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Some Aspects of the Life History of the Southern Redbelly Dace, Chrosomus Erythrogaster Rafinesque, in Ivy Creek, Warren County, Kentucky

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William H.

1974

SOME ASPECTS OF THE LIFE HISTORY OF THE SOUTHERN REDBELLY DACE, *CHROSOMUS ERYTHROGASTER* RAFINESQUE, IN IVY CREEK, WARREN COUNTY, KENTUCKY

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Master of Science

by

William H. Settles

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SOME ASPECTS OF THE LIFE HISTORY OF THE

SOUTHERN REDBELLY DACE, CHROSOMUS ERYTHROGASTER RAFINESQUE

IN IVY CREEK, WARREN COUNTY, KENTUCKY

Recommended July 18, 1974
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I wish to dedicate this paper to my mother, Mrs. Kathleen Settles, without whose support, both in spirit and materially, I could never have completed this study.

ABSTRACT

Various aspects of the biology of the southern redbelly dace, Chrosomus erythrogaster Rafinesque, were intensively studied on a population in Ivy Creek, Warren County, Kentucky from 1971 to 1972. Reproduction in the southern redbelly dace occurred from May through June. Older, sexually mature individuals spawned early in the reproductive period while those in their first year of life spawned during late June. The number of eggs shed annually ranged from 140 to 681 with an average of 385. A positive correlation existed between the number of eggs shed and standard length.

Differences between the sexes of the species were marked and included intensity and distribution of pigmentation, breeding tubercle development and length and shape of the pectoral fins. Males were most distinctive, having prominent scarlet ventral surfaces and breeding tubercles on the head and fins during the reproductive period. Males had more distinctive coloration as well as longer and broader pectoral fins. While more females than males were collected during this study, no significant deviation from the theoretical 1:1 sex ratio was observed.

The normal life span of the southern redbelly dace was about two years with a few individuals living into the autumn

of their third year (26-30 months). Males disappeared from the populations slightly earlier than females. Age Group 0, or individuals in their first year, constituted the dominant age group.

Growth in length was greatest during the first year of life while growth in weight was greatest during the second year and that portion of the third year survived. No statistically significant deviation was observed between the theoretical cubic response of growth in weight to length and that observed among the specimens in Ivy Creek.

Coefficient of Condition values were greater for males than females when gonad weight was excluded. Converse results were observed when the gonads of both sexes were included in the condition determinations. Seasonally, condition coefficients for both sexes combined were greatest during the spawning season, lower during the warm-water months and lowest during the cold-water months.

Food habits were generally non-specific with combinations of algal forms, (filamentous chlorophytes and diatoms) and organic detritus constituting the major dietary components. Aquatic insects were commonly found in the guts of larger specimens.

Southern redbelly dace existed as a part of a larger assemblage of fish species and because of their food habits and reproductive behavior co-existed successfully. Parasitism of the species was not obvious.

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INTRODUCTION

Until recent years, most life history studies of fishes have been concerned with species whose commercial value to man has given them priority as subjects of biological investigations. However, the increasing significance of studies concerned with the overall dynamics of aquatic ecosystems has led to investigations dealing with species of lesser economic importance but which are no less integral parts of their respective biological communities.

One such species is the southern redbelly dace, Chrosomus erythrogaster Rafinesque. Despite the fact that this minnow was first described from specimens collected from the Kentucky River drainage (Rafinesque, 1820), little information has been reported concerning the biology of the species in Kentucky. In this regard, the present study is an effort to describe some of the major aspects of the life history and ecology of the southern redbelly dace as represented in a Kentucky stream. Specimens for this investigation were collected from February 5, 1971 through January 8, 1972 from a relatively isolated population of dace inhabiting the upper reaches of Ivy Creek, Warren County, Kentucky.

It is hoped that data resulting from this study will be of value in understanding not only the biology of the southern

redbelly dace as a species, but also its role in the complex interactions of its aquatic community.

TAXONOMY AND DISTRIBUTION

Taxonomy

The taxonomy of members of the genus Chrosomus has been subject to much revision since Rafinesque (1820) first described specimens collected from the Kentucky River drainage. Though naming the first-described species Luxilus erythrogaster, the "Kentucky red belly", Rafinesque (1820) also applied the subgenus name Chrosomus to the species and suggested that Chrosomus was probably distinct enough to be elevated to generic status.

In September, 1861, E. D. Cope collected four specimens from Meshoppen Creek in Susquehanna County, Pennsylvania, which he recognized as being distinct from the "Kentucky red belly" of Rafinesque (Fowler, 1929). Naming this new eastern species Chrosomus eos, Cope apparently initiated the usage of Chrosomus as the genus for this complex of fishes (Phillips, 1968a). In later discussions of C. eos, it appears that Cope confused it with the as yet undescribed finescale dace, and gave features more applicable to the latter (Phillips, 1968a).

Cope (1869a,b) later emended his taxonomic treatment of the redbelly dace group. From specimens taken in Livingston County, Michigan, he described the finescale dace, Phoxinus neogaeus, and distinguished it from Chrosomus eos (Cope, 1869a).

In the same year, he described the mountain redbelly dace, Chrosomus oreas, from specimens collected in Montgomery County, Virginia (Cope, 1869b). Thus by 1869, the four presently recognized species in Chrosomus had been established.

In subsequent years, various workers have approached the taxonomy of this group in different ways. Jordon (1876) recognized three species of Chrosomus: C. eos, C. erythrogaster, and C. pyrrhogaster. Of these, only C. eos was synonymous to the original description of the species. It appears that C. pyrrhogaster was actually C. erythrogaster Rafinesque, and the "Chrosomus erythrogaster" of Jordon was more closely equivalent to C. oreas Cope (Phillips, 1968a). Jordon and Evermann (1896) referred to C. eos Cope as C. erythrogaster eos, a subspecies of its southern counterpart. The fact that Chrosomus erythrogaster and C. eos are distinct species has been shown by Phillips (1969b).

Jordon (1924) assigned Phoxinus neogaeus Cope to the genus Pfrille. Because Pfrille is the German equivalent of Phoxinus, it may be assumed that Jordon was attempting to distinguish this North American species from its Old World counterparts.

Hubbs (1955) included Pfrille neogaeus in the genus Chrosomus, thus uniting the four allied North American species into one genus. This treatment persisted until Banarescu (1964), in his volume on the fishes of Romania, expressed the opinion that Chrosomus and Phoxinus are congeneric and, because Phoxinus held page priority over Chrosomus, it should be retained.

Phillips (1968a,b; 1969a,b), who did extensive work on both the northern and southern redbelly dace in Minnesota, retained the usage of Chrosomus since adoption of Phoxinus was not widespread at that time.

In 1970, the American Fisheries Society formally adopted Phoxinus as the generic name for those species previously listed under Chrosomus and Pfrille (Bailey, et al., 1970). M. B. Trautman (1971, personal communication) agrees with this treatment, as does R. M. Bailey (1971, personal communication). In this regard, Bailey stated:

> "After seeing freshly preserved specimens of Phoxinus phoxinus from France I was struck with the basic similarity in many respects . . . of this species with our own . . .. Dr. Ted Cavender of Ohio State University while working in our laboratory made a careful comparison of most of the genera of American minnows and . . . he noted certain strong indicators of relationship between the European species and our own. Thus we feel confident of the wisdom of the generic merger."

However, McPhail and Lindsey (1970), in reference to the Canadian species, C. eos Cope and C. neogaeus (Cope), asserted that the merger of Chrosomus into Phoxinus was not warranted by existing evidence. This view is shared by Phillips (1972, personal communication) who feels that Chrosomus should be retained until substantial data can be amassed which will cast more light upon the taxonomic status of this complex. Because the finescale dace is somewhat different

from the other three Chrosomus species, Phillips does suggest that it be reassigned to Pfrille or possibly Phoxinus.

It is the opinion of the author that the usage of Phoxinus as opposed to Chrosomus, at least for the three closely related species (C. erythrogaster, C. eos, and C. oreas) is argumentative and that further study is needed before absolute assertions regarding the taxonomic position of the North American species involved can be made. In this light, the genus Chrosomus is retained in this study, and the southern redbelly dace shall be referred to as Chrosomus erythrogaster Rafinesque.

The following description of the southern redbelly dace is taken from Jordon (1882):

> "Body moderately elongate, little compressed; jaws normal; no barbels; teeth 4-5 or 5-5 moderately hooked, with oblong grinding surface; alimentary canal about twice as long as body; peritoneum more or less black; scales very small; lateral line short or wanting; dorsal behind ventrals; anal base short; size small."

To this description Trautman (1957) added:

> ". . . between 70-95 scales in lateral series. Length of upper jaw contained 3.2-4.0 times in standard head length. Intestine long with two crosswise coils and a loop . . .."

Fowler (1929) described the pigmentation of C. erythrogaster as follows:

"Brownish olive, often with black spots and a dusky median dorsal line. Sides silvery white between two black lateral bands, of which upper straight from upper angle of opercle to caudal, though sometimes broken up behind, and broader lower band curved down slightly to end in black spot on base of the caudal. Spring [breeding] males have sides between black bands pink, bases of vertical fins and belly bright vermillion [scarlet in Ivy Creek specimens]. Other fins orange [to yellow in Ivy Creek specimens] . . .. Females usually plainly colored, with little red . . .."

Within the genus, C. erythrogaster looks most like its northern counterpart, C. eos, but also quite closely resembles C. oreas. Outside the genus, the southern redbelly dace most resembles a small blacknose dace, Rhinichthyes atratulus (Hermann) and superficially resembles a small creek chub, Semotilus atromaculatus (Mitchell) (Trautman, 1957). During this study, young redbelly dace were observed to greatly resemble young-of-the-year bluntnose minnows, Pimephales notatus.

Range

The present distribution of the four species of Chrosomus appears to be the result of postglacial dispersal from their regions of origin. According to McPhail (1963) C. neogaeus arose in the Missouri refugium and migrated northward following glacial recession. Eddy (1969) described the present range

of C. neogaeus as extending from northwestern Canada to New Brunswick and New England, and southward to Montana, Colorado, northern Minnesota, Wisconsin and Michigan, with isolated populations in Nebraska and the Black Hills.

McPhail (1963) further suggested that C. eos arose from the Mississippi refugium and likewise migrated northward. Eddy (1969) reported the present range of C. eos to extend from upper British Columbia to the Hudson Bay drainage and Nova Scotia, and southward from Montana through Colorado, central Minnesota and Pennsylvania, with an isolated population in Nebraska.

Because of the similarity of C. oreas and C. erythrogaster to C. eos, it is highly possible that these species might also have originated in the Mississippi refugium. Chrosomus oreas has become isolated in the Allegheny region of Virginia and is now found in the drainages of the upper James, Roanoke and Kanawha Rivers (Cope, 1869b; Eddy, 1969).

Chrosomus erythrogaster has for the most part remained within the Mississippi River drainage. Its range extends northward to just below St. Anthony Falls in Minneapolis, Minnesota (Phillips, 1969b) and southward to Vicksburg, Mississippi (Hemphill, 1957). The western periphery of the range of the southern redbelly dace includes the Missouri and Des Moines River drainages of Iowa (Harlan and Speaker, 1956) and the eastern sectors of Kansas (Cross, 1967) and Oklahoma (Hill and Jensson, 1968). Eastward, C. erythrogaster is found in Pennsylvania (Carlander, 1969; Eddy, 1969) and southward

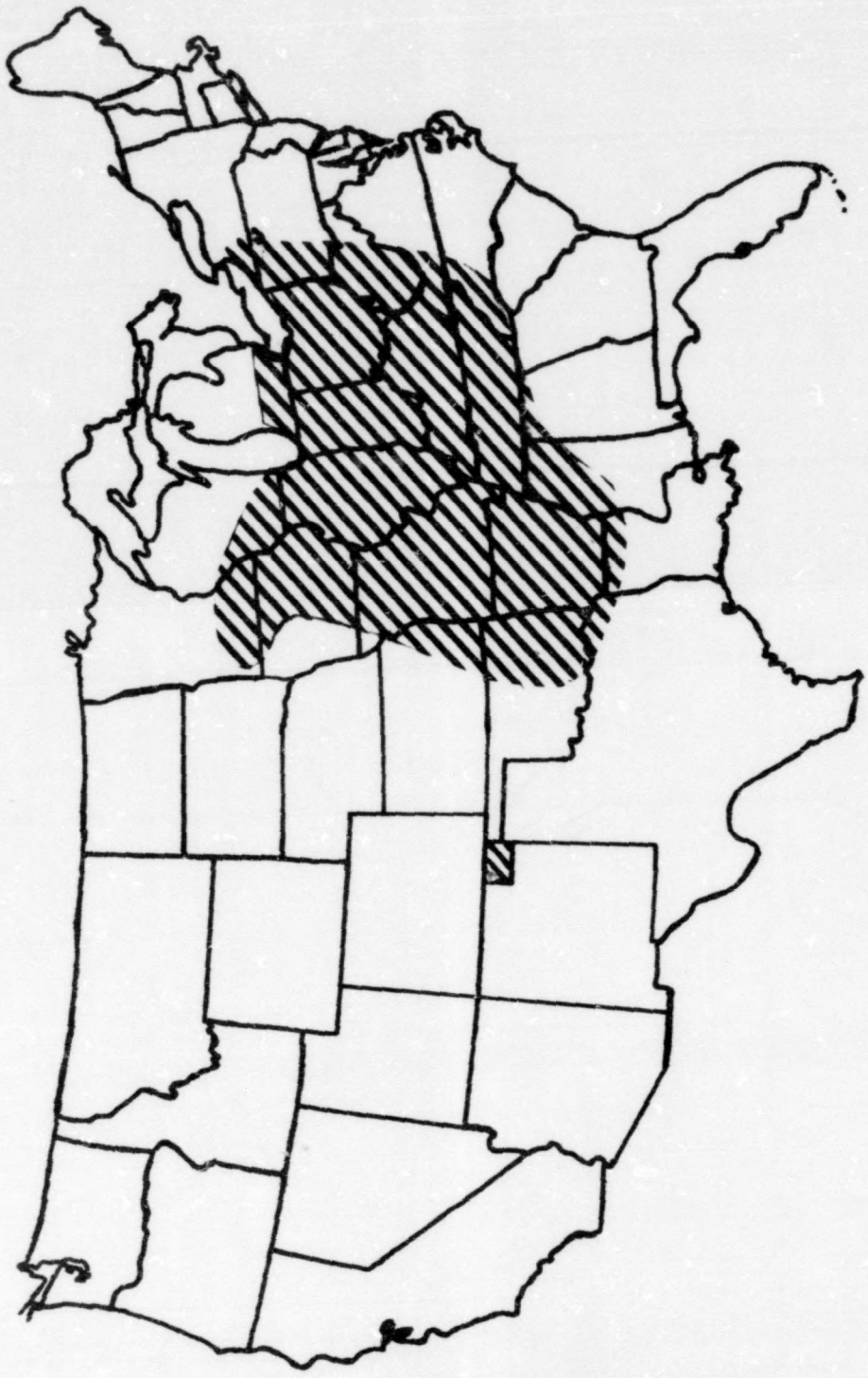
through the Appalachian Mountains (Fowler, 1929) to include Kentucky and Tennessee (Evermann, 1918). The southern range of the species includes northern Alabama and Arkansas (Eddy, 1969). Trautman (1957) reported an isolated population of southern redbelly dace in northeastern New Mexico and attributed its presence there to introduction as a bait or forage species. The range of C. erythrogaster, as best interpreted from the literature, is presented in Figure 1.

Habitat and Distribution in Kentucky

Chrosomus erythrogaster is a well-known inhabitant and indicator of cold, springwater habitats or permanent, clear headwater streams (Forbes and Richardson, 1920; Trautman, 1957). Fowler (1929) stated that "the 'red-bellied dace' lives in clear cold brooks of mountainous regions, often near spring heads." Smith (1908) reported the southern redbelly dace to be "by far the most abundant fish" in a brook characterized as small, with rapid current, and flowing over a "pebbly or sandy bottom." Trautman (1957) reported that the "largest populations of Redbelly Dace [in Ohio] occurred in permanent brooks . . . which flowed between wooded banks and contained long pools of moving water, and which had 'cut banks' overhung by vegetation."

The habitat specificity of the southern redbelly dace has a direct influence on the distribution of the species in Kentucky. Branson (1973) stated that the redbelly "inhabits clear, springfed creeks in Eastern Kentucky and to a lesser extent similar streams elsewhere in the state."

Figure 1. Range of the southern redbelly dace, Chrosomus erythrogaster Rafinesque in the United States.



The eastern portion of the state typically exhibits the steep-gradient streams which provide more suitable habitats for southern redbelly dace, thus accounting for their abundance there.

A study of the collection records of Western Kentucky University and the University of Louisville revealed that redbelly dace were frequently collected from several drainages in central Kentucky, but that the species was found in greater abundance in the upper reaches of streams where the gradient was more pronounced.

Dr. Morgan Sisk (1971, personal communication) stated that, to the best of his knowledge, the southern redbelly dace does not occur in the Tennessee River drainage, located in the extreme western portion of Kentucky, and that it is quite rare in the tributaries of the Cumberland River. In these systems, habitats are least suitable for C. erythrogaster.

METHODS AND MATERIALS

Field Collections

This study was initiated in November, 1970, with intensive sampling carried out from February 5, 1971, through January 8, 1972. Twenty-seven collections of redbelly dace were acquired throughout the study period as follows: two collections per month in February, July and August; four in April; six in May; three in March and June; and one collection monthly from September through January.

Collections were made by seining. A 10' x 4', 1/8-inch mesh nylon seine was used to capture adults and a 4' x 4' fine-mesh seine was used in collecting young-of-the-year. A total of 969 specimens were collected and fixed in 10% formalin while 534 dace, used in length studies, were measured in the field and returned to the stream.

