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SCALET, Charles George, 1942-
LIFE HISTORY OF THE ORANGEBELLY DARTER, _ETHEOSTOMA RADIOSUM CYANORUM_ (OSTEICHTHYES: PERCIDAE).

The University of Oklahoma, Ph.D., 1971
Zoology

University Microfilms, A XEROX Company, Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

LIFE HISTORY OF THE ORANGEBELLY DARTER

Etheostoma radiosum cyanorum

(OSTEICHTHYES: PERCIDAE)

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

CHARLES GEORGE SCALET

Norman, Oklahoma

1971

LIFE HISTORY OF THE ORANGEBELLY DARTER

Etheostoma radiosum cyanorum

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APPROVED BY

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DISSERTATION COMMITTEE

ACKNOWLEDGMENT

I wish to express my sincere appreciation to Dr. Loren G. Hill for his advice and encouragement during the course of this research. Thanks must also be extended to Dr. Hill for his efforts in obtaining for me financial help from the Oklahoma Biological Survey and the University of Oklahoma Biological Station. Appreciation must also be extended to Dr. Carl D. Riggs for his efforts in this area.

I greatly appreciate the critical reading of this manuscript by Drs. Loren G. Hill, Harley P. Brown, and Elroy L. Rice. Much gratitude is also extended to Dr. Andrew Robertson for his reading of the manuscript. I also wish to thank the University of Oklahoma for research space and equipment.

I would also like to thank Dr. Glenn L. Hoffman of the Eastern Fish Disease Laboratory for verifying my identification of various parasites encountered during the study.

Finally, I wish to thank my wife, Ginger, for her invaluable work in preparing this manuscript.

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LIFE HISTORY OF THE ORANGEBELLY DARTER

Etheostoma radiosum cyanorum

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CHAPTER I

INTRODUCTION

The orangebelly darter, *Etheostoma radiosum* (Hubbs and Black), is one of approximately one hundred members of the subfamily Etheostomatinae. These small fish are members of the family Percidae. It is the purpose of this paper to make known the life history of one of the subspecies of this darter, *Etheostoma radiosum cyanorum* (Moore and Rigney).

The specific name, *radiosum*, refers to the large number of soft dorsal rays which the fish possesses, while the subspecific epithet, *cyanorum*, describes where the subspecies is found, "of the Blues," referring to the Blue River in South Central Oklahoma.

There is a general paucity of information on the life history of this fish, probably because of its rather small range. Most recent works concerning this species deal mainly with hybridization, but some other information is available. From laboratory studies, Linder (1958) described its spawning behavior, but data concerning food, parasites, and various other phases of its life history are virtually nonexistent.

Numerous investigators have studied other species of darters, and some fairly comprehensive works have been recorded, notably Fahy's (1954) work on the greenside darter, E. blennioides. Early studies of darters consisted mainly of problems in taxonomy and distribution. These preliminary studies were followed by numerous others concerning the spawning behavior of various darter species.

In 1952 Moore and Rigney elevated the orangebelly darter to the specific rank of Poecilichthys radiosus and also described two new subspecies, one of which was P. r. cyanorus. Previously this fish was described by Hubbs and Black (1941) as a subspecies of P. whipplii. The original collection of P. whipplii was made by Girard (1859) in the area which is now Northeastern Oklahoma. The holotype for what eventually became Etheostoma radiosum was collected by John D. and Ruby Y. Black in 1938 in the Ouachita River system in Arkansas. The holotype of E. r. cyanorum was collected in 1949 by Moore in the Blue River of Oklahoma.

The present study began in the summer of 1968 and continued through the summer of 1970. The field work was conducted chiefly in the upper portions of the Blue River and its tributaries in South Central Oklahoma. The general outline for the writing of this paper primarily follows the recommendations made by Koster (1955) for ecological life history studies of fishes.

CHAPTER II

SYNONYMY

Etheostoma radiosum cyanorum (Moore and Rigney)
Orangebelly Darter

Etheostoma radiosum.--Bailey, Winn, and Smith, 1954 (Placed most darters back in genus Etheostoma).

Poecilichthys radiosus.--Moore and Rigney, 1952 (Original descriptions and ranges of subspecies, cyanorum and paludosus; Also raised radiosus to specific level).

Poecilichthys whipplii radiosus.--Hubbs and Black, 1941 (Description of radiosus as subspecies; range included; synonymy).

Etheostoma whipplei (Identification to species only).--Jordan and Gilbert, 1886 (Range, in part and description). Gilbert, 1887 (Range, in part). Jordan, 1888 (Range, in part). Meek, 1891 (Range, in part). Meek, 1894a (Records, in part). Meek, 1894b (Records, Arkansas).

Etheostoma whipplii.--Boulenger, 1895 (Description, synonymy, and range, in part). Meek, 1896 (Records, Red River system, Oklahoma and Texas). Jordan and Evermann, 1896 (Range, in part). Fowler, 1904 (Range, in part). Cockerell, 1913 (Range, in part).

Poecilichthys whipplii.--Cockerell, 1927 (Records). Ortenburger and Hubbs, 1927 (Records, Oklahoma). Hubbs and Ortenburger, 1929 (Records, Oklahoma and Arkansas).

