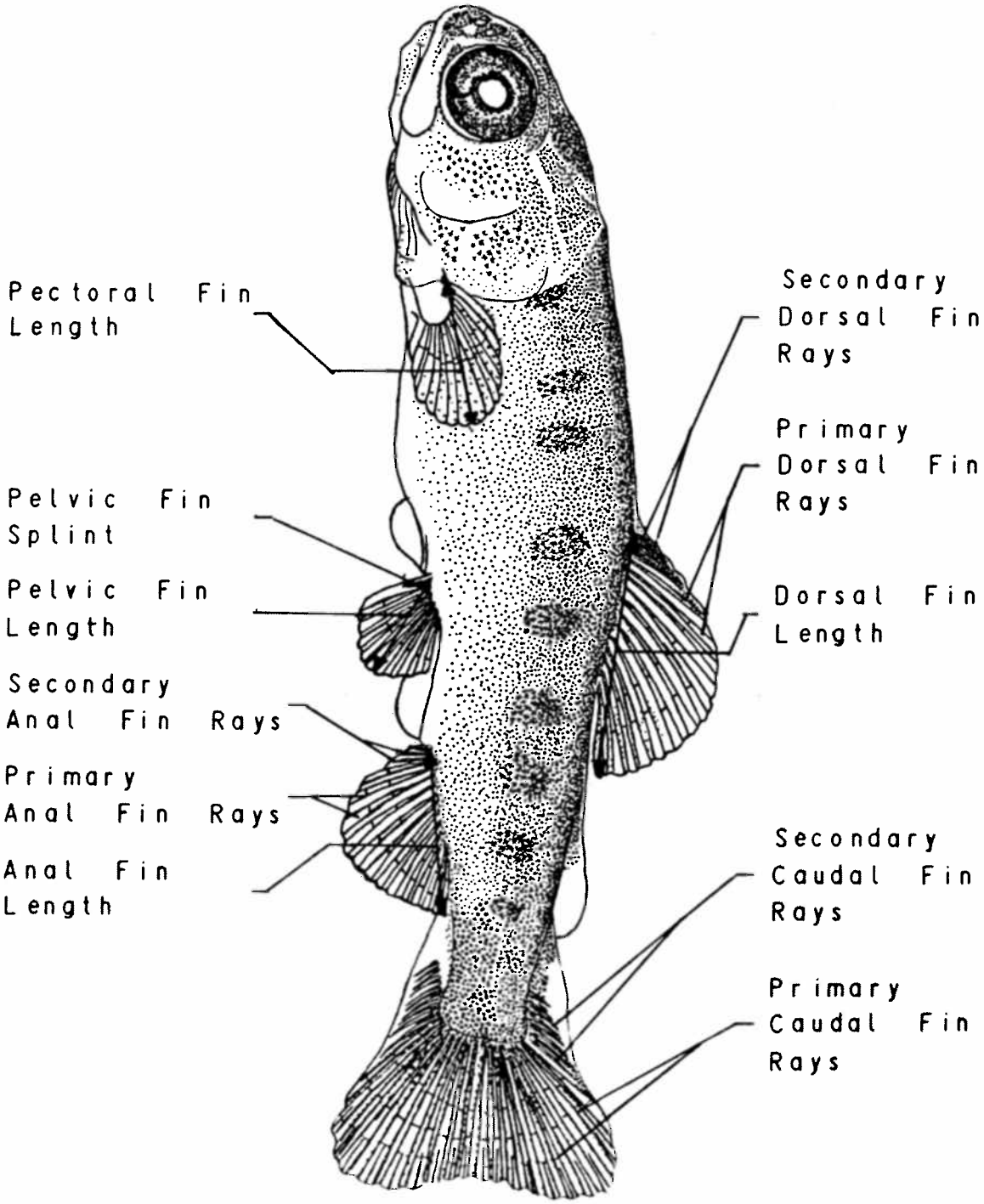

WIDTHS
BPE Behind Posterior Margin of Eye
OP1 Origin of Pectoral Fin
OD Origin of Dorsal Fin
MaxY Maximum Yolk
BPV Behind Posterior Margin of Vent
AMPM Anterior Margin of Most Posterior Myomere

Figure 7. Fin length measurements for morphometric analysis and primary (principal) and secondary rays as differentiated for meristic analysis of salmonid larvae and early juveniles.

FIN LENGTHS
AND
SECONDARY & PRIMARY RAYS



distance between the origin of the fin (anteriormost point of attachment) and its most distal margin (Fig. 7). Depths and widths were measured perpendicular to the longitudinal axis of the body (Figs. 6a and 6b). With one exception (AMPM), depth and width measurements were made at locations corresponding to specific points of reference for specific length measurements (Table 2). Typically recorded to the nearest tenth of a millimeter, measurements were later converted to percent standard length to facilitate comparisons betwen specimens of different sizes.

Meristics

The meristics considered in this study included fin ray and myomere counts. Fin ray counts included both principal and secondary elements (Fig. 7), which were recorded in Arabic and lower-case Roman numerals, respectively. Myomere counts were made from the most anterior unit, which was often deltoid in shape and located immediately behind the occiput, to a specific point or structure of reference. All myomeres transected by an imaginary vertical line from that point of reference were included in the count (Siefert 1969). To make myomeres more visible, it was sometimes necessary to gently scrape away heavily pigmented surface tissues. Several specimens were cleared with trypsin and glycerin and stained with alizarin red as described by Taylor (1967) to verify fin ray and total myomere counts via vertebral counts. Total myomere counts correspond almost one to one with counts of total vertebrae (Fish 1932, Snyder 1981). Vertebral counts included the first unit, which is fused to the cranium, but excluded the last three centra, which comprise the urostyle (Vladykov 1954). Compound or fused

vertebrae were occasionally observed but were easily distinguished by the presence of two hemal or neural spines and were counted as two units.

Analysis of Morphometric and Meristic Data

Following the developmental terminology recommended by Snyder (1976 and 1981), most specimens were designated as mesolarvae, metalarvae or early juveniles (a few prematurely hatched specimens lacked median fin rays and, therefore, qualified as protolarvae). Most of the morphometric and meristic characters were summarized according to developmental phase.

Distinguishing length measurements

Selected length measurements were graphed with standard length of the specimens on the y axis and percent standard length for specific characters on the x axis, thereby providing a visual representation of relationships between the various measures as fish increased in size. These graphs were done on transparent mylar sheets to allow direct comparison between species by overlays.

Multivariate statistical analysis

Discriminant function analysis and principal component analysis were used to classify trout larvae and early juveniles. Discriminant analysis assigns unknown individuals to a species by comparing them to data gathered from individuals of known identity. Principal component analysis uses data on larvae of unknown identity to assign similarly unknown larvae to a species. Morphometric and meristic data gathered

from complete series (recently hatched to early juvenile) of brook, brown, rainbow, and cutthroat trout, were used in both analyses. In the case of principal component analysis, these known series were assumed to be of unknown identity.

In discriminant analysis, a collection of distinct characters or discriminating variables, in the form of morphometric lengths and meristic counts, were chosen and expected to differ from species to species (Table 2). Certain characters varied significantly between species, while others were alike. The more a character deviated between species the greater was its discriminating weight and its ability to differentiate larval trout. Characters with significant discriminating weight were selected in a stepwise fashion using Mahalanobis D^2 criteria included in the Statistical Package for the Social Sciences (SPSS) computer program (Nie et al. 1975). Characters with little discriminating weight were rejected for use in segregating the species. The mathematical objective of discriminant analysis is to weight and linearly combine the discriminating characters in some fashion so that the species are as statistically distinct as possible. This linear combination of discriminating characters is a discriminant function. The objective of using discriminant analysis was to derive a limited number of discriminating characters having sufficient weight to correctly identify 95% of larval and juvenile trout.

The number of functions possible in discriminant function analysis is either one less than the number of groups (species) or equal to the number of discriminating characters, if there are more groups than variables. I investigated four groups or species and 48 morphometric

and meristic characters; therefore, three functions were possible. The first function (or linear combination of discriminating characters) distinguished the four trout species as much as possible. The second function maximized differentiation of these trout in a direction perpendicular to the first function. The third function provided maximal separation in another perpendicular direction. The end result was that the species were each clustered into distinct groups. The three functions in the study formed the axes of three-dimensional graphs, which aided in visualizing the separation of the larval trouts. Further discussion of the mathematical derivation and spacial distribution of discriminant functions is covered quite well by Klecka (1980) and Cooley and Lohnes (1971).

Principal component analysis was also performed with the SPSS package. Each morphometric and meristic character was linearly combined and weighted to determine the first component in principal component analysis. The first function in discriminant function analysis was similarly determined. The objective was to combine the characters in such a manner that the variance of the combination was as large as possible. Three components were derived to facilitate comparison with the three discriminant functions.

A 95% confidence ellipse was plotted for each species with a bivariate mean (Sokal and Rohlf 1969). The major and minor axes of the ellipse are represented by tick marks. Unequal scaling of the axes caused distortion of ellipses and angles between the major and minor axes. Scores of the functions and components were illustrated in oblique, three-dimensional plots.

Other Characters

Other characters considered in this investigation included the shape or form of the yolk-sac and oil globules, melanophore pigmentation patterns, and the size at which specific developmental events occurred. Emphasis was placed on potentially diagnostic structures, pigmentation, and events.

RESULTS

Species Accounts

Means and ranges of morphometrics, expressed as percent standard length, and myomere counts for each larval phase and early juveniles were recorded in Tables 3 through 6. Salmonid larvae typically bypass the protolarval phase and hatch as mesolarvae; therefore, data gathered from brook and cutthroat trout protolarvae (Tables 3 and 6, respectively) pertain to prematurely hatched larvae. Mesolarval trout can be differentiated using depth at origin of pectoral fin; rainbow trout average 33% SL (Table 5) and brook, brown, and cutthroat trout average 27%, 29%, and 25% SL, respectively (Tables 3, 4, and 6). This measurement could be questionable due to individual variation in yolk depth. All other lengths were similar between the species except in the vicinity of the yolk, where body widths and depths have standard deviations of 3 to 6 due to varied individual rates of yolk assimilation. Morphometrics to note on metalarvae include length from snout to origin of dorsal fin, which averaged 48% and 47% SL for brook and brown trout, respectively, and 52% and 51% SL for rainbow and cutthroat trout, respectively (Tables 3-6). Similarly, the body width at origin of dorsal fin on cutthroat trout was noticeably smaller (9% SL) than brook, brown, or rainbow trout (12%, 14%, and 12% SL, respectively) due primarily to emaciated cutthroat metalarvae. Accurate myomere counts were inhibited in all larval phases studied because developing pigmentation obscured myomere septa.

Table 3. Means and ranges of selected morphometrics of brook trout, expressed as percent standard length, and myomere counts for each larval phase and the early juveniles. See Table 2 for explanation of length measurements and abbreviations. Body depths and widths are measured perpendicular to the horizontal axis. Superscripts in the table indicate the number of specimens on which the value is based if different than the number given in the column heading.

	Protolarvae* N = 4		Mesolarvae N = 8		Metalarvae N = 26		Juveniles N = 15	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Size, mmSL-	10.7 ± 1.2	8.9-11.4	12.6 ± 1.6	10.8-15.4	19.7 ± 3.3	13.5-26.4	31.9 ± 5.5	24.9-42.0
mmTL-	11 ± 0.7	10.3-11.7	13.9 ± 1.9	12.0-17.3	22.7 ± 4.3	15.3-31.8	37.8 ± 6.4	29.5-49.0
Lengths, anterior margin of the snout to:								
AE -	3 ± 1	1-4	3 ± 1	1-5	4 ± 1	2-5	5 ± 1	4-6
PE -	14 ± 2	11-16	12 ± 2	10-15	12 ± 1	10-15	13 ± 1	12-15
OP1 -	26 ± 3	23-29	23 ± 1	21-25	24 ± 1	21-26	24 ± 2	22-26
OP2 -	65 ± 5	60-72	56 ± 2	53-59	53 ± 1	51-57	53 ± 2	51-57
OD -			50^{2} ± 1	49-51	48 ± 1	45-51	47 ± 1	46-50
ID -			65^{2} ± 2	63-66	62 ± 1	60-65	62 ± 2	60-65
OAD -					68^{22} ± 3	63-75	75 ± 2	72-78
PV -	83 ± 7	79-93	73 ± 2	70-77	70 ± 1	68-74	71 ± 2	68-76
IA -			86^{2} ± 0	86-87	82 ± 1	80-84	83^{14} ± 1	81-86
AFC -					117^{4} ± 2	113-118	116 ± 1	113-118
PC -	107 ± 9	100-120	110 ± 2	107-113	115 ± 3	111-120	119 ± 1	117-121
Fin lengths:								
P1 -	12 ± 1	11-12	11 ± 1	10-13	14^{23} ± 2	10-17	14^{5} ± 2	11-15
P2 -	5 ± 1	4-6	6 ± 1	5-8	10 ± 3	5-14	14 ± 2	11-19
D -			18^{2} ± 1	18-19	22 ± 3	16-26	25 ± 1	22-28
A -			15^{2} ± 4	11-14	16 ± 2	12-19	18^{14} ± 1	15-19
AD -					19^{20} ± 2	16-23	15 ± 2	12-18
Body depths at or just behind (B-):								
BPE -	19 ± 2	16-21	16 ± 1	15-17	16 ± 1	14-19	18 ± 1	17-19
OP1 -	31 ± 6	26-39	27 ± 4	21-30	18 ± 2	15-23	21 ± 1	19-23
OD -			28^{2} ± 0	28-28	21 ± 3	17-30	24 ± 1	22-26
BPV -	8 ± 1	7-9	10 ± 1	9-12	13 ± 1	11-16	16 ± 1	14-18
AMPM -			6 ± 1	5-6	7 ± 1	5-8	8 ± 1	6-9
Body widths at or just behind (B-):								
BPE -	18 ± 1	17-19	15 ± 1	14-16	15 ± 1	13-17	15 ± 1	14-17
OP1 -	27 ± 9	16-37	20 ± 6	14-29	15 ± 1	13-17	16 ± 1	15-18
OD -			19^{2} ± 0	19-19	12 ± 3	9-21	13 ± 1	11-15
BPV -	6 ± 1	4-7	5 ± 1	4-6	6 ± 0	5-7	7 ± 1	6-8
AMPM -			3 ± 0	2-3	3 ± 0	2-4	4 ± 0	3-4
Myomere counts:								
to OP2 -			23 ± 1	21-25	23 ± 1	21-25	24^{14} ± 1	23-25
to OD -			18 ± 1	17-18	19 ± 1	16-20	18^{14} ± 1	16-20
to PV -			36 ± 1	34-37	36 ± 1	35-39	38^{14} ± 1	36-40
PV-MPM -			17 ± 1	15-19	17 ± 1	13-19	15^{14} ± 2	13-18
total -			53 ± 1	53-53	53 ± 2	50-56	53^{14} ± 2	50-55

*Protolarvae believed to have hatched prematurely.

Table 4. Means and ranges of selected morphometrics of brown trout, expressed as percent standard length, and myomere counts for each larval phase and the early juveniles. See Table 2 for explanation of length measurements and abbreviations. Body depths and widths are measured perpendicular to the horizontal axis. Superscripts in the table indicate the number of specimens on which the value is based if different than the number given in the column heading

	Protolarvae N =		Mesolarvae N = 9		Metalarvae N = 25		Juveniles N = 2	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Size, mmSL-			13.3 ± 1.0	12.1-14.8	20.5 ± 2.6	16.4-26.2	30.9 ± 0.9	30.2-31.5
mmTL-			14.9 ± 1.3	13.0-16.7	24.1 ± 3.3	18.8-30.5	36.7 ± 1.0	36.0-37.4
Lengths, anterior margin of the snout to:								
AE -			3 ± 1	2-4	4^{24} ± 1	2-6	6 ± 1	5-6
PE -			10 ± 1	9-12	13 ± 1	11-16	14 ± 1	13-15
OP1 -			20 ± 2	18-23	24 ± 2	21-27	24 ± 1	23-25
OP2 -			55 ± 2	52-58	55 ± 1	53-57	55 ± 2	54-57
OD -			47^{6} ± 1	45-47	47 ± 1	45-49	46 ± 1	45-47
ID -			60^{2} ± 1	71-73	62 ± 1	59-64	62 ± 1	61-62
OAD -			61^{2} ± 1	60-61	74 ± 5	63-79		
PV -			73 ± 3	69-77	72 ± 1	70-75	74 ± 1	74-75
IA -			84^{2} ± 1	84-85	83 ± 1	79-85	84 ± 1	83-84
AFC -					116^{24} ± 1	114-119	116 ± 0	116-117
PC -			111 ± 2	107-114	118 ± 2	113- 21	119 ± 0	119-119
Fin lengths:								
P1 -			11 ± 1	9-12	18 ± 4	11-23	20 ± 2	19-21
P2 -			5^{8} ± 1	4-6	12 ± 3	5-16	15 ± 0	15-15
D -			15^{2} ± 0	15-16	24 ± 2	17-27	25 ± 1	25-25
A -			11^{2} ± 2	10-12	17^{24} ± 2	13-20	17 ± 0	17-17
AD -			27^{2} ± 1	26-27	16 ± 4	11-25		
Body depths at or just behind (B-):								
BPE -			15 ± 1	14-17	17 ± 1	15-18	18 ± 0	18-19
OP1 -			29 ± 3	23-33	18 ± 2	15-22	21 ± 0	21-21
OD -			41 ± 4	37-47	22 ± 3	18-32	22 ± 0	22-22
BPV -			9 ± 1	8-11	13 ± 1	12-15	15 ± 0	15-15
AMPM -			6 ± 1	5-7	8 ± 1	7-9	7 ± 0	7-7
Body widths at or just behind (B-):								
BPE -			14 ± 1	12-16	16 ± 1	15-21	16 ± 0	16-16
OP1 -			17 ± 3	12-21	15 ± 1	14-17	17 ± 0	17-17
OD -			32 ± 4	28-38	14 ± 3	11-25	14 ± 1	13-14
BPV -			6 ± 1	5-7	7^{24} ± 1	6-9	8 ± 1	7-8
AMPM -			3 ± 0	3-4	4^{21} ± 1	3-6	5 ± 2	4-7
Myomere counts:								
to OP2 -			24 ± 1	23-26				
to OD -			18 ± 2	14-20				
to PV -			37 ± 1	35-38				
PV-MPM -			18^{7} ± 2	15-22				
total -			54^{7} ± 2	52-59				

Table 5. Means and ranges of selected morphometrics of rainbow trout, expressed as percent standard length, and myomere counts for each larval phase and the early juveniles. See Table 2 for explanation of length measurements and abbreviations. Body depths and widths are measured perpendicular to the horizontal axis. Superscripts in the table indicate the number of specimens on which the value is based if different than the number given in the column heading.

	Protolarvae N =		Mesolarvae N = 9		Metalarvae N = 41		Juveniles N = 2	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Size, mmSL-			12.7 ± 0.9	11.6-14.0	23.4 ± 5.3	15.4-36.9	43.2 ± 0.9	42.6-43.8
mmTL-			13.9 ± 1.2	12.3-15.3	27.1 ± 6.3	17.3-43.8	50.8 ± 1.4	49.8-51.8
Lengths, anterior margin of the snout to:								
AE -			3 ± 1	2-4	5 ± 1	2-6	6 ± 0	5-6
PE -			11 ± 1	9-13	14 ± 2	10-16	13 ± 0	13-13
OP1 -			21 ± 1	20-23	26 ± 3	19-30	23 ± 1	23-23
OP2 -			54 ± 1	53-54	54 ± 2	50-58	56 ± 1	55-57
OD -					52 ± 2	50-58	50 ± 0	50-50
ID -					66 ± 3	60-70	65 ± 1	65-66
OAD -					76^{36} ± 7	61-84	81 ± 1	80-81
PV -			70 ± 2	67-72	71 ± 2	64-73	74 ± 3	71-76
IA -					83 ± 2	80-89	83 ± 2	81-84
AFC -					114^{32} ± 2	105-115	114 ± 1	113-115
PC -			109 ± 2	106-112	117^{40} ± 3	111-121	118 ± 1	117-118
Fin lengths:								
P1 -			10 ± 1	9-11	13^{38} ± 3	8-17	16 ± 1	15-16
P2 -			4^{8} ± 1	3-5	10 ± 4	4-30	13 ± 1	12-13
D -					22 ± 4	13-26	23 ± 1	23-24
A -					17^{38} ± 1	13-19	16 ± 0	15-16
AD -					14^{36} ± 6	7-27	9 ± 0	9-9
Body depths at or just behind (B-):								
BPE -			16^{8} ± 0	15-17	19 ± 2	13-21	19 ± 0	19-19
OP1 -			33 ± 4	27-38	21 ± 3	15-28	24 ± 0	24-24
OD -					21 ± 5	12-30	27 ± 1	27-28
BPV -			9 ± 1	8-10	15 ± 2	11-18	19 ± 0	19-19
AMPM -			5 ± 0	4-6	7 ± 1	6-9	8 ± 1	8-8
Body widths at or just behind (B-):								
BPE -			15 ± 1	14-16	15 ± 1	12-17	17 ± 1	16-17
OP1 -			25 ± 6	15-30	16 ± 2	12-19	18 ± 0	18-18
OD -					12 ± 3	9-22	18 ± 0	18-18
BPV -			5 ± 1	4-6	8 ± 1	6-9	9 ± 0	8-9
AMPM -			3 ± 0	2-3	4 ± 0	3-4	5 ± 0	5-5
Myomere counts:								
to OP2 -			26^{8} ± 1	24-27	27^{23} ± 1	25-30		
to OD -					24^{23} ± 2	20-29		
to PV -			40^{8} ± 1	39-41	41^{23} ± 1	38-43		
PV-MPM -			20^{8} ± 1	19-22	21^{23} ± 1	18-23		
total -			60^{8} ± 1	59-62	61^{23} ± 1	59-63		

Table 6. Means and ranges of selected morphometrics of cutthroat trout, expressed as percent standard length, and myomere counts for each larval phase and the early juveniles. See Table 2 for explanation of length measurements and abbreviations. Body depths and widths are measured perpendicular to the horizontal axis. Superscripts in the table indicate the number of specimens on which the value is based if different than the number given in the column heading.

	Protolarvae* N = 2		Mesolarvae N = 10		Metalarvae N = 39		Juveniles N =	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Size, mmSL-	10.5 ± 0.1	10.5-10.6	13.7 ± 1.6	10.5-15.6	23.8 ± 4.9	16.8-35.1		
mmTL-	11.4 ± 0.0	11.4-11.4	15.1 ± 1.8	11.3-17.2	28.3 ± 6.2	18.6-42.0		
Lengths, anterior margin of the snout to:								
AE -	2 ± 0	2-2	3 ± 1	2-4	4 ± 1	3-6		
PE -	11 ± 1	10-11	11 ± 1	9-12	13 ± 1	11-15		
OP1 -	20 ± 0	19-20	23 ± 1	21-24	26 ± 1	22-28		
OP2 -	54^{1}		54 ± 1	53-55	54 ± 1	51-58		
OD -			51^{2} ± 0	50-51	51 ± 1	48-53		
ID -			64^{2} ± 1	63-64	63 ± 1	60-66		
OAD -					73^{36} ± 5	63-79		
PV -	71 ± 0	71-71	71 ± 1	69-72	72 ± 1	69-74		
IA -			82^{2} ± 0	82-82	83 ± 1	81-84		
AFC -					115^{35} ± 1	112-117		
PC -	108 ± 0	108-109	110 ± 2	108-113	118 ± 3	111-122		
Fin lengths:								
P1 -	10 ± 0	9-10	10 ± 1	9-11	16 ± 2	11-19		
P2 -			5^{9} ± 1	4-7	12 ± 2	6-14		
D -			16^{3} ± 0	15-16	22 ± 2	15-24		
A -			14^{3} ± 0	13-14	16 ± 1	14-17		
AD -					15^{36} ± 4	11-23		
Body depths at or just behind (B-):								
BPE -	15 ± 0	15-15	16 ± 1	14-17	17^{38} ± 1	15-19		
OP1 -	35 ± 2	33-36	25 ± 4	20-33	19 ± 2	14-22		
OD -			27^{4} ± 2	24-30	19 ± 4	12-24		
BPV -	7 ± 1	6-7	10 ± 1	7-12	14 ± 2	11-18		
AMPM -	4 ± 0	3-4	5 ± 1	3-6	7 ± 1	6-8		
Body widths at or just behind (B-):								
BPE -	13 ± 0	12-13	15 ± 1	13-16	14 ± 1	13-16		
OP1 -	33 ± 2	28-34	17^{9} ± 5	13-28	14 ± 2	10-17		
OD -			14^{4} ± 3	9-15	9 ± 2	6-13		
BPV -	5 ± 0	5-5	6 ± 0	5-6	6 ± 1	5-8		
AMPM -	3 ± 0	3-3	3 ± 0	3-4	3 ± 0	3-3		
Myomere counts:								
to OP2 -	24 ± 0	24-24	25 ± 1	23-26	26^{41} ± 1	24-28		
to OD -			22^{2} ± 1	21-22	22^{41} ± 1	20-23		
to PV -	39 ± 0	39-39	38 ± 1	36-39	39^{41} ± 1	37-42		
PV-MPM -	18 ± 0	18-18	19 ± 0	18-20	17^{28} ± 2	14-20		
total -	57 ± 0	57-57	57 ± 1	55-58	57^{28} ± 1	55-58		

*Protolarvae believed to have hatched prematurely.

Meristics useful in identifying adult salmonids include number of anal fin rays (8-11, 8-10, 11-12, and 10-12 on brook, brown, rainbow, and cutthroat trout, respectively), number of dorsal secondary caudal fin rays (13-14, 14-15, 14-15, and 12 on brook, brown, rainbow, and cutthroat trout, respectively), number of pectoral fin rays (13, 13, 14-15, and 15-16 for brook, brown, rainbow, and cutthroat trout, respectively), and number of basibranchial teeth (0 on rainbow trout and 2-20 on cutthroat trout) (LaRivers 1962, Minckley 1973, Scott and Crossman 1973) (Tables 7-10). Size at the onset of selected developmental events can be useful in segregating larval trout (Tables 11-14). The most obvious event was the size of specimens at complete absorption of preanal finfold where brook, brown, rainbow and cutthroat trout larvae completed absorption of this finfold at approximately 28 mm, 25 mm, >44 mm, and >42 mm, respectively. Pelvic fin rays were first observed at 14 mm, 16 mm, 17 mm, and 17 mm SL for brook, brown, rainbow, and cutthroat trout, respectively. Pectoral fins developed a full adult complement of rays at 16-17 mm, 19 mm, 20 mm, and 21-22 mm SL, on brook, brown, rainbow and cutthroat trout metalarvae, respectively. Size of trout larvae when the yolk was completely absorbed varied with individual rate of assimilation and therefore could not be used diagnostically.

Drawings of larval trout in series, from recently hatched to late metalarvae or early juveniles, are most useful in correct identification of larvae in various stages of development. Prominent differences between these species, though discussed in detail elsewhere, deserve further mention. Size and number of oil globules in

Table 7. Selected adult meristics of brook trout. Mean or modal values are overlined, if significant, and rare or questionable extremes are enclosed in parentheses.

D rays: (ii)$\overline{\text{iii}}$(iv),(9)10-$\overline{\text{11}}$-12(14)	P1 rays: (11)$\overline{13}$(15)	Vertebrae: 58-62
A rays: ii-$\overline{\text{iii}}$(v),8-$\overline{9}$-$\overline{10}$-11(13)	Branchiostegal rays: 9-13	Scales lateral
C rays: (x)xiii-$\overline{\text{xiv}}$(xix),(16)18-$\overline{19}$(20),	Gill rakers: 14-22	line (11): 200-$\overline{230}$
(xi)xii-$\overline{\text{xiii}}$-xiv(xvii)	Basibranchial teeth:	above 11: 37
P2 rays: $\overline{8}$-10	Pyloric caeca: 23-$\overline{50}$-55	below 11: 30

Table 8. Selected adult meristics of brown trout. Mean or modal values are overlined, if significant, and rare or questionable extremes are enclosed by parentheses.

D rays: iii-iv, 10-$\overline{11}$-12(13)	P1 rays: 12-$\overline{13}$-14(15)	Vertebrae: 56-$\overline{58}$-$\overline{60}$-61
A rays: ii-iii,(7)8-$\overline{9}$-10(12)	Branchiostegal rays: 8-11	Scales, lateral
C rays: xiv-xv,19,x-xiii	Gill rakers: 14-17	line (11): 115-150
P2 Rays: (8)9(10)	Basibranchial teeth:	above 11:
	Pyloric caeca: 30-80	below 11:

Table 9. Selected adult meristics of rainbow trout. Mean or modal values are overlined, if significant, and rare or questionable extremes are enclosed in parentheses.

D rays: iii-iv,10-$\overline{11}$-$\overline{12}$-$\overline{13}$(14)	P1 rays: (11)14-15(17)	Vertebrae: 58-$\overline{62}$-66
A rays: (ii)$\overline{\text{iii}}$(iv),(8)11-$\overline{12}$(13)	Branchiostegal rays: 9-13	Scales, lateral
C rays: (xii)$\overline{\text{xiv}}$-xv(xvii),$\overline{19}$-20(23),	Gill rakers: 16-22	line (11): 100-160
(xi)xii-xiii(xiv)	Basibranchial teeth: 0	above 11: 23-32
P2 rays: 9-10(11)	Pyloric cacea: 27-$\overline{55}$-80	below 11: 20-30

Table 10. Selected adult meristics of cutthroat trout. Mean or modal values are overlined, if significant, and rare or questionable extremes are enclosed by parentheses.