Physical-Chemical Methods

Physical-chemical parameters of Ivy Creek were measured in the field or from water samples collected at the lower end of the study area. Determinations were made for stream discharge, stream temperature, dissolved oxygen concentration, hydrogen ion concentration (pH), total alkalinity, and total hardness. These determinations were made weekly from

February 5 through June 10, semi-monthly in July, and once monthly from August through January.

Stream Discharge

Stream discharge was estimated using the Embody method (Welch, 1948). Values for discharge estimations were expressed as cubic feet per second and estimations made within each calendar month were averaged for that month for graphic representation.

Stream Temperature and Dissolved Oxygen

Stream temperatures and dissolved oxygen concentrations were determined in the field with a Model 51A thermister and oxygen probe (Yellow Springs Instrument Co.). Determinations were made between 1100 and 1500 hours. Temperatures were recorded in degrees Celsius and dissolved oxygen as milligrams per liter. Data for each parameter were averaged monthly.

Hydrogen Ion Concentration, Total Alkalinity and Total Hardness

Hydrogen ion concentrations for Ivy Creek were determined using a Sargent-Welch Model PBL pH meter. Total alkalinity values were determined by titrating 50 ml samples of water with 0.02 N sulfuric acid to a pH of 4.0; the pH meter was used to determine end points. Total alkalinity values, expressed as milligrams per liter, were calculated by multiplying the number of milliliters of acid by 20 (Anonymous, 1956).

Total hardness, expressed as milligrams of Ca per liter, was determined using the EDTA method (Hach Chemical Company).

Each of these parameters were averaged monthly for graphic representation.

Reproduction

Gonad Weight - Body Weight Relationships

The gonad weight-body weight relationships, or gonosomatic ratios or indices, were used to determine spawning chronology of C. erythrogaster in Ivy Creek, Warren County, Kentucky. Gonosomatic indices were based on 269 male and 322 female southern redbelly dace collected from Ivy Creek from February 5, 1971 through January 8, 1972. For each specimen, the gonads were excised and weighed to the nearest 0.1 milligram on a Sartorius electric, single-pan balance. The total weight of both gonads was converted to a percentage of the total body weight.

For purposes of comparison, redbelly dace of each sex were separated into two length groups: 1) individuals having standard lengths (SL) of 30 to 39 mm (mostly sexually immature); and (2) those 39 mm SL and longer (mostly sexually mature). Specimens smaller than 30 mm SL were excluded because of difficulty in distinguishing the sex for those individuals. For each category, gonosomatic indices of individuals were averaged monthly.

Development of Ova

Because spawning chronology can be accurately determined by recording the diameters of ova as they develop within the ovary (Hickling and Rutenberg, 1936), this method was employed

to verify the chronology of the sexual cycle of southern redbelly dace in Ivy Creek. Since only primary ova are direct indicators of spawning condition, they alone were considered. The diameters of twenty primary ova, randomly selected from the left ovary of each of 35 gravid females, were measured to the nearest 0.01 mm using an ocular micrometer fitted to a compound dissecting microscope. The average diameters of ova for each of the four months included in the spawning season were calculated.

Fecundity

For the purpose of this study, fecundity was used to describe the number of primary ova produced by a single spawning female during one reproductive season. Fecundity of the southern redbelly dace in Ivy Creek was determined by counting the primary ova from both ovaries of each of 36 gravid females collected during May and June, 1971. The standard lengths of these specimens ranged from 39 to 65 mm. An empirical average of the numbers of primary ova enumerated from specimens of each millimeter of standard length was calculated and a regression line was fitted to the data using statistical methods patterned from Snedecor (1962).

Sex Ratio

The Chi-Square Test was applied to 768 male and female southern redbelly dace to determine if any departure from the 1:1 sex ratio had occurred at the 0.05 level of probability.

Only individuals 30 mm SL and longer were sexed due to the difficulty in distinguishing the sex of smaller specimens.

Sexual Dimorphisms

Dimorphic comparisons were limited to external differences in coloration, presence of breeding tubercles and the relative size and shape of fins. In regard to fin lengths, data were based on measurements for 51 males (30 to 58 mm SL) and 59 females (30 to 65 mm SL). Fin lengths were measured using procedures in Hubbs and Lagler (1964). Empirical averages for lengths of the pectoral, pelvic, anal and dorsal fins were plotted against standard body lengths and regression lines were fitted, using statistical methods of Snedecor (1962).

Age and Growth

All length and weight measurements for southern redbelly dace collected from Ivy Creek were made within three hours after capture in an effort to eliminate the necessity to convert preserved lengths and weights into live values. Specimens to be weighed were first blotted to remove excess water and weighed to the nearest 0.01 gram (g) on a Sartorius electric, single-pan balance. Total and standard lengths were measured to the nearest millimeter using methods prescribed by Hubbs and Lagler (1964). Standard length was used consistently throughout this study. A conversion factor based on 225 southern redbelly dace may be expressed as follows:

$$\frac{TL}{SL} = 1.23$$

Age Determinations

Length frequencies, verified by the scale method, were used to determine the age groups of 1,348 southern redbelly dace collected from Ivy Creek from February 5, 1971 through January 8, 1972. Samples studied were considered sufficiently large to be representative of the overall population. Data were arranged monthly in 2 mm SL increments for calculation of percentage frequencies, which were expressed graphically on a histogram. Scales examined for annuli were taken between the anterior base of the dorsal fin and the lateral scale series on the left side of each specimen. Scales were mounted in water under a coverslip and the number of annuli counted using 40x magnification.

Length-Weight Relationship

The relationship of standard length to total body weight was determined for 864 southern redbelly dace from Ivy Creek. Length-weight regressions were calculated using the following formula (Lagler, 1956):

$$W = aL^n$$

or

$$\log W = \log a + n \log L$$

where W = weight (g)
L = standard length (mm)
and a and n are constants

In an attempt to recognize seasonal differences, length-weight data were arranged according to season of capture.

The seasons were: (1) spawning season, March through June (N = 405); (2) warm-water period, July through October (N = 176); and (3) cold-water period, November through February (N = 283).

The length-weight equation was also applied to 328 males and 350 females to detect possible sexual differences. Finally, the length-weight relationship for all specimens collected during the study was determined.

The calculated length-weight regression for each treatment was plotted graphically and compared with empirical averages. Methods prescribed by Lagler (1956) were used to test length-weight regressions to determine the degree of adherence to the theoretical cubic response of growth in weight to growth in length. Analysis of covariance, patterned after Snedecor (1962) was used to determine any statistical differences among specimens collected during the different seasons, or between the sexes.

Coefficient of Condition

As a part of the study of length-weight relationships, the coefficient of condition (K), the mathematical expression of robustness or overall well-being was calculated for each of 269 male and 322 female southern redbelly dace using the following equation (Lagler, 1956):

$$K = \frac{W \times 10^5}{L^3}$$

where W = weight (g)
and L = standard length (mm)

To determine the effects of the gonadal component of the total weight on the coefficient of condition, the K value of each specimen was calculated with gonads intact and with gonads excised. The averages for these calculations were plotted monthly for each sex on a histogram.

Growth in Length and Weight

Growth curves were constructed from empirical and calculated data to represent absolute and relative growth in length and weight for each age group.

Food Habits

Specimens examined for gut contents were selected randomly from collections taken throughout the study period. The entire alimentary tract was excised and the contents examined microscopically in a wet mount to determine what categories of materials, both biotic and abiotic, had been ingested. Keys used in identifying biotic components were by Pennak (1953) and Smith (1950).

Meristics

Meristic studies on the southern redbelly dace were limited to a description of the meristic complement for each of the following characters: 1) the number of principal rays in the pectoral, pelvic, anal and dorsal fins, and (2) the number of scales in the lateral series.

For the purpose of enumerating fin rays, an assemblage of 100 specimens of representative sizes was selected. To

facilitate counts, specimens were stained with a solution of alizarin-carmine dye. Pectoral fins were removed and floated in water to insure accurate counts of principal rays. A dissecting microscope was employed while making ray counts. Principal rays were counted as outlined by Hubbs and Lagler (1964).

Scales in the lateral series were counted for 18 specimens of southern redbelly dace. Since C. erythrogaster has an incomplete lateral line, scales were counted along the existing lateral line to its extinction and then caudally within the same scale row to the hypural plate.

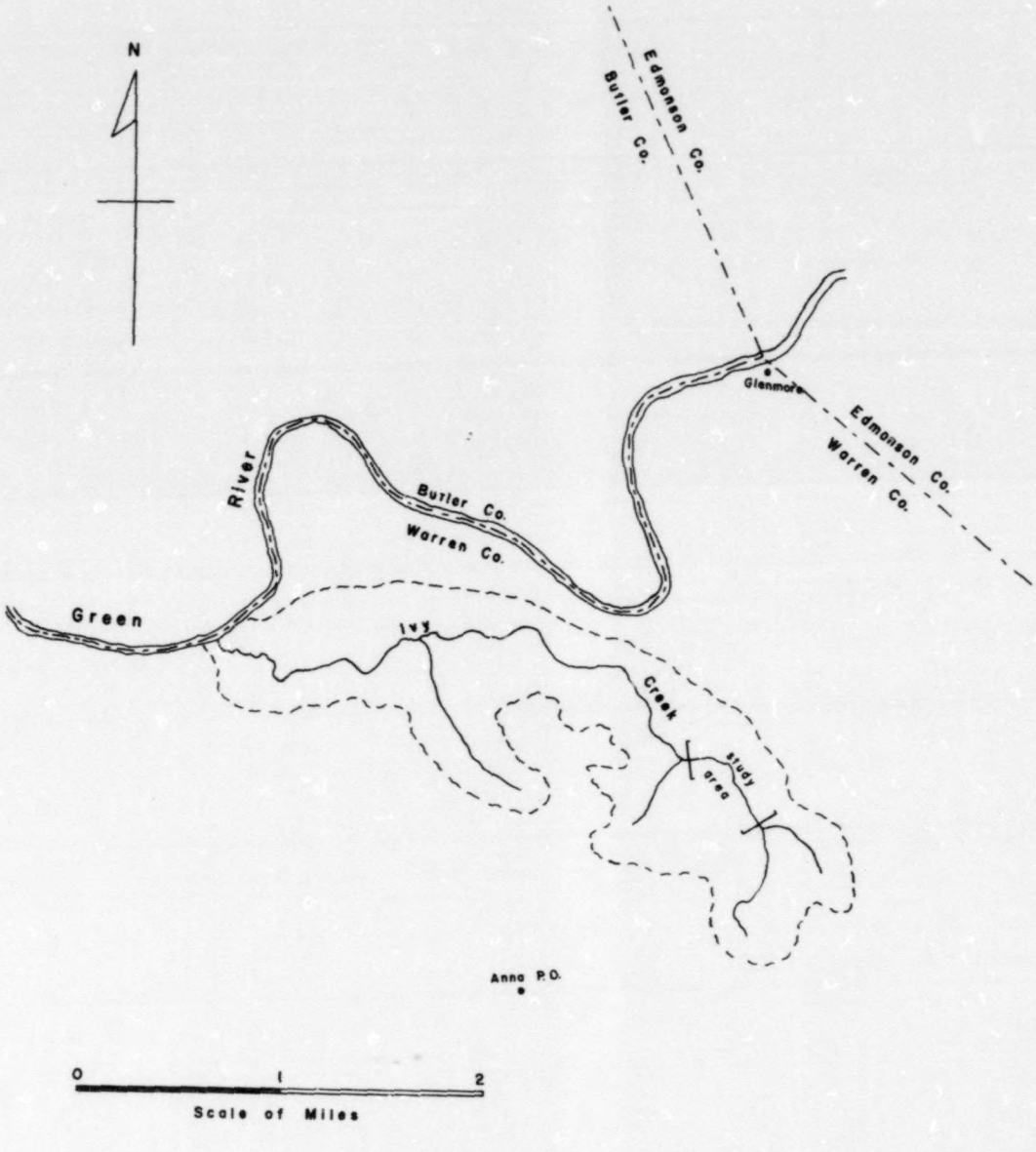
DESCRIPTION OF STUDY AREA

Ivy Creek is a small, springfed tributary of the Green River, originating in northern Warren County, Kentucky (37°09' N and 86°25' W), approximately fourteen miles from Bowling Green. It flows in a northwesterly direction for 4.4 miles before entering the Green River (Figure 2). Ivy Creek is fed primarily by two small source streams which converge after flowing approximately 0.7 mile from their origins. Numerous seepage streams also flow into Ivy Creek along its course. The stream flows through mildly karstic topography which characterizes the region. The upper reaches of Ivy Creek are at elevations ranging from 525 to 540 feet above mean sea level (msl) while the mouth lies at 430 above msl. The average gradient for Ivy Creek is 25 feet per mile.

The study area proper extended from just below the convergence of the two source streams (mile 0.8) to a point approximately 0.6 mile further downstream (Figure 2). This section of Ivy Creek flows alternately through wooded areas and open fields. Riparian vegetation is well developed along this section of stream. The sycamore (Platanus occidentalis L.), black walnut (Juglans nigra L.) and several species of maple (Acer spp.) provided most of the cover.

Within the study area, Ivy Creek ranged in width from three to 12 feet. Depths varied from two inches at riffles

Figure 2. Map of Ivy Creek, Warren County, Kentucky.


N
Edmonson Co.
Butler Co.
Glenmore
Edmonson Co.
Warren Co.
River
Butler Co.
Warren Co.
Green
Ivy
Creek
study
area
Anna P.O.
0
1
2
Scale of Miles

to three feet in deeper pools. The study area was characterized by frequent riffles between which lie long pools of moving water from one to two feet in depth. Undercut banks are common.

From February 5, 1971, to January 8, 1972, discharge for Ivy Creek ranged from less than one cubic foot per second to a maximum observed 26 cfs. Monthly averages ranged from 0.5 cfs in September and October to 14.4 cfs in February (Figure 3).

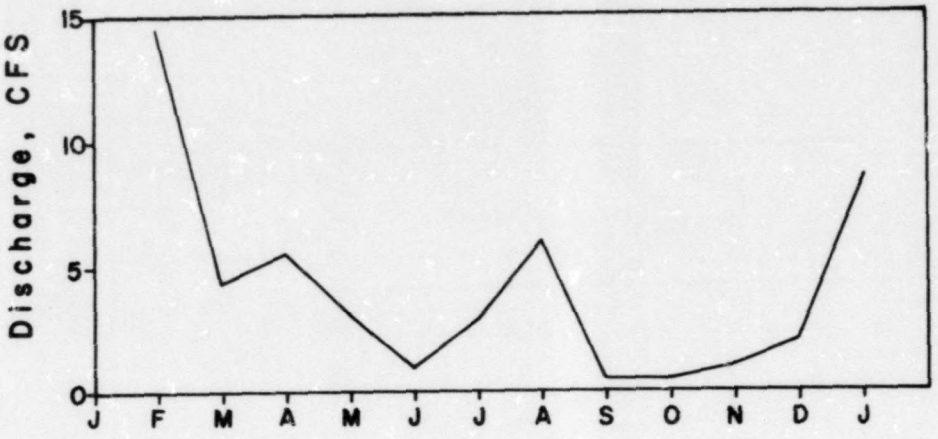
Observed extremes in stream temperature in Ivy Creek were five and 25 degrees Celsius (Figure 4). Dissolved oxygen concentrations averaged from 8 to 12 mg/l but fell to 6.2 and 5.0 mg/l during September and October, respectively. During these months the stream was choked with decaying leaf litter. In general, dissolved oxygen concentrations varied inversely with temperature (Figure 4).

Hydrogen ion concentrations were relatively stable with pH values ranging from 7.5 to 8.1 (Figure 5). Total alkalinity and total hardness ranged from 75 to 148 mg/l and 101 to 190 mg/l, respectively (Figure 6). Ivy Creek may thus be described as being a moderately hard-water stream. Generally, alkalinity and hardness decreased with increased discharge (Figures 3 and 6).

That portion of Ivy Creek designated as the study area corresponded well with the habitat requirements of C. erythrogaster previously described. The lower reaches of the

Figure 3. Stream discharge in cubic feet per second for Ivy Creek, Warren County, Kentucky, February, 1971 through January, 1972.

Figure 4. Stream temperatures in degrees Celsius (solid line) and dissolved oxygen concentrations in milligrams per liter (broken line) for Ivy Creek, Warren County, Kentucky, February, 1971 through January, 1972.