Claricola whipplii.--Jordan, 1929 (Range, in part). Jordan, Evermann, and Clark, 1930 (Range, in part).

CHAPTER III

DESCRIPTION

The orangebelly darter, Etheostoma radiosum cyanorum, is a rather small, brightly colored fish. Its fin-ray counts are: D. X-13; A. II,8; P_1, 12-12; P_2, I,5; C. 17 (15 branched). There are approximately 56 lateral-line scales of which 50 are pored and six are unpored. The back is little elevated, sloping in almost a straight line to the caudal peduncle which is approximately the same depth throughout. The head is quite blunt and is sharply decurved in profile from the eyes to the snout tip. The mouth is of moderate size and is very slightly oblique. There are seven scales between the lateral line and the origin of the second dorsal fin and 11 scales from the lateral line to the origin of the anal fin. The upper and posterior borders of the opercles have large, exposed scales. The cheeks, nape, and area near the eyes have smaller, exposed scales. The breast has embedded scales. The gill membranes are rather broadly joined. The average standard length of the fish is 45 millimeters, with a maximum length of approximately 70 millimeters. The fish weigh up to four grams, the average sized fish weighing approximately one and one-half grams (a 45 mm fish).

Body coloration varies with both season and sex. In general, the body is suffused with orange which intensifies on the belly and diminishes toward the lateral line. Above the lateral line the ground shade is between light brownish olive and buffy olive. Eight indistinct saddles are present on the back. The breast is dirty white except along its anterior margin where the orange of the gill membrane extends backward. A dark blue-green bar covers the black subocular bar and extends diagonally forward and downward to the edge of the mandible. From the occiput to the tip of the snout, including the preorbital region, the top of the head is blue-green slate. The basal half of the spinous dorsal fin is of mixed brown and buffy olive and is followed by an orange band one-fourth the height of the fin, bordered with a blue-green band of the same width as the orange band but not covering the last two spines. A very narrow, creamy-white band lies between the blue-green and orange bands. The soft dorsal fin and caudal fin are colored similarly to the spinous dorsal fin except that the creamy-white band is broader. The anal fin, basally orange, is tipped with blue-green. The pelvic fins of the male are blue-green with some orange near the tips of the anterior rays while the pelvic fins of the female are pale orange. The pectoral fins are primarily orange with pale tips. There is a distinct humeral spot which ranges in color from black to dark blue-green.

Various color changes occur prior to spawning. The coloration of the female tends to become washed out. The olives remain and darken while the blue-greens and oranges fade. The humeral spot becomes more blackish and the body coloration patterns become more mottled. The colors of the male intensify. The humeral spot becomes brilliant blue-green as does the anterior-most saddle, the pelvic fins darken their blue-green color, and the breast and belly become bright orange. The colors of the other fins and general body surface also intensify.

Hubbs and Black (1941) described the fish as having red blotches on the body both above and below the lateral line. This description is not in agreement with either my observations or those of Moore and Rigney (1952) or Jordan and Gilbert (1886). The lack of these red blotches is a prime characteristic in the differentiation of *E. radiosum* from the redfin darter, *E. whipplei*, and the eastern redfin darter, *E. artesiae*.

The subspecies of *Etheostoma radiosum* were described by Moore and Rigney (1952). These three subspecies were *E. r. cyanorum* from the Blue River in Oklahoma, *E. r. paludosus* from the Clear Boggy River in Oklahoma, and *E. r. radiosum* from rivers in Southeast Oklahoma and Southwest Arkansas. *E. r. cyanorum* differs from the other two subspecies in that it has more pored and fewer unpored lateral-line scales, fewer soft dorsal rays, a much blunter and more decurved snout, a deeper head, a larger and heavier body, and greater sexual dimorphism.

CHAPTER IV

DISTRIBUTION: RANGE

In 1941 Hubbs and Black gave the range of the subspecies *Poecilichthys whipplii radiosus* as extending eastward from Muddy Boggy Creek in Southeastern Oklahoma to Saline Creek in South Central Arkansas. Its range extended northward to the headwaters of the Ouachita River in Central Arkansas and southward to the Neches River near Nacogdoches, Texas. When Moore and Rigney (1952) elevated *P. w. radiosus* to specific rank, its known range was extended westward to include the Clear Boggy and Blue Rivers in South Central Oklahoma. These authors also lessened the range of the species by showing the Texas records to be erroneous.

The fish which this paper concerns, *Etheostoma radiosum cyanorum*, is found only in South Central Oklahoma in the Blue River system. Thus this subspecies represents the western limit of the range of the species. The fish are concentrated in greatest numbers in the upper two-thirds of the river system. Very few specimens have been taken in the more sluggish portions of the stream near the Red River, and none have been taken from the Red River proper. No *E. r. cyanorum* have been obtained from the Red River tributaries on the Texas side, although suitable darter habitat is present and the eastern redfin darter, E. artesiae, is found there. Thus it would seem that the Red River is an efficient barrier to the movement of these small fish across that river. The Red River also seems to be an efficient barrier for keeping the various subspecies of the orangebelly darter from coming together north of the Red River. Because the Red River is the only common waterway available to these subspecies, the Blue River, Clear Boggy, and more eastern drainages of the range each contains different subspecies of orangebelly darters which are isolated from one another.