D rays: ii-iii-$\overline{\text{iv}}$(v),(8)10-$\overline{11}$(12)	P1 rays: (12)15-16	Vertebrae: 59-$\overline{60}$-$\overline{63}$-64
A rays: ii-$\overline{\text{iii}}$-iv,(8)10-$\overline{11}$-12	Branchiostegal rays: 9-12	Scales: lateral
C rays: (ix)$\overline{\text{xii}}$(xiv),19,(x)$\overline{\text{xii}}$-xiv(xv)	Gill rakers: 14-22	line (11): 140-$\overline{160}$-$\overline{180}$-200
P2 rays: 9-10	Basibranchial teeth: 2-20	above 11:
	Pyloric caeca: 27-$\overline{35}$-$\overline{50}$-60	below 11:

Table 11. Size of brook trout (mm SL / TL) at the apparent onset of selected developmental events based on structures observable under low power magnification; rare or questionable extremes are enclosed in parentheses.

Hatching: (9)11 / (10)12
Eyes pigmented: prior to hatching
P1 bud formation: prior to hatching
P2 bud formation: prior to hatching
Yolk completely absorbed: 22 / 25
Finfold completely absorbed: 24 / 28
Segmentation evident in the principal rays of all fins: 24 / 28

Fin rays:	First observed	Adult complement
Principal C:	prior to hatching*	13-16 / 15-18
Secondary C:	16 / 18	25-26 / 30-32
Principal D:	11 / 12	13 / 15
Principal A:	12 / 13	13 / 15
All P1:	12-13 / 13-14	16-17(18) / 18-19(20)
All P2:	14(17) / 16(19)	19-20(22) / 22-23(25)

Scales: initial appearance: ?41 / 49
full coverage

Table 12. Size of brown trout (mm SL / TL) at the apparent onset of selected developmental events based on structures observable under low power magnification; rare or questionable extremes are enclosed in parentheses.

Hatching: 12 / 13
Eyes pigmented: prior to hatching
P1 bud formation: prior to hatching
P2 bud formation: prior to hatching
Yolk completely absorbed: 23 / 27
Finfold completely absorbed: 21 / 25
Segmentation evident in the principal rays of all fins: 20-21 / 24-25

Fin rays:	First observed	Adult complement
Principal C:	prior to hatching	16 / 19
Secondary C:	15 / 17	>26 / >30
Principal D:	11-13(14) / 14-15(16)	13-14 / 15-16
Principal A:	11-13 / 14-15	11-13(15) / 15-16
All P1:	13 / 15	19 / 22
All P2:	16 / 19	20 / 24

Scales: initial appearance: >26 / >30
full coverage:

Table 13. Size of rainbow trout (mm SL / TL) at the apparent onset of selected developmental events based on structures observable under low power magnification.

Hatching: 12 / 12-13
Eyes pigmented: prior to hatching
Pi bud formation: prior to hatching
P2 bud formation: prior to hatching
Yolk completely absorbed: 21 / 24
Finfold completely absorbed: >37 / >44
Segmentation evident in the principal rays of all fins: 21 / 25

Fin rays:	First observed	Adult complement
Principal C:	12 / 12	15 / 17
Secondary C:	15 / 17	21-24 / 24-28
Principal D:	14 / 15	15 / 17
Principal A:	14 / 15	15-16 / 17-18
All P1:	15 / 17	20 / 22-23
All P2:	17 / 19	20 / 22-23

Scales: initial appearance: 30 / 36
full coverage:

Table 14. Size of cutthroat trout (mm SL / TL) at the apparent onset of selected developmental events are based on structures observable under low power magnification; rare or questionable extremes are enclosed in parentheses.

Hatching: 11-13 / 11-14
Eyes pigmented: prior to hatching
P1 bud formation: prior to hatching
P2 bud formation: prior to hatching
Yolk completely absorbed: 25 / 30
Finfold completely absorbed: >35 / >42
Segmentation evident in the principal rays of all fins: 23 / 27

Fin rays:	First observed:	Adult complement
Principal C:	prior to hatching*	15-16 / 17
Secondary C	15-16 / 17	23 / ~~17~~27
Principal D:	13 / 14	14 / 15
Principal A:	13 / 14	14-15 / 15-17
All P1:	14 / 15	(19)21-22 / (23) 26
All P2:	17 / 19	19-20(21) / 23-24

Scales: initial appearance: >35 / >42
full coverage:

the yolk can be used to distinguish brook (Figs. 8 and 9) from brown (Figs. 13 and 14), rainbow (Figs. 17 and 18), and cutthroat trout (Figs. 21 and 22). Similarly, the shape of the yolk of recently transformed brown trout metalarvae (Fig. 15) differed distinctly from that of brook (Fig. 10), rainbow (Fig. 19), and cutthroat trout (Fig. 23). Preanal finfold absorption varied between brook (Fig. 11) and brown trout (Fig. 16), each of which had unilobed finfolds at all stages of absorption, and rainbow (Fig. 20) and cutthroat trout (Fig. 24), which had finfolds that initially were absorbed in the center between the pelvic fins, forming a bilobed structure, and then proceeded to be absorbed in an anterior-to-posterior direction. Another useful differentiating character was the appearance of abundant dorsal secondary parr marks on brook trout (Fig. 12); other trouts had few to no parr marks in this region.

Pigmentation

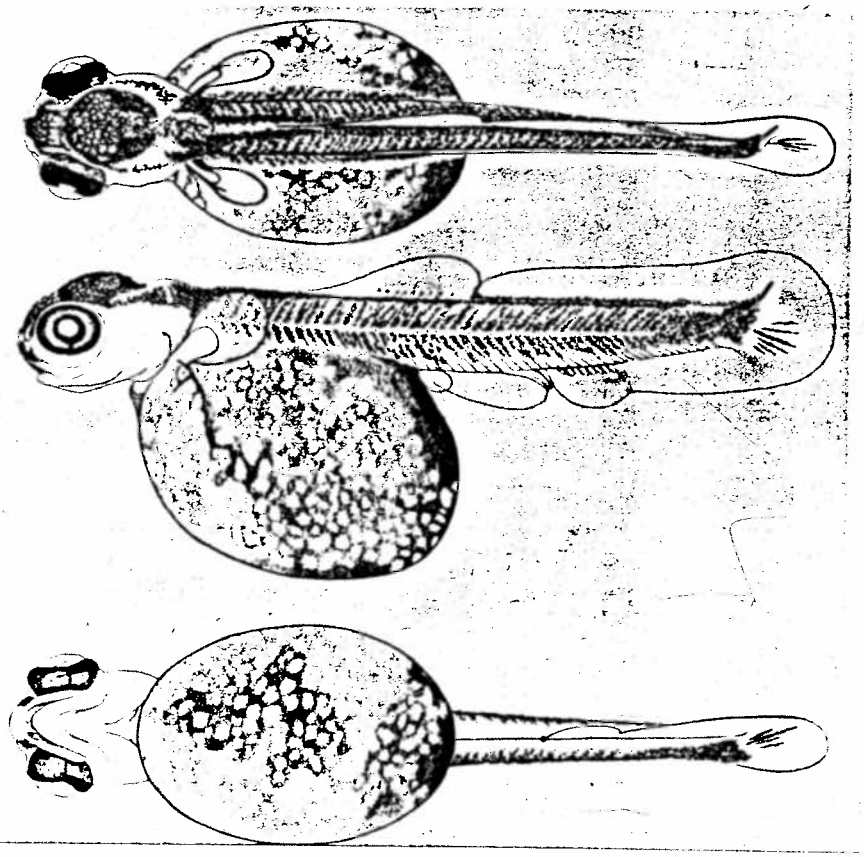
The eyes of salmonid embryos are pigmented before hatching, and at least the lateral surfaces of most trout and salmon embryos are pigmented immediately after hatching. The following discussion emphasizes differences in melanophore pigmentation of specific structures and regions and is summarized in Table 15.

Dorsal fin

Brook trout. Faint pigmentation first appeared on the anterior margin of the dorsal fin on recently hatched larvae, 13 to 16 mm TL. Dorsal fin pigmentation remained light throughout the development of most larvae and juveniles, whereas a dark anterior dorsal fin border was typical of rainbow and cutthroat trout.

Figure 8. Brook trout mesolarvae, recently hatched, 12.4 mm TL, 11.3 mm SL.

Figure 9. Brook trout mesolarvae, 14.0 mm TL, 12.5 mm SL.



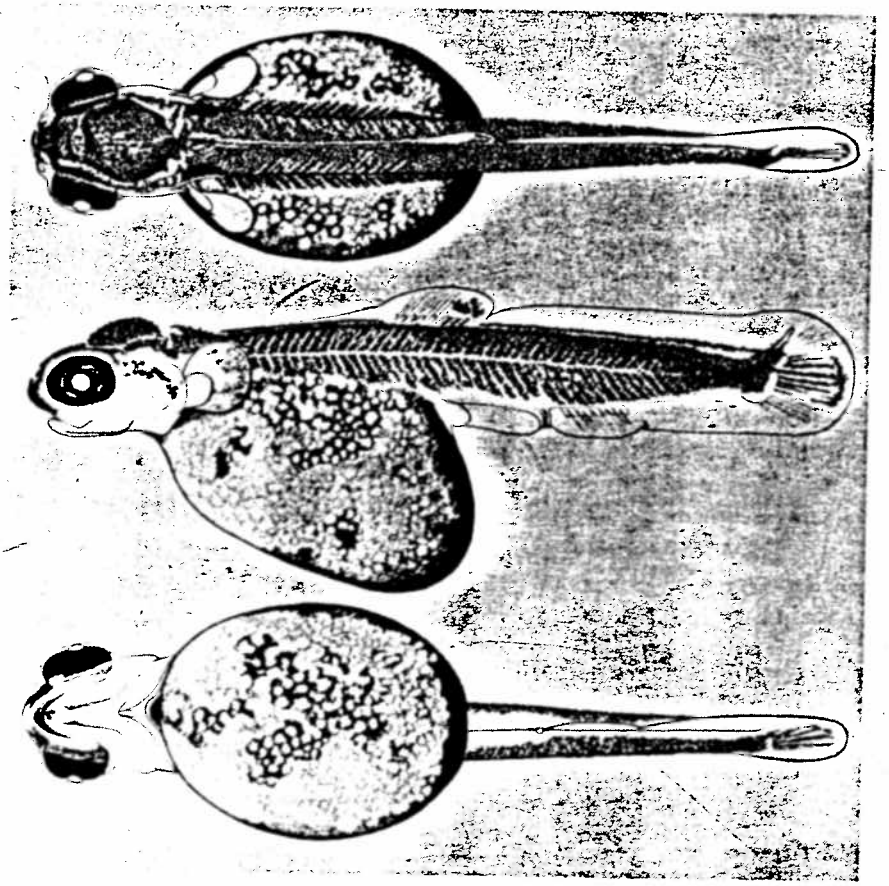
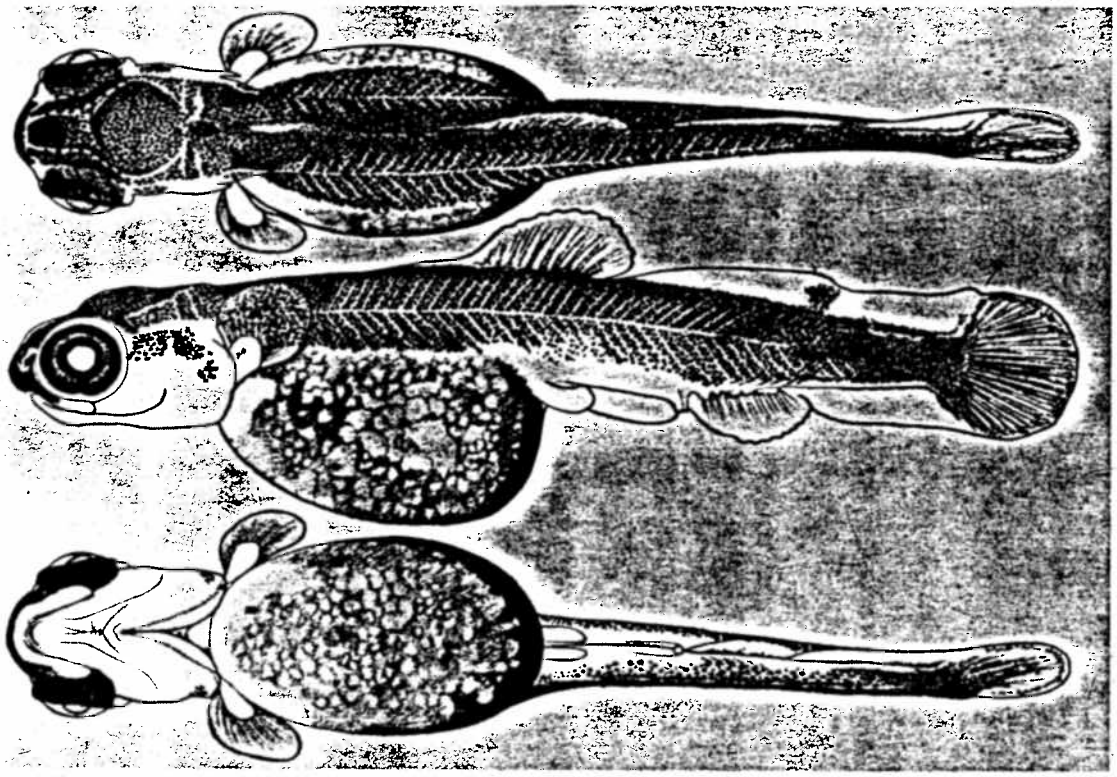


Figure 10. Brook trout metalarvae, recently transformed, 18.9 mm TL, 16.9 mm SL.

Figure 11. Brook trout metalarvae, 21.0 mm TL, 18.5 mm SL.



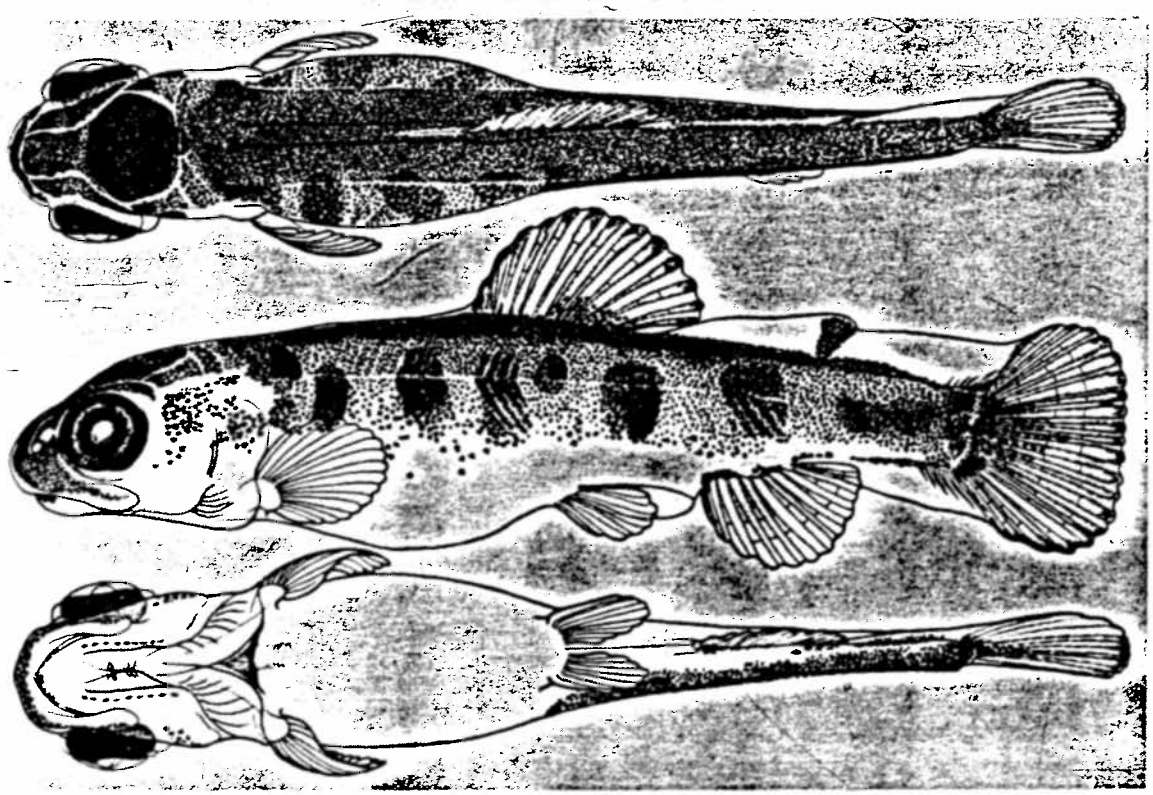
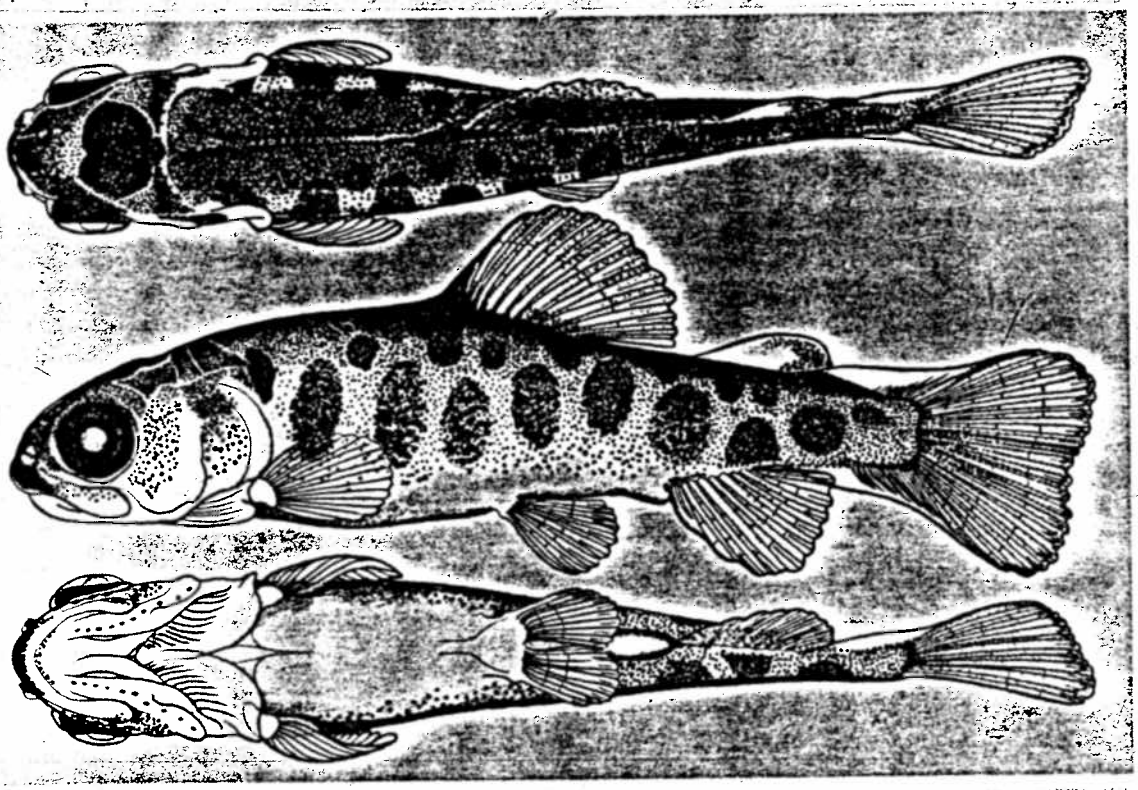


Figure 12. Brook trout juvenile, recently transformed, 29.5 mm TL, 25.1 mm SL.

Figure 13. Brown trout mesolarvae, recently hatched, 13.0 mm TL, 12.1 mm SL.



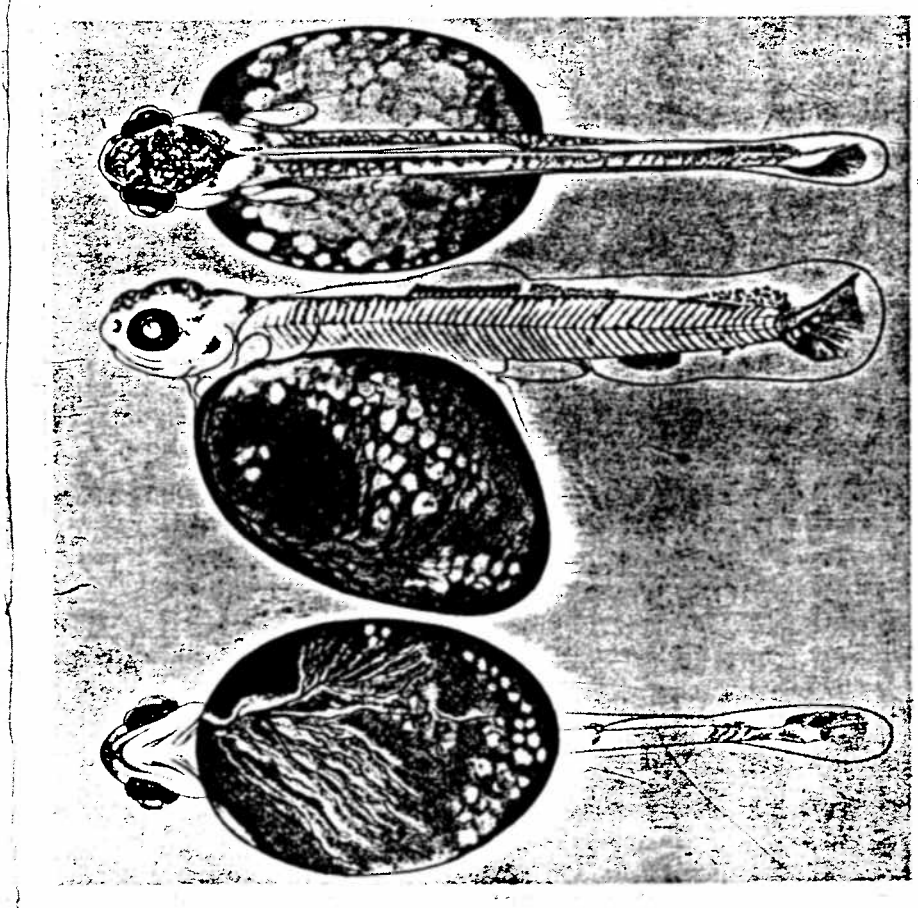
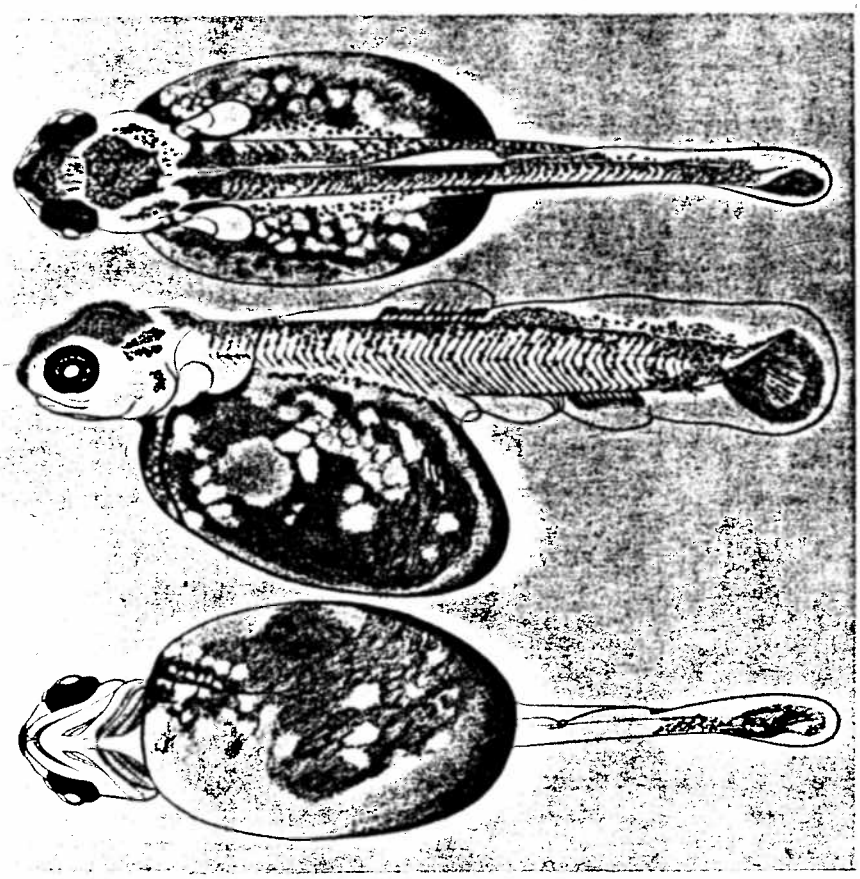


Figure 14. Brown trout mesolarvae, 14.4 mm TL, 12.9 mm SL.

Figure 15. Brown trout metalarvae, recently transformed, 19.0 mm TL, 16.7 mm SL.



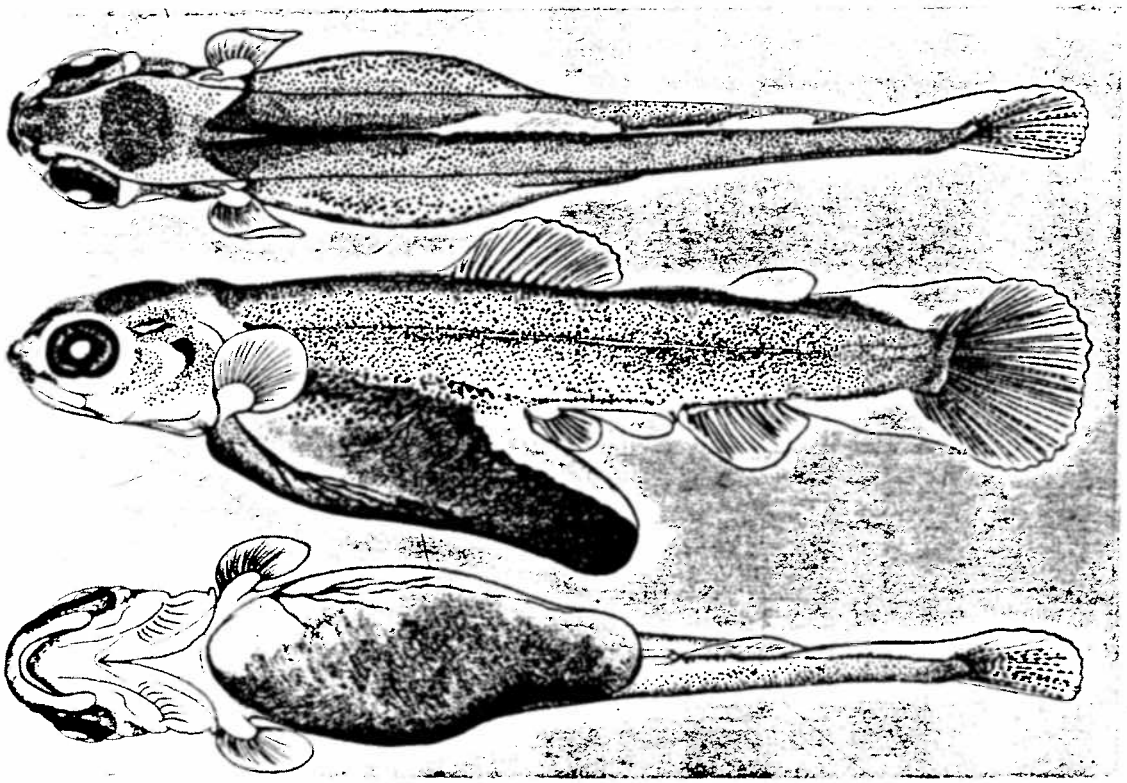
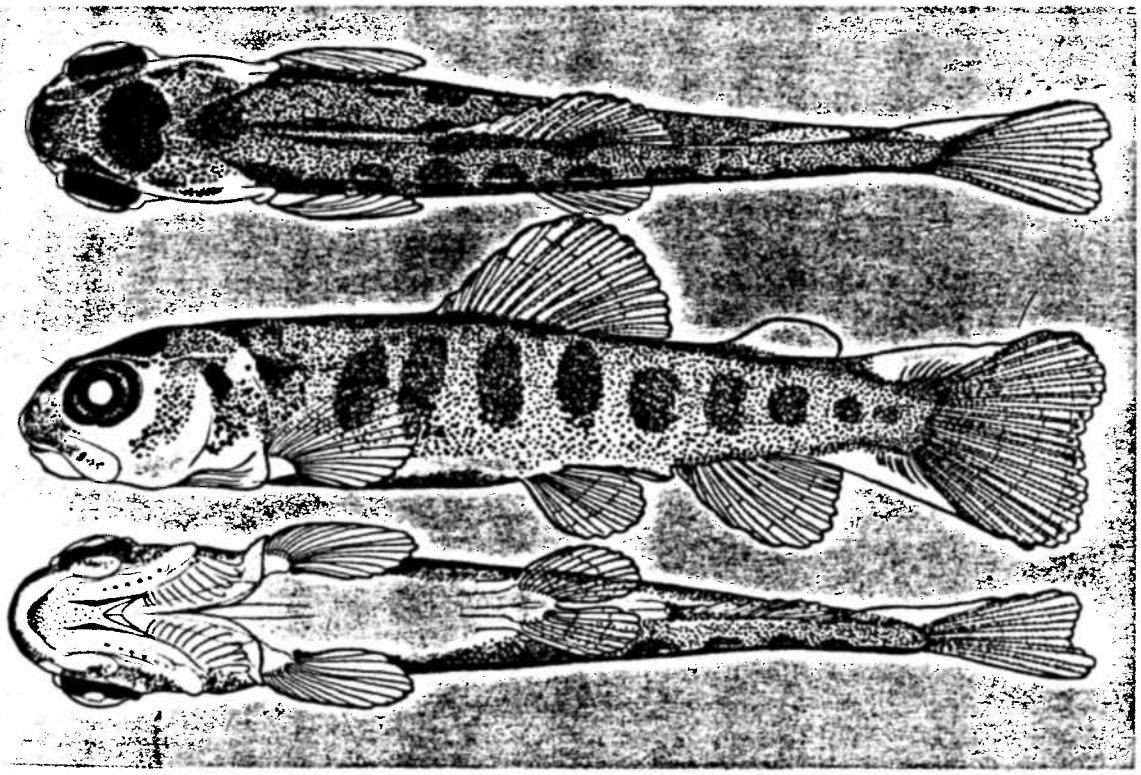


Figure 16. Brown trout metalarvae, 24.5 mm TL, 20.7 mm SL.