Discharge, CFS
15
10
5
0
J F M A M J J A S O N D J

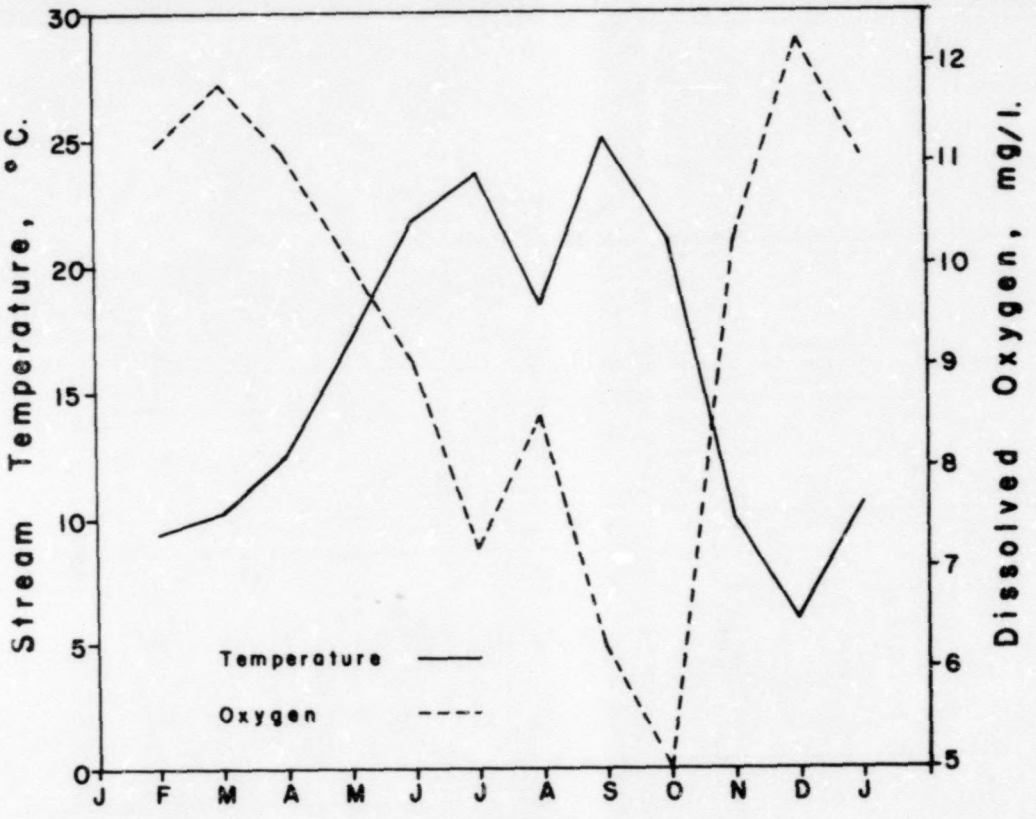
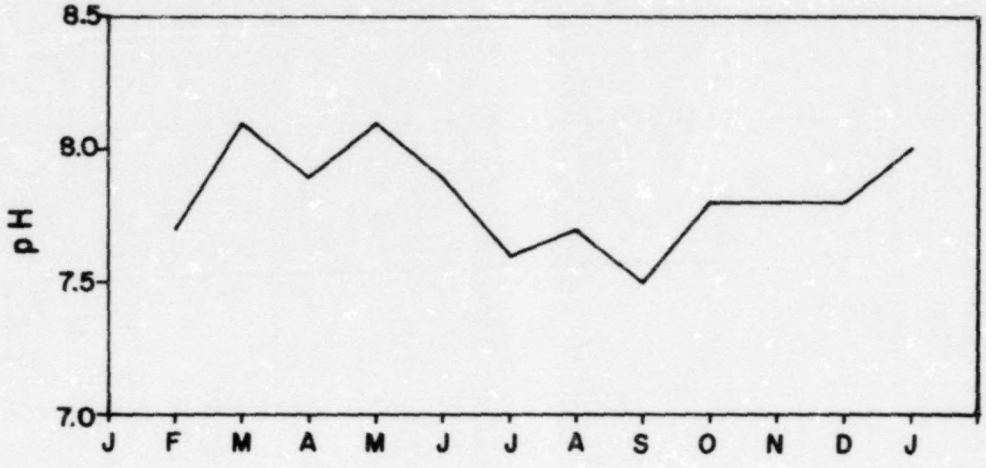
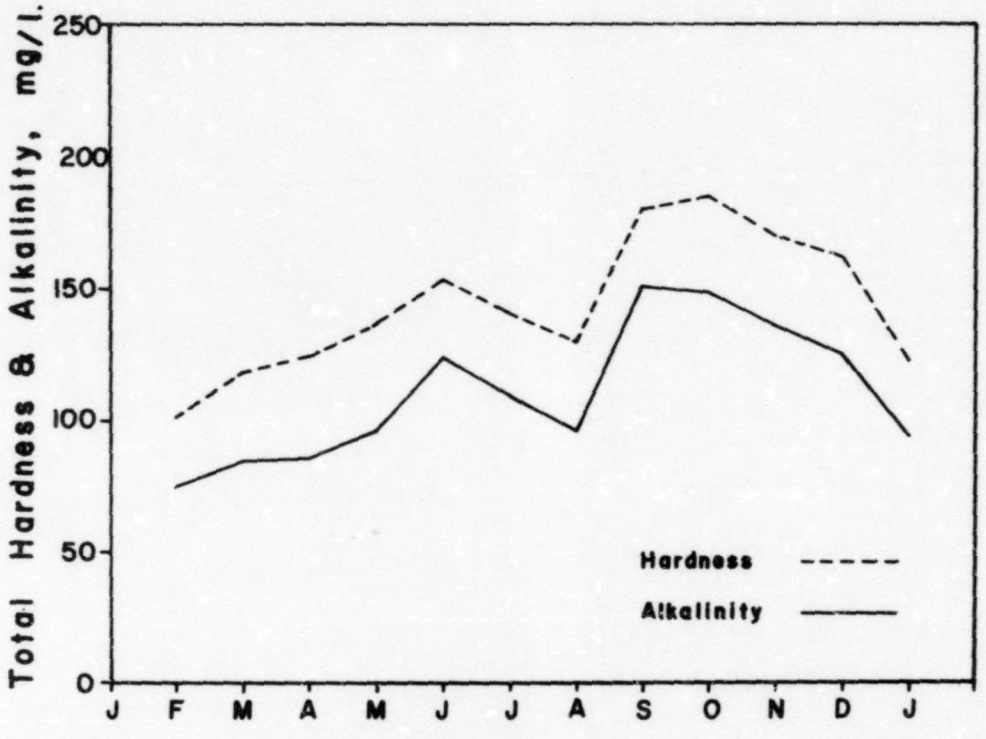

Stream Temperature, °C.
30
25
20
15
10
5
0
Dissolved Oxygen, mg/l.
12
11
10
9
8
7
6
5
Temperature
Oxygen
J F M A M J J A S O N D J

Figure 5. Hydrogen ion concentrations (pH) for Ivy Creek, Warren County, Kentucky, February, 1971 through January, 1972.

Figure 6. Total alkalinity (solid line) and total hardness (broken line), in milligrams per liter, for Ivy Creek, Warren County, Kentucky, February, 1971 through January, 1972.


8.5
8.0
7.5
7.0
pH
J F M A M J J A S O N D J


250
200
150
100
50
0
Total Hardness & Alkalinity, mg/l.
Hardness
Alkalinity
J F M A M J J A S O N D J

stream were quite different from the study area and consequently few, if any, redbelly dace occurred there.

RESULTS

Reproduction

Gonad Weight - Body Weight Relationships

The gonosomatic index provided a relatively clear picture of the spawning chronology of C. erythrogaster in Ivy Creek. Gonads of both sexes showed the first marked increase in size and condition during March and April (Table 1, Figure 7). Females designated as mature (39 mm SL and longer) reached a maximum ovarian development during May, with a mean gonosomatic index of 9.62%, followed by a subsequent decline in condition during June. By July, the condition of the ovaries had reached a minimum level.

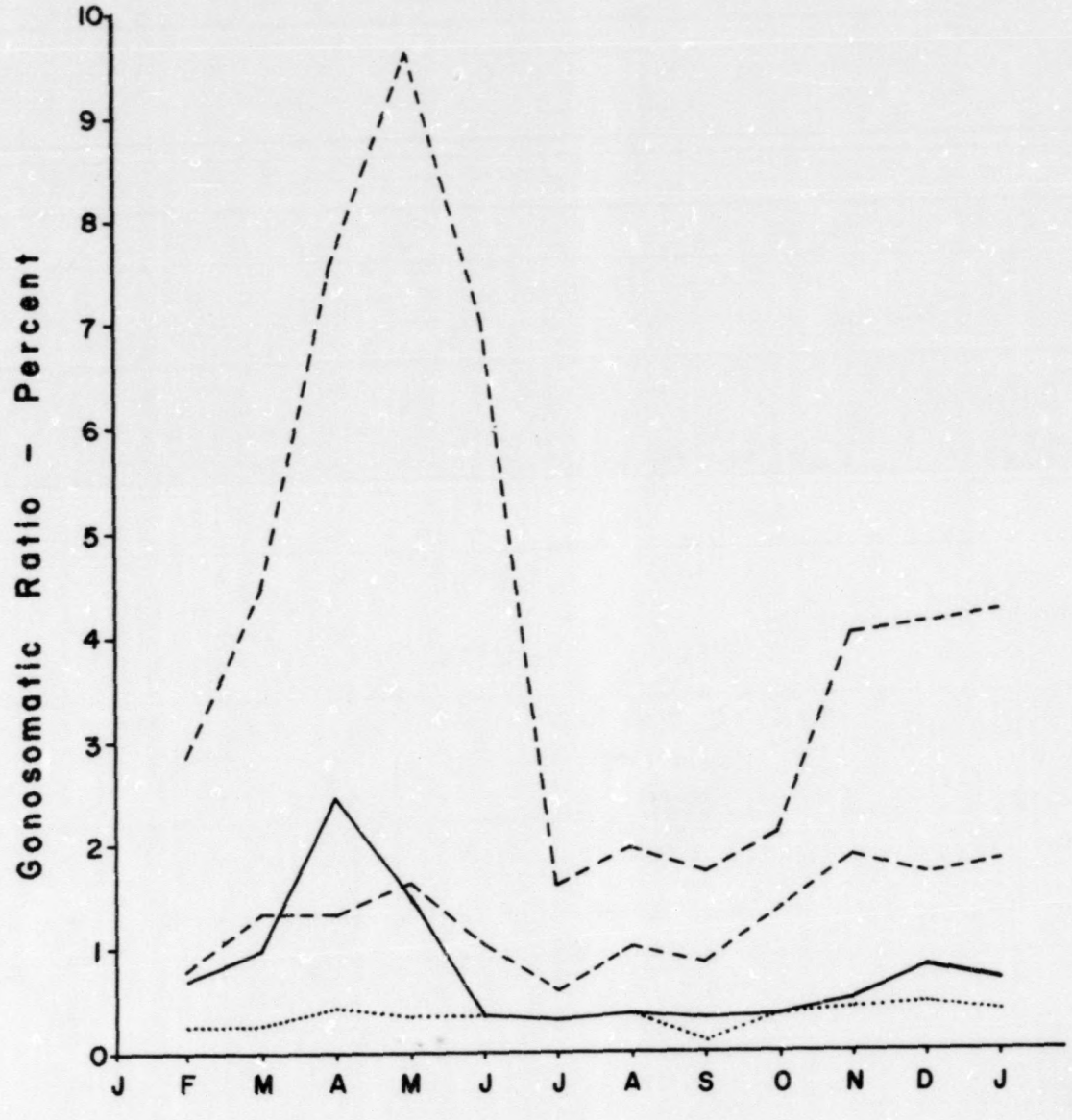
The pattern of gonadal development among "mature" males was characterized by a rapid increase in the size of the testes during March and April (Table 1, Figure 7). However, unlike the females, the mean gonosomatic index declined in May and the lowest average values were recorded in June.

The maximum individual gonosomatic indices observed during this study were 23.40% and 4.97% for a female (39 mm SL) and a male (54 mm SL), respectively. The smallest gravid female collected was 38 mm SL, and the smallest mature male, as judged by gonadal condition and secondary sexual characteristics, was 39 mm SL. The largest gravid female observed was 65 mm SL while the largest male was 57 mm SL.

TABLE 1. Average monthly gonosomatic ratios of two length groups of male and female southern redbelly dace from Ivy Creek, Warren County, Kentucky, from February, 1971 through January, 1972.

	0-38 mm SL		39-65 mm SL	
Month	Males	Females	Males	Females
February	0.26%	0.79%	0.70%	2.87%
March	0.27%	1.34%	1.00%	4.49%
April	0.43%	1.35%	2.48%	7.59%
May	0.38%	1.65%	1.51%	9.62%
June	0.38%	1.05%	0.38%	7.03%
July	---	0.61%	0.34%	1.63%
August	0.39%	1.03%	0.37%	1.99%
September	0.12%	0.88%	0.33%	1.75%
October	0.39%	1.40%	0.39%	2.13%
November	0.44%	1.90%	0.51%	3.96%
December	0.48%	1.75%	0.82%	4.16%
January	0.41%	1.89%	0.70%	4.27%

Figure 7. Relationship of gonad weight to body weight for two size groups of male and female southern redbelly dace from Ivy Creek, Warren County, Kentucky from February, 1971 through January, 1972. Dashed lines represent females of two size groups. Solid line represents males 39 mm SL and longer; dotted line represents males below 39 mm SL.


Gonosomatic Ratio - Percent
10
9
8
7
6
5
4
3
2
1
0
J
F
M
A
M
J
J
A
S
O
N
D
J

It was concluded that size grouping of males produced skewed results in the mean gonosomatic indices for May and June. Because of somatic growth, 52% of the males which had been designated to the mature size group (39 mm SL and longer) were sexually immature. This resulted in a mean gonosomatic index of 1.51% for all males in May (Table 1, Figure 7), which indicated an apparent deline in the condition of the testes when compared with the April mean of 2.48%. In reality, the remaining 48% of the males that had actually reached sexual maturity had a mean gonosomatic value of 2.63%. During June, only one male which bore secondary sexual characteristics was found among the samples.

Data also indicated that four large females (54 to 61 mm SL) had, by April, attained a relative degree of ovarian development as was attained by smaller females during May and June. Similarly, two males (53 and 54 mm SL) reached a degree of gonadal development by April similar to that attained by smaller males during May and June. It was also observed that dace in their first year of life which did reach spawning condition did not do so until June.

Development of Ova

Primary ova were first recognized from specimens collected during early March. Those females were larger and clearly older than other mature females. The primary ova ranged up to 1.00 mm in diameter and had average diameter of 0.75 mm (Table 2). No primary ova were found among females smaller than 50 mm SL during March.

TABLE 2. Monthly increase in mean diameters of primary ova from female redbelly dace collected from Ivy Creek, Warren County, Kentucky, during 1971

Month	Mean Ova Diameter	
	39 to 50 mm SL	51 mm and longer
March, early	---	0.62 mm
March, late	---	0.82 mm
April, early	---	0.98 mm
April, late	0.81 mm	0.98 mm
May, early	1.04 mm	1.06 mm
May, late	1.11 mm	---
June, early	1.18 mm	---
June, late	1.23 mm	---

By April, primary ova were distinguishable among the smaller mature females and had average diameters of 0.81 mm. The larger females (those 50 mm SL and longer) bore ova up to 1.34 mm in diameter with an average diameter of 0.98 mm (Table 2).

The largest means for diameters of ova in May were 1.06 mm for the larger females and 1.04 mm for the smaller specimens (Table 2).

By late May, no gravid females longer than 50 mm SL were found among the samples. Other smaller females bore ova averaging 1.11 mm in diameter. In June, primary ova averaged 1.19 mm in diameter during the first two weeks and 1.23 mm during the last two weeks of the month. The largest recorded ovum had a diameter of 1.44 mm and was taken from a specimen collected on June 17.

Spawning Behavior

Spawning was not observed during the course of this study. However, activity thought to be related to spawning was observed on June 10. At that time, redbelly dace were very active directly above a well defined gravel indentation on the stream bottom. This indentation, suggestive of a nest, was circular in form and about 18 inches in diameter. It was bordered by silt and sand. At the time of this observation, the water temperature was 21 C and the dissolved oxygen concentration was 8.5 mg/l.

Appearance of Fry

The first recognizable fry of C. erythrogaster were collected in a riffle at the mouth of a small feeder stream. They ranged from 14 to 25 mm SL and occurred in rather homogeneous groups with occasional fry of the white sucker, Catostomus commersoni (Lacepede), also present. Fry as small as 14 mm SL were collected through the August 3 sample.

Fecundity

Primary ova, totaling 11,368, were counted from the ovaries of 36 gravid females ranging from 39 to 65 mm SL. Extremes ranged from 140 primary ova, from a female of 41 mm SL, to 681 from a specimen 61 mm SL. The empirical mean was 385 ova per specimen.

A positive correlation ($r = 0.83$) existed between the average number of mature ova and standard body length. This relationship was shown statistically to be linear and the following linear regression formula was computed:

$$Y = -495.0 + 17.4\ X$$

where Y = the number of ova, and

X = standard length (mm)

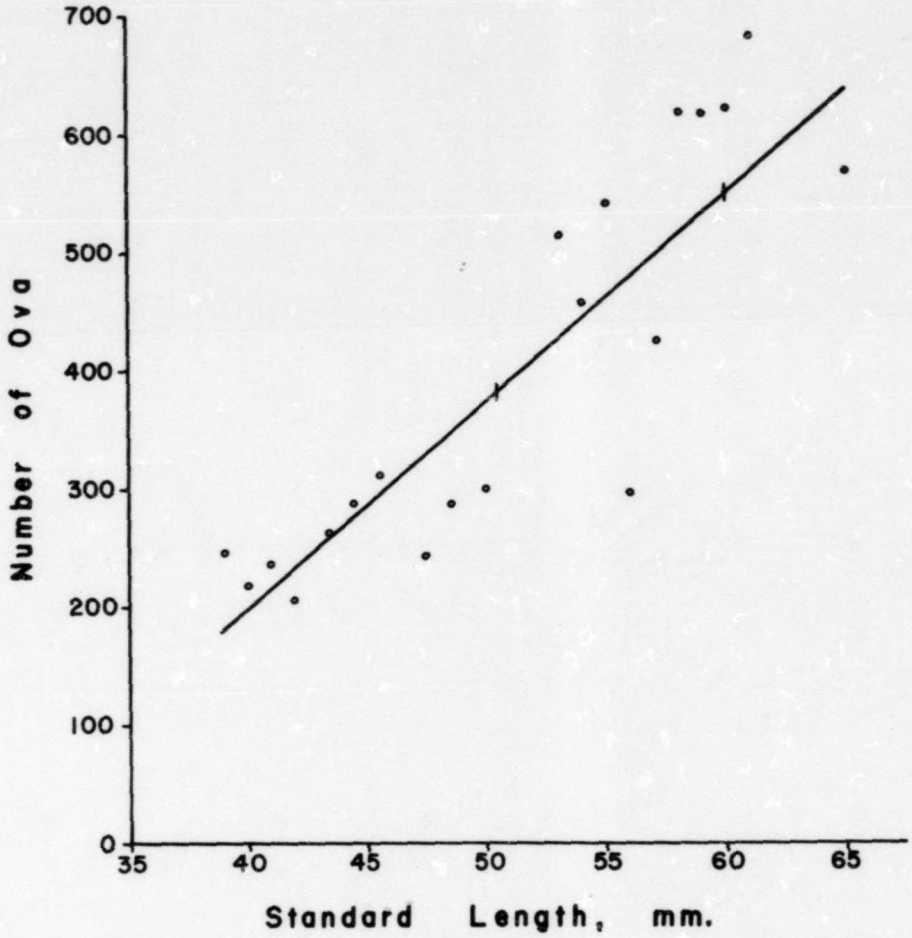
Graphic illustration of this relationship is presented in Figure 8.