CHAPTER V

DISTRIBUTION: HABITAT

General

The Blue River is located in Bryan, Johnston, and Pontotoc Counties of Oklahoma. It rises in Pontotoc County, six miles west of Fittstown, Oklahoma, and flows in a southeasterly direction for approximately 110 miles to where it joins the Red River. The mean annual discharge is approximately 37 cubic feet per second, with a maximum of 160 cubic feet per second in the spring and a minimum of 15 cubic feet per second in the late winter. Elevations at the headwaters are about 1,250 feet above sea level, decreasing to approximately 500 feet above sea level at the mouth of the river (Miser, 1954). The gradient averages 9.4 feet per mile and ranges from three to 50 feet per mile. The watershed covers approximately 800 square miles which is vegetated by mixed areas of post and blackjack oak forest and tall grass prairie. The average annual precipitation of the area is approximately 38 inches (Hornuff, 1957).

The Blue River and its tributaries can be divided into three types of habitat: the pool areas characterized by rather slow flow and deep water, the raceway areas characterized by medium flow and water of medium depth, and the riffle areas characterized by rapid flow and shallow depth.

The adult orangebelly darters inhabit all three habitats, but the far greatest numbers are found in the raceway areas. The females tend to be in the slower, deeper portions of the raceways, while the males are usually found in the swifter portions of the raceways. In both sexes the larger fish are generally found in the swifter parts of the raceways. At times it is difficult to describe an area as either a raceway or a riffle. In these cases the water movement is fast, as in a riffle area, but deep and rocky, as in a raceway area. The darters often inhabit these riffle-raceways. Large numbers of these fish are never found in the rapid shallow-riffle portions of the stream.

During the spawning season, the fish are found in those portions of the raceways which have moderate current and depth. The eggs hatch where they are deposited in the raceways or in quiet water areas where the water current washes them. The larval forms complete the first phases of their lives in the quiet water or pool areas of the stream. As the fish increase in size they slowly move back into the swifter portions of the stream. By the end of their first year the fish are found in their respective adult habitats.

Associated Species

Table 1 is a list of those species of fishes which have been collected in association with *Etheostoma radiosum cyanorum*. The list is a combination of data taken from Linder (1955), the University of Oklahoma Museum of Zoology, and personal collections. Figure 1 illustrates the locations of these collections. Those fish most commonly found in association with the orangebelly darter are the stoneroller, *Campostoma*

Table 1. List of fishes collected in association with the orangebelly darter, *Etheostoma radiosum cyanorum*, in the Blue River, Oklahoma.

Scientific Name	Common Name	Scientific Name	Common Name
Aplodinotus grunniens	Freshwater drum	**Notemigonus crysoleucas*	Golden shiner
**Campostoma anomalum*	Stoneroller	*Notropis atherinoides*	Emerald shiner
Dorosoma cepedianum	Gizzard shad	*Notropis blennius*	River shiner
Etheostoma chlorosomum	Bluntnose darter	**Notropis boops*	Bigeye shiner
Etheostoma gracile	Slough darter	**Notropis chrysocephalus*	Striped shiner
Etheostoma microperca	Least darter	*Notropis fumeus*	Ribbon shiner
**Etheostoma spectabile*	Orangethroat darter	*Notropis lutrensis*	Red shiner
Fundulus notatus	Blackstripe topminnow	*Notropis rubellus*	Rosyface shiner
Gambusia affinis	Mosquitofish	*Notropis stramineus*	Sand shiner
Hybognathus placitus	Plains minnow	**Notropis umbratilis*	Redfin shiner
Ictalurus furcatus	Blue catfish	*Notropis venustus*	Blacktail shiner
**Ictalurus melas*	Black bullhead	*Notropis volucellus*	Mimic shiner
Ictalurus natalis	Yellow bullhead	*Noturus nocturnus*	Freckled madtom
Ictalurus punctatus	Channel catfish	**Percina caprodes*	Logperch
**Lepomis cyanellus*	Green sunfish	**Percina copelandi*	Channel darter
Lepomis gulosus	Warmouth	*Percina maculata*	Blackside darter
Lepomis humilis	Orangespotted sunfish	*Percina sciera*	Dusky darter
Lepomis macrochirus	Bluegill	*Phenacobius mirabilis*	Suckermouth minnow
**Lepomis megalotis*	Longear sunfish	*Phoxinus erythrogaster*	Southern redbelly dace
Lepomis microlophus	Redear sunfish	**Pimephales notatus*	Bluntnose minnow
**Micropterus punctulatus*	Spotted bass	*Pimephales promelas*	Fathead minnow
**Micropterus salmoides*	Largemouth bass	*Pimephales vigilax*	Bullhead minnow
Minytrema melanops	Spotted sucker	*Pomoxis annularis*	White crappie
Moxostoma duquesnei	Black redhorse	*Pomoxis nigromaculatus*	Black crappie
Moxostoma erythrurum	Golden redhorse	*Pylodictis olivaris*	Flathead catfish
**Nocomis biguttatus*	Hornyhead chub		

*Species most consistently found in association with *E. r. cyanorum*.