Figure 17 Rainbow trout mesolarvae, recently hatched, 12.3 mm TL, 11.7 mm SL.



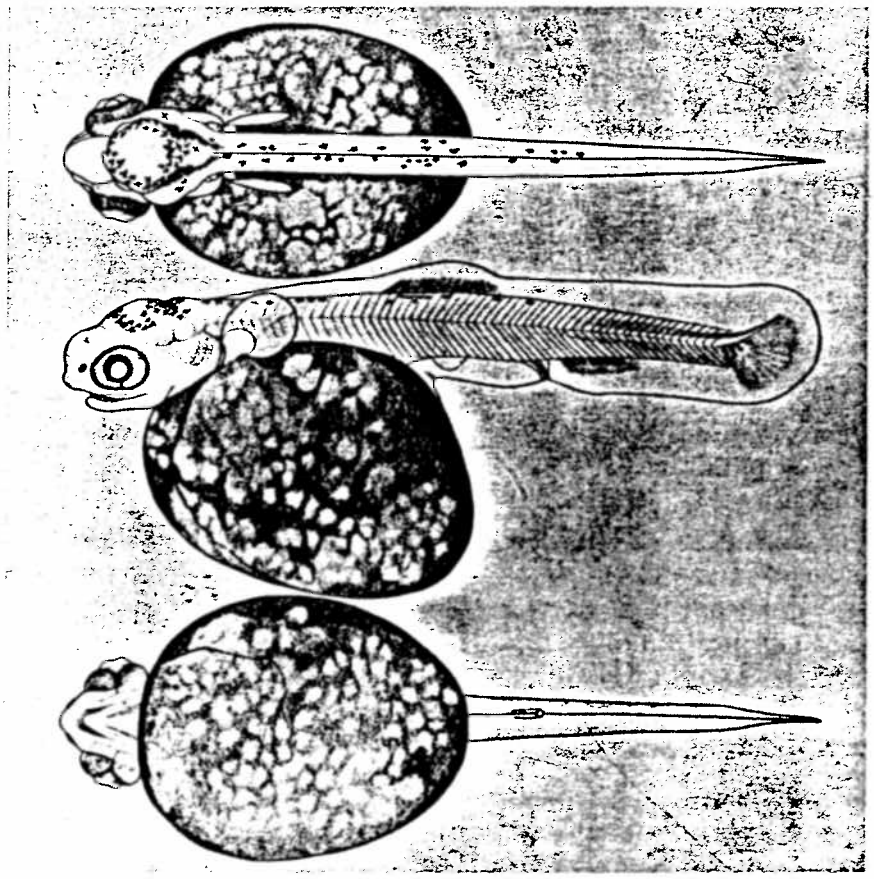
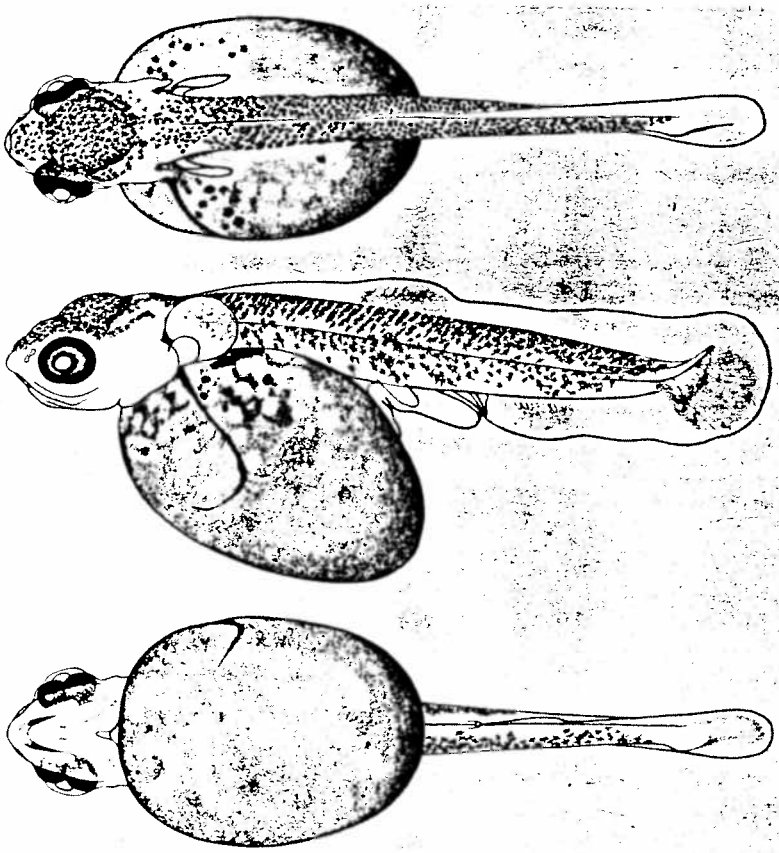


Figure 18. Rainbow trout mesolarvae, 14.3 mm TL, 13.3 mm SL.

Figure 19. Rainbow trout metalarvae, recently transformed, 17.3 mm TL, 15.5 mm SL.



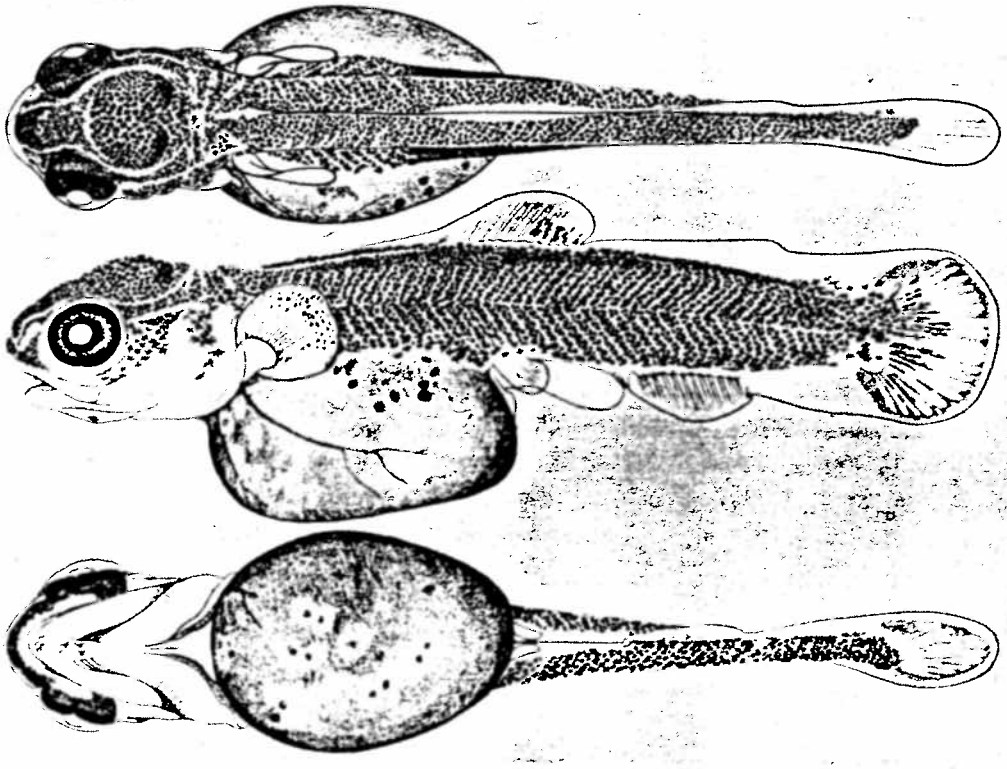
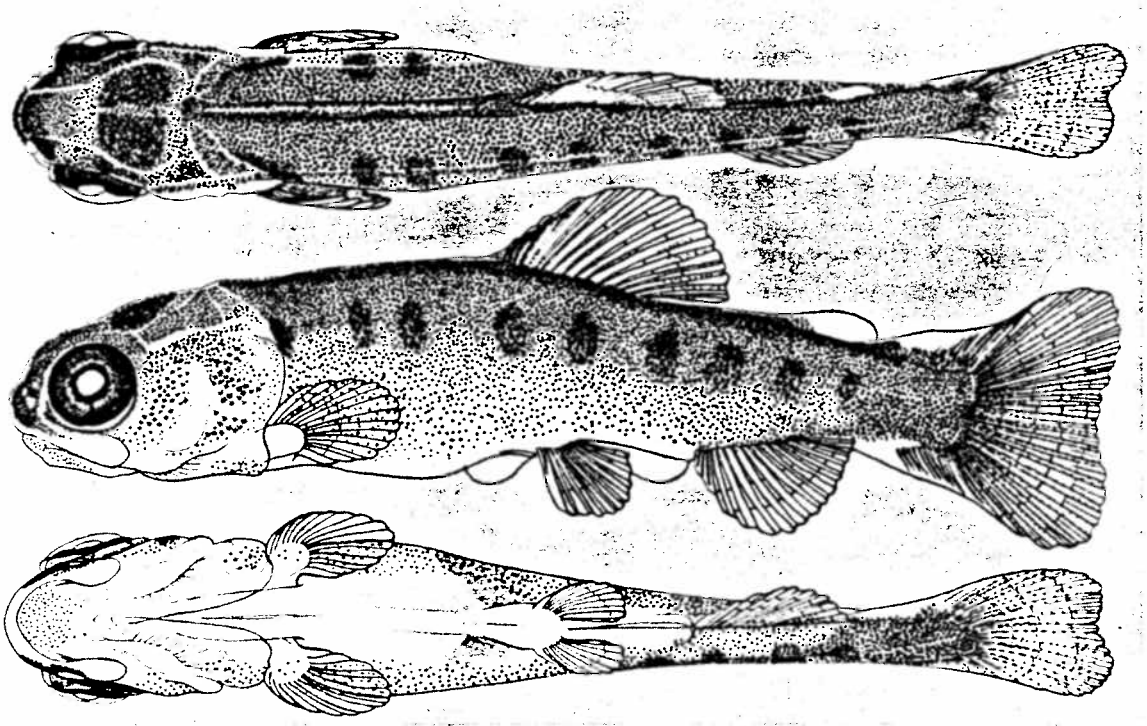


Figure 20. Rainbow trout metalarvae, 25.0 mm TL, 21.6 mm SL.

Figure 21. Cutthroat trout mesolarvae, recently hatched, 14.2 mm TL, 12.9 mm SL.



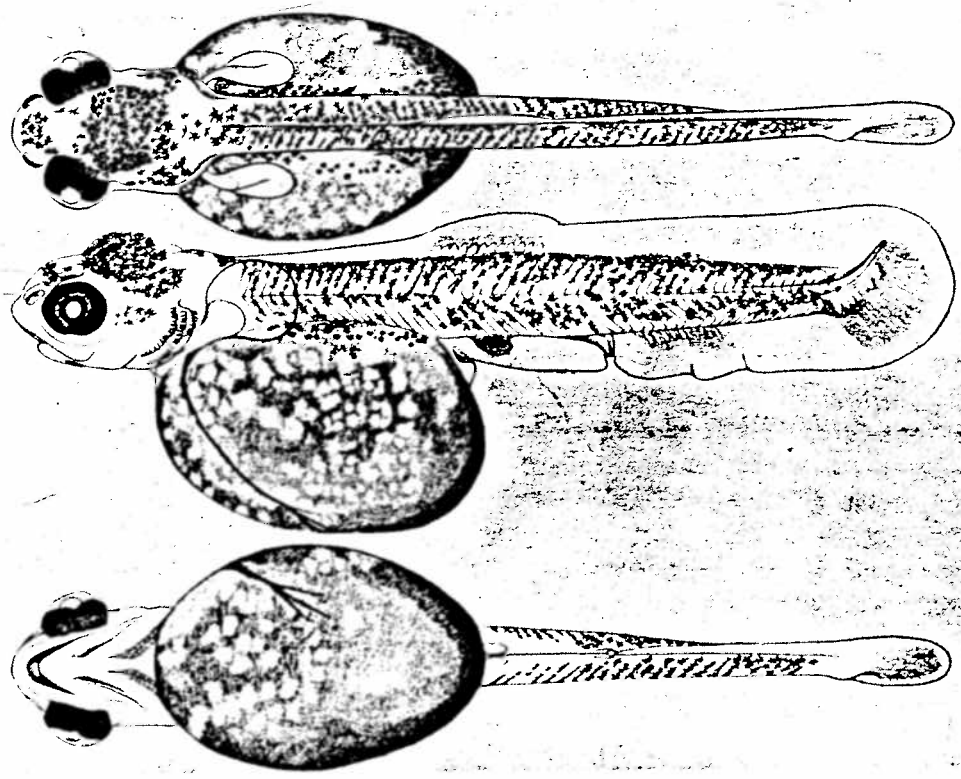
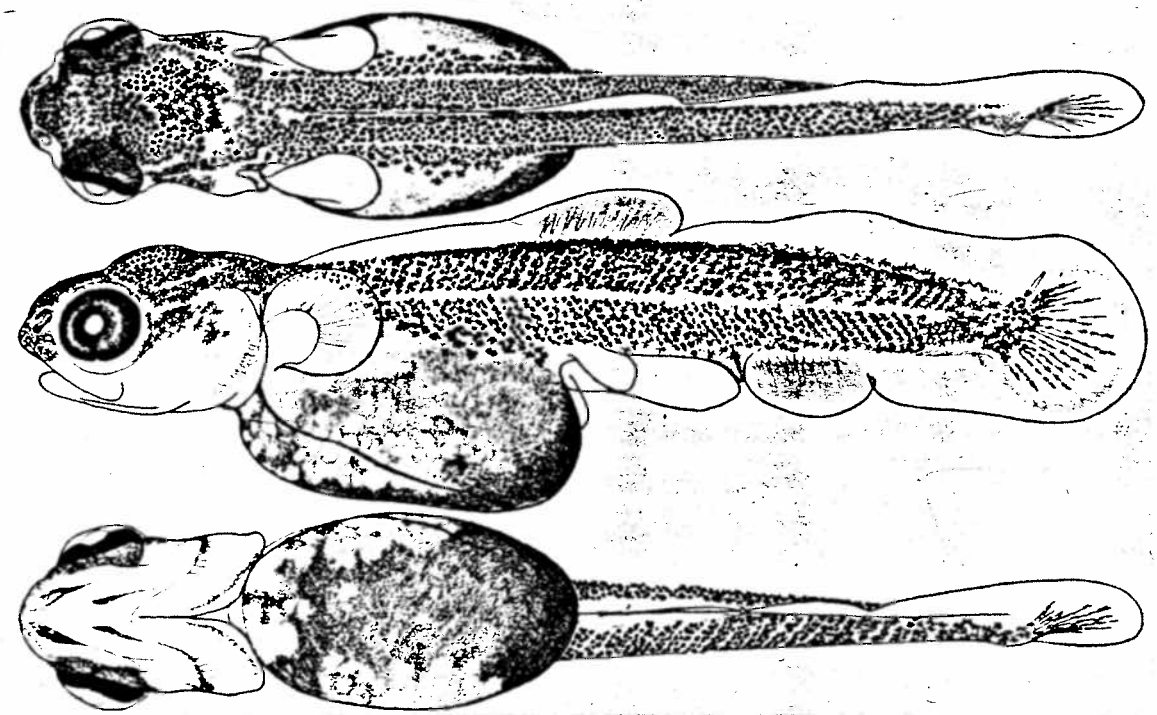


Figure 22. Cutthroat trout mesolarvae, 16.6 mm TL, 15.0 mm SL.

Figure 23. Cutthroat trout metalarvae, recently transformed, 19.3 mm TL, 17.2 mm SL.



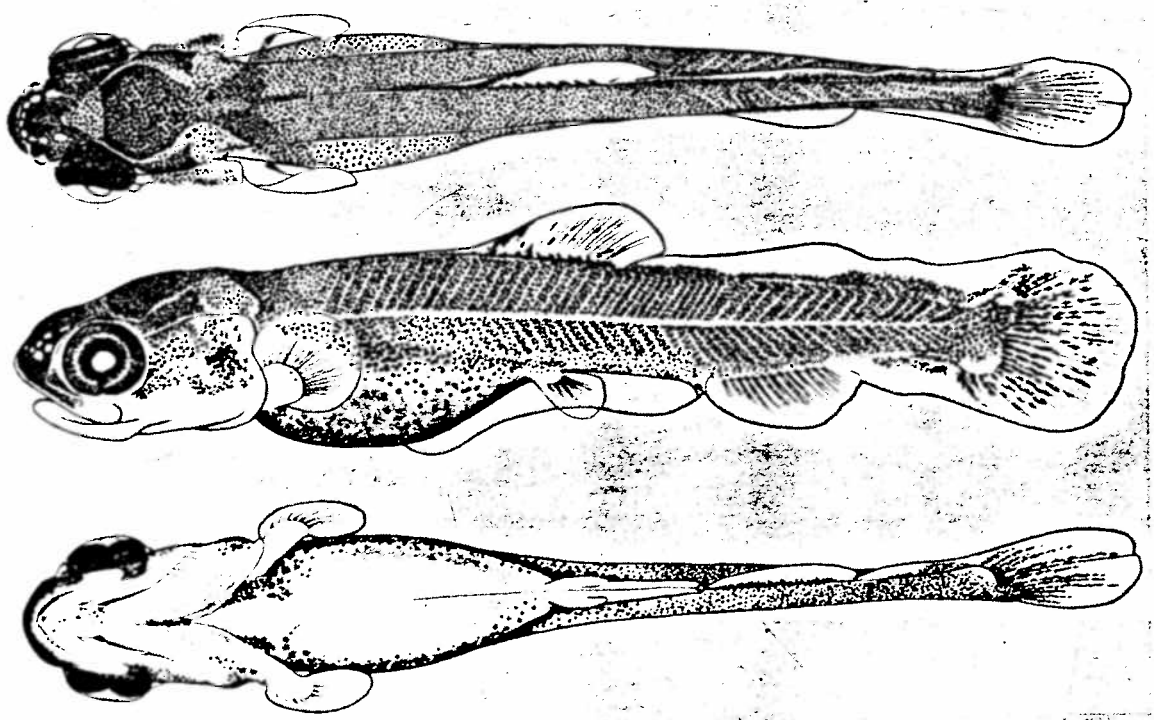


Figure 24. Cutthroat trout metalarvae, 26.3 mm TL, 22.1 mm SL.

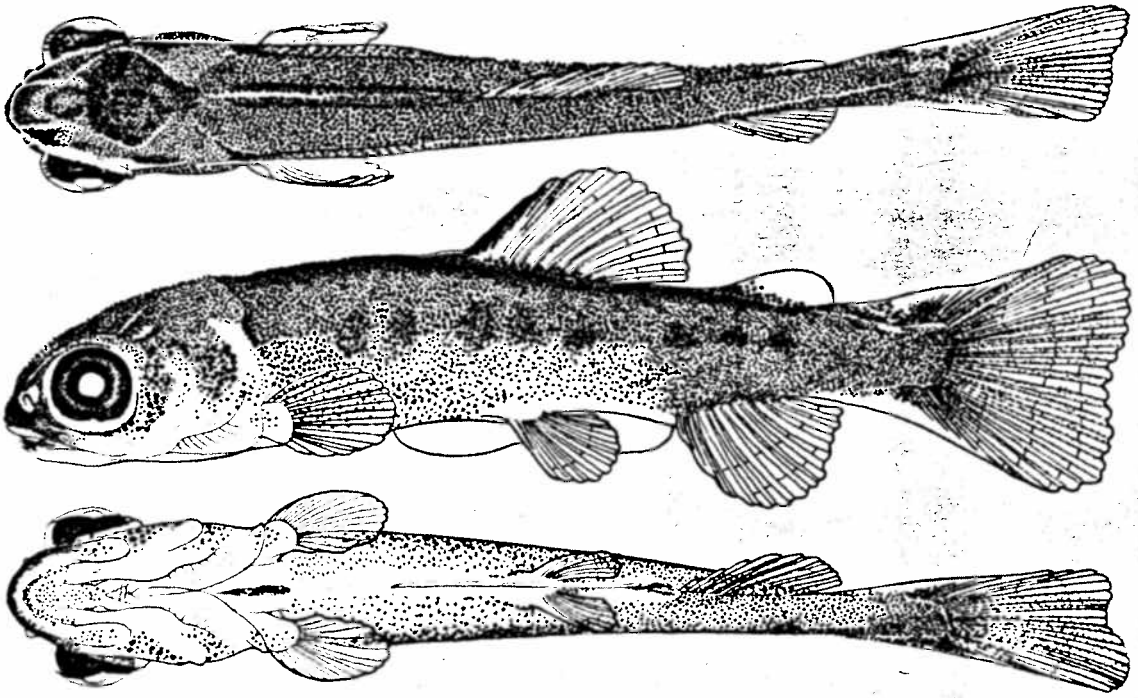


Table 15. Summary of melanophore pigmentation patterns on selected structures for separating brook, brown, rainbow, and cutthroat trout larvae. Length measurements are total lengths.

Size Range Examined	Brook 12-32 mm TL	Brown 12-30 mm TL	Rainbow 12-44 mm TL	Cutthroat 10-44 mm TL
Dorsal Fin	-Light pigmentation on the anterior margin, >16 mm	-Light pigmentation on the anterior margin, ≥22 mm	-Bold pigmentation on the anterior margin, >22 mm	-Bold pigmentation on the interior margin, ≥19 mm
Adipose Fin	-Bold pigmentation on the posterior margin, ≥20 mm	-Scattered pigmentation over entire fin with no areas of concentration, >29 mm	-Light pigmentation on the posterior margin, ≥23 mm	-Light, inconspicuous pigmentation an the posterior margin, ≤37 mm -Distinct pigment on the posterior margin, >37 mm
Caudal Fin	-Heavy pigmentation on the area of the horizontal midline, 12-32 mm	-Scattered pigment tended to line the distal portions of the principle rays ≥19 mm	-Pigment scattered distally with no pattern or areas of concentration, ≥22 mm	-Pigment scattered distally with no pattern or areas of concentration, ≥31 mm
Anal Pterygiophores	-Dense pigment on the anterior anal pterygiophores, >21 mm	-Pigment forming shallow "V" which envelopes the anus, pointing posteriorly, ≥23 mm	-Scattered pigment with no areas of concentration, >23 mm	-Scattered pigment with no aras of concentration, >20 mm
Throat and Anterior Margin of the Lower Jaw	-Little to no pigment on the throat, > 15 mm	-Scattered pigment on the throat, ≥17 mm	-Scattered pigment over entire mandible with no areas of concentration, >23 mm	-Scattered pigment over entire mandible with no areas of concentraiton, ≥21 mm
	-Dense pigment on the anterior margin of the lower jaw, ≥15 mm	-Dense pigment on the anterior margin of the lower jaw, ≥22 mm		
Pectoral Fins	-Pigment rarely present between rays	-Light inconspicuous pigment between distal tips of at least anterior rays, ≥24 mm	-Pigment rarely present between rays	-Pigment rarely present between rays

Table 15. Continued.

Size Range Examined	Brook 12-32 mm TL	Brown 12-30 mm TL	Rainbow 12-44 mm TL	Cutthroat 10-44 mm TL
Parr Marks				
Primary	-Average 7, range 4-10, >25 mm	-Commonly 7 or 8, range 7-10, >22 mm	-Average 8, range 5-10, >21 mm	-Average 8, range 7-11, >27 mm
Ventral	-Average 2, range 0-6, >25 mm	-Rare	-None	-None
Dorsal	-Average 6, range 2-8, >25 mm	-Few, >29 mm	-Seldom any, never more than 3, >32 mm	-Rarely any marks
Marks Above Dorsal Parr Marks	-Numerous small marks on dorsal lateral, surfaces, ≥30 mm	-Range 1-5, on dorsal surface, >22 mm	-None	-None
Yolk and Abdomen				
Dorsal Surface of Yolk	-Pigment terminating in horizontal line, 14-25 mm	-Scattered pigment, 14-19 mm	-Scattered pigment, >17 mm	-Scattered pigment, >15 mm
Lateral Surface of Yolk	-No pattern	-Pigment in diagonal rows, 19-22 mm	-No pattern	-No pattern
Abdominal Region	-None	-Pigment approaches ventral midline but doesn't meet, except in anterior region, 22-27 mm	-Pigment subcutaneous, on dorsal surface of yolk, beneath myomeres, 18-28 mm	-Pigment joins ventral midline, 25-41 mm
Pelvic Fins				
Between Fins	-None	-Scattered pigment, >22 mm	-Most had no pigment but several specimens, 23-28 mm, had melanophores	-Sparse, scattered pigment, ≥34 mm
On Pelvic Fins	-Rare	-Proximally pigmented on several specimens, >22 mm	-None	-None

Brown trout. Although the dorsal finfold in the vicinity of the anterior portion of the future dorsal fin was faintly pigmented in many recently hatched larvae (13-14 mm TL), distinct, light pigmentation along the anterior margin of the dorsal fin was not evident until about 22 mm TL and was noticeable on all longer specimens (Fig. 16). When present, this pigmentation covered the tips of the secondary rays and first principal ray. Brown trout larvae between 20 and 29 mm TL typically displayed pigment only along lateral aspects of principal rays (Fig. 16), while all larvae longer than 30 mm TL exhibited pigment on and between the rays. Specimens approximately 27 mm TL and longer had pigmentation on the distal region of at least the anterior principal rays and often on all the rays (Fig. 16).

Rainbow trout. Dorsal fin pigmentation first appeared at about 19 to 20 mm TL and remained inconspicuous on specimens less than 22 to 23 mm TL, while all larvae longer than 23 mm TL exhibited dark, bold pigmentation over all secondary rays and the distal half of the first principal ray (Fig. 20). Pigmentation on the dorsal fin was scattered on and between the proximal portion of rays in specimens over 22 mm TL, with the middle region remaining sparsely pigmented and the distal portions exhibiting reticulated pigment between the rays. Arlee rainbow trout juveniles, unlike the Tasmanian variety which served as the basis for most of this description, displayed heavy pigmentation over the entire dorsal fin with even heavier concentrations on the anterior margin and distal and proximal regions.

Cutthroat trout. Pigmentation on the anterior margin of the dorsal fin was visible on specimens as small as 19 mm TL and was nearly identical to that of the rainbow trout (Figs. 23 and 24).

Adipose fin

Brook trout. Finfold pigmentation in the vicinity of the future adipose fin appeared shortly after hatching on larvae of about 13 mm TL. By approximately 15 mm TL, pigmentation became quite bold and restricted to the distal posterior edge of the developing fin (Figure 10). By about 20 mm TL, this dense pigmentation curved anteriorly along the distal margin, with lightly scattered melanophores typically covering the anterior margin.

Brown trout. Sparse finfold pigmentation in the vicinity of the future adipose fin appeared shortly after hatching on larvae about 14 mm TL (Fig. 14). As the adipose fin developed, pigmentation was essentially restricted to the proximal half until about 22 mm TL. Pigment radiated over the rest of the fin until the fish reached about 29 mm TL, at which point all but the most distal edge was covered with light, scattered pigmentation.

Rainbow trout. Pigmentation was first observed in the vicinity of the developing adipose fin in larvae of about 15 mm TL. Until approximately 23 mm TL, pigmentation was restricted to the posterior margin of the adipose fin, while pigmentation on longer specimens became light and reticulated posteriorly and light and dappled anteriorly.

Cutthroat trout. Development and distribution of pigment in the adipose fin was very similar to that of the rainbow trout, except that it tended to remain scattered over the posterior margin without reticulation until approximately 37 mm TL.

Caudal fin

Brook trout. Newly hatched larvae, approximately 12-14 mm TL, developed strong pigmentation between the principal rays immediately ventral to the horizontal axis of the caudal fin (Fig. 8). Similar pigmentation was rarely observed dorsal to the axis on larvae shorter than 17 mm TL. This central concentration of caudal pigmentation remained distinctive until about 32 to 36 mm TL, when it spread and became aligned along the margins of the individual fin rays (Fig. 12). Less-prominent caudal pigmentation on specimens 15 to 22 mm TL included sparsely scattered melanophores on the posterior portions of the dorsal and ventral lobes. Pigmentation in these regions was often aligned alongside the principal rays on larvae longer than 22 mm TL.

Brown trout. Newly hatched larvae (approximately 13-17 mm TL) developed inconspicuous pigmentation between the principal rays (Fig. 13). Proximal pigmentation on the caudal fin developed on and between the rays in specimens longer than 17 mm TL, while distal pigmentation most often aligned along the principal rays in larvae 19 mm TL and longer (Fig. 15).

Rainbow trout. Pigmentation first appearing between the principal rays of larvae approximately 17 mm TL developed in an anterior-to-posterior direction along the principal rays; it then extended dorsally and ventrally from the central region. No pattern or areas of concentration were observed on specimens longer than 22 mm TL, in which central caudal pigmentation was scattered between the principal rays proximally and appeared on and between the rays distally (Fig. 20).

Cutthroat trout. Pigmentation first appeared ventral to the horizontal midline of the caudal fin, in the region of the newly formed

principal rays, on larvae approximately 15 mm TL. It persisted in this region until it spread in the same manner as described for rainbow trout. Small cutthroat trout, less than 21 mm TL, had less well-defined reticulate pigmentation than larger trout, longer than 31 mm TL, which had confined dappled pigmentation that was scattered distally with no pattern or area of concentration (Figs. 23 and 24).