Of the 123 females examined during May and June, 40 (32.4%) were judged mature and capable of spawning.

Sex Ratio

Sex was determined for 768 southern redbelly dace. Of these, 364 were male and 404 were female. This resulted in

Figure 8. Relationship of number of primary ova and standard length of gravid females from Ivy Creek, Warren County, Kentucky, March through June, 1971.


700
600
500
400
300
200
100
0
35
40
45
50
55
60
65
Number of Ova
Standard Length, mm.

a 0.9:1 male-to-female ratio. A Chi-Square value of 2.082 indicated that there was no significant deviation from the expected 1:1 sex ratio at the 5% level of probability (P = 0.10-0.20).

Sexual Dimorphisms

Sexual differences in coloration were most accented during the reproductive season at which time the breeding males bore the characteristic scarlet ventrals. The pigmentation extended from the mandible posteriorly to the caudal peduncle. Mature females often bore sprinklings of red on their abdomens but not to the extent exhibited by the males. Fins of breeding males also appeared a brighter yellow than did those of females. Throughout the year, the colors and color patterns of males appeared deeper and more distinct than that of the females. This was particularly true in regard to the clarity of the lateral bands. Coloration was never used alone to sex southern redbelly dace in Ivy Creek because of its lack of reliability.

Mature male redbelly dace developed obvious breeding tubercles on their heads, backs and fins. The first tuberculated males were collected in late April, primarily among the larger specimens. Tubercles were less distinct among smaller breeding males and did not appear until mid-May. Tubercles remained through July for most mature males.

The relationships between fin length and standard body length for male and female southern redbelly dace in Ivy Creek are represented by the following formulae:

Left Pectoral Fin:	Males	$Y = -2.07 + 0.256X$
	Females	$Y = 0.34 + 0.168X$
Left Pelvic Fin:	Males	$Y = -1.07 + 0.179X$
	Females	$Y = 0.76 + 0.122X$
Anal Fin:	Males	$Y = 0.36 + 0.189X$
	Females	$Y = 0.15 + 0.182X$
Dorsal Fin:	Males	$Y = 0.86 + 0.197X$
	Females	$Y = 1.05 + 0.183X$

where Y = fin length (mm), and
X = standard length (mm)

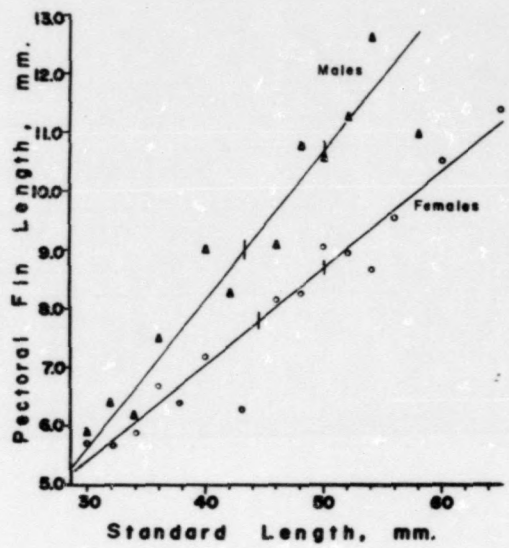
Graphic representations of the fin length to standard length relationships are shown in Figure 9.

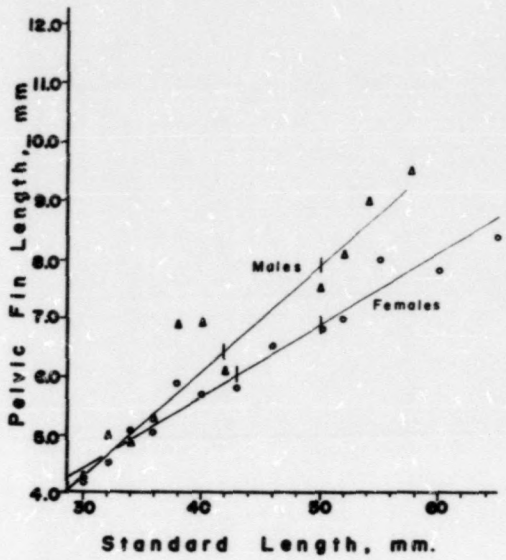
Though the relative length of all fins measured were longer for males than females (Figure 9), the size and appearance of the pectoral fins provided the most dependable means of sexing southern redbelly dace externally. The pectorals of males were relatively longer than those of females, and were rounded distally, while those of females were conspicuously shorter and pointed distally.

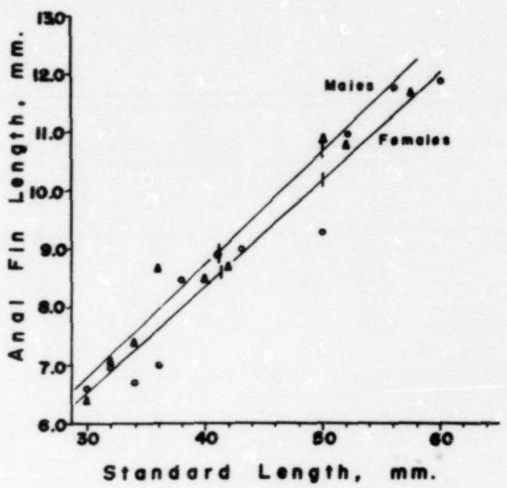
General Discussion

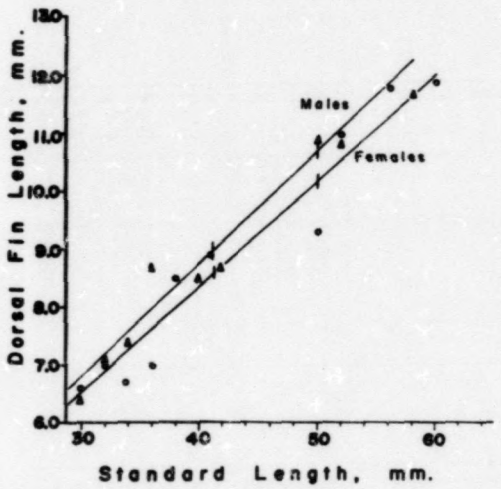
Spawning of C. erythrogaster in Ivy Creek occurred primarily in late May and throughout most of June. This corresponds well with published information regarding the reproductive chronology of other geographical representatives of the species. Smith (1908) observed spawning activities from May 17 to June 14 for southern redbelly dace in Illinois.

Figure 9. Relationship of fin length to standard body length for male and female southern redbelly dace. A. Pectoral fins, B. Pelvic fins, C. Anal fins, and D. Dorsal fins.


Pectoral Fin Length, mm.
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
Males
Females
30
40
50
60
Standard Length, mm.


Pelvic Fin Length, mm
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
Males
Females
30
40
50
60
Standard Length, mm.


Anal Fin Length, mm.
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
Males
Females
30
40
50
60
Standard Length, mm.


Dorsal Fin Length, mm.
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
Males
Females
30
40
50
60
Standard Length, mm.

Breeding seasons during May and June were reported for redbelly dace in Pennsylvania (Koff, 1961), Minnesota (Phillips, 1968a), and Wisconsin (Cahn, 1927). The universality of spawning chronology for the species over a wide geographical range may be attributed to extrinsic environmental factors such as photoperiod (Harrington, 1959), though it has also been suggested that some cyprinids may possess genetically controlled internal rhythms which may act in the absence of environmental factors, though less precisely (Bullough, 1939).

The size and age of redbelly dace also appeared to influence the time of spawning. Individuals in their second year of life (48 to 54 mm SL), which represented the most important age group in regard to the reproductive potential of the southern redbelly dace in Ivy Creek, spawned during the period indicated for the overall population (i.e., late May through June). However, larger dace appeared to have reached reproductive condition earlier and may have spawned during late April and early May. Because specimens of the larger group were not collected after mid-May, it was assumed that they spawned earlier and then succumbed to the rigors of spawning. In further support of this hypothesis, there were a small number of fry, collected in July, which were distinctly larger than their peers and which may have represented the progeny of early spawns.

In June, redbelly dace completing their first year of life, ranged from 29 to 44 mm SL. Those 29 to 38 mm were nearly all sexually immature, while most of those 39 to 44 mm

reached spawning condition during the latter half of June and presumably participated in the spawn. The size range of specimens in the first year dace, as well as the differential observed in sexual maturation, suggested that the larger individuals were products of the earlier spawns of the previous year. Frost (1943) noted a similar pattern for Phoxinus phoxinus (L.) and also attributed it to a somewhat protracted reproductive season.

Though actual spawning was not observed during the current study, a particularly vivid account of the breeding activities of redbelly dace in Illinois was published by Smith (1908). In this account, dace were described as spawning "en masse in shallow swift water." Activities thought to be related to spawning were observed in Ivy Creek under similar circumstances.

The specific activities involved with spawning were recorded by Smith (1908) in such detail that the following passage will be quoted directly from the original text.

> "Several males pursue one female; as the foremost male gains a position alongside the female, the flight and pursuit attain almost lightning-like rapidity. At length two males spawn with a single female as follows: One on each side presses the side of his head against that of the female, all three facing upstream. The two males then crowd laterally against the female, held between them; their entire flanks are thus pressed against the

sides of the female. While the males are in this position, a rapid vibration of their bodies occurs. The wave of pressure begins at the anterior end of the body and passes backward as a sidewise undulating movement. Other males may attempt to crowd in. So far as observed, the female remains passive."

Smith (1908) noted that variations in this basic pattern included groups of four or more fish crowding together to spawn and occasionally groups of six, composed of two trios, actively engaged. Also observed was a single male spawning with one female by pressing her body against the stream bottom.

During the current study, activities believed to be related to spawning were observed above what appeared to be a circular nest. Study of the literature revealed that members of the genus Chrosomus frequently utilize nests constructed by other species. Hankinson (1932) observed redbelly dace spawning over nests constructed by members of the genus Hybopsis. Smith (1908) reported spawning over "an abandoned dace's nest" but failed to report the species of the dace. Raney (1947) observed similar behavior for the mountain redbelly dace, C. oreas. The nest observed in Ivy Creek best approximated the descriptions of nests typically constructed by the stoneroller minnow, Campostoma anomalum (Rafinesque), as reported in Breder and Rosen (1966). Because the stoneroller was very abundant in Ivy Creek, the possibility exists that C. erythrogaster utilized such nests for spawning.

The number of primary ova produced during a single reproductive season was related linearly to the standard length. That is, the larger the fish, the more ova which become ripe during one spawning season. The empirical mean of 385 eggs per specimen is relatively low for a species which gives little or no attention to the eggs after they are deposited. It was assumed that the lack of large numbers of large females may have contributed to the low fecundity. The environmental effects on fecundity were not determined. Total egg counts (i.e., the sum of all primary, secondary and tertiary ova) were not determined for the southern redbelly dace in Ivy Creek. However, Phillips (1968a) reported total egg counts ranging from 5,708 to 18,888 for redbelly dace in Minnesota.

There was no deviation from the expected 1:1 sex ratio (P = 5%) among the southern redbelly dace in Ivy Creek. This indicates that sex was genetically controlled and that no extrinsic forces existed which may have altered the sexual structure of the Ivy Creek population. Smith (1908) observed an approximate 6.5:1 male-to-female ratio over spawning areas but stated that this was not necessarily a reflection of the overall population, but rather was a result of the mode of spawning behavior for the species.

Hybridization between C. erythrogaster and other species was not observed in Ivy Creek. However, the southern redbelly dace has been reported to hybridize with the following species: Campostoma anomalum (Rafinesque)(Hubbs and Bailey, 1952),

Clinostomus elongata (Kirtland) (Trautman, 1957), Dionda nublia (Forbes) (Phillips and Etnier, 1969), Notropis cornutus (Mitchell) (Trautman, 1957), and Semotilus atromaculatus (Mitchell) (Cross and Minckley, 1960). Phillips (1969a) found no evidence of hybridization between C. erythrogaster and its northern counterpart, C. eos.

Age and Growth

Age Determination

Evaluation of length frequency distributuions indicated the presence of two distinct age groups in Ivy Creek, with isolated individuals representing a third age group (Figure 10). Redbelly dace in their first year of life were designated age group 0; those in their second year as age group I; and those individuals in their third year comprised age group II.

From February through June, age group 0 (spawned in 1970) represented the dominant age group in Ivy Creek and comprised 81.8% to 97.4% of each of the samples (Table 3, Figure 10). During the same period, age group I dace declined rapidly in relative numbers and were nearly depleted by June (Table 3, Figure 10). The only age group II specimens represented during that time period were two females, 63 and 65 mm SL captured in March (Table 3, Figure 10).

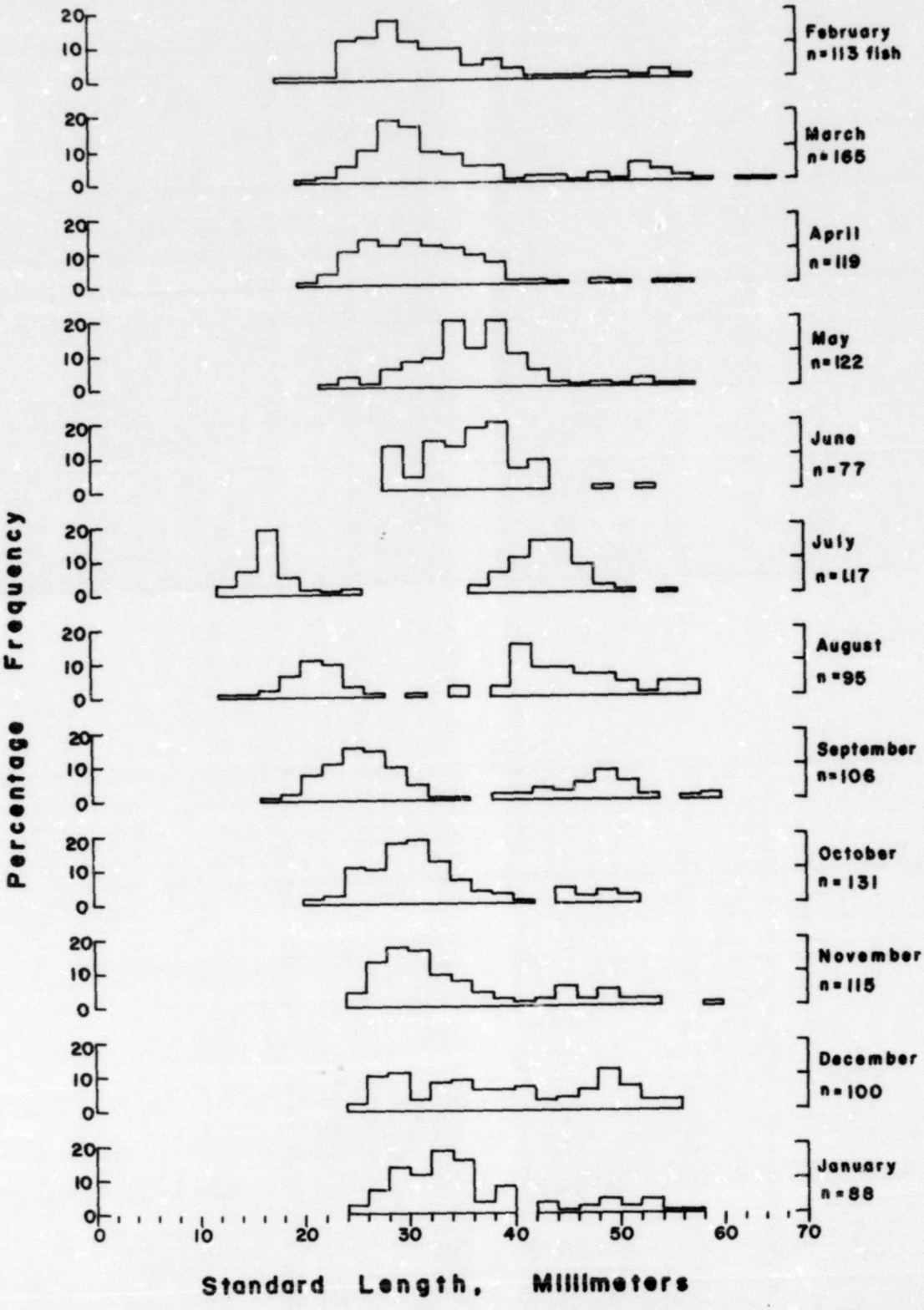
In July, the age group composition was altered as a result of the introduction of young-of-the-year individuals into the general population. Each of the age groups which had inhabited Ivy Creek prior to that time were then assigned

TABLE 3. Estimated age group composition at monthly intervals for 1348 southern redbelly dace collected from Ivy Creek, Warren County, Kentucky, from February, 1971 to January, 1972.

	Year Spawned								
	1971			1970			1969		
	Age Group	N	% Sample	Age Group	N	% Sample	Age Group	N	% Sample
Feb.	---	---	---	0	102	90.3	I	11	9.7
Mar.	---	---	---	0	135	81.8	I	28	17.0**
Apr.	---	---	---	0	114	95.8	I	5	4.2
May	---	---	---	0	113	92.6	I	9	7.4
June	---	---	---	0	75	97.4	I	2	2.6
July	0	44	37.6	I	72	61.5	II	1	0.9
Aug.	0	37	38.9	I	50	52.6	II	8	8.4
Sept.	0	70	66.0	I	33	31.1	II	3	2.8
Oct.	0	114	87.0	I	17	13.0	---	---	---
Nov.	0	93	80.9	I	22	19.1	---	---	---
Dec.	0	65	65.0	I	35	35.0	---	---	---
Jan.	0	73	83.0	I	15	17.0	---	---	---

**In March, two specimens of Age Group II, Year Class 1968, were collected and represented 1.2% of the total sample.

Figure 10. Length-frequency distributions at monthly intervals for southern redbelly dace from Ivy Creek, Warren County, Kentucky, February, 1971 to January, 1972.