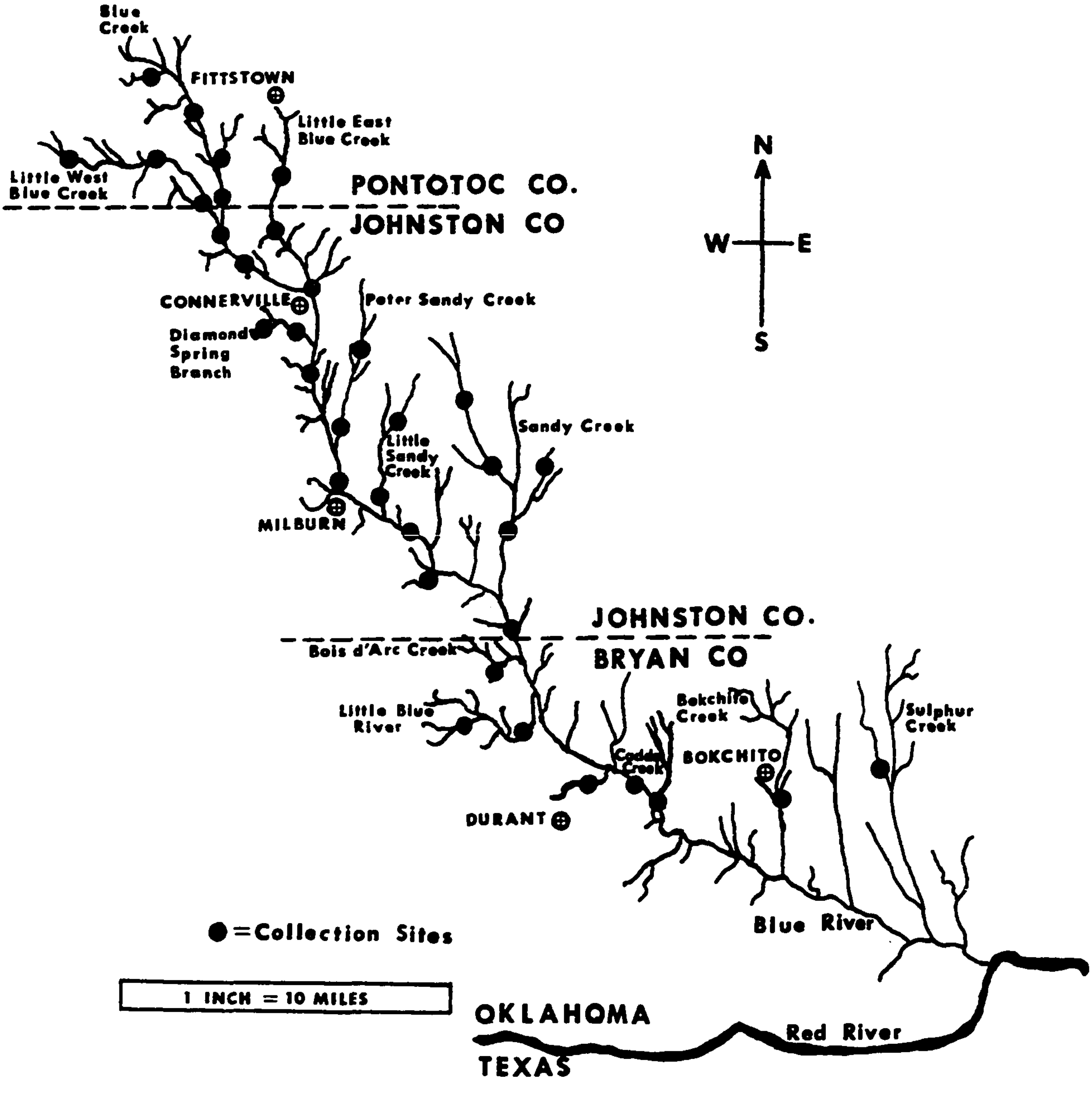


Figure 1. Location of collection sites where the orangebelly darter, Etheostoma radiosum cyanorum, and its associated species were collected in the Blue River, Oklahoma.

anomalum; the orangethroat darter, Etheostoma spectabile; the hornyhead chub, Nocomis biguttatus; the black bullhead, Ictalurus melas; the green sunfish, Lepomis cyanellus; the longear sunfish, L. megalotis; the spotted bass, Micropterus punctulatus; the largemouth bass, M. salmoides; the golden shiner, Notemigonus crysoleucas; the bigeye shiner, Notropis boops; the striped shiner, N. chrysocephalus; the redfin shiner, N. umbratilis; the logperch, Percina caprodes; the channel darter, P. copelandi; and the bluntnose minnow, Pimephales notatus. The other species listed in Table 1 are found only in small numbers in specialized localities. Some are more characteristic of the headwaters while others are found only in the more sluggish lower portions of the river.