Anal pterygiophores

Brook trout. Pigmentation was not observed in the vicinity of the anal pterygiophores on brook trout less than 16 mm TL. Several specimens smaller than 21 mm TL had pigmentation concentrated in the anterior region of the pterygiophores, while larger specimens (21 to 28 mm TL) had dark, bold pigmentation in this region, and larvae longer than 30 mm TL had similar, though less distinct, pterygiophore pigmentation (Figs. 11 and 12). In a ventral view, pigmentation concentrations on the anterior pterygiophores were most noticeable directly posterior to the vent (Fig. 11).

Brown trout. Pigmentation was concentrated noticeably on the anal pterygiophore ridge of newly hatched larvae (approximately 15 mm TL), and bold pigmentation developed by approximately 19 mm TL (Fig. 15). Melanophores on the pterygiphore ridge were evenly distributed on brown trout less than 22 mm TL and concentrated on the anterior and posterior regions of this ridge on longer specimens. All specimens longer than 23 mm TL had a shallow "V" pointing posteriorly and enveloping the vent (Fig. 16).

Rainbow trout. Pigmentation first became apparent on the posterior region of the anal pterygiophore ridge at approximately 17 mm

TL. Pigmentation spread in an anterior direction until about 23 mm TL; then the ridge was covered with evenly distributed pigmentation. Unlike brook and brown trout, rainbow larvae did not develop concentrations, nor patterns, of pigmentation in this region (Fig. 20).

Cutthroat trout. As in rainbow trout, newly hatched cutthroat trout (15 mm TL) had anal pterygiophore pigmentation which appeared posteriorly and spread anteriorly; complete coverage occurred at 20 mm TL (Fig. 23). Thereafter, pigmentation remained scattered without areas of concentration (Fig. 24).

Throat and anterior margin of the lower jaw

Brook trout. Pigmentation first appeared on the anterior margin of the lower jaw at approximately 12 mm TL; it became bold on all specimens longer than 15 mm TL (Figs. 10 and 11). Small, inconspicuous melanophores were rarely observed on the throats of larval brook trout; however, if such pigmentation was present, the melanophores never numbered more than fifteen.

Brown trout. Larvae approximately 19 mm TL first showed pigmentation on the anterior margin of the lower jaw (Fig. 15). It became concentrated at about 22 mm TL (Fig. 16). Throat pigmentation was first discerned on larvae 14 to 17 mm TL, and all longer specimens had scattered pigmentation, with no areas of concentration, in this region (Fig. 16).

Rainbow trout. Pigmentation on the anterior margin of the lower jaw and throat was initially observed on larvae 17 to 23 mm TL (Fig. 19). Occasionally, pigmentation on the anterior margin of the lower

jaw was limited to one melanophore. Most larvae, however, had scattered pigmentation over the entire jaw with no areas of concentration (Fig. 20).

Cutthroat trout. Throat pigmentation was present on newly hatched larvae (approximately 14 mm TL), while pigmentation on the anterior margin of the lower jaw was not present on specimens under 19 mm TL (Fig. 23). All specimens longer than 20 mm TL had scattered pigmentation extending over both the throat and anterior lower jaw with no areas of concentration (Fig. 24).

Pectoral fins

Sparse pectoral fin pigmentation, initially observed on brook trout larvae 19 to 21 mm TL, was located on the base of the fins and rarely developed between the fin rays. However, brown trout pigmentation developed on both the fin base (at approximately 22 mm TL) and between the fin rays (at about 24 mm TL), while inconspicuous melanophores aligned with the anterior fin ray tips and spread, with growth, to the posterior fin ray tips. As in brook trout, pigmentation initially appeared on the fin bases of rainbow and cutthroat trout at approximately 22-23 mm TL and 19 mm TL, respectively, and pigmentation was rare between the fin rays (Figs. 20 and 24).

Parr marks

Brook trout. Parr marks first appeared on the anterior-lateral aspects of brook trout at approximately 17 mm TL and developed in a posterior direction. Number of primary parr marks gradually increased with development (to approximately 25 mm TL); longer larvae averaged

seven marks (with a range of four to ten). Dorsal parr marks appeared at approximately 23 mm TL, averaged six in number, and ranged from two to eight on specimens longer than 25 mm TL (Fig. 12). Similarly ventral parr marks, when present, ranged from one to six with an average of two. Numerous small parr marks located next to and above the dorsal parr marks were present on all larvae 30 mm TL and longer.

Brown trout. Inconspicuous primary parr marks appeared on larvae 21 mm TL and became prominent on specimens over 22 mm TL. These marks numbered seven to ten, with seven or eight being most common. Unlike brook trout, brown trout usually had parr marks (initially appearing on larvae 25 to 29 mm TL) dorsal to the lateral line and rarely ventral to it. Unlike all other trouts studied, brown trout larvae over 22 mm TL had parr-like marks on the dorsal surface (Fig. 16).

Rainbow trout. All larvae longer than 21 mm TL had parr marks ranging in number from five to ten, with seven to nine being most common (Fig. 20). Dorsal parr marks occasionally appeared on specimens 32 mm TL and longer and never exceeded three in number. No ventral parr marks developed on rainbow trout larvae.

Cutthroat trout. Primary parr marks initially appearing on larvae about 22 mm TL increased in number up to 27 mm TL, at which point they ranged from seven to eleven in number with eight or nine being most common. Rarely did cutthroat trout larvae have dorsal parr marks, and they never had ventral parr marks.

Yolk and abdomen

Brook trout. Pigmentation was first observed on the dorsal surface of the yolk in larvae about 14 mm TL. By 19 mm TL, this

pigmentation was evenly distributed, and it abruptly terminated in a horizontal line on the dorsal surface of the yolk (Fig. 10). Parr mark formation disrupted this even distribution on specimens longer than 19 mm TL (Fig. 11). Further disruption occurred with sparse pigmentation developing on the lateral yolk surface. Pigmentation did not appear on the ventral surface of the yolk, nor was it visible on the ventral body surface following yolk absorption (Fig. 12). Abdominal pigmentation visible on some specimens was subcutaneous and restricted to the jugular region, between the pectorals (Fig. 11). Clarity of this pigmentation was dependent on the thickness and transparency of the epidermal tissue.

Brown trout. Pigmentation first appearing on the dorsal surface of the yolk of larvae about 13 mm TL spread with development over the dorsal and anterior-lateral aspects of the yolk (Fig. 15). This lateral pigmentation, on specimens 19 to 22 mm TL, lined up in diagonal rows arranged in a posterior-dorsal to anterior-ventral direction. With absorption of the yolk, this lateral pigmentation approached the ventral midline, but did not meet, except in the anterior region between or just posterior to the pectorals. As in brook trout, subcutaneous pigmentation was located between the pectorals, but it became obscure in specimens longer than 26 mm TL due to the development of thick epidermal tissue.

Rainbow trout. Dorsal yolk pigmentation was first observed on larvae about 17 mm TL (Fig. 19). Yolk pigmentation on all specimens was evenly scattered with no apparent pattern. Unlike brook and brown trout, several rainbow trout had pigmentation extending under the

myomeres on the dorsal surface of the yolk. This pigmentation was seen on the lateral abdomen, below the epidermal tissue, during and following yolk absorption. Occasional specimens had both epidermal and subcutaneous ventro-lateral abdominal pigmentation. Other specimens 18 to 28 mm TL, as in brook and brown trout, had subcutaneous pigmentation between the pectorals, which was gradually covered with opaque epidermal tissue. Upon absorption of the yolk, epidermal tissue became thick and opaque, making all subcutaneous pigmentation invisible.

Cutthroat trout. Light inconspicuous pigmentation appeared on the dorsal surface of the yolk of larvae 14 to 15 mm TL (Fig. 21). This pigmentation joined on the ventral surface, following yolk absorption, at about 25 mm TL (Fig. 24). Gradual thickening of epidermal tissue obscured all abdominal pigmentation by 27 to 41 mm TL. As in the previously mentioned trouts, cutthroat trout develop subcutaneous jugular pigmentation at approximately 19 mm TL (Fig. 23); this was covered by epidermal tissue by about 31 mm TL. Jugular pigmentation also developed on the epidermal tissue between the pectorals of larvae 34 mm TL and longer.

Pelvic fins

Pigmentation between the pelvic fins was absent on all brook trout, while all brown trout longer than 22 mm TL had scattered pigmentation in this region. Rainbow trout occasionally had pigmentation between the pelvic fins, but it was sparse and scattered; the number of melanophores never exceeded ten and was normally less than five. All cutthroat trout over 34 mm TL had sparse, scattered pigmentation in this region.

Brook, rainbow and cutthroat trouts had no pigmentation on the pelvic fins. Yet, approximately half of the brown trout observed had proximal pigmentation on the pelvic fins.

Oil Globules

Differences were observed in the size and abundance of oil droplets near the surface of the yolk (Table 16) in mesolarvae and early metalarvae, which possess substantial amounts of yolk. Due to yolk assimilation, larval trout larger than approximately 19 mm TL no longer had distinct oil globules.

Distinguishing Length Measurements

Since many length or position characters exhibit some degree of overlap and may be valid for only a limited size range, caution is required when using them diagnostically. All characters listed in Table 17 should be used to enhance correct identification.

Mesolarvae

Length measurements of mesolarvae were inadequate for separating rainbow and cutthroat trout larvae. The origin of the preanal finfold was useful in separating brook trout (58% SL) from rainbow and cutthroat trout (54% SL each). Measurement of posterior yolk allowed segregation of the eliptical yolk of most brown trout from more spherical yolk of other species. Percent standard length of the posterior yolk averaged 67% for brown trout but 60%, 58%, and 56% SL for brook, rainbow, and cutthroat trout, respectively (Table 18). Insertion of the yolk was more often located more posteriorly on brook trout than in the other trouts. Insertion of the yolk averaged 55% SL

Table 16. Summary of the abundance and size distribution of oil droplets observed on the surface of yolk of mesolarvae and early metalarvae of brook, brown, rainbow, and cutthroat trout. All measurements are of oil globule diameters.

Oil Globules	Brook	Brown	Rainbow	Cutthroat
<0.5 mm	very numerous none larger than about 0.4 mm	many	many	many
0.5-1.0 mm	none	several	several, seldom over 0.8 mm	rarely larger than about 0.5 mm
>1.0 mm	none	0-4	none	very rare, only in one specimen

Table 17. Length measurements expressed as percent standard length (from tip of the snout to designated character or length of character) useful in differentiation between brook, brown, rainbow, and cutthroat trout metalarvae.

	Brook	Brown	Rainbow
Brown	OPAF OAD ODF IY AD length P_1 length PY	———	———
Rainbow	OPAF OAD AD length ODF OD ID IY	PY OD ID OPAF P_1 length P_2 length	———
Cutthroat	OPAF ODF IY OD OAD AD length	OPAF OD PY P_1 length	ID OAD

Table 18. Summary of percent standard length data via means, standard deviations, ranges, and sample sizes for mesolarval and metalarval brook, brown, rainbow, and cutthroat trout. Significant morphometric lengths, recorded as percent standard lengths, useful in the segregation of these trout species included length from the snout to OPAF - origin of preanal finfold, OAD - origin of adipose fin, PY - posterior margin of yolk, IY - insertion of yolk, ODF - origin of dorsal finfold, OD - origin of dorsal fin, ID - insertion of dorsal fin, and lengths of pectoral (P_1) and adipose (AD) fins.

	Larval stage	Brook				Brown				Rainbow				Cutthroat			
		Mean	s	Range	n	Mean	s	Range	n	Mean	s	Range	n	Mean	s	Range	n
OPAF	meso.	58	3	55-64	8	56	2	53-60	9	54	2	51-58	9	54	2	51-57	10
	meta.	57	2	53-61	22	63	4	54-67	12	56	9	43-68	41	54	10	39-71	39
OAD	meso.					61	1	60-61	2								
	meta.	68	3	63-75	22	74	5	63-79	25	76	7	61-84	36	73	5	64-79	36
AD	meso.					27	1	26-27	2								
	meta.	19	2	16-23	20	16	4	11-25	25	14	6	7-27	36	15	4	11-24	36
P_1	meso.	11	1	11-13	8	11	1	9-12	9	10	1	9-11	9	10	1	9-11	10
	meta.	14	2	10-18	23	18	4	11-23	25	13	3	8-17	38	16	2	11-19	39
PY	meso.	60	3	56-64	8	67	3	60-70	9	58	3	54-62	9	56	3	52-61	10
	meta.	54	3	51-63	15	61	7	51-68	9	52	5	48-62	12	55	4	48-60	8
IY	meso.	55	2	53-58	7	51	7	49-57	9	50	3	45-54	9	48	2	43-50	6
	meta.	53	5	47-57	3	54	2	51-56	8	53	2	50-55	6				
ODF	meso.	37	4	32-45	8	27	2	25-30	9	24	1	23-26	9	25	2	21-30	10
	meta.	38	3	32-42	15	34	3	29-38	6	28	2	24-32	13	30	4	24-36	10
OD	meso.	50	1	49-51	2	47	1	45-47	6					51	0	50-51	2
	meta.	48	1	45-51	26	47	1	45-49	25	52	2	50-58	41	51	1	48-53	39
ID	meso.	65	2	63-66	2	60	0	60-60	2					64	1	63-64	2
	meta.	62	1	60-65	26	62	1	59-64	25	66	3	61-70	41	63	1	60-66	39

in brook trout mesolarvae and 51%, 50%, and 48% SL for brown, rainbow, and cutthroat mesolarvae, respectively. The origin of the dorsal finfold was more posterior on brook trout than the other trouts; measurements ranged from 32-45% SL for brook trout (Fig. 25) to 25-30%, 23-26%, and 21-30% SL for brown (Fig. 26), rainbow (Fig. 27), and cutthroat trout (Fig. 28), respectively. The origin and insertion of the dorsal fin were more anterior on brown trout than brook and cutthroat trout. Data are lacking for rainbow trout mesolarvae due to dorsal fin deformities. The origin of the dorsal fin in brown trout measured 45-47% SL versus 49-51% and 50-51% SL in brook and cutthroat trout, respectively. Measures of the insertion of the dorsal fin averaged 60% SL for brown trout as opposed to 65% and 64% SL for brook and cutthroat trout, respectively.

Metalarvae

Although brook and brown trout had unilobed preanal finfolds (which absorbed in an anterior-to-posterior direction), this structure was used to distinguish these species from each other and from rainbow and cutthroat trout, which had bilobed preanal finfolds after attaining lengths from approximately 20 to 24 mm SL. The bilobed finfolds were absorbed first in the center to produce the bilobed structure; then the anterior lobe was absorbed before the posterior lobe in an anterior-to-posterior direction. This finfold was farther posterior and was completely absorbed at a smaller size (21 mm SL) in brown trout (Fig. 30) than in brook (24 mm SL) (Fig. 29), rainbow (32 mm SL) (Fig. 31), or cutthroat trout (35 mm SL) (Fig. 32). The range of length measurements to the origin of this finfold for rainbow and cutthroat

Figure 25. Brook trout larva morphometric length data (from tip of snout to ODF - Origin of dorsal finfold, OD - Origin of dorsal fin, IY - Insertion yolk, ID - Insertion dorsal fin, PY - Posterior yolk, OAD - Origin adipose fin, and lengths of; P_2 - pelvic fin, and A - Anal fin) recorded as percent standard length and graphed against standard length.

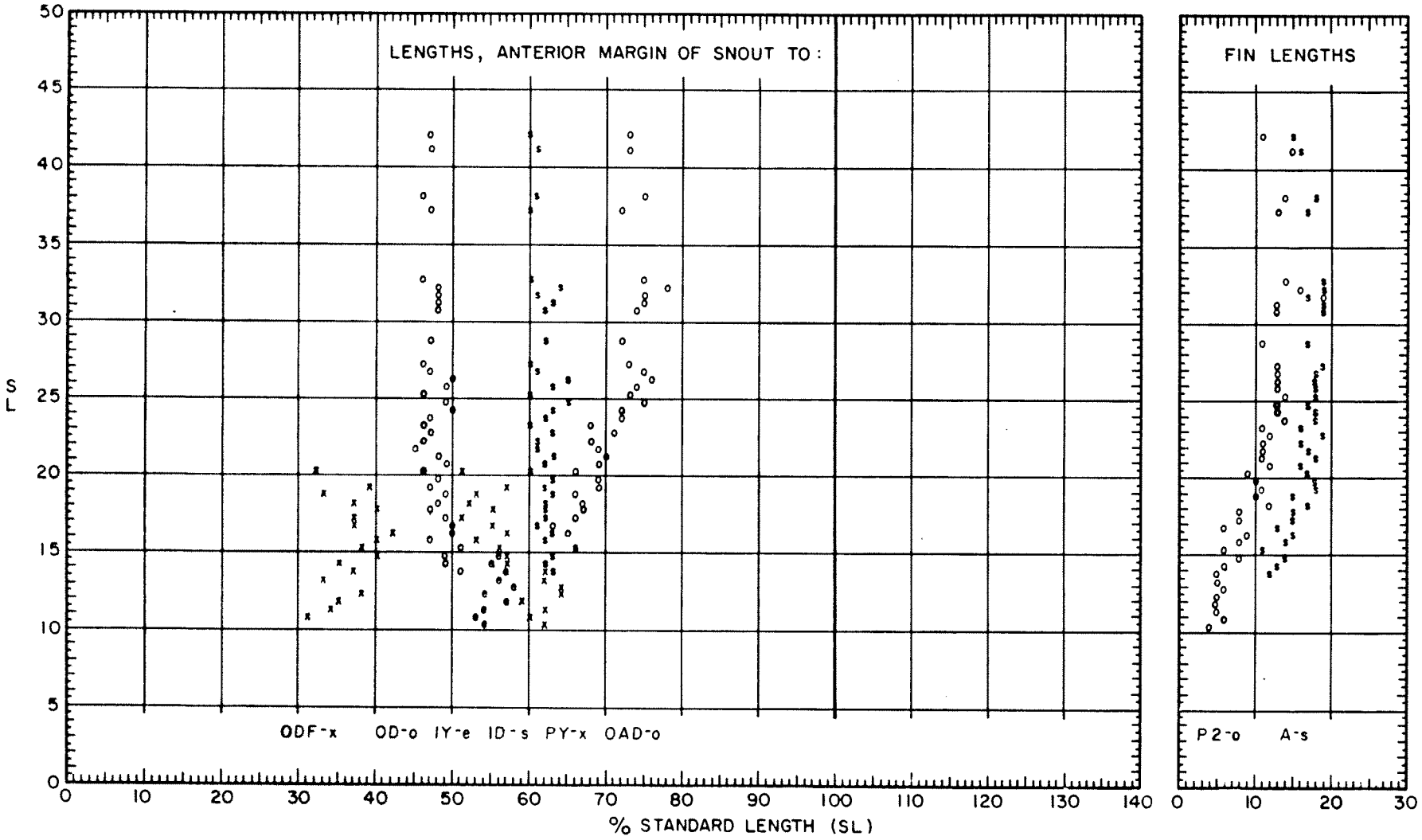

LENGTHS, ANTERIOR MARGIN OF SNOUT TO:
FIN LENGTHS
ODF-x OD-o IY-e ID-s PY-x OAD-o
P2-o A-s
% STANDARD LENGTH (SL)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
0 10 20 30
0 5 10 15 20 25 30 35 40 45 50

Figure 26. Brown trout larva morphometric length data (from tip of snout to ODF - Origin of dorsal finfold, OD - Origin of dorsal fin, IY - Insertion yolk, ID - Insertion dorsal fin, PY - Posterior yolk, OAD - Origin adipose fin, and lengths of; P_2 - Pelvic fin, and A - Anal fin) recorded as percent standard length and graphed against standard length.

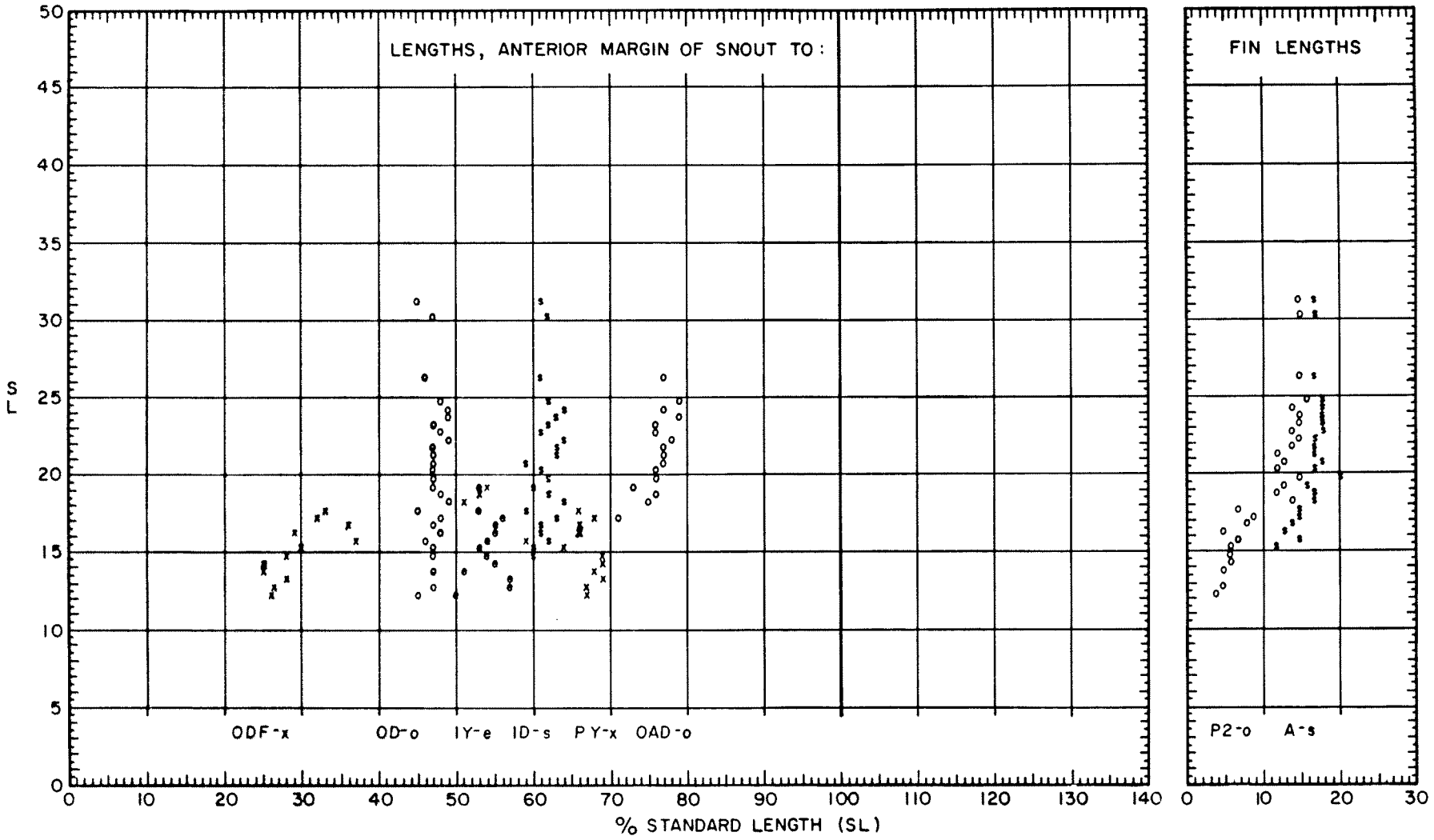

LENGTHS, ANTERIOR MARGIN OF SNOUT TO:
FIN LENGTHS
ODF-x
OD-o
IY-e
ID-s
PY-x
OAD-o
P2-o
A-s
% STANDARD LENGTH (SL)

Figure 27. Rainbow trout larva morphometric length data (from tip of snout to ODF - Origin of dorsal finfold, OD - Origin of dorsal fin, IY - Insertion yolk, ID - Insertion dorsal fin, PY - Posterior yolk, OAD - Origin adipose fin, and lengths of; P_2 Pelvic fin, and A - Anal fin) recorded as percent standard length and graphed against standard length.

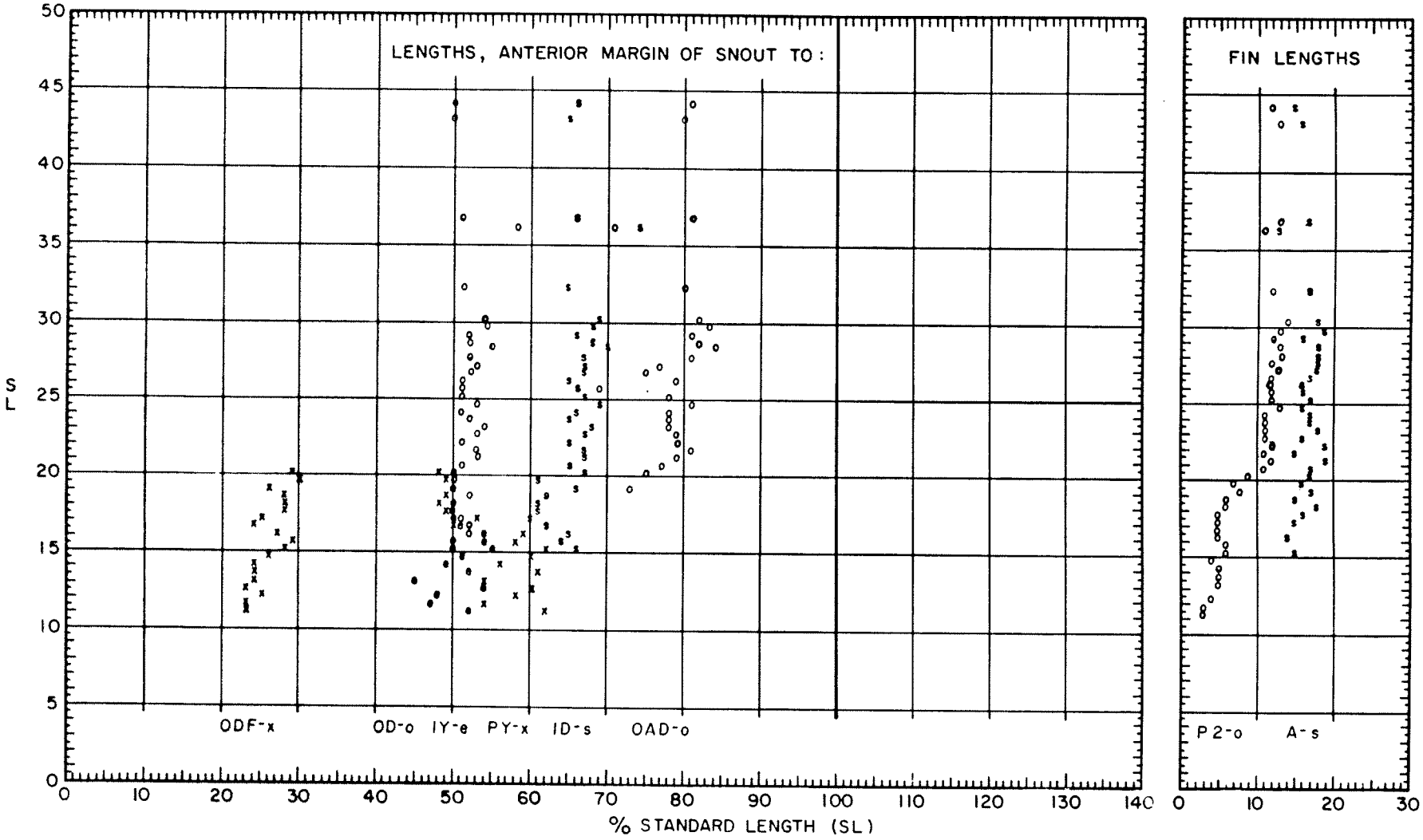
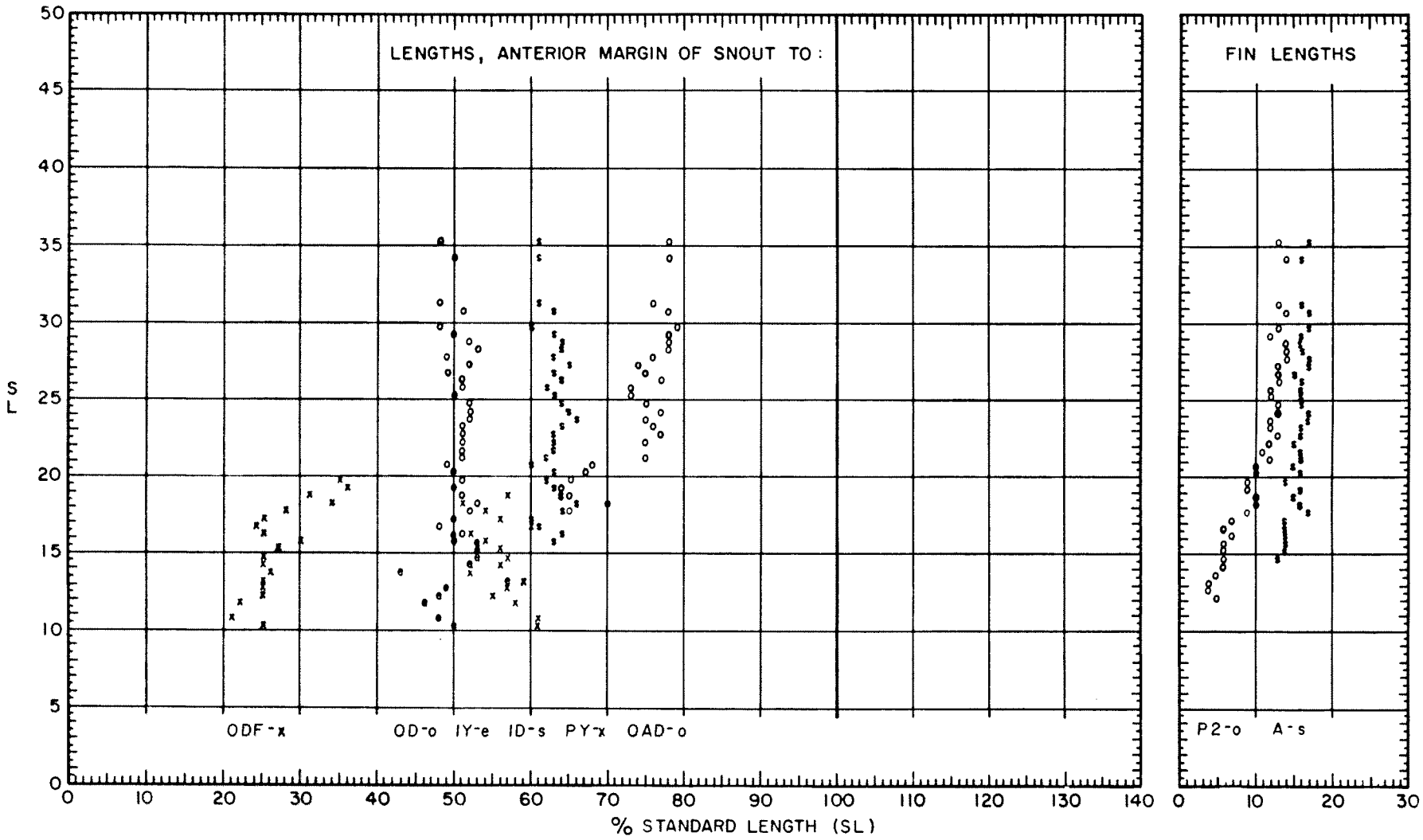

LENGTHS, ANTERIOR MARGIN OF SNOUT TO:
FIN LENGTHS
ODF-x
OD-o
IY-e
PY-x
ID-s
OAD-o
P2-o
A-s
% STANDARD LENGTH (SL)
SL
0
5
10
15
20
25
30
35
40
45
50
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
0
10
20
30

Figure 28. Cutthroat trout larva morphometric length data (from tip of snout to ODF - Origin of dorsal finfold, OD - Origin of dorsal fin, IY - Insertion yolk, ID - Insertion dorsal fin, PY - Posterior yolk, OAD - Origin adipose fin, and lengths of; P_2 Pelvic fin, A - Anal fin) recorded as percent standard length and graphed against standard length.