Percentage Frequency
20
10
0
February
n=113 fish
March
n=165
April
n=119
May
n=122
June
n=77
July
n=117
August
n=95
September
n=106
October
n=131
November
n=115
December
n=100
January
n=88
0
10
20
30
40
50
60
70
Standard Length, Millimeters

to the next age group category. Thus from July through September, age groups 0 and I, with a very few individuals of age group II, were found in Ivy Creek (Table 3, Figure 10). The increase in the percentage frequency of age group 0 dace was primarily the result of mortality among the older age groups.

By October, only age groups 0 and I specimens were collected from Ivy Creek. It was likely that some age group II individuals existed but were so rare that none were collected.

It was concluded that most southern redbelly dace in Ivy Creek had life spans of somewhat less than two years, with only a very few individuals surviving into their third year of life. Most individuals which did live into their third year did not survive the following winter.

Growth in Length

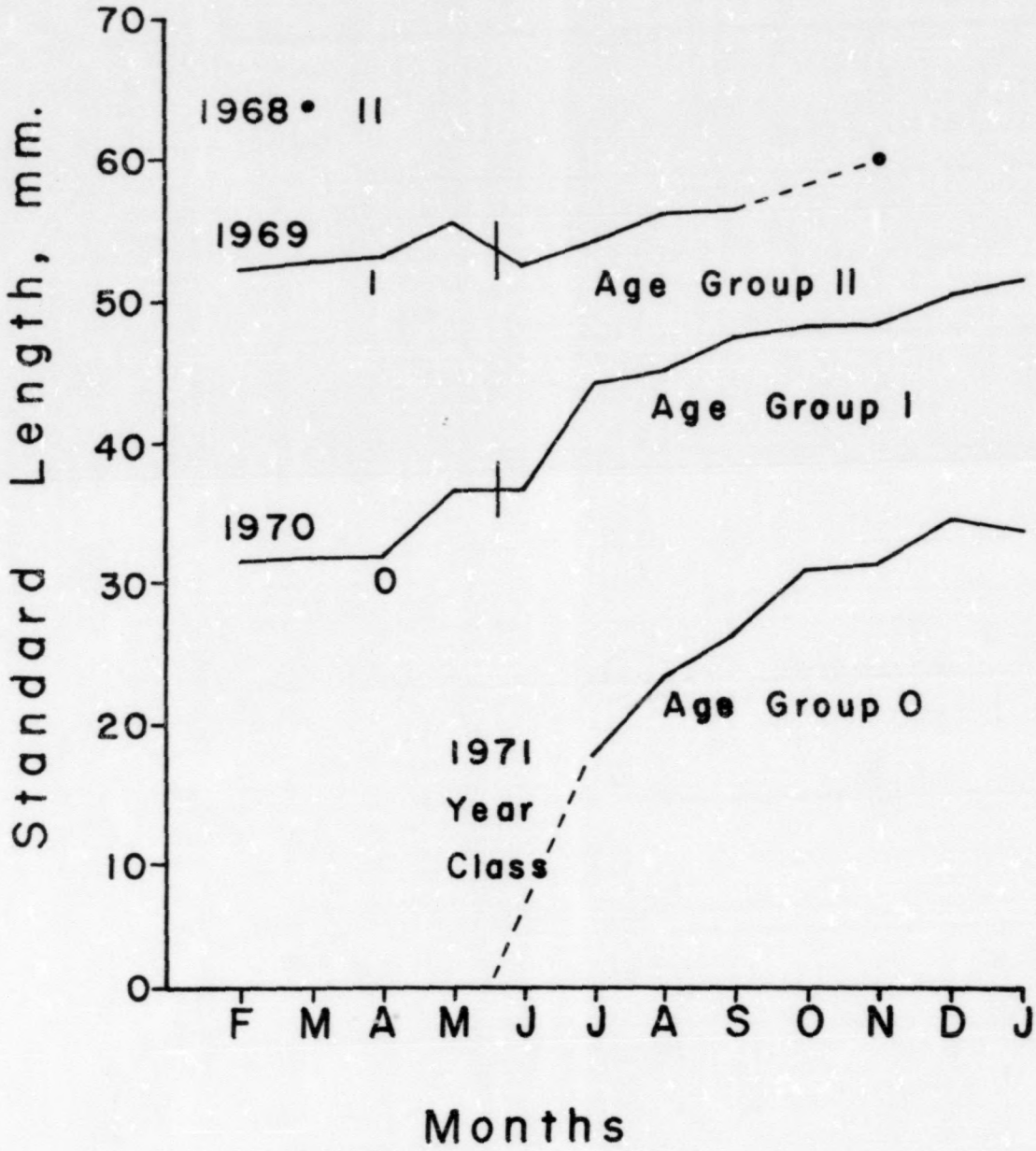
Upon the establishment of age groups, the monthly standard length ranges and mean lengths were calculated for each category (Table 4). These data were used to construct Figure 11. Young-of-the-year redbelly dace were first collected in July and had a SL range of 14 to 25 mm, with a mean SL of 18 mm (Table 4, Figure 11). Growth among age group 0 individuals was rapid through October, at which time lengths ranged from 21 to 41 mm and averaged 31 mm. Some growth occurred during the winter, but appreciable growth did not resume until April (Figure 11). At the end of their first year of life (i.e., in June), redbelly dace ranged from 29 to 44 mm and averaged 37 mm SL.

TABLE 4. Average monthly standard lengths and ranges for three year classes of southern redbelly dace, based on 1348 specimens from Ivy Creek, Warren County, Kentucky, from February, 1971 to January, 1972.

	Year Classes								
	1971			1970			1969		
	Age Group	Range (mm)	Mean (mm)	Age Group	Range (mm)	Mean (mm)	Age Group	Range (mm)	Mean (mm)
Feb.				0	20-43	32	I	45-58	52
Mar.				0	22-43	32	I	46-60	53**
Apr.				0	22-45	32	I	52-60	56
May				0	23-45	36	I	48-57	52
June				0	29-44	37	I	50-53	52
July	0	14-25	18	I	37-52	44	II	-56	56
Aug.	0	14-36	23	I	40-53	45	II	56-58	57
Sept.	0	18-35	26	I	40-54	48	II	57-61	60
Oct.	0	21-41	31	I	45-52	48			
Nov.	0	25-43	32	I	45-53	50			
Dec.	0	26-44	34	I	45-56	50			
Jan.	0	25-44	33	I	46-57	51			

**In March, two female dace of Age Group II, Year Class 1968, were captured. Their standard lengths were 63 and 65 mm, respectively.

Figure 11. Average monthly standard lengths for three year classes of southern redbelly dace based on measurements of 1348 specimens from Ivy Creek, Warren County, Kentucky, February, 1971 to January, 1972.


Standard Length, mm.
70
60
50
40
30
20
10
0
1968 • II
1969
I
Age Group II
Age Group I
1970
0
Age Group 0
1971
Year
Class
F M A M J J A S O N D J
Months

Age group I dace grew slowly and averaged over 50 mm SL at the end of their second year (Figure 11). However, insufficient numbers of specimens of age group I prevented an accurate determination of mean standard length. Age group II dace ranging from 57 to 61 mm SL and averaging about 60 mm SL were collected in September, while one individual, 60 mm SL was collected in November. The oldest age group II specimens were collected in March and averaged 64 mm.

The greatest absolute growth in length occurred during the first year of life, with a gradual decline in the rate of growth during the second and third years (Table 5, Figure 12).

Length-Weight Relationships

The length-weight equation yielded the following formulae for three seasonal periods in Ivy Creek:

Spawning Period (March - June)

$$W = 1.177 \times 10^{-5} L^{3.096}$$

or

$$\log W = -4.9293 + 3.096 \log L$$

Warm Water Period (July - October)

$$W = 1.360 \times 10^{-5} L^{3.045}$$

or

$$\log W = -4.8665 + 3.045 \log L$$

Cool Water Period (November - February)

$$W = 1.457 \times 10^{-5} L^{3.006}$$

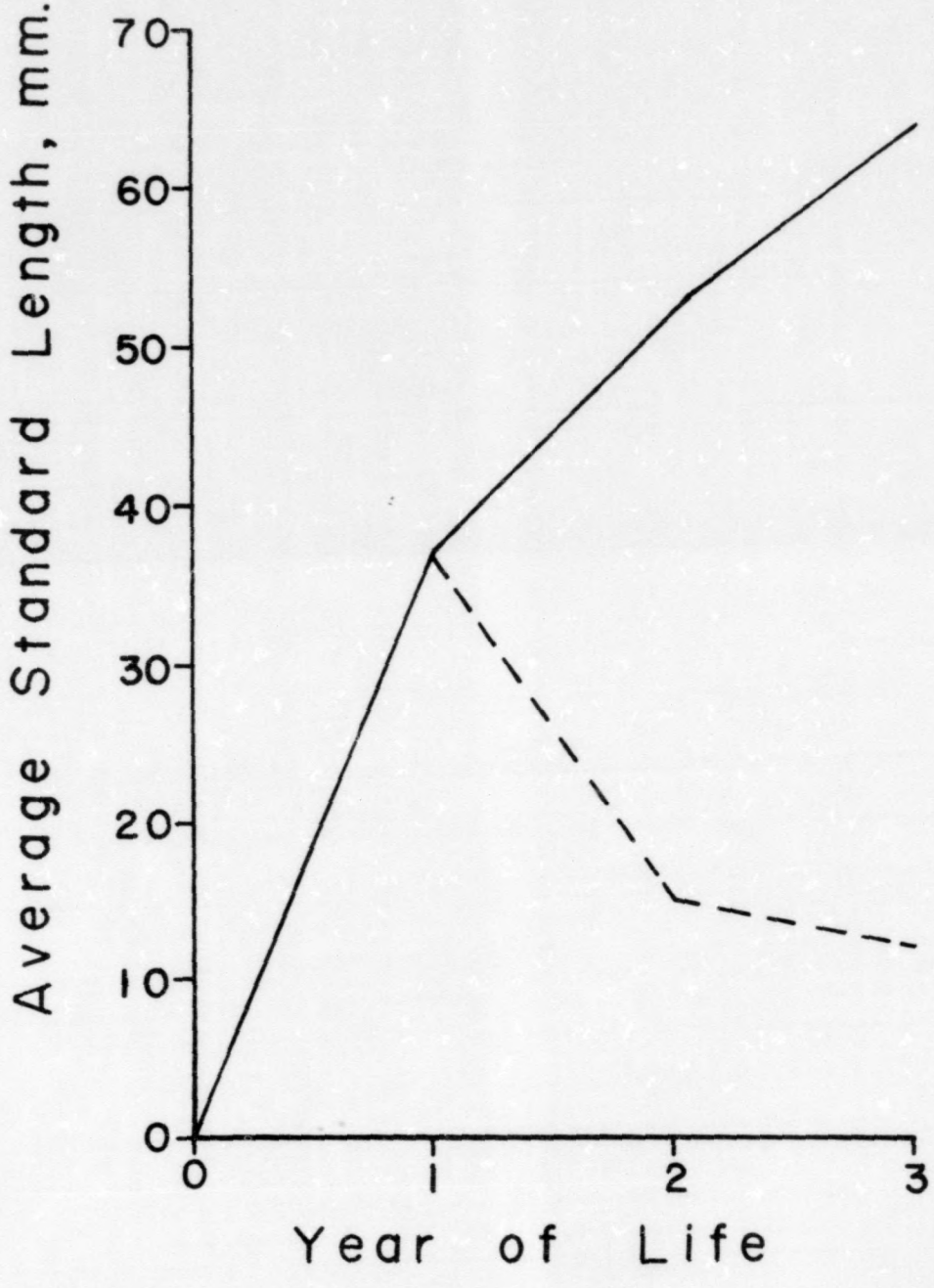
or

$$\log W = -4.8356 + 3.006 \log L$$

TABLE 5. Average standard lengths, annual length increments, and annual percentages of increase in standard lengths and absolute growth of southern redbelly dace in Ivy Creek, Warren County, Kentucky, from February, 1971 to January, 1972.

	Year of Life		
	1	2	3
Standard Length (mm)	37	52	64
Length Increment (mm)	37	15	12
Percentage Increase	--	41	23
Percent of Total Absolute Growth	57	24	19

Figure 12. Average calculated standard length at end of each year of life (solid line) and average yearly increment of growth (broken line) of southern redbelly dace in Ivy Creek, Warren County, Kentucky, collected from February, 1971 to January, 1972.


Average Standard Length, mm.
70
60
50
40
30
20
10
0
0
1
2
3
Year of Life

Analyses of covariance revealed no significant deviation from the theoretical cubic response of increase in weight to the increase in length (P = 5%) for any of the seasonal equations. However, calculated values (Table 6, Figure 13) revealed some visually discernible differences in the length-weight relationship among the three seasonal periods. The highest length-weight values were observed for specimens during the warm-water and cool-water periods, respectively.

Length-weight equations for each sex were as follows:

$$\text{Males } W = 3.332 \times 10^{-5} L^{2.809}$$

or

$$\log W = -4.4774 + 2.809 \log L$$

$$\text{Females } W = 2.220 \times 10^{-5} L^{2.916}$$

or

$$\log W = -4.6537 + 2.916 \log L$$

An analysis of covariance revealed no significant deviation from the cubic response at the 5% level of probability. However, calculated values (Table 7, Figure 14) revealed that male southern redbelly dace in Ivy Creek were proportionally heavier than females until approximately 46 mm SL was attained. At that length, a reversal of the trend occurred, as illustrated by the crossing of regression lines in Figure 14.

The overall length-weight relationship for 864 southern redbelly dace from Ivy Creek was as follows:

$$W = 1.412 \times 10^{-5} L^{3.033}$$

or

TABLE 6. Length-weight relationship and coefficients of condition (K) of southern redbelly dace based on empirical averages and calculated weights of fish collected during three seasons, from Ivy Creek, Warren County, Kentucky, February, 1971 to January, 1972.

Standard Length (mm)	Empirical Average			Calculated Weights			K		
	Spawning Season	High Temp.	Low Temp.	Spawning Season	High Temp.	Low Temp.	Spawning Season	High Temp.	Low Temp.
14		0.043			0.042			1.57	
18		0.093			0.090			1.59	
22	0.130	0.164		0.165	0.166		1.22	1.54	
24	0.230	0.213		0.221	0.217		1.66	1.54	
26	0.280	0.275	0.239	0.283	0.277	0.262	1.59	1.56	1.36
28	0.335	0.360	0.318	0.356	0.347	0.327	1.52	1.64	1.45
30	0.449	0.463	0.426	0.440	0.428	0.402	1.66	1.71	1.58
32	0.571	0.525	0.480	0.538	0.521	0.488	1.74	1.60	1.46
34	0.671	0.700	0.594	0.649	0.626	0.586	1.71	1.78	1.51
36	0.841	0.760	0.745	0.776	0.745	0.696	1.80	1.63	1.60
38	1.018	0.790	0.792	0.916	0.879	0.819	1.86	1.44	1.44
40	1.142	1.040	1.063	1.073	1.026	0.956	1.78	1.63	1.66
42	1.317	1.254	1.090	1.248	1.192	1.106	1.78	1.69	1.47
44	1.570	1.433	1.330	1.442	1.374	1.273	1.84	1.68	1.56
46	1.363	1.553	1.503	1.655	1.573	1.455	1.40	1.60	1.54
48	1.830	1.734	1.701	1.887	1.789	1.652	1.65	1.57	1.54
50	2.085	2.023	1.857	2.142	2.028	1.869	1.67	1.62	1.49
52	2.650	2.260	2.066	2.418	2.284	2.103	1.88	1.61	1.47
54	2.258	2.455	2.340	2.718	2.563	2.355	1.43	1.56	1.49
56	2.780	2.783	2.530	3.041	2.863	2.628	1.58	1.58	1.44
58		2.920	2.140		3.185	2.919		1.50	1.10
60	4.120		3.260	3.767		3.234	1.91		1.51
65	4.020			4.824			1.46		

Figure 13. Relationship between standard length and body weight of southern redbelly dace during three seasonal periods in Ivy Creek, Warren County, Kentucky, February, 1971 to January, 1972. A. During the spawning season (March - June), B. During the warm-water period (July - October), and C. During the cool-water period (November - February).