Many aquatic plants are found in the Blue River system, but only those which are most closely associated with the orangebelly darter are mentioned. The aquatic mosses Fontinalis sp. and Fissidens sp. are common in the upper portions of the river, as are the water willow, Justicia americana; smartweed, Polygonum sp.; filamentous algae, Cladophora sp.; and the water milfoil, Myriophyllum heterophyllum. Other plants which are often found associated with the darter, but only in limited portions of the stream, are the thallose liverwort, Riccia fluitans; the water cress, Nasturtium officinale; and the ditch stonecrop, Penthorum sedoides.

Temperature

Temperature records over a period of two years showed a minimum water temperature of 41°F in late winter and a maximum of 74°F in late summer. The annual mean temperature was approximately 61°F. Temperature fluctuations were quite prevalent after heavy rains but at no time did the water temperature change more than two or three degrees per day. No ice cover was ever observed on either the river or its flowing tributaries.

Current

Hornuff (1957) described the flow of the Blue River near Connerville, Oklahoma, as being moderate, but flow in the various types of habitat varied from slight to swift. He designated a slight current as being one foot per second or less, moderate current as one to three feet per second, and swift current as exceeding three feet per second. The rate of flow decreased from the riffles to the raceways and from the raceways to the pools. The raceway areas, where the darters were most commonly found, could be classified as having a moderate current.

Depth

The depth of the Blue River proper averaged from four to five feet, but in the upper portions of the river, where most of the study darters were found, the depth averaged from one to two feet. The shallowest portions of the river were the riffle areas; the raceway and pool portions were progressively deeper.

Turbidity

In the upper portion of the Blue River system, the water was usually very clear. After heavy rains, however, the water would occasionally become turbid until the runoff water had passed downstream. Light penetration was sufficient throughout the upper parts of the stream system to support dense stands of rooted vegetation and abundant growths of periphyton even in the deeper portions of the stream. In general, the tributaries of the river tended to be clearer than the river proper. They also cleared more quickly after rain than did the main channel. The river became progressively more turbid in its lower reaches.

Substratum

The substratum varied from mud and debris to bedrock. In the river proper the bottom was usually either sand, gravel, small rocks, large rocks, or bedrock. The substratum in tributaries tended to be either mud and debris, small rocks, large rocks, gravel, or bedrock. The substratum was dictated to a large degree by the portion of the stream which was observed. The pool areas tended to have a mud or rocky bottom; the raceway portions contained areas of gravel, sand, small and large rock, and bedrock; and the riffle areas were generally of gravel or small and large rocks. In some areas the substratum was densely covered by aquatic plants. The substratum was usually silt free, with the exception of some of the pool areas.

CHAPTER VI

PREDATORS

During the course of this study numerous fishes were collected to ascertain the extent of their predation on the orangebelly darter (Table 2). Some fishes were seined with either a 20 x 4 or 6 x 4 foot, one-eighth inch mesh seine; some were collected by electrofishing with a 110-volt generator; others, notably the more piscivorous forms, were obtained by hook and line. These fishes were retained in ten-percent formalin until their stomach contents could be examined.

None of the fishes represented in Table 2 were found to contain any orangebelly darters or their eggs. The only evidence of any predation on *Etheostoma radiosum cyanorum* was four eggs found in the stomachs of two orangebelly darters. These were two of approximately 600 juvenile and adult orangebelly darters examined. Linder (1958) reported that *E. radiosum* ate their own eggs, but his study was conducted under laboratory conditions.

This lack of predation on the orangebelly darter was not surprising. Fahy (1954), in his study of the greenside darter, *E. blennioides*, found no direct evidence of predation either by fishes, birds, or reptiles, although he did state that eggs were eaten by an unknown predator. Lake (1936) suggested that small crayfish may have

Table 2. Species, numbers, and size ranges of fishes examined for predation on the orangebelly darter, *Etheostoma radiosum cyanorum*, in the Blue River, Oklahoma.

Species	Number Sampled	Size Range (Standard length in mm)
Campostoma anomalum, Stoneroller	16	32-114
Etheostoma microperca, Least darter	14	29- 43
Etheostoma spectabile, Orangethroat darter	35	35- 51
Fundulus notatus, Blackstripe topminnow	1	47
Gambusia affinis, Mosquitofish	3	27- 34
Lepomis cyanellus, Green sunfish	23	41-141
Lepomis humilis, Orangespotted sunfish	6	47- 67
Lepomis macrochirus, Bluegill	1	121
Lepomis megalotis, Longear sunfish	22	22-141
Micropterus punctulatus, Spotted bass	26	61-232
Micropterus salmoides, Largemouth bass	24	78-224
Nocomis biguttatus, Hornyhead chub	7	35-182
Notemigonus crysoleucas, Golden shiner	35	41-112
Notropis chrysocephalus, Striped shiner	35	23-110
Notropis umbratilis, Redfin shiner	1	39
Percina caprodes, Logperch	2	55- 61
Percina copelandi, Channel darter	10	32- 51
Phoxinus erythrogaster, Southern redbelly dace	5	40- 51
Pomoxis annularis, White crappie	1	127

fed upon the eggs of the fantail darter, E. flabellare. In 1967 Braasch and Smith reported that the slough darter, E. gracile, and other darters were not utilized to any degree as a forage organism by piscivorous fishes.