LENGTHS, ANTERIOR MARGIN OF SNOUT TO:
FIN LENGTHS
ODF-x
OD-o IY-e ID-s PY-x OAD-o
P2-o A-s
% STANDARD LENGTH (SL)
0
5
10
15
20
25
30
35
40
45
50
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
0 10 20 30

48

Figure 29. Brook trout larva morphometric length data (from tip of snout to AE - Anterior eye, PE - Posterior eye, OP_1 - Origin pectoral fin, OP_2 - Origin pelvic fin, OPAF - Origin preanal finfold, PV - Posterior vent, IA - Insertion anal fin, AFC - Anterior fork caudal fin, PC - Posterior caudal fin, and lengths of; AD - Adipose fin, P_1 - Pectoral fin, and D - Dorsal fin) recorded as percent standard length and graphed against standard length.

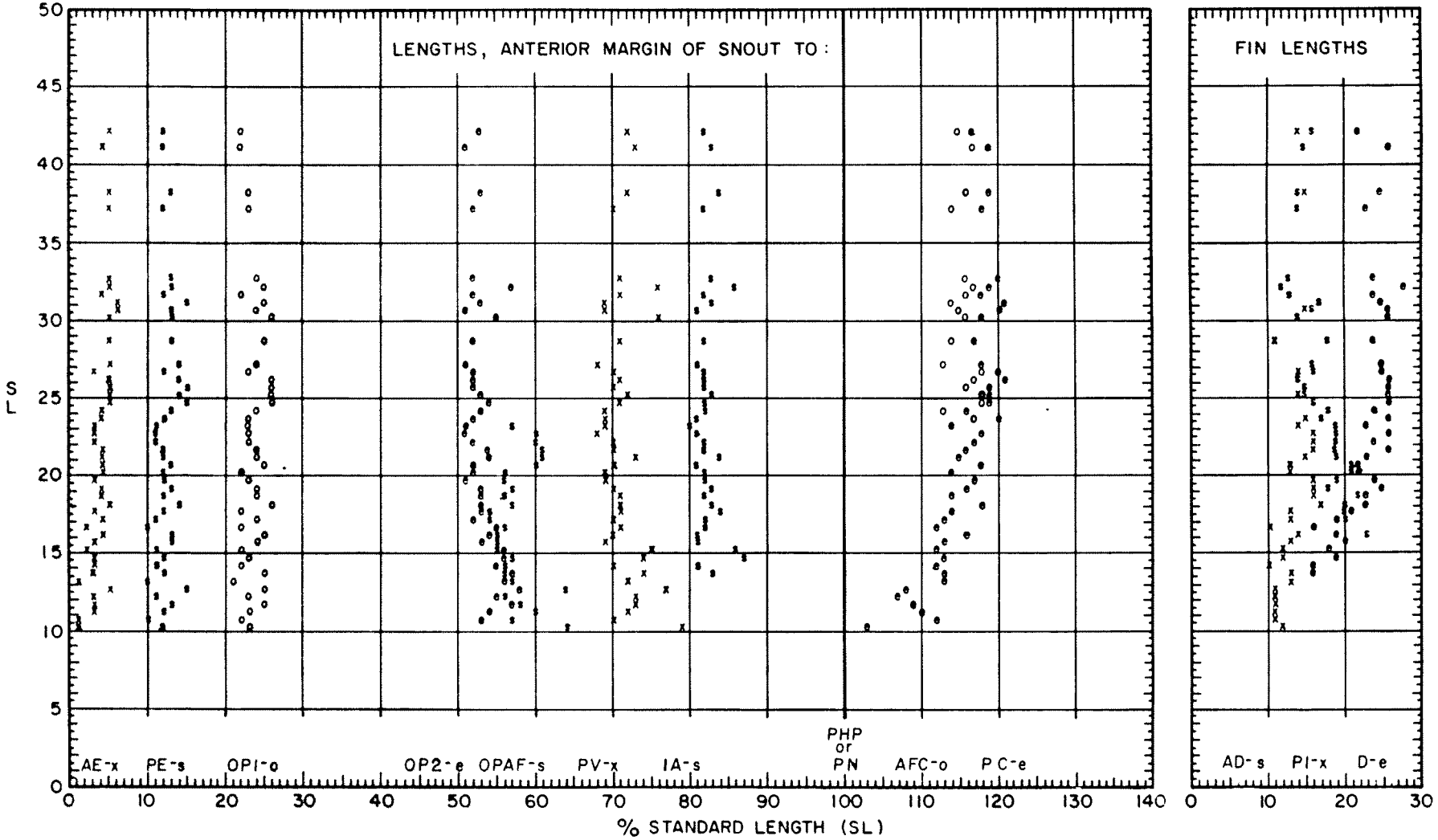

LENGTHS, ANTERIOR MARGIN OF SNOUT TO:
FIN LENGTHS
SL
% STANDARD LENGTH (SL)
AE-x
PE-s
OP1-o
OP2-e
OPAF-s
PV-x
IA-s
PHP or PN
AFC-o
PC-e
AD-s
PI-x
D-e

Figure 30. Brown trout larva morphometric length data (from tip of snout to AE - Anterior eye, PE - Posterior eye, OP_1 - Origin pectoral fin, OP_2 - Origin pelvic fin, OPAF - Origin preanal finfold, PV - Posterior vent, IA - Insertion anal fin, AFC - Anterior fork caudal fin, PC - Posterior caudal fin, and lengths of; AD - Adipose fin, P_1 - Pectoral fin, and D - Dorsal fin) recorded as percent standard length and graphed against standard length.

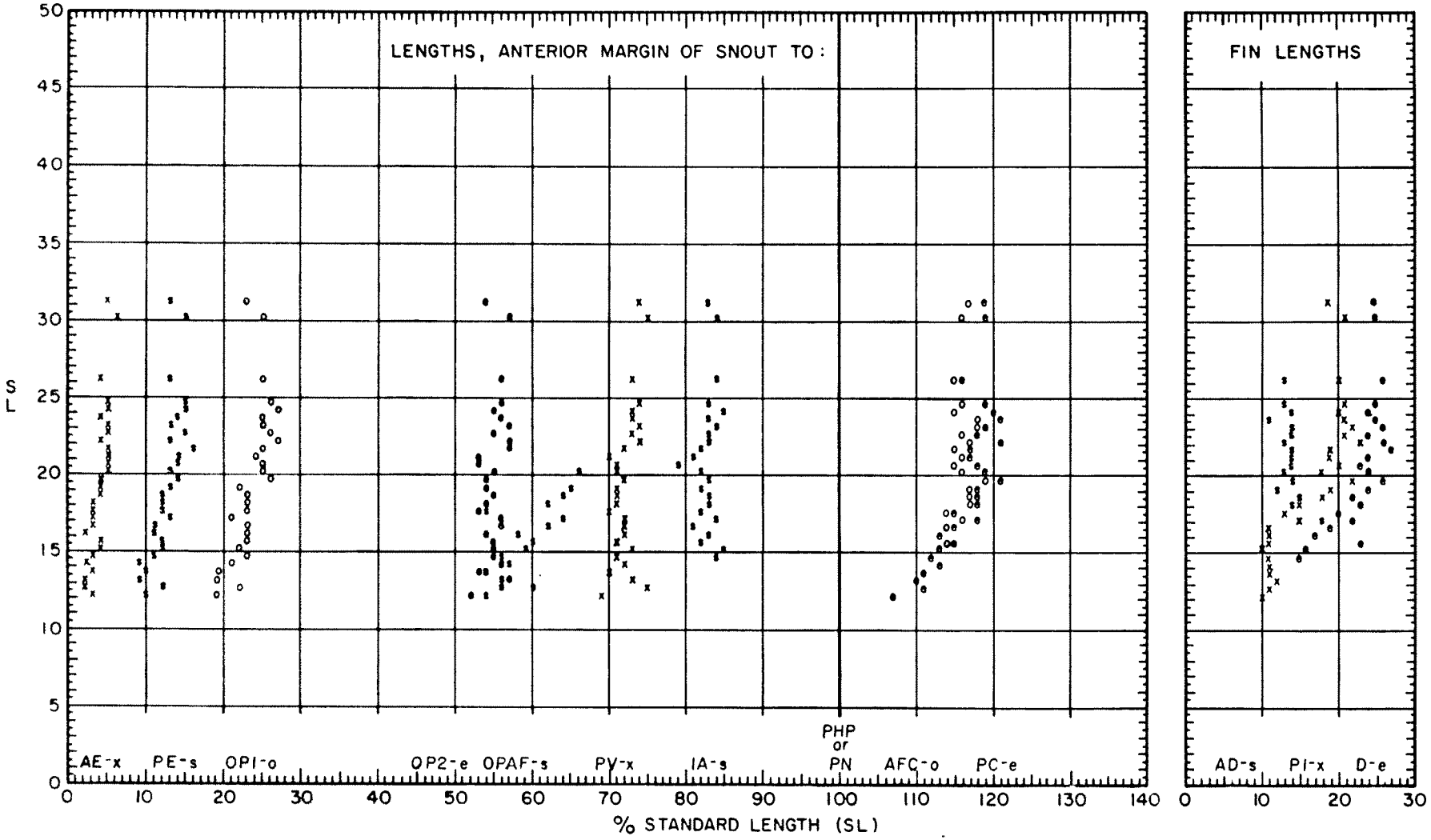

LENGTHS, ANTERIOR MARGIN OF SNOUT TO:
FIN LENGTHS
SL
% STANDARD LENGTH (SL)
AE-x PE-s OPI-o OP2-e OPAF-s PV-x IA-s PHP or PN AFC-o PC-e
AD-s PI-x D-e
0 5 10 15 20 25 30 35 40 45 50
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
0 10 20 30

Figure 31. Rainbow trout larva morphometric length data (from tip of snout to AE - Anterior eye, PE - Posterior eye, OP_1 - Origin pectoral fin, OP_2 - Origin pelvic fin, OPAF - Origin preanal finfold, PV - Posterior vent, IA - Insertion anal fin, AFC - Anterior fork caudal fin, PC - Posterior caudal fin, and lengths of; AD - Adipose fin, P_1 - Pectoral fin, and D - Dorsal fin) recorded as percent standard length and graphed against standard length.

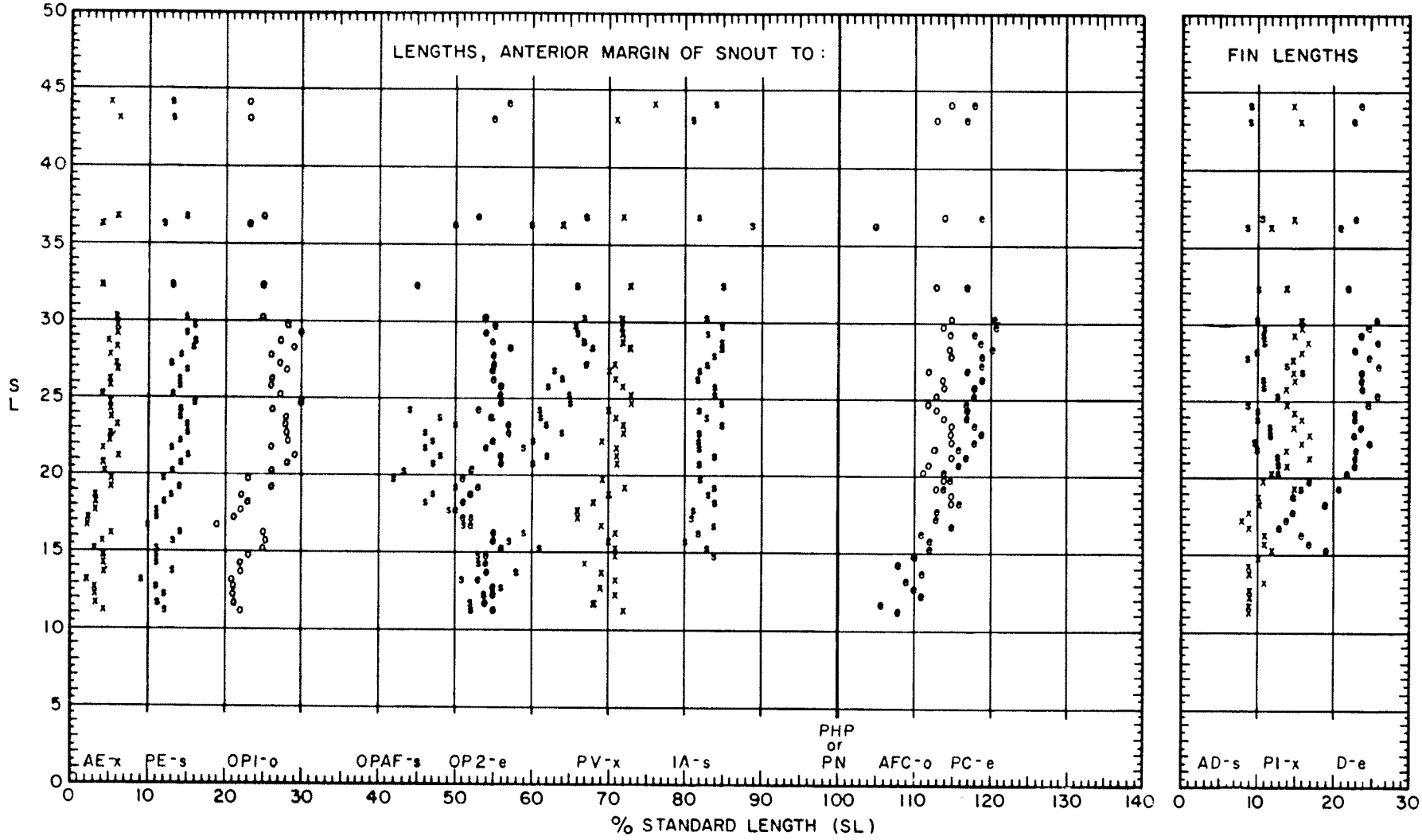
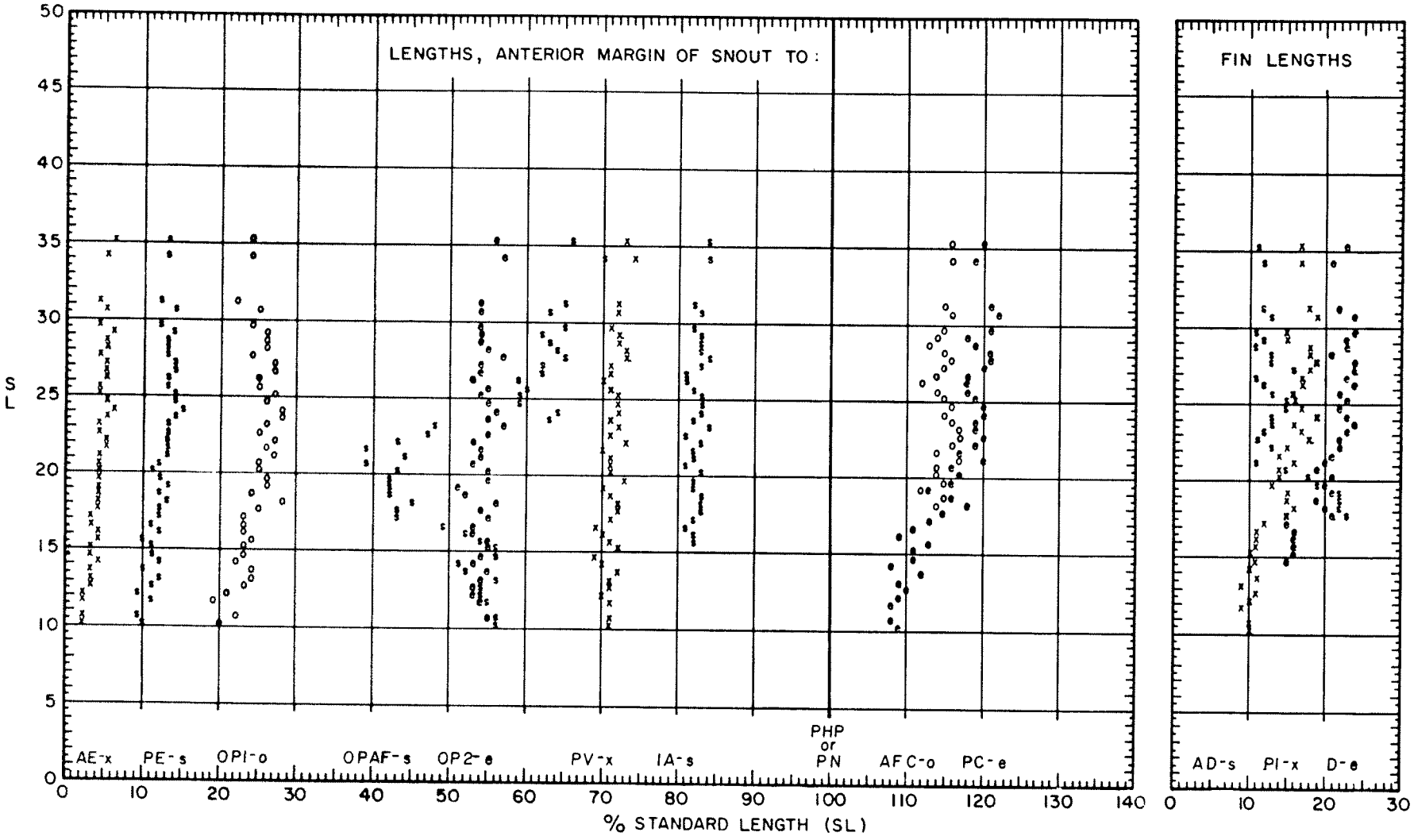

LENGTHS, ANTERIOR MARGIN OF SNOUT TO:
FIN LENGTHS
AE-x PE-s OPI-o OPAF-s OP2-e PV-x IA-s PHP or PN AFC-o PC-e
AD-s PI-x D-e
% STANDARD LENGTH (SL)

Figure 32. Cutthroat trout larva morphometric length data (from tip of snout to AE - Anterior eye, PE - Posterior eye, OP_1 - Origin pectoral fin, OP_2 - Origin pelvic fin, OPAF - Origin preanal finfold, PV - Posterior vent, IA - Insertion anal fin, AFC - Anterior fork caudal fin, PC - Posterior caudal fin, and lengths of; AD - Adipose fin, P_1 - Pectoral fin, and D - Dorsal fin) recorded as percent standard length and graphed against standard length.


LENGTHS, ANTERIOR MARGIN OF SNOUT TO:
FIN LENGTHS
SL
% STANDARD LENGTH (SL)
AE-x
PE-s
OPI-o
OPAF-s
OP2-e
PV-x
IA-s
PHP or PN
AFC-o
PC-e
AD-s
PI-x
D-e

trout (43-68% SL and 39-71% SL, respectively) greatly exceeded those of brook and brown trout (53-61% SL and 54-67% SL, respectively).

The origin of the adipose fin is usually more anterior in brook trout (averaging 68% SL) than in brown, rainbow, or cutthroat trout (averaging 74%, 76%, and 73% SL, respectively). Because of the anterior projection of the adipose fin, it was also longer in brook trout (averaging 19% SL) than in brown, rainbow, or cutthroat trout (averaging 16%, 14%, and 15% SL, respectively), ranging from 16 to 25 mm SL. One of two characters useful in segregating rainbow and cutthroat trout was origin of the adipose fin (Table 17). It was consistently farther posterior in rainbow trout than cutthroat trout (Figs. 27 and 28). Unlike the adipose fin, the pectoral fin was often longer in brown trout (averaging 18% SL) than in brook, rainbow, or cutthroat trout (averaging 14%, 13%, and 16% SL, respectively), ranging from 18 to 31 mm SL (Figs. 29 through 32).

As discussed for mesolarvae, the yolk of metalarvae extended farther back in brown trout than in brook, rainbow, or cutthroat trout (Figs. 25 through 28). Length from snout to posterior yolk averaged 61% SL for brown trout and only 54%, 52%, and 55% SL for brook, rainbow, and cutthroat trout, respectively (Table 18).

Origin of the dorsal finfold was more posterior in brook trout than in brown trout and generally more posterior in brown trout than in rainbow or cutthroat trout. The origin of this finfold averaged 38% SL in brook trout, 34% SL in brown trout, and 28% and 30% SL in rainbow and cutthroat trout, respectively (Table 18). The origin of the dorsal fin, (in specimens 15 to 43 mm SL), unlike that of the finfold, was

farther back in rainbow and cutthroat trout (52% and 51% SL, respectively) than in brook and brown trout (48% and 47% SL, respectively). Similarly, insertion of the dorsal fin was more posterior in rainbow trout than brook, brown, or cutthroat trout; it averaged 66% SL in rainbow trout, 62% SL in brook and brown trout, and 63% SL in cutthroat trout (Table 18) (Figs. 25 through 28).

Multivariate Statistical Analysis

As previously mentioned, discriminant functions and principal components were formulated by combining morphometric and meristic characters in such a manner that the variance of the combination was as large as possible. Each of the three functions and components analyzed constituted a percentage of this total variance.

Discriminant function analysis, mesolarvae

With the aid of discriminant analysis 37 of 38 mesolarvae (97.4%) were correctly assigned to their respective species (Table 19). Nine of 18 characters applicable to mesolarvae had substantial discriminating weight, which allowed their use in the formation of the three functions (Table 2). Function one comprised 82.2% of the total variance and clustered brook and brown trout by separating them into distinct groups (Figs. 33 and 34) with rainbow and cutthroat trout making a third group (Fig. 33). Characters with most discriminating weight included depth at origin of pectoral fin, length of yolk, depth of yolk, and depth at anterior margin of most posterior myomere (Table 20). Yolk measurements may not practically be used in distinguishing between mesolarvae since yolk size is related to the rate of

Table 19. Percentage of brook, brown, rainbow, and cutthroat trout mesolarvae correctly classified using discriminant function analysis.

Actual Group	Number of Cases	Predicted Group Membership			
		1	2	3	4
Group 1 Rainbow	10	9 90%	1 10%	0 0%	0 0%
Group 2 Cutthroat	10	0 0%	10 100%	0 0%	0 0%
Group 3 Brown	10	0 0%	0 0%	10 100%	0 0%
Group 4 Brook	8	0 0%	0 0%	0 0%	8 100%

Percent of grouped cases correctly classified = 97.4

Figure 33. Plot of the first two discriminant functions for 38 specimens of mesolarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.

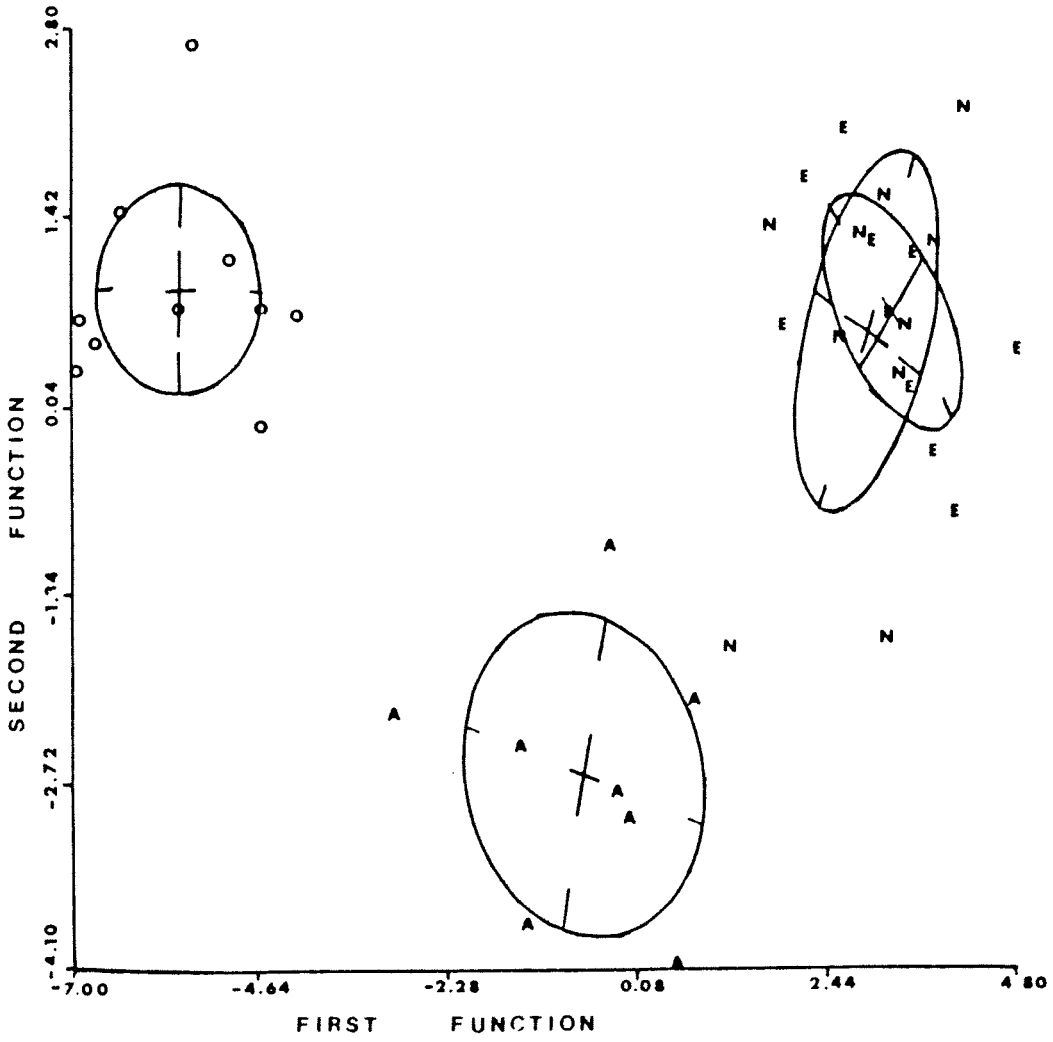

SECOND FUNCTION
2.80
1.42
0.04
-1.34
-2.72
-4.10
-7.00
-4.64
-2.28
0.08
2.44
4.80
FIRST FUNCTION
O
N
E
A

Figure 34. Plot of the first and third discriminant functions for 38 specimens of mesolarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.