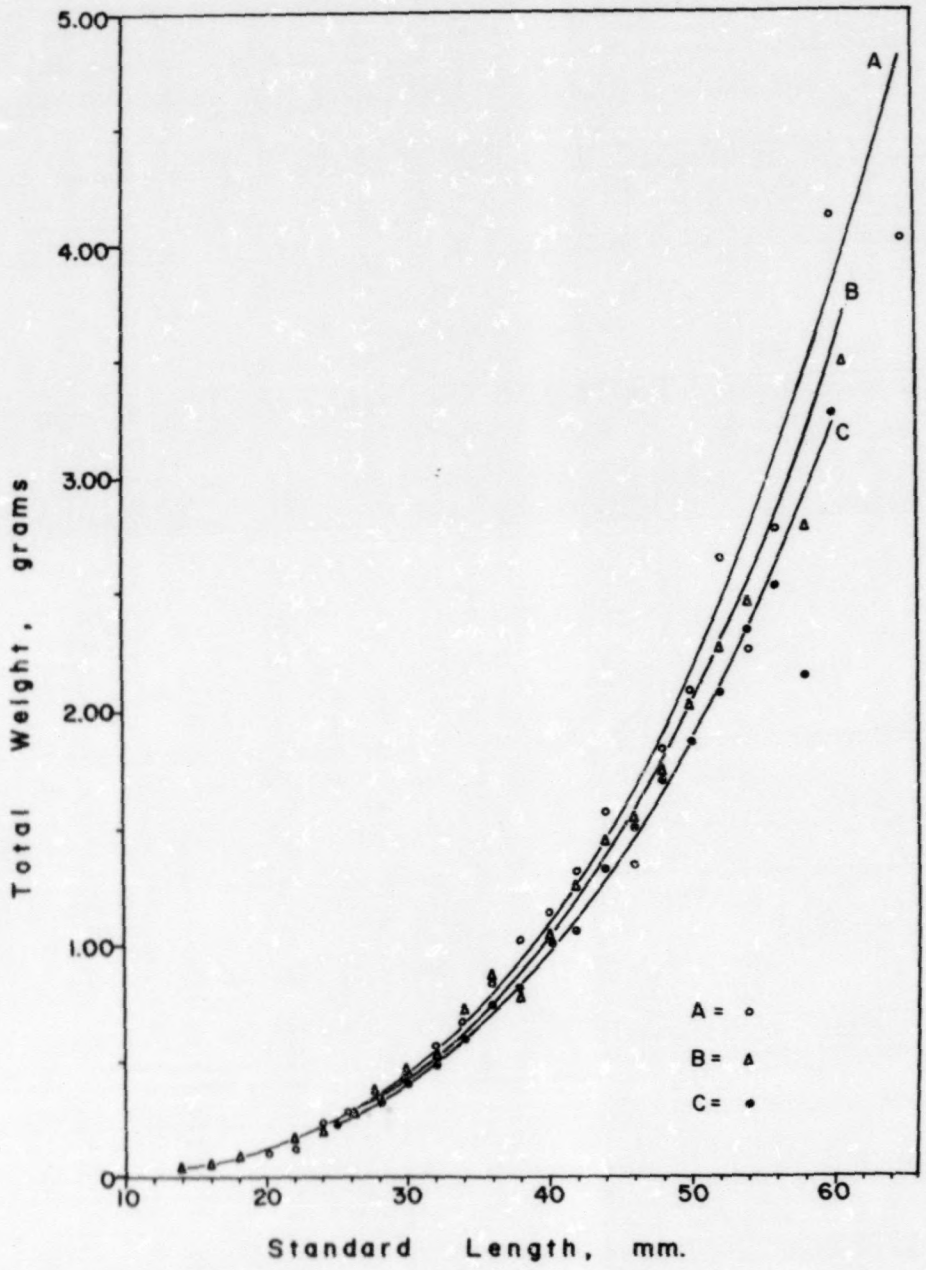
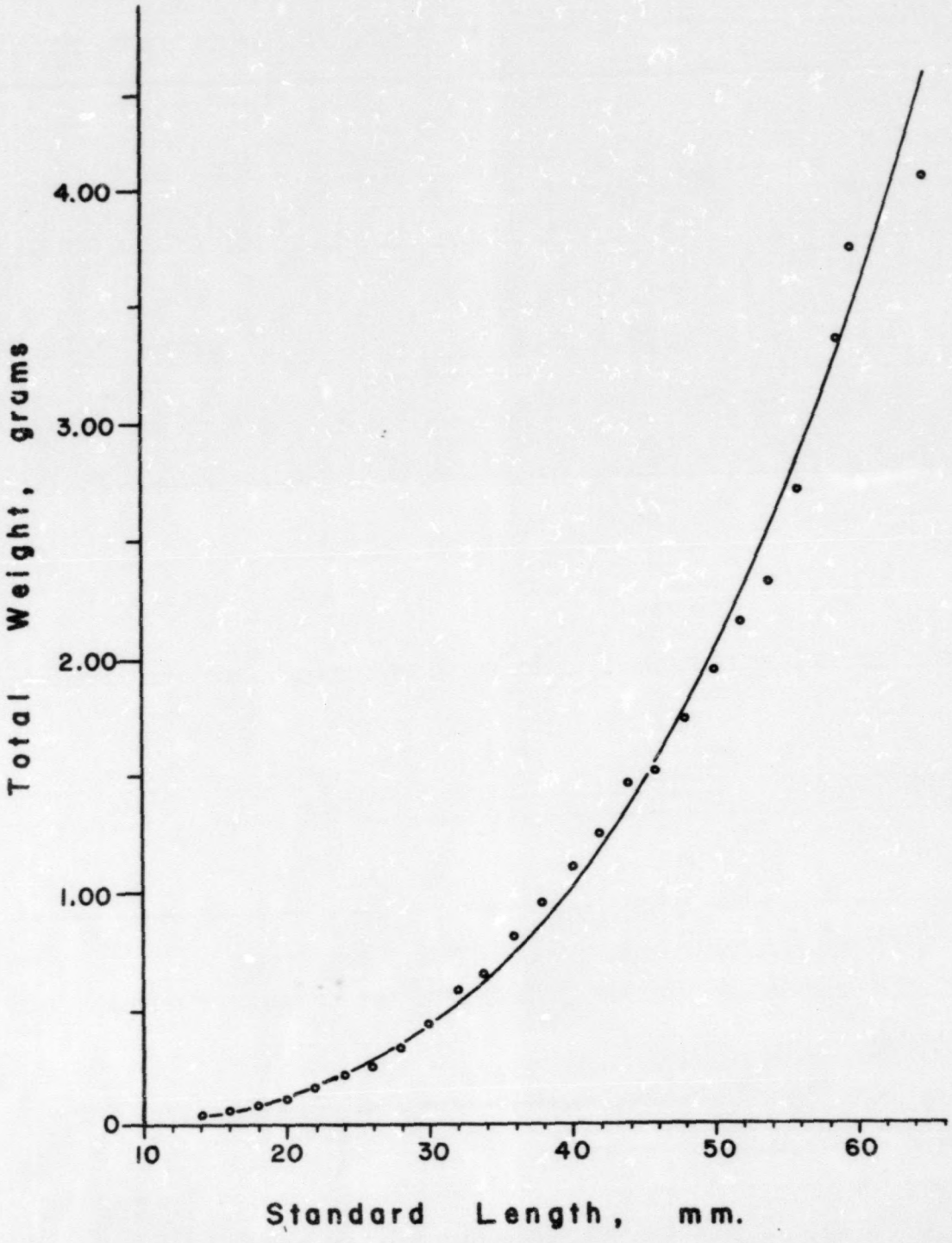

5.00
4.00
3.00
2.00
1.00
0
Total Weight, grams
10
20
30
40
50
60
Standard Length, mm.
A
B
C
A = ○
B = △
C = ●

TABLE 7. Length-weight relationship and coefficients of condition (K) of male and female southern redbelly dace, based on empirical and calculated weights of 678 fish, arranged in 2-mm increments, from Ivy Creek, Warren County, Kentucky, February, 1971 to January, 1972.

Standard Length (mm)	Average Empirical Weight (g)		Calculated Weight (g)		K	
	Males	Females	Males	Females	Males	Females
30	0.456	0.431	0.470	0.450	1.69	1.60
32	0.521	0.564	0.563	0.544	1.59	1.72
34	0.652	0.629	0.668	0.649	1.66	1.60
36	0.818	0.805	0.784	0.767	1.75	1.73
38	1.016	0.890	0.913	0.877	1.85	1.62
40	1.167	1.090	1.054	1.043	1.82	1.70
42	1.224	1.265	1.209	1.201	1.65	1.71
44	1.473	1.433	1.378	1.376	1.73	1.68
46	1.502	1.509	1.561	1.567	1.54	1.55
48	1.746	1.723	1.759	1.773	1.58	1.56
50	1.928	1.964	1.973	1.998	1.54	1.57
52	2.153	2.162	2.202	2.240	1.53	1.54
54	2.436	2.208	2.449	2.501	1.55	1.40
56	2.700	2.711	2.712	2.781	1.54	1.54
58	2.140	2.920	2.992	3.079	1.10	1.50
60		3.690		3.400		1.71
65		4.020		4.292		1.46

Figure 14. Relationship between standard length and body weight in male and female southern redbelly dace from Ivy Creek, Warren County, Kentucky, February, 1971 to January, 1972.


Total Weight, grams
4.00
3.00
2.00
1.00
0
10
20
30
40
50
60
Standard Length, mm.

$$\log W = -4.8502 + 3.033 \log L$$

Calculated values are represented in Table 8 and Figure 15.

Coefficient of Condition

The coefficients of condition derived from calculated data for specimens collected during three seasonal periods, for each sex, and for all fish collected are listed in Tables 6, 7, and 8, respectively. These data indicated no detectable patterns of variation for K values calculated for different length increments.

Coefficients of condition calculated from empirical data, indicated that body condition was lowest during cool-water months and immediately after spawning (Table 9, Figure 16). Highest K values were recorded directly prior to spawning and during the warm-water period following recovery from the spawn.

With the exceptions of February and March, males were generally more robust than females (Table 9, Figure 16). During May, females had higher overall coeffients of condition, but much of the weight component used to calculate their K values was due to the gonadal component. Condition coefficients calculated with gonads excised revealed that males were more robust somatically than were females (Figure 16).

Growth in Weight

The absolute growth in weight proceeded very slowly during the first year of life, but accelerated weight increases occurred during the second and third years of life (Table 10, Figure 17). Redbelly dace in Ivy Creek attained

TABLE 8. Length-weight relationship and coefficients of condition (K) of southern redbelly dace, based on empirical averages and calculated weights of 864 fish, arranged in 2-mm increments, from Ivy Creek, Warren County, Kentucky, February, 1971 through January, 1972.

Standard Length (mm)	Empirical Weight (g)	Calculated Weight (g)	K
14	0.043	0.042	1.57
16	0.060	0.063	1.46
18	0.093	0.091	1.59
20	0.122	0.125	1.53
22	0.158	0.166	1.48
24	0.221	0.217	1.60
26	0.263	0.276	1.50
28	0.325	0.346	1.48
30	0.444	0.426	1.64
32	0.545	0.519	1.66
34	0.641	0.623	1.63
36	0.813	0.742	1.74
38	0.953	0.874	1.74
40	1.123	1.011	1.75
42	1.238	1.183	1.67
44	1.457	1.363	1.71
46	1.505	1.560	1.55
48	1.736	1.774	1.57
50	1.946	2.009	1.56
52	2.150	2.262	1.53
54	2.322	2.537	1.46
56	2.710	2.832	1.54
58	2.530	3.149	1.30
60	3.690	3.492	1.71
65	4.020	4.449	1.46

Figure 15. Length-weight relationship for 864 southern redbelly dace collected from Ivy Creek, Warren County, Kentucky, from February, 1971 to January, 1972.

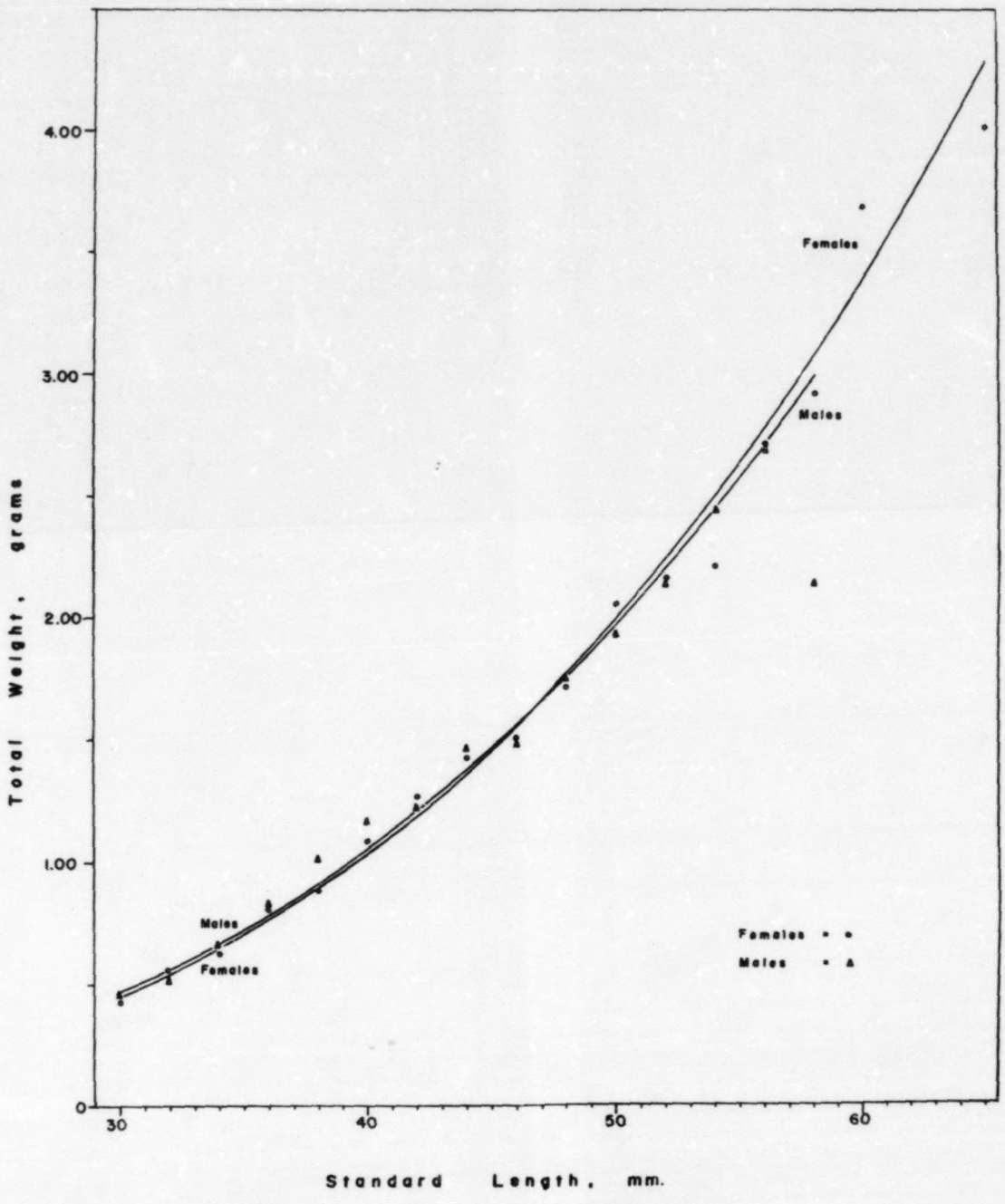

4.00
3.00
2.00
1.00
0
30
40
50
60
Total Weight, grams
Standard Length, mm.
Females
Males
Males
Females
Females
Males

TABLE 9. Monthly averages of coefficients of condition (K) for male and female southern redbelly dace with gonads intact and with gonads excised.

	Males		Females	
Month	Gonads Intact	Gonads Excised	Gonads Intact	Gonads Excised
February	1.21	1.20	1.25	1.24
March	1.43	1.42	1.49	1.46
April	1.82	1.80	1.80	1.73
May	1.80	1.78	1.84	1.73
June	1.75	1.74	1.70	1.59
July	1.56	1.56	1.51	1.49
August	1.69	1.69	1.64	1.61
September	1.57	1.56	1.57	1.55
October	1.65	1.64	1.60	1.56
November	1.61	1.60	1.64	1.59
December	1.54	1.53	1.51	1.45
January	1.58	1.57	1.57	1.52

Figure 16. Monthly averages of coefficients of condition (K) for male and female southern redbelly dace from Ivy Creek, Warren County, Kentucky, February, 1971 to January, 1972. Solid bar represents females, scored bar represents males, and stippled bar segments represent gonadal components of total condition values.