Some darters, however, have been reported as primary food organisms. Collette (1962) cited a series of earlier papers indicating that the swamp darter, E. fusiforme, was quite vulnerable to predation by the chain pickerel, Esox niger, and the largemouth bass, Micropterus salmoides; one observation was that 25 percent of the food of young Esox niger consisted of Etheostoma fusiforme.

Lachner (1950) stated that darter eggs may be taken by the hornyhead chub, Nocomis biguttatus. It was possible that orangebelly darter eggs were utilized by N. biguttatus in this study. In my field observations of orangebelly darter spawnings, it was not uncommon to find large numbers of fishes present in the spawning area. The following fishes were the most common: the hornyhead chub, Nocomis biguttatus; the striped shiner, Notropis chrysocephalus; the stoneroller, Campostoma anomalum; the logperch, Percina caprodes; the golden shiner, Notemigonus crysoleucas; and juvenile spotted bass, Micropterus punctulatus. These fishes were quite active in places where darters were spawning or had just completed spawning and they appeared to be feeding in these areas; however, when collected and examined, no darter eggs were found in their digestive tracts. Apparently these examined fishes were not feeding on darter eggs but on organisms which were dislodged from the substratum by the vigorous spawning activities of the darter.

The adults of most species of darters apparently constitute only a very small part of the diet of larger fishes since their size and maneuverability enable them to hide under rocks and in crevices and thus avoid the larger fishes of prey. Being a benthic fish, the orangebelly darter would seldom provide as obvious a target as some of its more pelagic associates. It is likely that predator pressure upon the orangebelly darter depends upon the presence of other, more easily caught, species.

A number of other animals may have been predatory on the orangebelly darter. Although no stomachs were examined, the following predators were quite common in the study area: the common water snake, Natrix sipedon; the common snapping turtle, Chelydra serpentina; the belted kingfisher, Megaceryle alcyon; the little blue heron, Egretta caerulea; and the green heron, Butorides virescens. Various predaceous aquatic invertebrates were also found in great numbers in the study area. These invertebrates could conceivably prey upon darter eggs and young.

It is interesting to note that the fish have a rather low reproductive capability (See Fecundity). This reduced capability may be a reflection of low predator pressure on this species.

CHAPTER VII

PARASITES

No parasites have previously been reported from *Etheostoma radiosum*. Hoffman (1967) gave a good review of parasites found in other darter species. Those which have been most extensively worked are the johnny darter, *E. nigrum*; the rainbow darter, *E. caeruleum*; the Iowa darter, *E. exile*; the fantail darter, *E. flabellare*; and the logperch, *Percina caprodes*. Although no special effort was made to study parasitism, casual observations were made for parasites during the routine examination of the darters. Most parasites found were stained with carmine and mounted on microscope slides for later identification.

A leech, *Illinobdella moorei*, was the most commonly found parasite. It was present on 19.2% of the fish examined and of those infested, each harbored approximately two leeches. The leeches were most prevalent in the summer and early fall months. The pectoral and pelvic fins were the areas most often infested; the pectoral fins had 43.6% of the leeches while the pelvic fins had 28.8%. In both cases the vast majority of the parasites were attached to the proximal surfaces of the fins. The caudal, anal, and dorsal fins harbored 13.5, 9.6, and 4.5%, respectively. The largest number of leeches found on a single fish was six, and this fish showed no obvious adverse effects. There have, however, been many reports of leech epizootics (Meyer, 1946) with damage done to the fish being proportional to the number of leeches present and the amount of blood removed. Hoffman (1967) reported I. moorei and other illinobdellid leeches from numerous members of the family Percidae.

Another parasite found in the course of this study was Crepidostomum cooperi. This parasite is a digenetic trematode of the family Allocreadiidae. Only about one dozen of these parasites were found during the examination of approximately 600 darters. These trematodes were present in the digestive tract of the fish. Hoffman (1967) stated that the metacercariae of this parasite are found in aquatic insects, while the xiphidiocercariae are found in sphaeriid clams. These clams are quite abundant in the Blue River system. C. cooperi has been reported from numerous species of fishes, including other darters. It is possible that C. cooperi was not a true parasite of this fish, but instead was only present in the guts because of ingestion by the fish of aquatic invertebrates which harbored this parasite.

One orangebelly darter examined had a heavy infestation of the strigeoid trematode, Uvulifer amblopites. This parasite, the black-spot or black-grub, reported from numerous fish species, was found just under the integument of the fish. Many of the fishes found in the Blue River, especially the centrarchids, were infested with the black-grub. Parasitized fish were easily recognizable in the field; therefore, this one parasitized darter, of the thousands of darters observed, probably represented an "accidental" infection. If the darters were an important host for the parasite, more than one fish of those inspected would have harbored this common parasite. Hoffman and Putz (1965) unsuccessfully attempted to infect numerous etheostomatine species with this parasite.

One other parasite was found on the orangebelly darter. This was an opaque white cyst which harbored the spore stage of a myxosporidian parasite. This parasite was found on only one fish and was located on a primary gill filament. Unfortunately, the specimen was lost before complete identification of the myxosporidian could be accomplished.