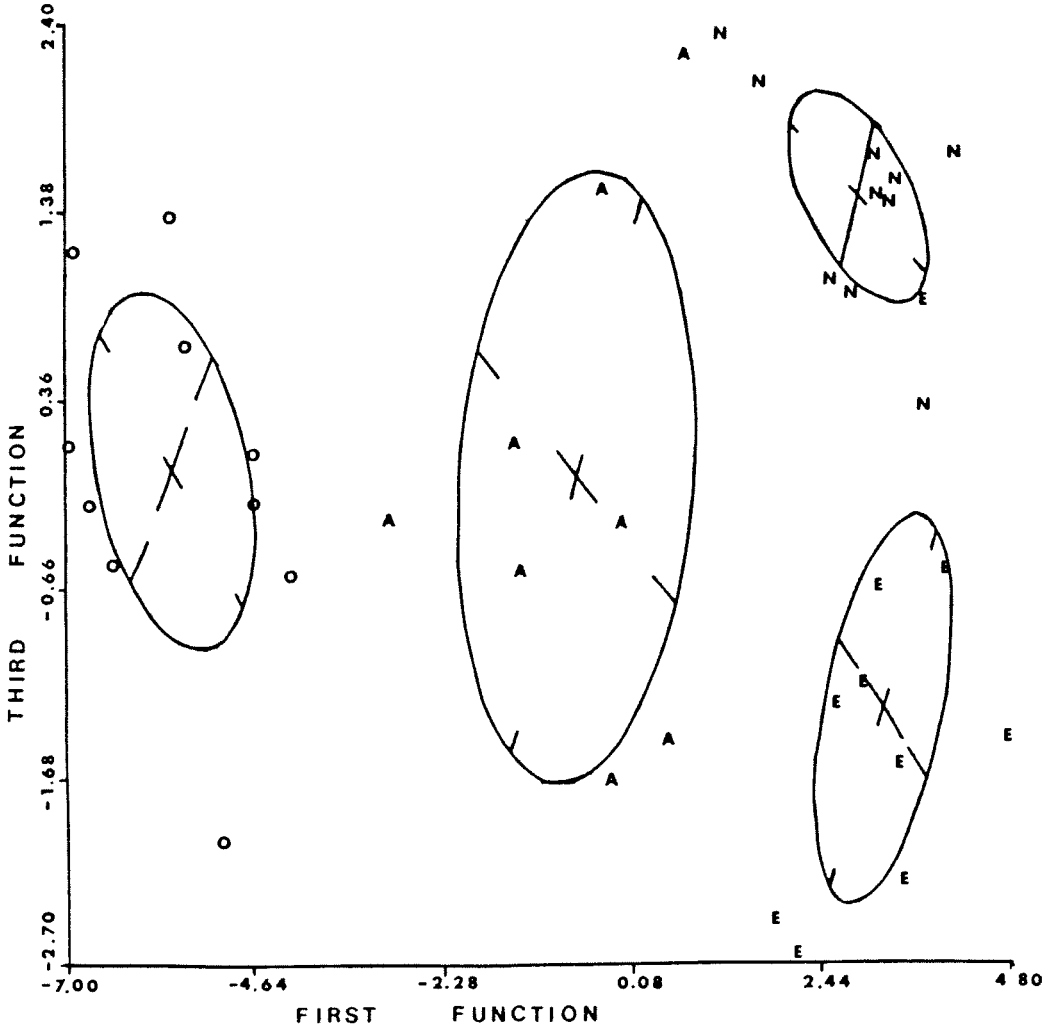

THIRD FUNCTION
2.40
1.38
0.36
-0.66
-1.68
-2.70
-7.00
-4.64
-2.28
0.08
2.44
4.80
FIRST FUNCTION

Table 20. Standardized canonical discriminant function coefficients for brook, brown, rainbow, and cutthroat trout mesolarvae. Abbreviated meristic and morphometric characters are; PV - posterior vent, OPAF - origin of preanal finfold, OP_1 - origin pectoral fin, AMPM - anterior margin of eye, BPV - behind posterior margin of vent.

Meristic and Morphometric Character	Function 1	Function 2	Function 3
Anterior snout to;			
PV	-0.74245	-0.51717	0.32610
OPAF	0.16519	-0.71203	0.01608
Depth at;			
OP_1	1.54282	1.41204	- 0.13799
AMPM	-1.06262	-0.41661	- 0.29306
Y	-1.26830	-0.43277	- 0.58482
Width at;			
BPE	0.71058	-0.32399	- 0.90540
OP_1	0.34423	-0.94131	- 0.55572
BPV	-0.11424	1.37995	0.18681
Length of;			
Y	-1.39601	0.24251	0.01816

development. Function two comprised 11.7% of the total variance and, like function one, clustered brook and brown trout into separate groups (Figs. 33 and 35). Three morphometric lengths had significant weight in this function; depth and width at origin of pectoral fin, and width immediately behind posterior margin of vent (Table 20). Function three constituted 6.1% of the total variance and clustered rainbow and cutthroat trout into separate groups (Figs. 34 and 35). Characters with most discriminating weight were width behind posterior margin of eye, depth of yolk, and width at origin of pectoral fin (Table 20). Characters with low weight in each of the three functions were anterior margin of snout to both posterior margin of vent and origin of preanal finfold. Due to the low number of variables originally considered, these characters should be included when identifying trout larvae. Depth and position of clusters illustrated in figures 33, 34, and 35 are clarified in two three-dimensional plots (Figs. 36 and 37).

Discriminant function analysis, metalarvae

Of the original 27 characters used in the discriminant model, 17 were found to have substantial discriminating weight (Table 2). These 17 characters were used to establish the three discriminant functions. Use of these functions resulted in 110 out of 112 metalarvae (98.2%) being correctly assigned to their respective species (Table 21). One of the two incorrectly identified specimens had two of the 17 characters missing due to deformities.

Function one constituted 77.9% of the total variance and separated brook and brown trout, and rainbow and cutthroat trout into two distinct groups (Figs. 38 and 39). The most discriminating characters

Figure 35. Plot of the second and third discriminant functions for 38 specimens of mesolarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.

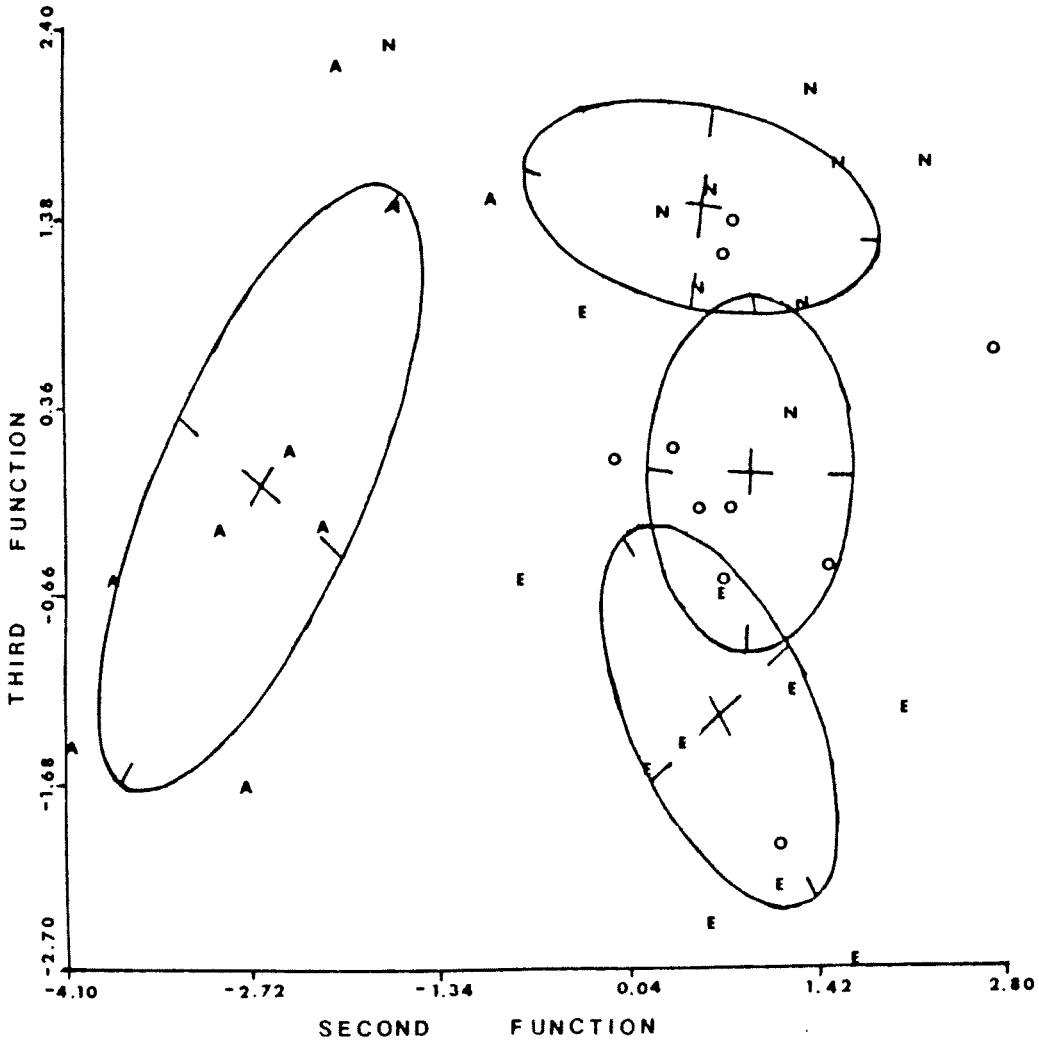

THIRD FUNCTION
2.40
1.38
0.36
-0.66
-1.68
-2.70
-4.10
-2.72
-1.34
0.04
1.42
2.80
SECOND FUNCTION

Figure 36. Oblique three-dimensional plot of the three functions for 38 specimens of mesolarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout.

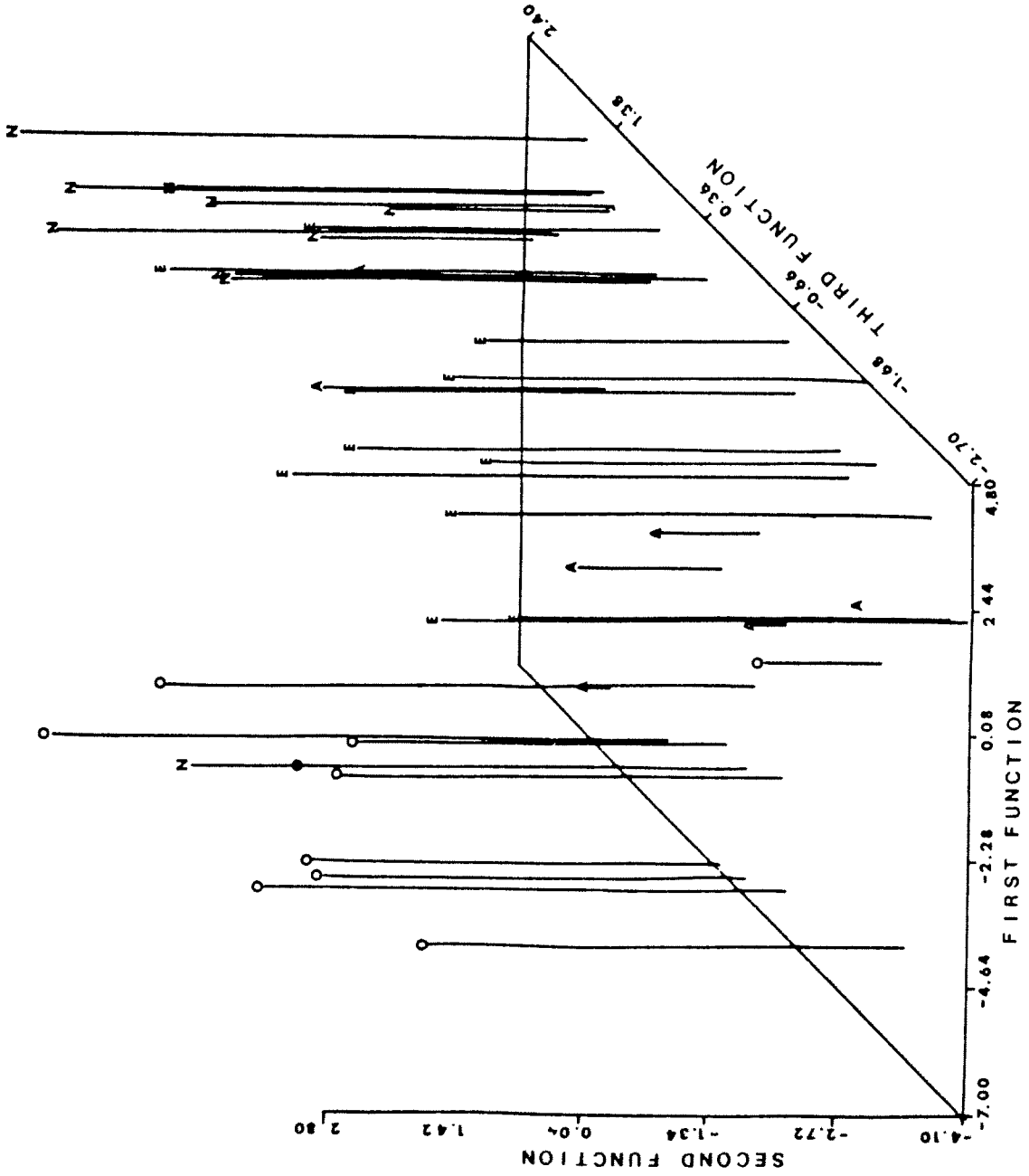

SECOND FUNCTION
-4.10
-2.72
-1.34
0.04
1.42
2.80
THIRD FUNCTION
2.40
1.38
0.36
-0.66
-1.68
-2.70
FIRST FUNCTION
-7.00
-4.64
-2.28
0.08
2.44
4.80

Figure 37. Oblique three-dimensional plot of the first three discriminant functions for 38 specimens of mesolarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout.

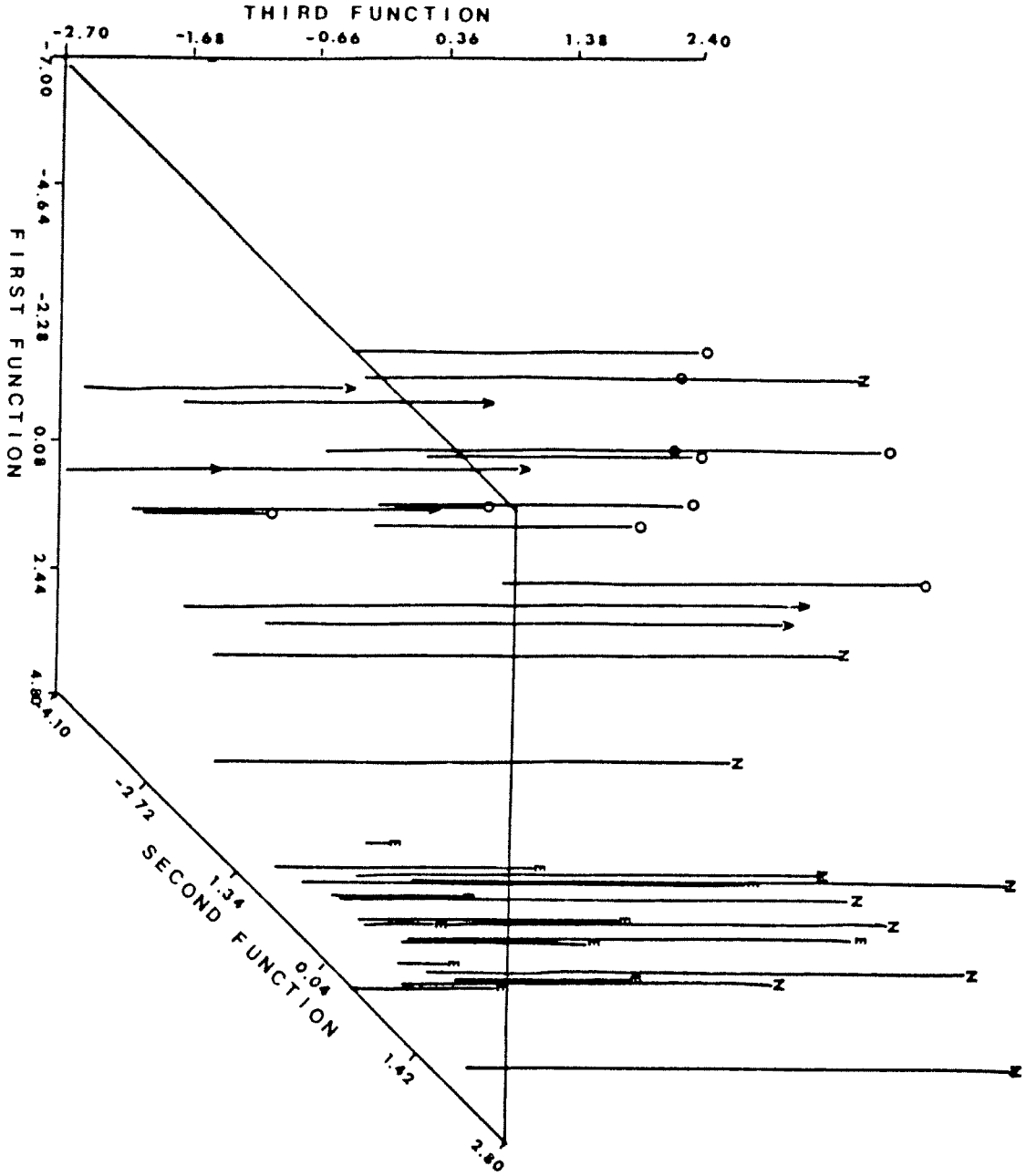

THIRD FUNCTION
-2.70
-1.68
-0.66
0.36
1.38
2.40
FIRST FUNCTION
-7.00
-4.64
-2.28
0.08
2.44
4.80
SECOND FUNCTION
-2.72
-1.34
0.04
1.42
2.80
4.10

Table 21. Percentage of brook, brown, rainbow, and cutthroat trout metalarvae correctly classified using discriminant function analysis.

Actual Group	Number of Cases	Predicted Group Membership			
		1	2	3	4
Group 1 Rainbow	35	34 97.1%	1 2.9%	0 0%	0 0%
Group 2 Cutthroat	36	0 0%	36 100.0%	0 0%	0 0%
Group 3 Brown	22	0 0%	0 0%	21 95.5%	1 4.5%
Group 4 Brook	19	0 0%	0 0%	0 0%	19 100%

Percent of grouped cases correctly classified = 98.2

Figure 38. Plot of the first and second discriminant functions for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, 0 = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.

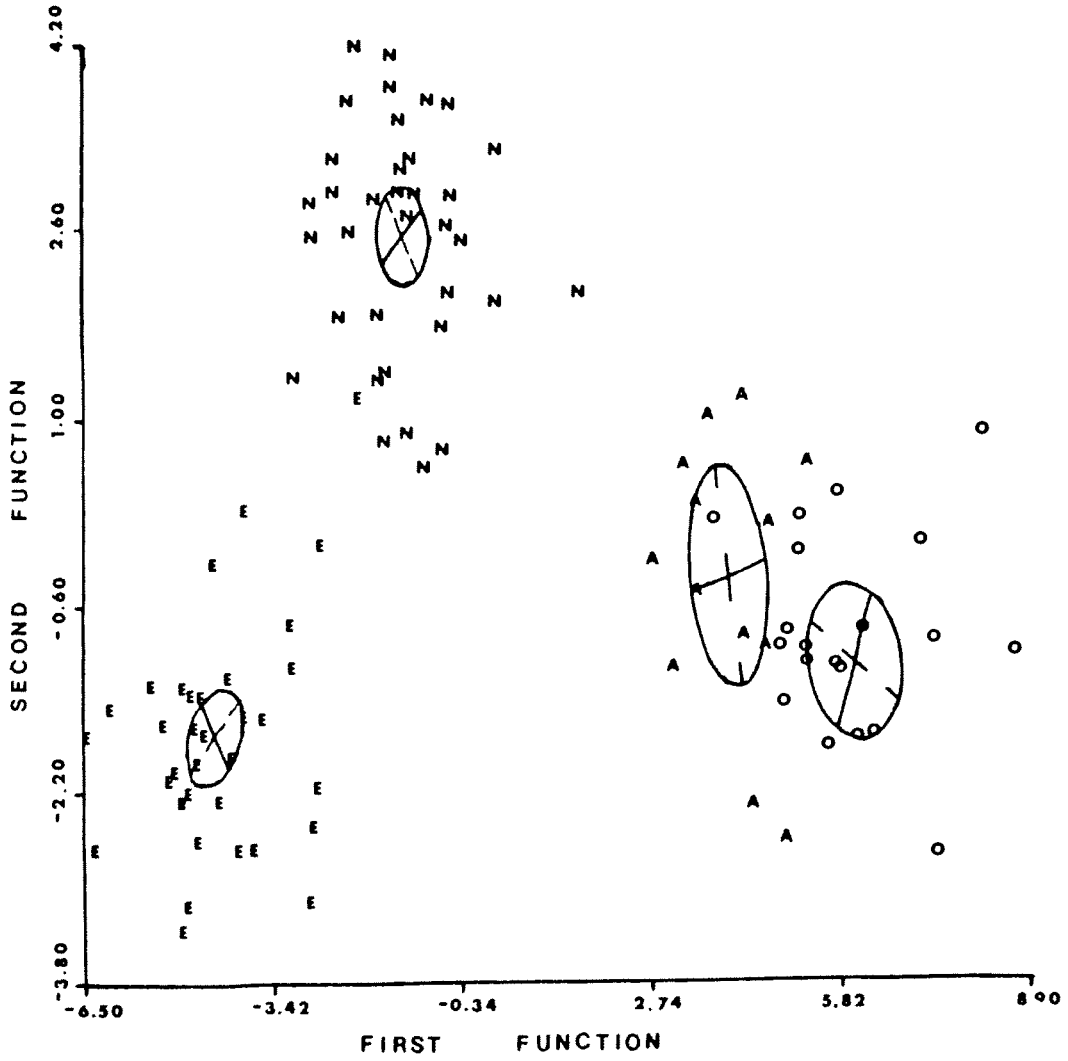
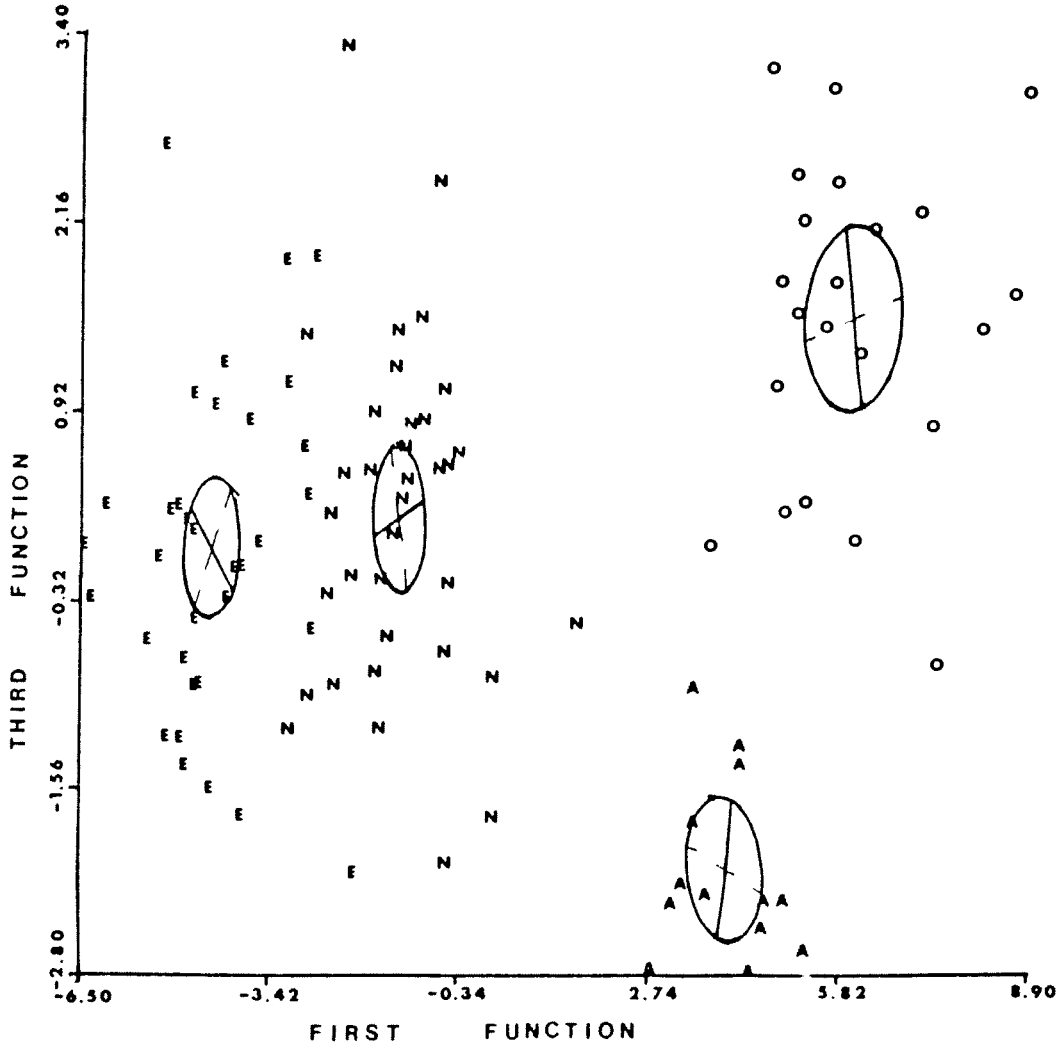

4.20
2.60
1.00
-0.60
-2.20
-3.80
SECOND FUNCTION
-6.50
-3.42
-0.34
2.74
5.82
8.00
FIRST FUNCTION

Figure 39. Plot of the first and third discriminant functions for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.


3.40
2.16
0.92
-0.32
-1.56
-2.80
THIRD FUNCTION
-6.50
-3.42
-0.34
2.74
5.82
8.90
FIRST FUNCTION

were pelvic and adipose fin length, length from snout to origin of adipose fin, and depth at origin of dorsal fin and immediately behind posterior margin of vent (Table 22). Depth at origin of dorsal fin may have been in error due to variable yolk sac depth and stomach distention. Adipose fin length may also be questioned due to probable inclusion of a receding finfold in the measurement.

Function two comprised 16.4% of the total variance and clustered rainbow and cutthroat trout into distinct groups (Figs. 38 and 40). Pelvic fin length had three times the discriminating weight of the next highest character (Table 22). Other characters with significant discriminating weight were number of dorsal fin rays, length from snout to origin of adipose fin, and number of secondary anal rays.

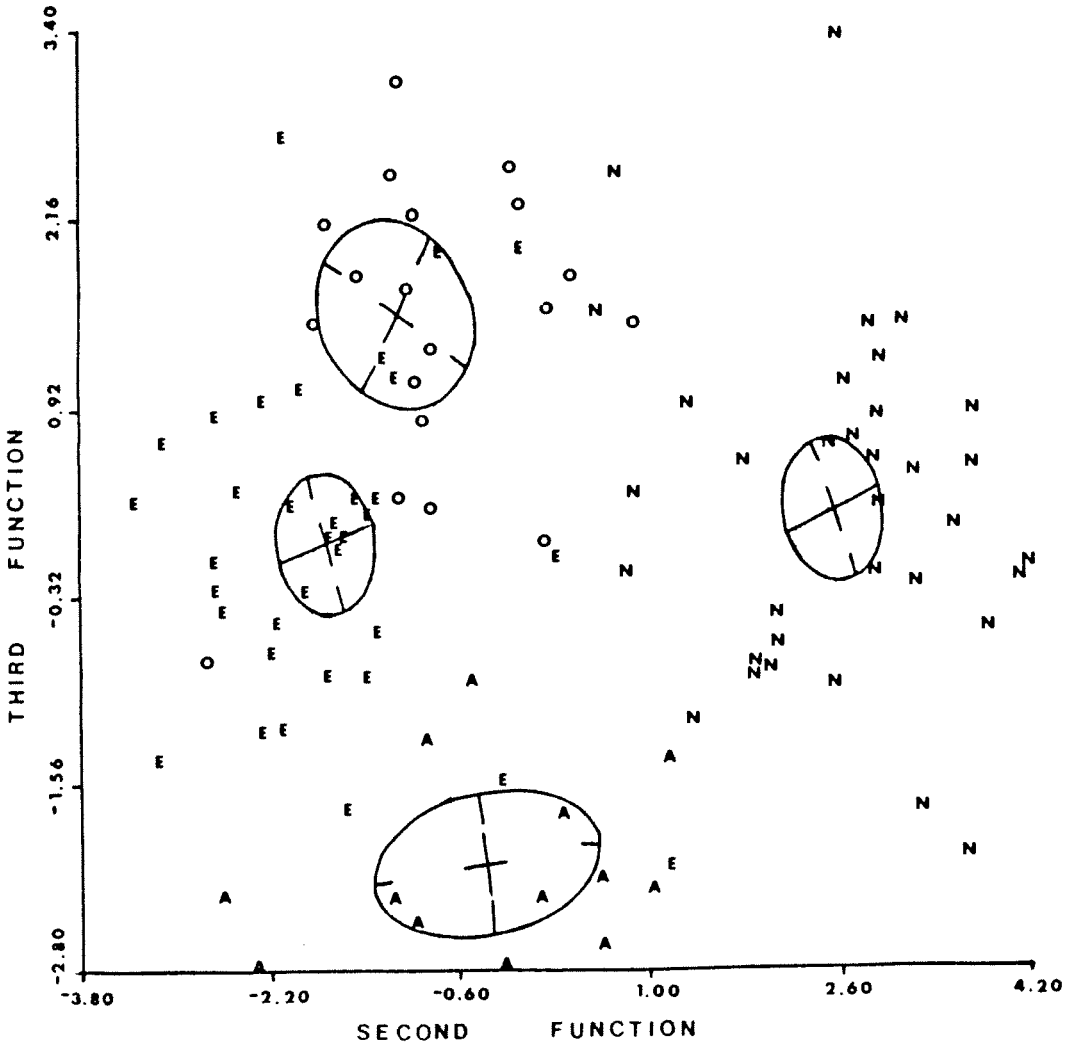
Function three comprised 5.8% of the total variance and separated brook from brown trout by clustering them into groups (Figs. 39 and 40). Characters with considerable discriminating weight included length from anterior margin of snout to origin of adipose fin, length of dorsal and adipose fins, and depth immediately behind posterior margin of vent (Table 22).