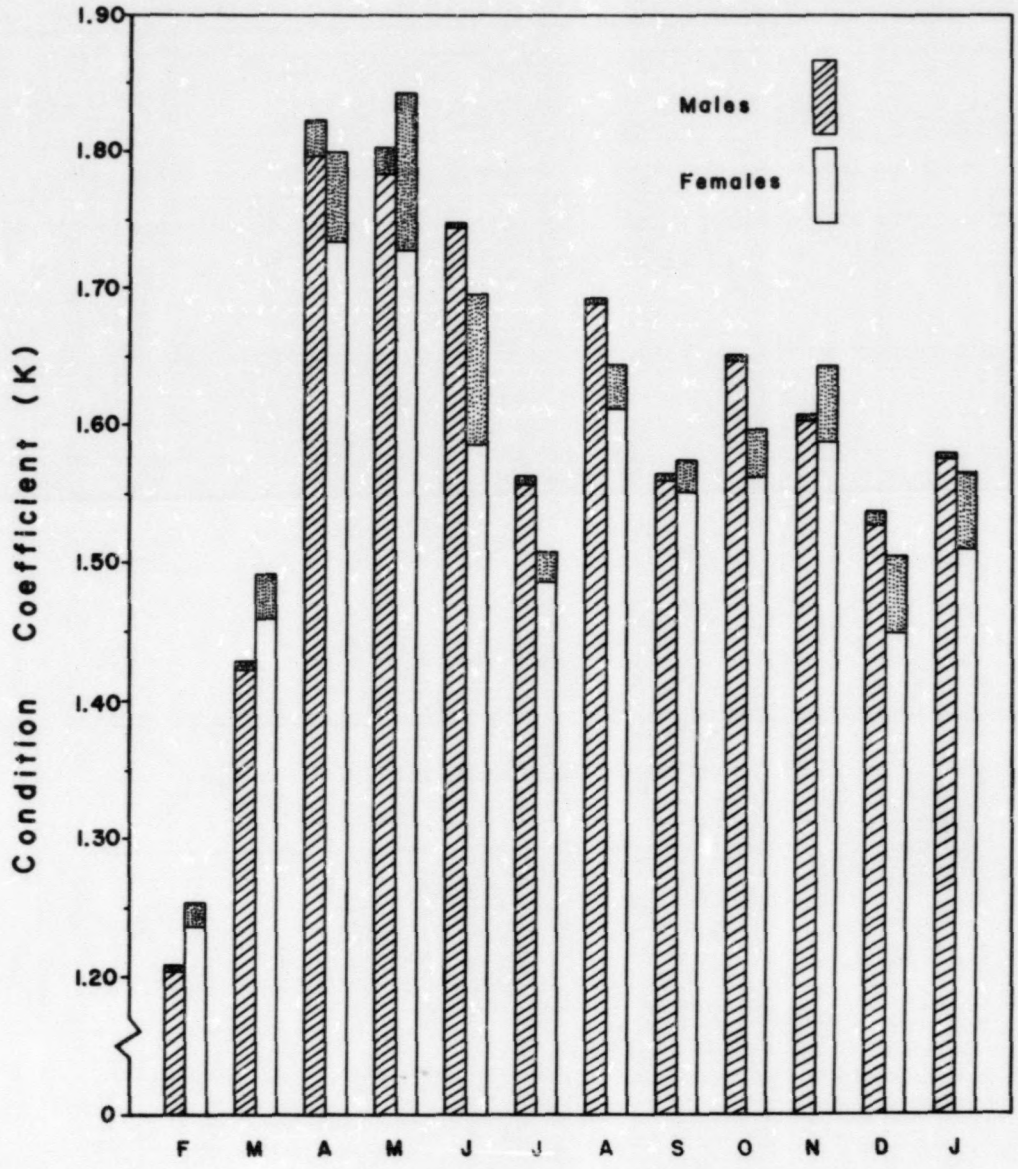
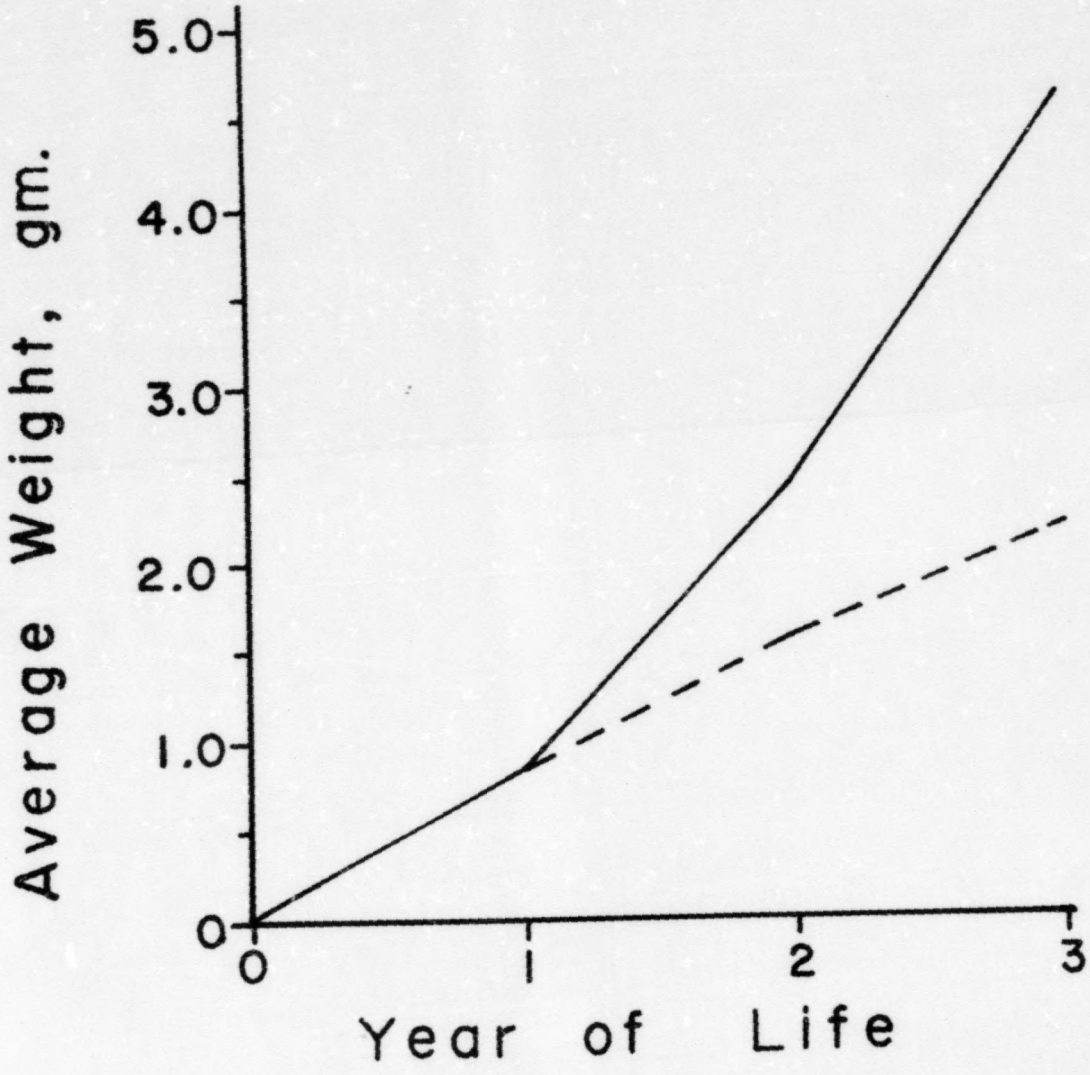

Condition Coefficient (K)
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
0
Males
Females
F
M
A
M
J
J
A
S
O
N
D
J

TABLE 10. Average calculated weights, annual weight increments, and annual percentage weight increase and percent of total weight gain for southern redbelly dace in Ivy Creek, Warren County, Kentucky, February, 1971 to January, 1972.

	Year of Life		
	1	2	3
Calculated average weight (g)	.84	2.42	4.60
Weight Increment (g)	.84	1.58	2.18
Percentage of Increase	---	188.00	138.00
Percentage of total weight	18.00	34.00	48.00

Figure 17. Average calculated weight at the end of each year of life (solid line) and average yearly increment of growth (broken line) of southern redbelly dace in Ivy Creek, Warren County, Kentucky, February, 1971 to January, 1972.


Average Weight, gm.
5.0
4.0
3.0
2.0
1.0
0
0
1
2
3
Year of Life

only 18% of their total weight potential during their first year of life and 34% during the second year. The remaining 48% of total weight growth occurred during the third year.

General Discussion

At the time of this writing, no extensive reports concerned with the age and growth of C. erythrogaster could be found in the literature. Trautman (1957) reported that young-of-the-year redbelly dace in Ohio ranged from 0.7 to 1.5 inches in October. Presumably, these data represented total lengths and were translated to 18 to 38 mm. Using the calculated factor of 1.23 (TL/SL), it was deduced that redbelly dace reported by Trautman (1957) ranged from 15 to 31 mm SL in October. During the present study, young-of-the-year southern redbelly dace ranged from 21 to 41 mm in October.

Trautman (1957) also reported that redbelly dace in Ohio ranged from 1.0 to 1.8 inches at the end of "about" one year. Translated into metric units, those values indicated ranges of 25 to 46 mm and 20 to 37 mm for total and standard lengths, respectively. Standard lengths ranged from 29 to 44 mm for year-old southern redbelly dace in Ivy Creek.

In regard to older dace, Trautman (1957) reported that "adults" ranged in length from 1.5 to 3.0 inches or 38 to 76 mm. Standard length equivalents would have ranged from 31 to 69 mm. Ivy Creek specimens ranged from 37 to 65 mm SL during their second and third years.

It appeared that southern redbelly dace in Ivy Creek grew somewhat faster during their first year than did Ohio

representatives of the species. Barlow (1961) reported that "differences between populations of a fish species are environmentally induced, unless a genetic basis can be established experimentally." He further stated that "northern representatives of a species grow slower . . . than do their southern counterparts." It is thus quite feasible that differences in environmental factors may have resulted in variations in growth rates between southern redbelly dace in Ohio and their more southern counterparts in Ivy Creek. Because length ranges for "adults" reported by Trautman (1957) were relatively consistent with those of Ivy Creek, it may also be assumed that length maxima were comparable, though they may have been reached earlier in life among Ivy Creek representatives.

Age groups were assigned to 900 southern redbelly dace, collected on two occasions in Oklahoma during July, by Hill and Jenssen (1968). Specimens up to 24 mm SL were assigned to age group 0, from 30.0 to 39.5 mm to age group I, and individuals 40 to 55 mm SL to age group II. Assignments of age group 0 specimens appeared valid since they were distinct on the length-frequency distribution. This range closely coincided with the 14 to 25 mm range observed for age group 0 specimens collected from Ivy Creek in July.

However, Hill and Jenssen (1968) used the acquisition of secondary sexual characteristics to separate age groups I and II, stating that dace 30.0 to 39.5 mm lacked such characteristics and were thus representative of age group I. Individuals 40 mm SL and longer were sexually mature and were thus

designated to age group II. This criterion was invalid for southern redbelly dace in Ivy Creek because most age group I fish were sexually mature and ranged to 52 mm SL in July. This might also have been applied to specimens studied by Hill and Jenssen because they lacked long-range length-frequency data on which to base their conclusions.

It was observed that Oklahoma and Ivy Creek representatives of C. erythrogaster acquired secondary sexual characteristics at approximately the same lengths (39 to 40 mm SL) and had comparable size ranges for young-of-the-year specimens. It was thus concluded that rates of growth and maturation followed the same chronological sequence for Oklahoma and Ivy Creek southern redbelly dace.

Length-weight data revealed that southern redbelly dace in Ivy Creek adhered statistically to the cube law, or the tendency to acquire weight in proportion to the cube of length. There were no statistical differences in cubic regressions among the three designated seasonal periods, or between the sexes. However, it was observed that specimens were generally more robust during the spawning period due to gonadal development. Specimens collected during the warm-water period (July through October) were proportionally heavier than those collected during the cool water period. That difference may be attributed to the availability and acquisition of food, which varied greatly between the two latter seasonal periods.

Coefficients of condition reflected the length-weight relationships. Values were highest during the spawning season for both sexes and for both somatic and overall condition. Condition declined sharply immediately after spawning and then showed recovery during the warm-water period. Somewhat lower conditions were observed during the cool water period.

Though the length-weight relationships between males and females were basically similar, it was observed that males were slightly heavier-bodied until standard lengths greater than about 40 mm were attained. At these lengths, females tended to overtake the males and become somewhat heavier proportionally. Because sexual maturation occurred at approximately 39 mm SL, it was concluded that increase in ovarian development accounted for the apparent reversal in the length-weight relationships between males and females. With few exceptions, males were somatically more robust than were females.

Allometry

Though allometric studies of C. erythrogaster in Ivy Creek were not attempted (with the exception of fin lengths, included under Sexual Dimorphisms in the discussion of reproduction), a work by Phillips (1969b), regarding the allometric relationships in the southern redbelly dace, was found valuable in understanding overall growth and development of the species.

Phillips (1969b) used computor analyses on 24 morphological characters from 230 specimens of C. erythrogaster in Minnesota. Resulting means for each character were paired with each remaining character and analyzed for possible correlation. Results yielded correlation coefficients greater than 0.9 for each pair of characters. This indicated that each morphological character tested increased proportionately with total length. That is, southern redbelly dace tended to retain the same basic body form throughout life.

The greatest ontogenetic change involved the angle of the mouth which became less oblique as growth proceeded. The mean angulation of the mouth was 54° for specimens averaging 27.5 mm TL and 48° for those averaging 75.0 mm TL.

Food Habits

Components of the Diet

Sand, silt and detritus represented the only consistently ingested dietary components for southern redbelly dace in Ivy Creek. Biotic components of the diet were represented chiefly by diatoms which included Navicula spp., Coconeis spp., Gomphonema spp., Nitzschia spp., Cymbella spp., and Melosira spp. Among the specimens smaller than 35 mm SL, diatoms apparently provided the major component of the diet.

Southern redbelly dace of moderate size (i.e., 35 to 50 mm SL) also depended heavily on the microscopic components of the diet, but midge largae (Chironomidae) were often found in the gut contents. Larger dace, those longer than

50 mm SL, frequently ingested immature insect forms of the orders Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly).

From May through August, specimens of all sizes ingested large quantities of the filamentous green alga Spirogyra. In some specimens, large masses of this alga filled most of the alimentary tract, though it was difficult to detect the degree to which digestion had taken place.

Discussion

Feeding behavior among southern redbelly dace in Ivy Creek appeared to have been a non-selective ingestion of sand and silt which contained algae and non-descript bits of organic material, as well as some predation on insects. This was consistent with the findings of Forbes and Richardson (1920) who stated that, among specimens collected in Illinois, food ". . . is evidently obtained by nibbling or sucking the surface slime from stones and other objects on the bottom. It consists . . . mainly of mud containing algae . . .." Similar observations were recorded by Phillips (1969a).

Because of the tendency toward random, non-selective feeding behavior, it might be expected that materials ingested by dace should have reflected that which was available in the stream at the time of capture. Collections from the stream proper and its sediments indicated that algal forms most frequently found among the gut contents of southern

redbelly dace in Ivy Creek were also most abundant in the stream. Phillips (1969a) reported that Navicula was the most abundant dietary component for redbelly dace in Minnesota. This was also the case for specimens from Ivy Creek. Similarly, Phillips (1969a) reported Gomphonema and Nitzschia to be frequently found in the diets of dace, as was the case for Ivy Creek specimens. The requirements of habitat and other environmental factors shared by both Minnesota and Ivy Creek representatives of the species no doubt resulted in similarities in diet.

From May through August, Spirogyra was used extensively as food by southern redbelly dace in Ivy Creek. Records for that period indicated that the appearance of that alga in the diet coincided precisely with its profuse growth along the stream's edge. This was also indicative of the opportunistic feeding behavior of C. erythrogaster. In regard to the utilization of Spirogyra as food, Phillips (1969a) found it to be "nutritionally unimportant to C. erythrogaster in the stream" but that it was "readily eaten in aquarium experiments." During periods of abundance, Spirogyra formed a significant component of the diet for redbelly dace in Ivy Creek.

Cladophora, another green alga, was found growing abundantly in Ivy Creek but was rarely found in the diets of redbelly dace. Phillips (1969a) stated that this alga was eaten by C. erythrogaster in Minnesota ". . . only when starved and

when no other food was present." This he attributed to the rough texture of Cladophora and its thick-walled cells.

Faunal components of the diet of southern redbelly dace in Ivy Creek included immature forms of various aquatic insects. When only fragments of such forms were observed in the guts of specimens it was difficult to tell whether the entire insect had been eaten or if those fragments had been passively ingested with silt and sand. However, on some occasions, entire bodies of aquatic insects were found partially digested in the alimentary tracts of dace. The size of the fish appeared to dictate the size of the food item consumed. It was assumed that such insects were actively pursued and ingested. It was reported that C. erythrogaster in New York actively preyed upon midge larvae (Needham, 1908).

Though no attempt was made to study the daily cyclic feeding behavior of the southern redbelly dace in Ivy Creek, Phillips (1969a) found that dace in Minnesota fed most actively "around midday" with a marked decrease in activity at night.

Meristics

Pectoral Fin Rays

The number of rays in the pectoral fins showed the greatest variation of all characters studied (Table 11). A range of 11 to 17 rays was observed with 42% of the sample having 15 rays. The mean for the sample was 15.25

Pelvic Fin Rays

The modal tendency for pelvic fin rays was 8, with 82% of the sample demonstrating that trend (Table 11). Two percent of the sample bore 7 rays while 16% had 9. The mean number of rays in the pelvic fins was 8.14.

Anal Soft Rays

The number of principal rays in the anal fin was generally 8, with 95% of the sample demonstrating that trend (Table 11). Two percent of the sample had 7 rays while 3% had 9. The mean number of anal soft rays was 8.01.

Dorsal Soft Rays

The mode for the number of principal soft rays in the dorsal fins was 8 (Table 11). Only one specimen had 7 rays and two specimens had 9. The average number of dorsal soft rays was 8.01.

Scales of the Lateral Row

The number of scales in the lateral row showed much variation in southern redbelly dace in Ivy Creek (Table 12). Of the 18 specimens examined, the distribution of scale counts was as follows: counts of 72, 74, 77, 78, 84, 85 and 92 were made on one specimen each; counts of 81, 82, 91 and 95 scales were made for two specimens each; and three specimens had 83 lateral row scales. The mean for this highly variable range was 83.8.

TABLE 11. Distribution of fin ray counts among specimens of Chrosomus erythrogaster collected from Ivy Creek, Warren County, Kentucky.

Fin	Number of Rays											
	7	8	9	10	11	12	13	14	15	16	17	$\bar{x}$
Pectoral					1	1	5	8	42	36	7	15.25
Pelvic	2	82	16									8.14
Dorsal	1	97	2									8.01
Anal	2	95	3									8.01

TABLE 12. Distribution of lateral row scale counts among 18 specimens of Chrosomus erythrogaster collected from Ivy Creek, Warren County, Kentucky.

Scale Count	N	Scale Count	N	Scale Count	N
72	1	80		88	
73		81	2	89	
74	1	82	2	90	
75		83	3	91	2
76		84	1	92	1
77	1	85	1	93	
78	1	86		94	
79		87		95	2

Discussion

Meristic counts, described as the number of elements in serially repeated characters (Barlow, 1961), are of taxonomic significance and thus are generally included in the complete description of a fish species. Meristic characters are often quite variable within a species or population. Both environmental factors and genetic controls seem operative in the development of meristic characters. Included as environmental controls of meristic expression are temperature, salinity and dissolved oxygen concentration (Barlow, 1961), light duration (Lindsey, 1958), light intensity (McHugh, 1954), and radiation (Egami, 1963).

During the present study, a range of 11 to 17 pectoral fin rays was observed, with a mode of 15. Hill and Jenssen (1968) observed a range of 13 to 19 and a mode of 15 for pectoral fin rays among southern redbelly dace in Oklahoma. In tabulating data reported by Phillips (1968a), pectoral fin ray counts ranged from 13 to 17, with a mode of 14 and a mean of 14.5, for southern redbelly dace in Minnesota. Thus from all available data, the pectoral fin ray count for C. erythrogaster ranged from 11 to 19 with an overall mean of about 15. The variability of this character makes it a poor diagnostic feature for the species.

The pelvic fin rays demonstrated much less variability than did the pectoral fins. Phillips (1968a, 1969b) reported that all southern redbelly dace examined bore 8 pelvic fin rays. The Ivy Creek specimens showed some variability for

the character but the modal value of 8 rays was consistent with that found among the Minnesota representatives of the species.