CHAPTER VIII

GENERAL BEHAVIOR

Lacking a swim bladder and inhabiting swift water, the orangebelly darter is forced to spend most of its life in contact with the stream bottom. Movement is accomplished in sudden darts for a distance of several inches or feet. The caudal and large pectoral fins are the chief agents responsible for these rapid movements. The pelvics and other fins are used primarily as steering aids. Breder (1924) suggested that forward movement of darters may also be aided by the expulsion of water through the gill clefts.

While resting, the weight of the body of the fish is distributed throughout the pelvic and caudal fins and the base of the caudal peduncle. In this position the head is raised several millimeters above the bottom and the angle of the body axis to the horizontal is approximately ten degrees. The tail region of the fish is usually held at a sharp angle to the body axis, which gives the animal a "snake"- or "lizard"-like appearance. This appearance is enhanced by the slight ability of the animal to move its head laterally.

There was no consistent response to current direction. The fish could maintain a stable position whether facing directly into the current or otherwise. The general body shape of the darter, which is fusiform, aids them in the maintenance of their position in the stream. They also appear to utilize their fins as hydrofoils. When facing into the current, their pectoral fins are positioned so that the dorsal portions of the fins are posterior and the ventral portions are anterior, thus the water flow creates a downward force on the fin and, consequently, the body of the fish. When the darters are facing downstream, this arrangement is reversed, the dorsal portions of the fins being anterior and the ventral being posterior. The caudal and dorsal fins are also used in this manner. This downward application of force tends to maintain the animal in a stationary position. By using its fins in this manner a darter is able to maintain any position in the stream, even in situations where its body axis is perpendicular to the direction of the water flow. The fish can achieve this stationary position in the swiftest, most exposed, portions of the stream.

This ability to remain stationary in strong current allows the darters to stay in rapidly flowing portions of the stream without swimming action. It also allows them to feed and spawn in the stream without regard to the direction of the water flow. The other fishes present, such as the notropids and centrarchids, have to show a positive rheotactic response or be swept out of the swift water areas. These other fishes must constantly expend energy swimming to maintain their positions.

It should be observed here that current speed and direction differ in the various microhabitats of the stream. These factors vary depending on whether the fish are behind rocks, on gravel areas, or in any other number of areas where physical changes in the substrata affect the speed or direction of the water current.

CHAPTER IX

FOOD AND FEEDING

Feeding Behavior

Field observations of the feeding behavior of adult orangebelly darters showed that the fish move along the stream bottom foraging upon aquatic invertebrates which are attached to rocks and plants. This activity is accomplished by the movement of one or both pectoral fins. When feeding upon the accessible undersides of rocks, the maneuvers of the darter are more elaborate; they use their caudal fins for propulsion, and they are often forced to assume a sideways position in order to obtain a particular food item.

The feeding responses of the orangebelly darter are elicited primarily by visual cues. In the field, as well as the laboratory, the fish actively feed on moving food items; they shun items which remain immobile. Roberts and Winn (1962) stated that the johnny darter, *Etheostoma nigrum*, responds mainly to visual cues in feeding but that some olfactory cues are also used. It is possible that the orangebelly darter also uses olfactory, as well as visual cues, in feeding.

The fish are quite selective as to what they eat. Almost no extraneous material was found in the guts of the adult and juvenile fish examined. Some contained a few sand grains, while others had a strand or two of filamentous algae, but these were rare cases.

General Food Habits

The food of most species of darters consists mainly of small aquatic invertebrates. The younger fishes feed almost exclusively on minute crustaceans and dipteran larvae, later increasing the amount of dipteran larvae at the expense of the minute crustaceans. Still later the young fishes turn to larger insect larvae which constitute their staple adult food (Turner, 1921; Karr, 1963; Fahy, 1954).

Every two weeks for a period of one year a sample of 30 to 40 orangebelly darters was collected. These fish were collected in the main river or a tributary stream (Figure 2) with a 6 x 4 foot, one-eighth inch mesh seine. Collecting consisted of setting the seine in the stream, making sure that the lead line was touching the bottom, and vigorously kicking rocks, rubble, and vegetation located upstream. Using this method one person could easily collect all the darters needed. For the collection of larval and juvenile stages a habitat seine was used. The mesh of this seine was small enough so that no darters, regardless of their size, could pass through the net.

The fish samples were placed in ten-percent formalin and transported to the laboratory. Four days following collection the fish were removed from the formalin solution, thoroughly washed, and placed in a 70-percent ethyl alcohol solution. In this condition the fish could be held indefinitely. Stomach contents of the fish were examined under a Bausch and Lomb dissecting microscope at magnifications of from 7X to 30X.