Characters with relatively low weight in each of the three functions were depth at anterior margin of most posterior myomere, width at posterior margin of eye, and number of pelvic fin rays (Table 22). These characters could be eliminated without significantly affecting the classification results. Characters such as length of dorsal and anal fins, depth at origin of pectoral fin, number of anal fin rays and secondary rays on dorsal caudal fin contribute some discriminating weight and should be considered when identifying

Table 22. Standardized canonical discriminant function coefficients for brook, brown, rainbow, and cutthroat trout metalarvae. Abbreviated meristic and morphometric characters are; OP_2 - origin of pelvic fin, OD - origin of dorsal fin, O. Adipose - origin of adipose fin, P_2 - pelvic fin, D - dorsal fin, A - anal fin, AD - adipose fin, OP_1 - origin pectoral fin, BPV - behind posterior margin of vent, AMPM - anterior margin of most posterior myomere, and BPE - behind posterior margin of eye.

Meristic and Morphometric Character	Function 1	Function 2	Function 3
Anterior snout to;			
OP_2	-0.01749	-0.12979	0.63149
OD	-0.68498	0.23234	-0.47988
O. Adipose	1.45511	-0.63189	2.13688
Length of;			
P_2	1.60673	1.81127	0.88898
D	0.03885	-0.38582	-1.33469
A	0.32125	-0.57799	-0.11805
AD	1.54090	0.00188	1.18461
Depth at;			
OP_1	-0.65943	-0.47732	0.13647
OD	1.08766	0.07663	-0.27723
BPV	-1.07412	0.17615	-1.10160
AMPM	0.14950	-0.46541	0.38112
Width at;			
BPE	-0.03012	-0.42279	0.28036
Fin ray number;			
D	-0.17066	-0.62493	0.05547
A	-0.69947	0.47740	0.33189
P_2	-0.48545	0.43780	0.45171
Upper Caudal 2nd rays	-0.71160	-0.28769	0.10536
A 2nd rays	-0.48908	0.62865	-0.23976

Figure 40. Plot of the second and third discriminant functions for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.


3.40
2.16
0.92
-0.32
-1.56
-2.80
THIRD FUNCTION
-3.80
-2.20
-0.60
1.00
2.60
4.20
SECOND FUNCTION

metalarvae. Two oblique three-dimensional plots, viewed from different angles, clarify the position and depth of clusters in Figures 38, 39, and 40 (Figs. 41 and 42).

Principal component analysis, mesolarvae

Little information was obtained from principal component analysis of mesolarvae other than need for a larger sample size. A high degree of overlap of confidence ellipses indicated inability of this statistical model to segregate mesolarvae of the trout species studied (Figs. 43, 44, and 45). Components two and three (Table 23) separated brown trout from the other trouts (Fig. 45) on the basis of measurements from anterior margin of snout to posterior margin of vent and origin of preanal finfold, depth at anterior margin of most posterior myomere, and length and depth of yolk.

Principal component analysis, metalarvae

Sixteen characters (Table 2) had significant discriminating weight and were used in the final principal component model (Table 24). Metalarval trout were more easily identified using principal component analysis than were the less-developed mesolarvae. This was due primarily to small sample size of mesolarvae. A certain degree of overlap prevented absolute identification of each metalarval specimen.

Component one constituted 68.0% of the total variance and clustered brook and brown trout into groups which slightly overlapped (Figs. 46 and 47). All characters had approximately the same weight except number of dorsal fin rays, length from anterior margin of snout to origin of dorsal fin and depth at anal fin, which had little discriminating weight (Table 24).

Figure 41. Oblique three-dimensional plot of the first three discriminant functions for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout.

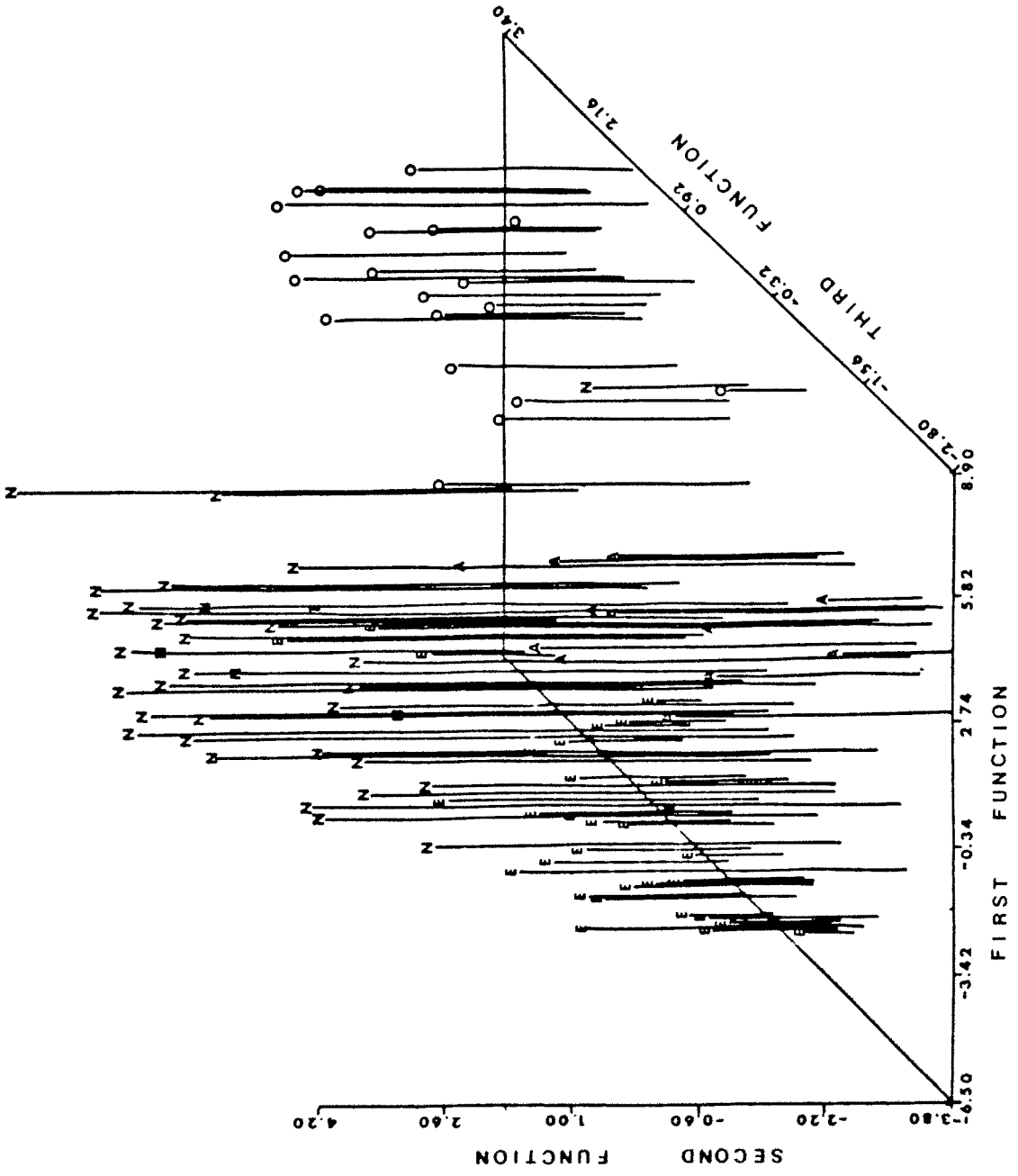

FIRST FUNCTION
8.90
5.82
2.74
-0.34
-3.42
-6.50
SECOND FUNCTION
-3.80
-2.20
-0.60
1.00
2.60
4.20
THIRD FUNCTION
-2.80
-1.56
-0.32
0.92
2.16
3.40

Figure 42. Oblique three-dimensional plot of the first three discriminant functions for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout.

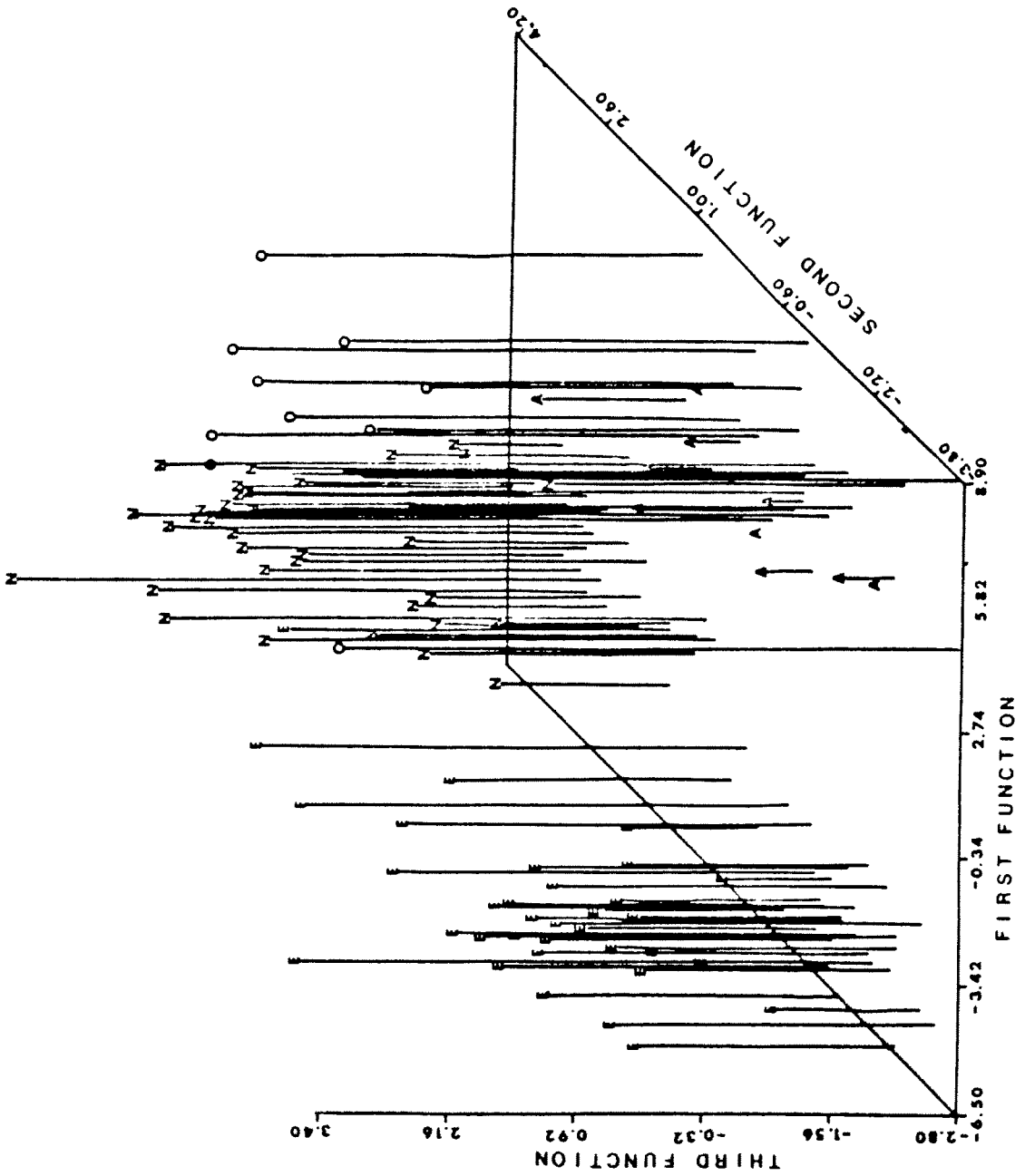

THIRD FUNCTION
-2.80
-1.36
-0.32
0.92
2.16
3.40
FIRST FUNCTION
-6.50
-3.42
-0.34
2.74
5.82
8.90
SECOND FUNCTION
-3.80
-2.20
-0.60
1.00
2.60
4.20

Figure 43. Plot of the first two principal components analyzed of 38 specimens of mesolarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.

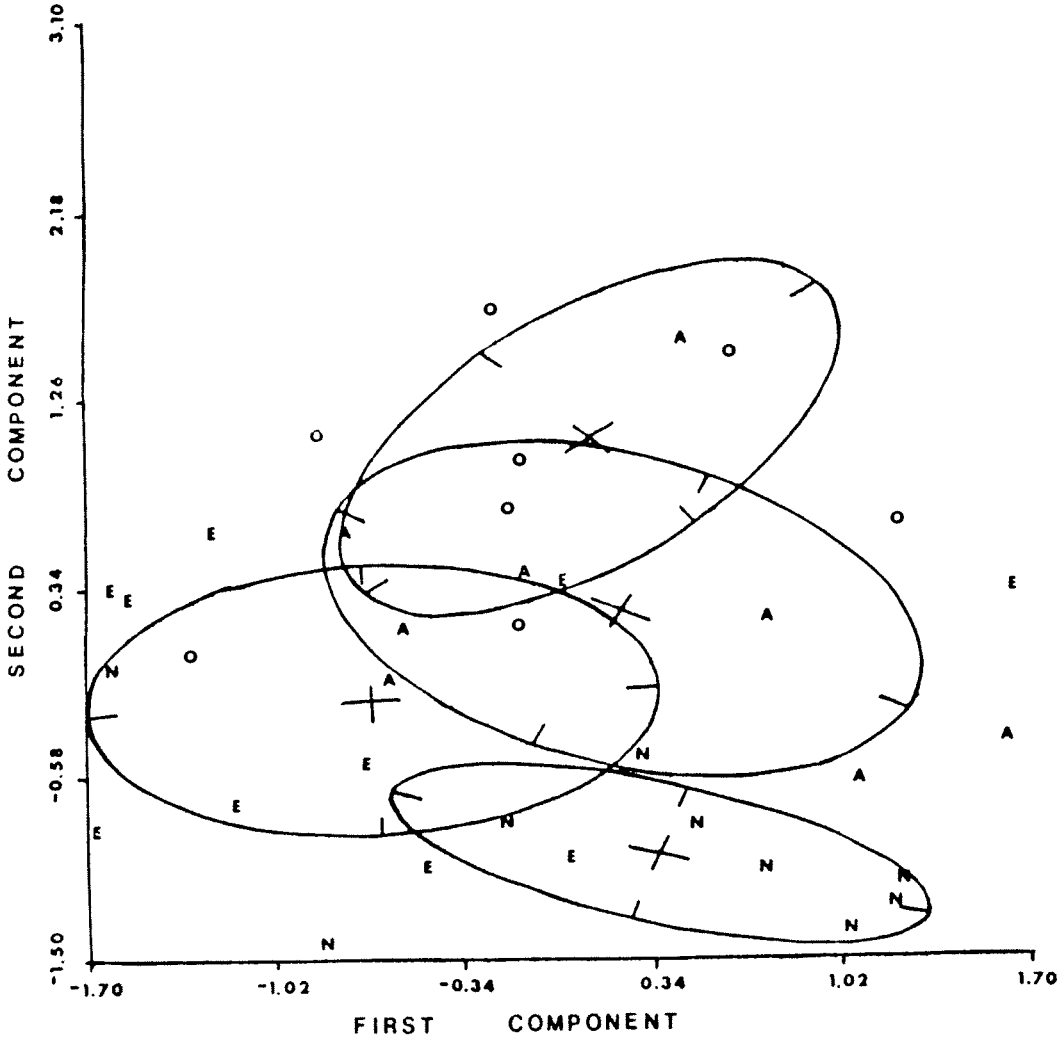

SECOND COMPONENT
3.10
2.18
1.26
0.34
-0.58
-1.50
-1.70
-1.02
-0.34
0.34
1.02
1.70
FIRST COMPONENT

Figure 44. Plot of the first and third principal components analyzed for 38 specimens of mesolarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.

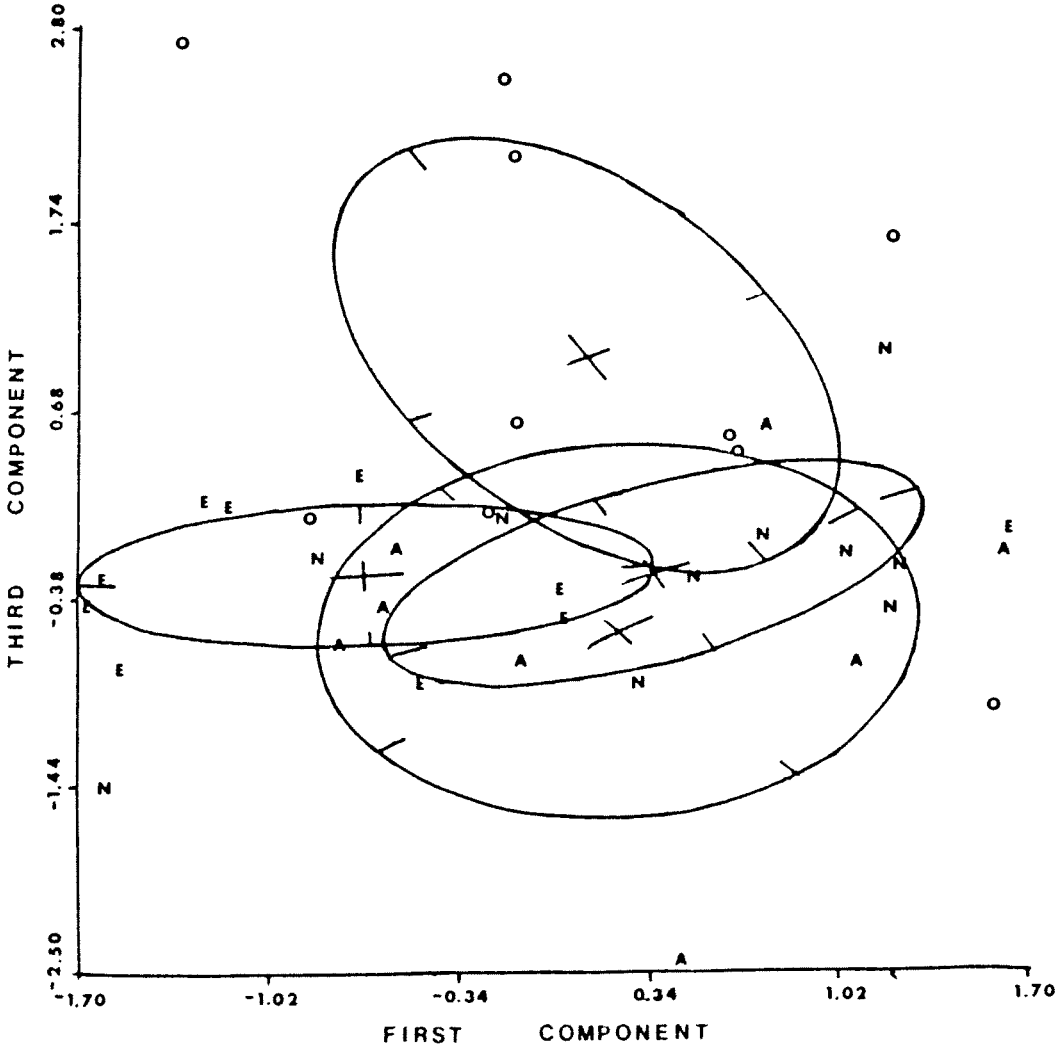

THIRD COMPONENT
2.80
1.74
0.68
-0.38
-1.44
-2.50
-1.70
-1.02
-0.34
0.34
1.02
1.70
FIRST COMPONENT

Figure 45. Plot of the second and third principal components analyzed for 38 specimens of mesolarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.

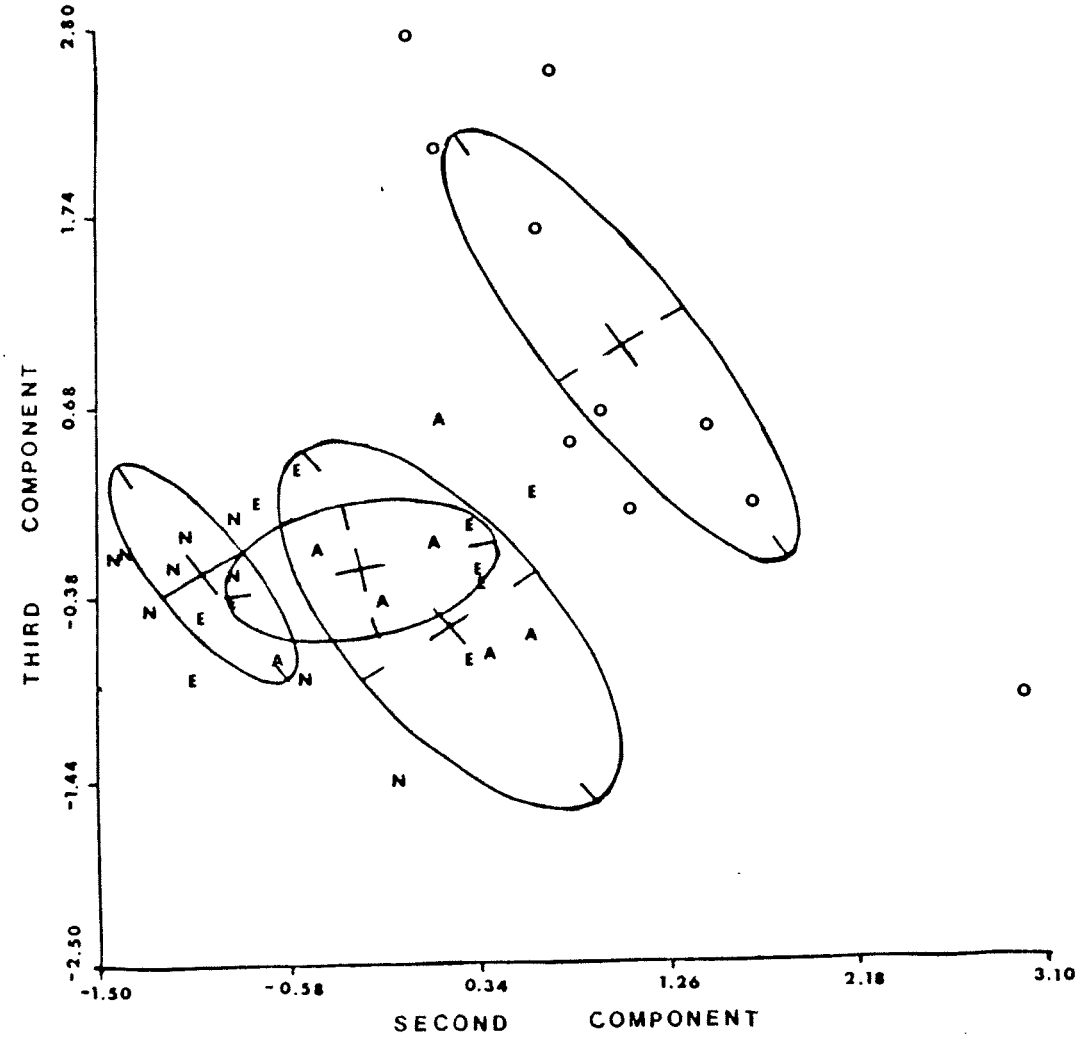

THIRD COMPONENT
2.80
1.74
0.68
-0.38
-1.44
-2.50
-1.50
-0.58
0.34
1.26
2.18
3.10
SECOND COMPONENT

Table 23. Principal component matrix and score coefficients for mesolarval brook, brown, rainbow, and cutthroat trout. Abbreviations of meristic and morphometric characters are; PV - posterior vent, OPAF - origin of preanal finfold, OP_1 - origin of pectoral fin, AMPM - anterior margin of most posterior myomere, Y - yolk, BPE - behind posterior eye, and BPV - behind posterior vent.

Meristic and Morphometric Character	Component 1		Component 2		Component 3	
	Matrix	Score	Matrix	Score	Matrix	Score
Anterior margin; of snout to;						
PV	0.44055	0.13365	0.65655	0.27464	-0.33511	-0.36764
OPAF	0.34673	0.10518	0.70469	0.29478	-0.33782	-0.37062
Depth at;						
OP_1	-0.80281	-0.24354	0.42595	0.17818	-0.02930	-0.03214
AMPM	0.58568	0.17767	0.23974	0.10029	0.62837	0.68937
Y	-0.64623	-0.19604	0.67425	0.28205	0.13115	0.14388
Width at;						
BPE	0.58685	0.17803	0.29360	0.12282	-0.29063	-0.31885
OP_1	-0.79357	-0.24074	0.00735	0.00307	-0.19859	-0.21787
BPV	0.69821	0.21181	0.28706	0.12008	0.13397	0.14698
Length of;						
Y	-0.33960	-0.10302	0.77507	0.32422	0.36102	0.39606

Table 24. Principal component matrix and score coefficients for metalarval brook, brown, rainbow, and cutthroat trout. Abbreviations of meristic and morphometric characters are; OP_2 - origin of pelvic fin, OD - origin of dorsal fin, OAD - origin of adipose fin, OP_1 - origin of pectoral fin, BPV - behind posterior vent, AMPM - anterior margin of most posterior myomere, A - anal fin, BPE - behind posterior eye, P_2 - pelvic fin, AD - adipose fin, and D - dorsal fin.

Meristic and Morphometric Character	Component 1		Component 2		Component 3	
	Matrix	Score	Matrix	Score	Matrix	Score
Anterior margin; of snout to;						
OP_2	0.62679	0.07962	-0.05324	-0.02275	-0.28817	-0.21098
OD	0.39169	0.04975	0.75436	0.32229	-0.19359	-0.14174
OAD	0.93801	0.11915	-0.02300	-0.00982	-0.10405	-0.07618
Depth at;						
OP_1	0.80779	0.10261	0.32221	0.13766	0.08945	0.06549
OD	0.76581	0.09727	-0.10810	-0.04619	0.33216	0.24319
BPV	0.85132	0.10813	0.19659	0.08399	0.16571	0.12132
AMPM	0.70011	0.08893	-0.20685	-0.08837	0.44730	0.32749
A	-0.02286	-0.00290	0.93733	0.40047	0.04315	0.03159
Width at;						
BPE	0.54167	0.06880	-0.22738	-0.09715	0.49344	0.36128
Length of;						
P_2	0.77519	0.09846	-0.51467	-0.21989	-0.17335	-0.12692
A	0.57684	0.07327	-0.22328	-0.09540	0.30163	0.22084
AD	-0.86870	-0.11034	0.03369	0.01439	0.26759	0.19592
Fin Ray Number;						
D	0.35264	0.04479	0.51316	0.21925	0.41039	0.30047
P_2	0.79362	0.10080	-0.00366	-0.00156	-0.39849	-0.29175
Upper Caudal 2nd	0.89834	0.11411	0.20117	0.08595	-0.11939	-0.08741
Anal 2nd	0.67032	0.08514	-0.14578	-0.06228	-0.33042	-0.24192

Figure 46. Plot of the first two principal components analyzed for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.