The median fins appeared to be most constant in regard to numbers of principal rays. Specimens in Ivy Creek had a mode of 8 and a mean of 8.01 for both the anal and dorsal soft ray counts. Phillips (1968a, 1969b) observed means of 8.00 and 7.94 for the dorsal and anal fins, respectively. Hill and Jenssen (1968) reported modes of 10 and 11 for the dorsal and anal fins, respectively. However, they also reported that all visible rays were counted. It was likely that they counted the rudimentary anterior rays, as well as recording the last bisected ray as two rays. According to Hubbs and Lagler (1964) rudimentary rays should not be counted as principal rays and bisected rays should be counted as one. Because the anal and dorsal fins bear two and one rudimentary rays, respectively, as well as one bisected ray, it must be assumed that these were incorrectly enumerated by Hill and Jenssen (1968). This would account for the differences between their data and those of this study.

Counts of the principal rays of the caudal fin were not undertaken during the current study. However, Phillips (1968a, 1969b) reported that southern redbelly dace in Minnesota generally had 19 principal rays in the caudal fin, with a few fish having 18.

The number of scales in the lateral series were extremely difficult to enumerate because of their minute size.

Lateral scale counts ranged from 72 to 95 for Ivy Creek specimens, with a weak mode of 83 and a mean of nearly 84. Phillips (1969b) reported a mean count of 83.5 while Eddy (1969) reported "about" 85 scales in the lateral series. Other published ranges for lateral scale counts of C. erythrogaster were: 84 to 92 (Fowler, 1929), 77 to 91 (Koff, 1962), and 70 to 95 (Trautman, 1957). The data of the present study appeared consistent with published information regarding this character.

It was concluded that the genetic factors controlling the expression of meristic characters in C. erythrogaster are relatively constant throughout its geographical range, as judged by the overall consistency in the expression of those characters. The specific habitat requirements of the species may also have been involved with such consistency. The variations which were observed were believed to be the products of environmental factors which may have altered the phenotypic expression of the meristic traits studied.

Faunal Associations

Associated Ichthyofauna

In Ivy Creek, C. erythrogaster was second in relative abundance only to the bluntnose minnow, Pimephales notatus. Consistently collected with southern redbelly dace were the rosefin shiner, Notropis ardens, spottail darter, Etheostoma squamiceps, creek chub, Semotilus atromaculatus, and the stoneroller, Campostoma anomalum. A list of the ichthyofauna

in Ivy Creek, in descending order of relative abundance, appears in Table 13.

Phillips (1968a) found that, in Minnesota streams, C. erythrogaster was most frequently found associated with the following: Notropis cornutus (Mitchell), N. dorsalis (Agassiz), Pimephales notatus (Rafinesque), Etheostoma nigrum (Rafinesque), and Campostoma anomalum (Rafinesque).

Predators

No direct evidence was found regarding the degree to which C. erythrogaster in Ivy Creek was preyed upon by other species. Potential predators included the white sucker, longear sunfish, and large creek chubs. Other predators may have been the snapping turtle, Chelydra serpentina L., the water snake, Natrix sipedon (L.) and possibly crayfish.

Perhaps man represents the greatest threat to southern redbelly dace in their natural habitat. The suitability of C. erythrogaster as a bait fish and its susceptibility to seining may lead to severe depletion of the species in frequently seined streams. Trautman (1957) stated: "Schooling dace were extremely vulnerable to capture by bait seiners, and in a few hours two commercial bait seiners could capture 75% of the dace population in a half-mile stream."

Parasites

No detailed study of the parasites of the southern redbelly dace in Ivy Creek was undertaken. However, none of the specimens examined during the course of the study were

TABLE 13. A listing of the ichthyofauna of Ivy Creek, in order of decreasing relative abundance, Warren County, Kentucky, February, 1971 to January, 1972.

Pimephales notatus (Rafinesque), Cyprinidae, Bluntnose minnow

Chrosomus erythrogaster Rafinesque, Cyprinidae, Southern Redbelly dace

Notropis ardens (Cope), Cyprinidae, Rosefin Shiner

Etheostoma squamiceps Jordan, Percidae, Spottail Darter

Semotilus atromaculatus (Mitchill), Cyprinidae, Creek Chub

Etheostoma simoterum (Cope), Percidae, Tennessee Snubnose Darter

Cottus carolinae (Gill), Cottidae, Banded Sculpin

Etheostoma caeruleum Storer, Percidae, Rainbow Darter

Catostomus commersoni (Lacepede), Catastomidae, White Sucker

Lepomis megalotis (Rafinesque), Centrarchidae, Longear Sunfish

Etheostoma flabellare Rafinesque, Percidae, Fantail Darter

Campostoma anomalum (Rafinesque), Cyprinidae, Stoneroller Minnow

Notropis cornutus (Mitchill), Cyprinidae, Common Shiner

Erimyzon oblongus (Mitchill), Catostomidae, Creek Chubsucker

noticeably parasitized externally or internally. Phillips (1968a) found that southern redbelly dace from Minnesota streams were lightly parasitized by "neascus" cercariae (Trematoda), a condition commonly called "blackspot". Phillips (1968a) also concluded that redbelly dace were far less susceptible to blackspot, as well as to other parasites, than were other cyprinids living in association with them.

SUMMARY

Aspects of the life history of the southern redbelly dace, Chrosomus erythrogaster Rafinesque, in Ivy Creek, Warren County, Kentucky, were studied from February, 1971 to January, 1972.

Redbelly dace inhabit streams from the northern boundary of the United States southward to Mississippi and Alabama, and from the Atlantic coastal states westward to Kansas and Oklahoma. Within this geographical range dace are found only in streams which meet the rigid habitat requirements of the species. Headwater areas of springfed streams which are clear, free from pollution, with steep to moderate gradients, cover, and rocky or pebbly substrata, represent the most ideal habitats for redbelly dace. In Kentucky, such streams are found primarily in the eastern and central portions of the state but not in the extreme west.

Gonosomatic indices, development of ova and the appearance of fry indicate that spawning takes place from latter May through June. Older dace may spawn earlier in May while those Age Group 0 fish which mature late in the reproductive season spawn later in June.

Fecundity for C. erythrogaster appeared relatively low for a species which provides no protection for eggs. Numbers

of primary ova ranged from 140 to 681 with a positive correlation between the number of primary ova and the standard length of the fish.

Dimorphisms between the sexes included coloration, the presence of breeding tubercles, and the size of the pectoral fins. Males typically had more distinct color markings, particularly during the reproductive season when the abdomen turned scarlet. Also during the spawning season, males developed distinct breeding tubercles on the head and fins. At all times of the year males had longer and broader pectoral fins than did females.

The Chi-Square test, applied to 768 southern redbelly dace, revealed no statistically significant deviation from the 1:1 sex ratio at the 5% level of probability.

Studies of age, length and growth revealed that redbelly dace in Ivy Creek lived about two years with a few living to autumn of their third year. Males appeared to have a shorter lifespan than did females.

Age Group 0 dace were the dominant year-class in the overall population.

The greatest rate of growth in length took place during the first year of life, while growth in weight was greatest during the second and third years. At the end of their first year, southern redbelly dace in Ivy Creek averaged 37 mm SL and 0.84 grams in weight. After two years, standard lengths averaged over 50 mm and dace had a mean weight of 2.42 g.

Third year fish had standard lengths and weights which averaged 60 mm and 4.60 g respectively.

Length-weight studies indicate that there was no statistically significant deviation from the theoretical cubic response of weight growth to length growth. Slight differences were observed in the length-weight relationships during different seasons and between the sexes, though these were not considered significant.

Studies concerning the coefficient of condition (K) indicated that, somatically, males were more robust than were females, but that during some months, primarily during the spawning season, females had higher apparent total condition values due to ovarian development. Coefficients of condition for both sexes were highest during the spawning season, followed by the warm-water months, and were lowest during the cold-water periods.

Southern redbelly dace are opportunistic feeders which depend primarily on algal and organic materials passively ingested with silt and sand as a source of food. Aquatic insects may be actively pursued and eaten by larger dace.

Averages for principal rays in the pectoral, pelvic, dorsal, and anal fins were 15, 8, 8, and 8 respectively. The mean lateral scale count was about 84.

Chrosomus erythrogaster in Ivy Creek appears to be most often associated with Pimephales notatus, Notropis ardens, Etheostoma squamiceps and Semotilus atromaculatus. Predation is limited to a few larger species of fish as well

as by the snapping turtle, water snake and possibly crayfish. Man represents a serious threat to C. erythrogaster because of their susceptibility to seining. Southern redbelly dace in Ivy Creek appear to be relatively resistant to parasitism.

LITERATURE CITED

Anonymous. 1965. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, New York. 769 p.

Bailey, R. M., J. E. Fitch, E. S. Herald, E. A. Lachner, C. C. Lindsey, C. R. Robins and W. B. Scott. 1970. A List of the Common and Scientific Names of Fishes from the United States and Canada. 3rd Ed. Amer. Fish. Soc., Spec. Publ. 6. 150 p.

Banarescu, P. 1964. Fauna Republicii Populare Romine (Pisces-Osteichthyes). Volumul XIII. Acad. Republ. Pop. Romine, Bucuresti. pp. 336-337.

Barlow, G. W. 1961. Causes and significance of morphological variation in fishes. Syst. Zool., 10:105-117.

Branson, B. A. 1973. Seldom-seen Kentucky fish. The Courier-Journal & Times Magazine, Louisville, Kentucky, February 25, 1973:26-33.

Breder, C. M. and D. E. Rosen. 1966. Modes of Reproduction in Fishes. The Natural History Press, Garden City, N. Y. 941 p.

Bullough, W. S. 1939. A study of the reproductive cycle of the minnow in relation to the environment. Proc. Zool. Soc. London, 109:79-102.

Cahn, A. R. 1927. An ecological study of southern Wisconsin fishes. The brooks silversides (Labidesthes sicculus) and the cisco (Leucichthyes artedi) in their relation to the region. Illinois Biol. Monogr., 11:1-152.

Carlander, K. D. 1969. Handbook of Freshwater Fishery Biology. Vol. 1. The Iowa St. Univ. Press, Ames. 752 p.

Cope, E. D. 1869a. Synopsis of the Cyprinidae of Pennsylvania. Trans. Amer. Philos. Soc., 13:351-399.

_____. 1869b. On the distribution of freshwater fishes in the Allegheny region of southwestern Virginia. J. Acad. Nat. Sci., Philadelphia. 6:207-247.

Cross, F. B. 1967. Handbook of Fishes of Kansas. Univ. Kansas Mus. Nat. Hist., Lawrence. 357 p.

Cross, F. B. and W. L. Minckley. 1960. Five natural hybrid combinations in minnows (Cyprinidae). Publ. Univ. Kansas Mus. Nat. Hist. 13:1-18.

Eddy, S. 1969. How to Know the Freshwater Fishes. Wm. C. Brown Publishers, Dubuque, Iowa. 286 p.

Egami, N. 1963. Studies on variation in numbers of anal fin rays in Oryzias latipes. Effect of X-radiation. Copeia, 1963:592-593.

Evermann, B. W. 1918. The fishes of Kentucky and Tennessee: a distributional catalogue of the known species. Bull. U. S. Bur. Fish., 35:295-368.

Forbes, S. A. and R. E. Richardson. 1920. The Fishes of Illinois. Illinois Dept. Registration and Educ., Div. Nat. Hist. Survey. 357 p.

Fowler, H. W. 1929. The red bellied dace (Chrosomus erythrogaster). Fish Culturist, 9:40-41.

Frost, W. E. 1943. The natural history of the minnow, Phoxinus phoxinus. J. Anim. Ecol., 12:139-162.

Hankinson, T. L. 1932. Observations on the breeding behavior and habits of fishes in southern Michigan. Paps. Michigan Acad. Sci., Arts. Letts., 15:411-424.

Harlan, J. R. and E. P. Speaker. 1956. Iowa Fish and Fishing. Iowa Conserv. Comm., Des Moines. 377 p.

Harrington, R. W. 1959. Photoperiodism in fishes in relation to the annual sexual cycle. In Photoperiodism and Related Phenomena in Plants and Animals, Ed. R. B. Withrow, Amer. Assoc. Adv. Sci., Washington, D.C. 903 p.

Hemphill, A. F. 1957. The southern redbelly dace, Chrosomus erythrogaster erythrogaster, from the lower Mississippi drainage. Copeia, 1957:53.

Hickling, C. F. and E. Rutenberg. 1936. The ovary as an indicator of the spawning period in fishes. J. Mar. Biol. Assoc. United Kingdom, 21:311-318.

Hill, L. G. and T. A. Jenssen. 1968. A meristic study of the redbelly dace, Chrosomus erythrogaster (Cyprinidae), from a stream in southern Oklahoma. Southwestern Naturalist, 13:55-60.

Hubbs, C. L. 1955. Hybridization between fish species in nature. Syst. Zool., 4:1-20.

Hubbs, C. L. and R. M. Bailey. 1952. Identification of Oxygeneum pulverulentum Forbes, from Illinois, as a hybrid cyprinid fish. Paps. Michigan Acad. Sci., Arts, Letts., 37:143-152.

Hubbs, C. L. and K. F. Lagler. 1964. Fishes of the Great Lakes Region. Univ. Michigan Press, Ann Arbor. 213 p.

Jordon, D. L. 1882. Report on the fishes of Ohio. In Report of the Geological Survey of Ohio, Vol. 4, Part 1, Section 4, p. 737-1000. Ohio Div. Geol. Survey, Columbus.

Jordon, D. S. 1876. Manual of the Vertebrates of the Northern United States, Including the District East of the Mississippi River, and North of North Carolina and Tennessee, Exclusive of Marine Species. Jansen, McClure and Company, Chicago. 342 p.

_____. 1924. Concerning the American dace allied to the genus Leusiscus. Copeia, 1924:70-72.

Jordon, D. S. and B. W. Evermann. 1896. The Fishes of North and Middle America. Bull. U. S. Natl. Mus., No. 47, Part 1. 954 p.

Koff, W. 1961. Red-bellied dace Chrosomus erythrogaster (Rafinesque). Fish Culturist, 40:60.

Lagler, K. F. 1956. Freshwater Fishery Biology. Wm. C. Brown Company Publishers, Dubuque, Iowa. 421 p.

Lindsey, C. C. 1958. Modification of meristic characters by light duration in Kokanee, Oncorhynchus nerka. Copeia, 1958:134-137.

McHugh, J. L. 1954. The influence of light on the number of vertebrae in the grunion, Leuresthes tenuis. Copeia, 1954:23-25.

McPhail, J. D. 1963. The post-glacial dispersal of freshwater fishes in northern North America. Ph. D. Thesis, Dept. Zool., McGill Univ., Montreal.

McPhail, J. D. and C. C. Lindsey. 1970. Freshwater Fishes of Northwestern Canada and Alaska. Fish. Res. Bd. Canada, Bull. 173, Ottawa, Ontario. 381 p.

Needham, J. G. 1908. Report of the entomological field station conducted at Old Forge, N.Y., in the summer of 1905. New York State Mus. Bull., 124:156-248.

Pennak, R. W. 1953. Freshwater Invertebrates of the United States. The Ronald Press Company, New York. 769 p.

Phillips, G. L. 1968a. Chrosomus erythrogaster and Chrosomus eos (Osteichthyes:Cyprinidae): taxonomy, distribution, ecology. Ph.D. Thesis, Dept. Zool., Univ. Minnesota. 217 p.

_____. 1968b. A note on distribution of Chrosomus erythrogaster (Cyprinidae) in the Missouri River System. Amer. Midl. Nat., 80:564-565.

_____. 1969a. Diet of minnow Chrosomus erythrogaster (Cyprinidae) in a Minnesota stream. Amer. Midl. Nat., 82:99-109.

_____. 1969b. Morphology and variation of the American cyprinid fishes Chrosomus erythrogaster and Chrosomus eos. Copeia, 1969:501-509.

Phillips, G. L. and D. A. Etnier. 1969. A 'new' hybrid minnow. J. Minnesota Acad. Sci., 35:96-97.

Rafinesque, C. S. 1820. Ichthyologia Ohiensis. W. G. Hunt, Lexington, Kentucky. 90 p.

Raney, E. C. 1947. Nocomis nests used by other breeding cyprinid fishes in Virginia. Zoologica, 32:125-132.

Smith, B. G. 1908. The spawning habits of Chrosomus erythrogaster Rafinesque. Biol. Bull., 15:9-18.

Smith, G. M. 1950. The Freshwater Algae of the United States. McGraw-Hill Book Company, New York. 518 p.

Snedecor, G. W. 1962. Statistical Methods. Iowa St. Univ. Press, Ames. 534 p.

Trautman, M. B. 1957. The Fishes of Ohio. The Ohio St. Univ. Press, Columbus. 683 p.

Welch, P. S. 1948. Limnological Methods. McGraw-Hill Book Company, New York. 381 p.

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A STUDY OF THE GRADES OF THE WESTERN KENTUCKY STATE TEACHERS COLLEGE DURING THE YEARS 1929-30, 1930-31, 1931-32

BY

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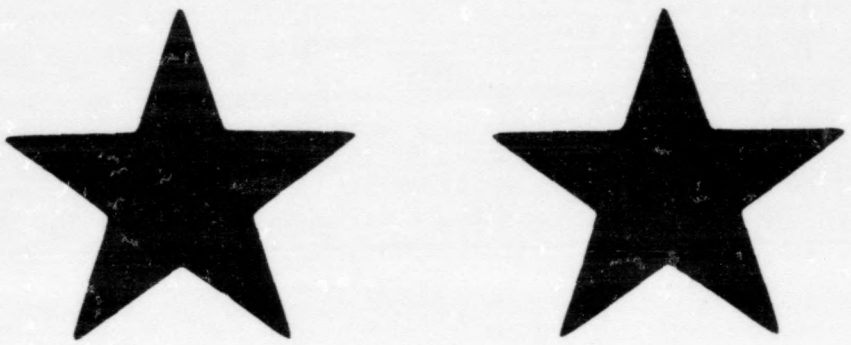

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