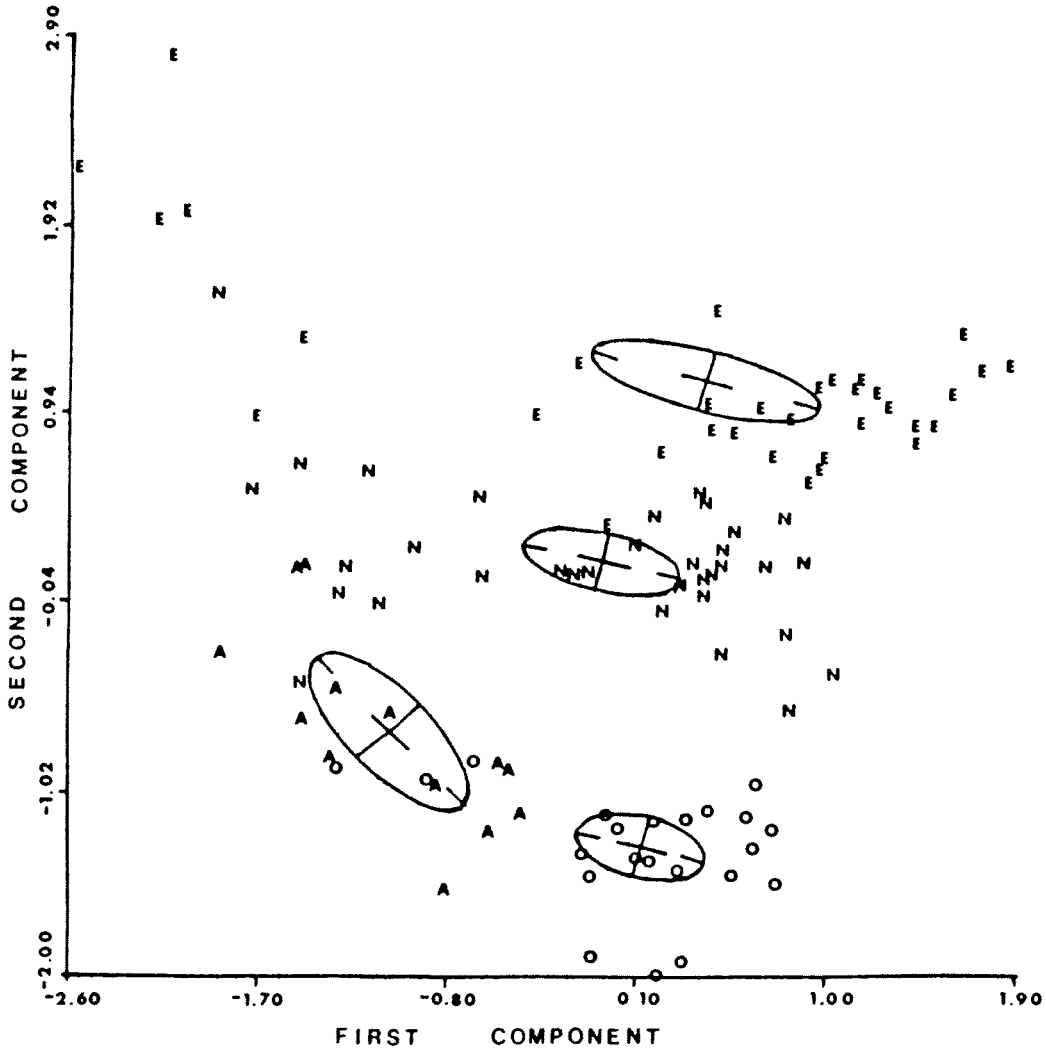
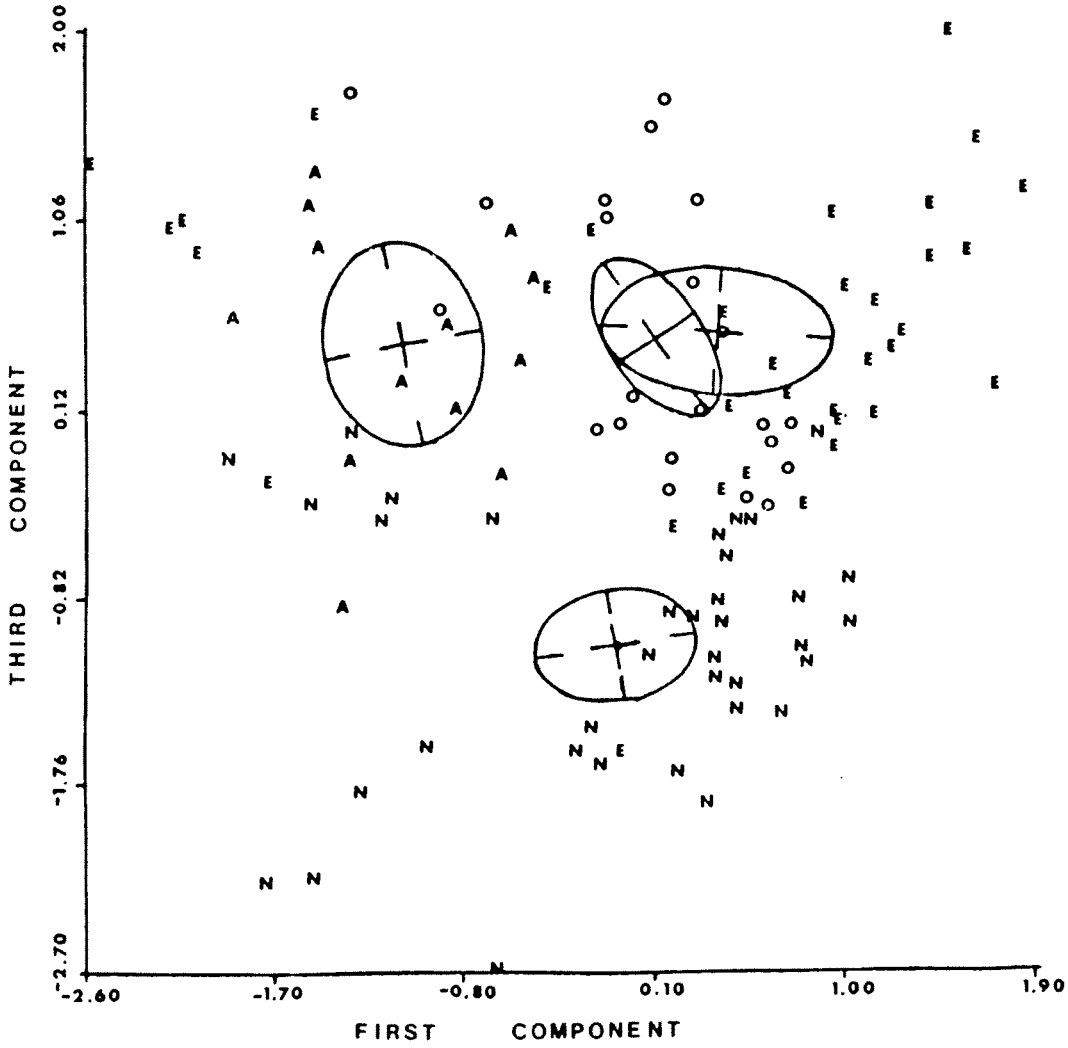

SECOND COMPONENT
2.90
1.92
0.94
-0.04
-1.02
-2.00
-2.60
-1.70
-0.80
0 10
1.00
1.90
FIRST COMPONENT

Figure 47. Plot of the first and third principal components analyzed for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.


THIRD COMPONENT
2.00
1.06
0.12
-0.82
-1.76
-2.70
-2.60
-1.70
-0.80
0.10
1.00
1.90
FIRST COMPONENT

Component two constituted 20.3% of the total variance and separated, with minor overlap, each of the four species (Figs. 46 and 48). As opposed to component one, characters with significant weight in component two included number of dorsal fin rays, length from anterior margin of snout to origin of dorsal fin, depth at anal fin, and length of pelvic fin (Table 24).

Component three comprised 11.8% of the total variance and clustered rainbow and cutthroat trout into groups which similarly overlapped (Figs. 47 and 48). Characters with the most weight were depth at anterior margin of most posterior myomere, width immediately behind posterior margin of eye, and number of dorsal fin rays (Table 24).

Discriminating characters in principal component analysis included anterior margin of snout to origin of dorsal fin, depth at origin of anal fin, depth at anterior margin of most posterior myomere, and width immediately behind posterior margin of eye (Table 24). This differed from the results of discriminat analysis, which applied little weight to the above characters. Clarification of spacial distribution of the clusters illustrated in figures 46, 47, and 48 is shown in two three-dimensional plots (Figs. 49 and 50).

Figure 48. Plot of the second and third principal components analyzed for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout. Ellipses represent the 95% confidence region of the bivariate mean for each species.

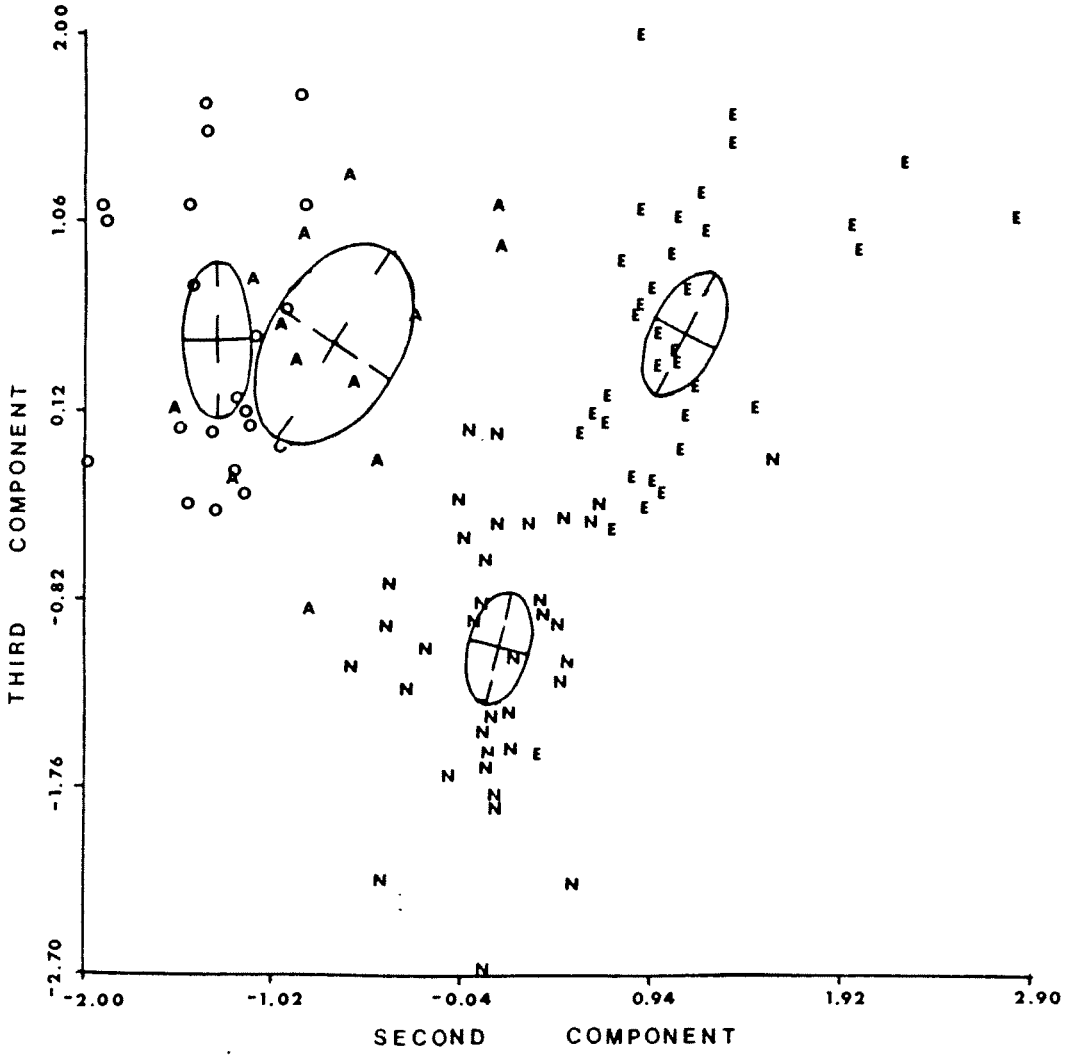

2.00
1.06
0.12
-0.82
-1.76
-2.70
THIRD COMPONENT
-2.00
-1.02
-0.04
0.94
1.92
2.90
SECOND COMPONENT

Figure 49. Oblique three-dimensional plot of the first three components for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout.

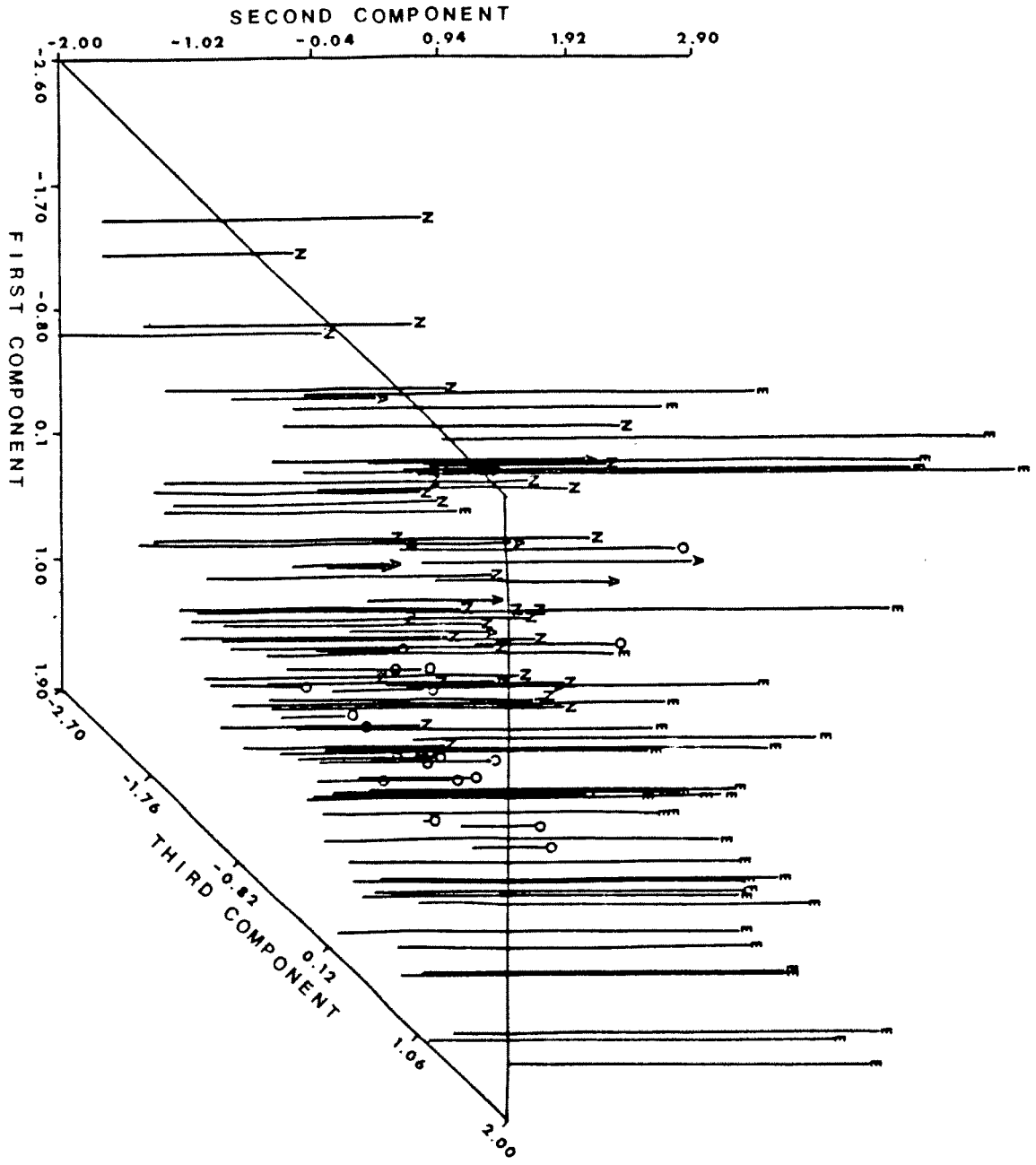
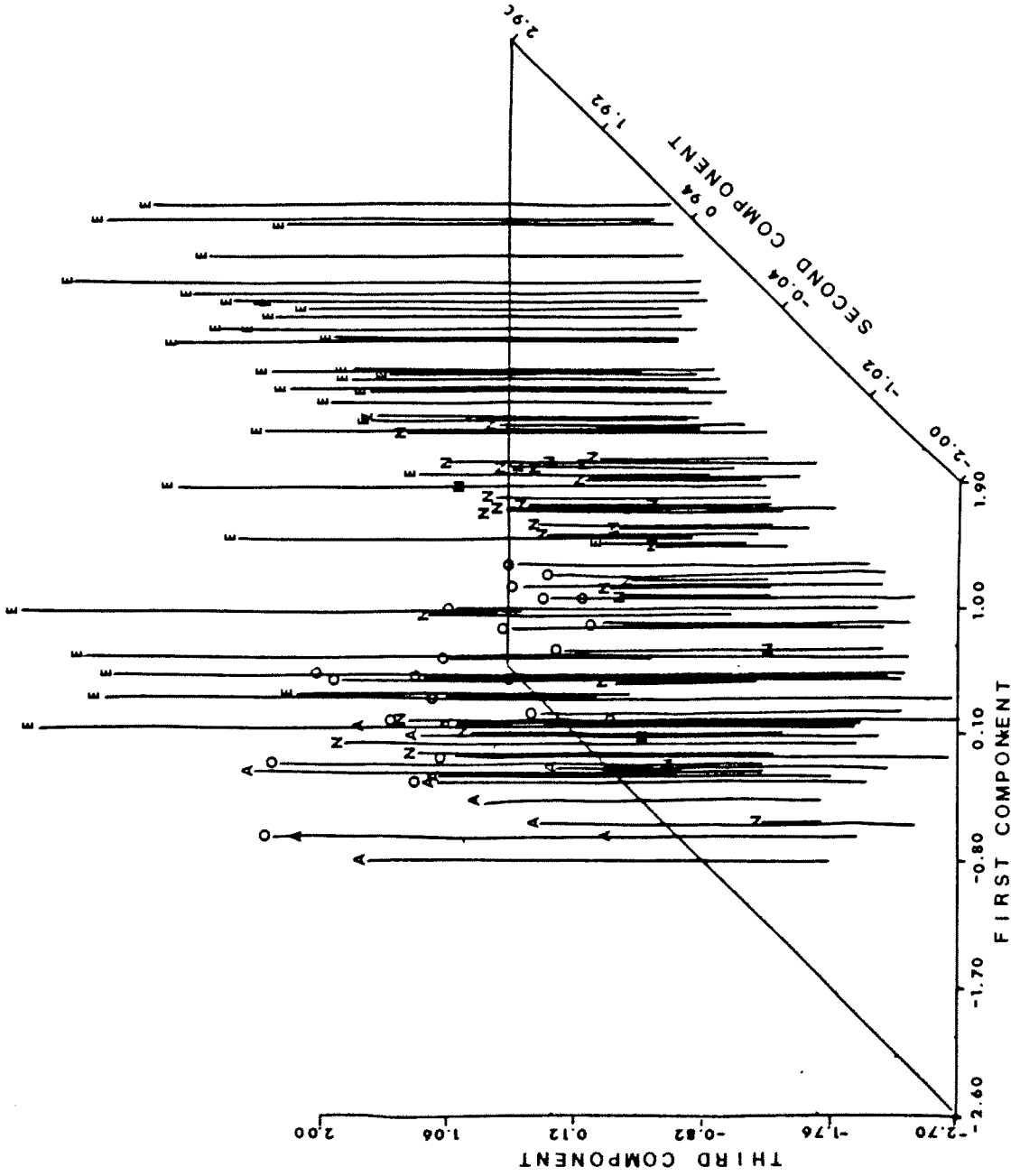

SECOND COMPONENT
-2.00
-1.02
-0.04
0.94
1.92
2.90
FIRST COMPONENT
-2.60
-1.70
-0.80
0.1
1.00
1.90
THIRD COMPONENT
-2.70
-1.76
-0.82
0.12
1.06
2.00

Figure 50. Oblique three-dimensional plot of the first three components for 112 specimens of metalarval trout; E = rainbow trout, N = cutthroat trout, O = brown trout, A = brook trout.


THIRD COMPONENT
-2.70
-1.76
-0.82
0.12
1.06
2.00
FIRST COMPONENT
-2.60
-1.70
-0.80
0.10
1.00
1.90
SECOND COMPONENT
-2.00
-1.02
-0.04
0.94
1.92
2.9C

DISCUSSION

All pigmentation patterns discussed as diagnostic for identifying trout species were often inappropriate for mesolarval identification and occasionally unsuitable for less-developed metalarvae. Although pigmentation patterns were observed on most of the specimens in the size ranges indicated (Table 15), they cannot be considered characteristic in all cases due to individual variation. It is, therefore, advisable for future investigators to consider melanophore distribution and concentration in all of the body regions discussed.

Oil globule analysis, unlike pigmentation, was most useful for mesolarval identification. However, with yolk assimilation this method became inadequate at approximately 19 mm TL. Because brown, rainbow, and cutthroat trout had very similar oil globule size and abundance, it was difficult to segregate these species from one another using this method. Newly hatched brook trout, however, were easily recognized by their numerous minute oil globules (Table 16).

The elliptical yolk observed in brown trout (versus the bulbous yolk found in other larval trouts) was most useful as a character in segregating brown trout mesolarvae from other trout mesolarvae when measured from tip of snout to posterior yolk (Table 18). The elliptical yolk configureation observed in the brown trout studied may have been an artifact of hatchery rearing. Until hatchery and wild brown trout mesolarvae are examined further, this character should be used with prudence.

Other characters useful in identifying mesolarval trout included length from snout to origin of preanal finfold, insertion of yolk, origin of dorsal finfold, origin of dorsal fin, and insertion of dorsal fin.

All length measurements useful in segregating mesolarvae, except insertion of yolk, were also useful in identifying metalarvae. The most diagnostic length measurement for identifying metalarval trout was origin of preanal finfold. This finfold was bilobed in rainbow and cutthroat trouts (Figs. 20 and 24) and unilobed in brown and brook trout (Figs. 11 and 16). In brook and brown trout metalarvae, this finfold was absorbed at a much smaller size than in rainbow or cutthroat trout metalarvae (Figs. 29, 30, 31 and 32). Length and position of the adipose fin also facilitated separation of brook trout metalarvae from other trout metalarvae. Brown trout metalarvae were segregated from other trout by their characteristically longer pectoral fin. Rainbow and cutthroat trout larvae could not readily be distinguished from each other using length measurements. Origin of adipose fin and insertion of dorsal fin could almost separate rainbow and cutthroat metalarvae (Table 17), but overlapping ranges (of percent standard length) limited their usefulness (Table 18).

Discriminant function analysis allowed segregation of mesolarvae primarily by use of heavily weighted width and depth measurements (Table 20). Of the three length measurements found to have discriminating weight for mesolarval identification, only length of yolk had substantial weight; lengths from snout to origin of preanal finfold and to posterior vent had very little weight. Unlike

mesolarvae, metalarval trout were primarily separated by only two heavily weighted depth measurements (depth at origin of dorsal fin and posterior margin of vent) and no width measurements. Two length measurements with significant weight (adipose fin length and length from snout to origin of adipose fin) were useful in both discriminant analysis and analysis of percent standard lengths when identifying metalarval trouts (Tables 18 and 22). Meristic counts with some weight, chosen by the metalarval discriminant analysis model, included number of dorsal principal rays and anal secondary rays. Length of pelvic fin had the most weight in the first and second functions.

Mesolarval trout could not be identified using principal component analysis because of a high degree of overlap of confidence ellipses (Figs. 43, 44 and 45). Metalarval trout, though retaining a certain degree of overlap, could be segregated (Figs. 46, 47, and 48). All characters used in principal component analysis for identification of metalarvae had sufficient weight for inclusion in the final statistical analysis except length of dorsal fin and width at origin of pectoral fin, both of which lacked weight and were eliminated from the analysis (Table 1). However, length of dorsal fin had significant weight for identifying metalarvae in discriminant analysis. Two characters useful in both principal component analysis and discriminant analysis were number of dorsal fin rays and length of pelvic fin. Length from snout to origin of dorsal fin was helpful in identifying trout metalarvae by principal component analysis and analysis of percent standard lengths.

Key

Characters discussed in this key may have overlapping ranges of percent standard length and similar pigmentation patterns. However,

this key should prove satisfactory for segregating brook trout mesolarvae from brown, rainbow and cutthroat trout mesolarvae and determining the identity of brook and brown trout metalarvae. Rainbow and cutthrtoat trout metalarvae, though distinguishable from the other two species of trout, are indistinguishable from each other unless discriminant function analysis is used. Identifications based on this key should be verified by consulting illustrations and less-diagnostic characters provided in the text. An alternative identification method for the trout larvae discussed herein was possible by using discriminant function analysis (previously discussed); however, in the interest of reducing complexity, this analysis was not included in the key.

Mesolarvae

1a. Many oil globules $\geq$ 0.5 mm in diameter. Caudal pigmentation, if present, indistinct and scattered, never bold and concentrated at the horizontal midline. Length from snout to origin of dorsal finfold $\leq$ 30% SL 2

1b. Numerous oil globules with diameter of approximately 0.4 mm, none > 0.5 mm. Bold caudal fin pigmentation on and below the horizontal midline. Length from snout to origin of dorsal finfold >30% SL . . . . . Brook trout

2a. Length from snout to posterior yolk most often $\geq$ 60% SL. . . . . Brown trout

2b. Length from snout to posterior yolk generally < 60% SL. . . . . Rainbow or Cutthroat trout*

Note: Other characters useful in identifying these species but with overlapping ranges of % SL include:

Length from snout to	Brook	Brown	Rainbow	Cutthroat
Origin of preanal finfold	55-64%	53-60%	51-58%	51-57%
Insertion of yolk	53-58%	49-57%	45-54%	43-50%

Metalarvae

1a. Pelvic fin rays appear on specimens > 14 mm SL. Scattered pigmentation present on throat of specimens ≥ 15 mm TL. Dorsal and ventral parr marks, if present, seldom exceed 3 in number. 2

1b. Pelvic fin rays on specimens < 14 mm SL. No pigmentation on throat of specimen > 15 mm TL. Numbers of dorsal and ventral parr marks average 6 and 2, respectively . . . . . Brook trout

2a. Length of specimen at final absorption of preanal finfold is approximatley 21 mm SL. Chin pigmentation bold on specimens ≥ 22 mm TL. Pigmentation on anterior margin of dorsal fin light and inconspicuous on specimens ≥ 22 mm TL . . . . . Brown trout

2b. Length of specimen at final absorption of anal finfold ≥ 35 mm SL. Chin pigmentation scattered with no areas of concentration on all specimens with pigment in this region. Pigmentation on anterior margin of dorsal fin bold on specimens ≥ 22 mm TL. . . . . Rainbow or cutthroat trout*

* Discriminant function analysis is the best method for segregating rainbow trout larvae from cutthroat trout larvae.

LITERATURE CITED

Bacon, E. H. 1954. Field characters of prolarvae and alevins of brook, brown and rainbow trout in Michigan. Copeia 3:232.

Ballard, W. W. 1973. Normal embryonic stages for salmonid fishes based on Salmo gairdneri Richardson and Salvelinus fontinalis (Mitchill). Journal of Experimental Zoology 184:7-26.

Balon, E. K. 1980. Early ontogeny of the brook charr, Salvelinus (Baione) fontinalis. Pages 631-666 in E. K. Balon, editor. Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk, The Hague, Netherlands.

Baxter, G. T. and J. R. Simon. 1970. Wyoming fishes. Wyoming Game and Fish Department Bulletin 4:1-167.

Behnke, R. J. 1979. Monograph of the native trouts of the genus Salmo of western North America. Regional Forester. Lakewood, Colorado, USA.

Behnke, R. J. and D. E. Benson. 1983. Endangered and threatened fishes of the upper Colorado River basin. Colorado State University, Fort Collins, Colorado, USA.

Clay, W. M. 1975. The fishes of Kentucky. Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky, USA.

Cooley, W. W. and P. R. Lohnes. 1971. Multivariate data analysis. John Wiley and Sons, New York, New York, USA.

Crawford, D. R. 1925. Field characters identifying young salmonid fishes in fresh waters of Washington. University of Washington Publications in Fisheries 1:64-76.

Cross, F. B. and J. T. Collins. 1975. Fishes in Kansas. University of Kansas Public Education Series 3. Lawrence, Kansas, USA.

Eddy, S. and J. C. Underhill. 1974. Northern Fishes. Third edition. University of Minnesota Press, Minneapolis, Minnesota, USA.

Farris, D. A. 1963. Shrinkage of sardine (Sardinops caerulea) larvae upon preservation in buffered formalin. Copeia 1:185-186.

Fish, M. P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bulletin of the United States Bureau of Fisheries 47:293-398.

Klecka, W. R. 1980. Discriminant analysis. Sage Publications, Beverly Hills, California, USA.

Knight, A. E. 1963. The embryonic and larval development of the rainbow trout. Transactions of the American Fisheries Society 92:344-355.

Kuhne, E. R. 1939. A guide to the fishes of Tennessee and the mid-south. Department of Conservation, State of Tennessee, Nashville, Tennessee, USA.

LaRivers, I. 1962. Fishes and fisheries of Nevada. Nevada State Fish and Game Commission, Carson City, Nevada, USA.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. North Carolina Biological Survey Publication 1980-12. Raleigh, North Carolina, USA.

Lister, D. B. 1980. Stream enhancement guide. Ministry of Environment, Vancouver, British Columbia, Canada.

MacCrimmon, H. R. 1971. World distribution of rainbow trout (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 28:663-704.

MacCrimmon, H. R. and J. S. Campbell. 1969. World distribution of brook trout, Salvelinus fontinalis. Journal of the Fisheries Research Board of Canada 26:1699-1725.

MacCrimmon, H. R. and T. L. Marshall. 1968. World distribution of brown trout, Salmo trutta. Journal of the Fisheries Research Board of Canada 25:2527-2548.

MacCrimmon, H. R., T. L. Marshall, and B. L. Gots. 1970. World distribution of brown trout, Salmo trutta; further observation. Journal of the Fisheries Research Board of Canada 27:811-818.

Marcinko, M. T. 1978. Morphological and enzymatic identification of wild brook trout and brown trout eyed eggs, prolarvae, and larvae. M.S. Thesis. Sourhtern Illinois University, Carbondale, Illinois, USA.

Minckley, W. L. 1973. Fishes of Arizona. Arizona Game and Fish Department. Simms Printing Company Incorporated, Phoenix, Arizona, USA.

Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley and Los Angeles, California, USA.

Nie, N. H., C.H. Hull, J. G. Jenkins, K. Steinbrenner and D. H. Brent. 1975. Statistical Package for the Social Sciences. McGraw-Hill Book Co., New York, New York, USA.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri, USA.

Scarola, J. F. 1973. Freshwater fishes of New Hampshire. New Hampshire Fish and Game Department, Division of Inalnd and Marine Fisheries, Concord, New Hampshire, USA.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184. Ottawa, Ontario, Canada.

Siefert, R. E. 1969. Characteristics for separation of white and black crappie larvae. Transactions of the American Fisheries Society 98:326-328.

Sigler, W. F. and R. R. Miller. 1963. Fishes of Utah. Utah State Department of Fish and Game, Salt Lake City, Utah, USA.

Simpson, J. and R. Wallace. 1978. Fishes of Idaho. The University Press of Idaho, Moscow, Idaho, USA.

Smith, P. W. 1979. The fishes of Illinois. University of Illinois Press, Chicago, Illinois, USA.

Snyder, D. E. 1976. Terminologies for intervals of larval fish development. Pages 41-58 in J. Boreman, editor. Great Lakes fish egg and larvae identification; proceedings of a workshop. United States Fish and Wildlife Service, FWS/OBS - 76/23. Ann Arbor, Michigan, USA.

Snyder, D. E. 1981. Contributions to a guide to the cypriniform fish larvae of the Upper Colorado River System in Colorado. Biological Sciences Series Number 3. Colorado State Office, United States Bureau of Land Management, Denver, Colorado, USA.

Sokal, R. K. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co., San Francisco, California, USA.

Taylor, W. R. 1967. An enzyme method of clearing and staining small vertebrates. Proceedings of the United States National Museum 122:1-17.

Vladykov, V. D. 1954. Taxonomic characters of the eastern North American chars (Salvelinus and Cristivomer). Journal of the Fisheries Research Board of Canada 11:905-931.

Wales, J. H. 1941. Development of steelhead trout eggs. California Fish and Game 27:250-260.

Weisel, G. F. 1966. Young salmonid fishes of western Montana. Proceedings of the Montana Academy of Sciences 26:1-21.

Werner, R. G. 1980. Freshwater fishes of New York State. Syracuse University Press, Syracuse, New York, USA.

Wydoski, R. S. and R. R. Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle, Washington, USA.