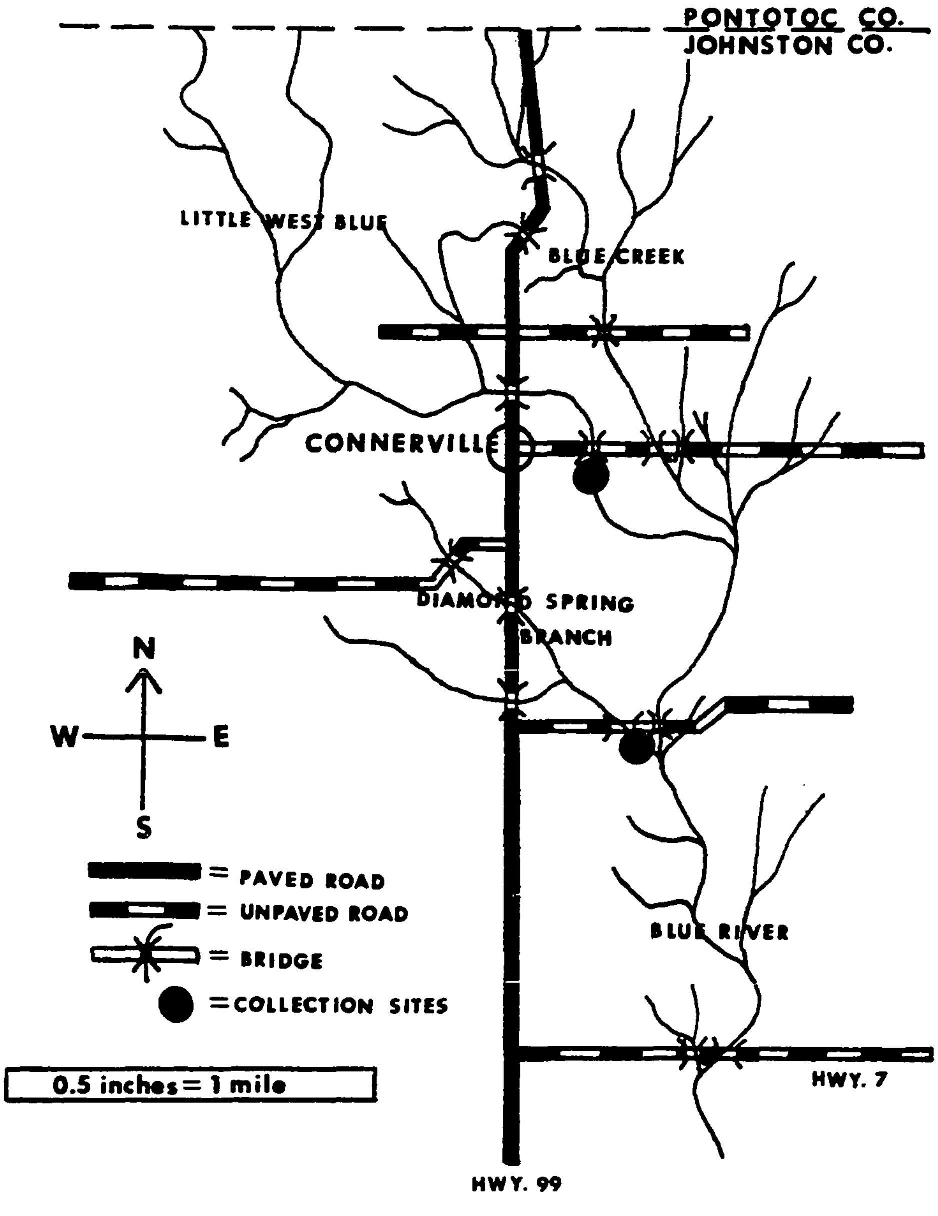


Figure 2. Sites sampled in the Blue River, Oklahoma, for the food study of the orangebelly darter, <u>Etheostoma radiosum cyanorum</u>.

In most stomachs the whole food item was present and easily identifiable. In others the contents were in a more advanced stage of digestion and only masses of partially digested food items were present. In these cases the head portions of most items, because of their resistance to digestion, were still identifiable, and each head was counted as one food item. The whole gut was examined in the early postlarval darters because no distinct stomach was present at this stage of development. In the adult fish only the stomachs were examined. Food organism identification was made with the aid of Pennak (1953) and Edmondson (1959). The stomach contents of 20 or more adult darters were examined for all sampling periods. This was accompanied by examination of postlarval and juvenile fish in the spring and summer months when these stages were available.

Postlarval and Juvenile Food Habits

The food of the postlarval and juvenile orangebelly darters varied with the length of the fish. Table 3 illustrates the kinds of food taken, their average number, and the percentage of fish containing each particular food item. Those fish with a total length of 30 mm or less were considered as juvenile and postlarval stages (See Age and Growth). Copepods and cladocerans were the primary food items of fish 15 mm or smaller. Fish 16 to 21 mm in total length used fewer copepods and cladocerans and more ephemerids and dipteran larvae. Fish ranging in size from 22 to 30 mm total length relied primarily on small ephemerids, dipteran larvae, hydropsychids, and baetids. Ostracods were utilized mainly by fish over 16 mm but less than 20 mm in total length. Various other organisms were used to lesser degrees.

Table 3. Kinds, percent of fish containing food item (%), and average number of food items (avg) found in different sized postlarval and juvenile orangebelly darters, <u>Etheostoma radiosum cyanorum</u>, in the Blue River, Oklahoma.

Organism	Total length of fish in mm															
	7-9 (25 fish)		10-12 (25 fish)		13-15 (25 fish)		16-18 (25 fish)		19-21 (25 fish)		22-24 (25 fish)		25-27 (25 fish)		28-30 (25 fish)	
	%	avg	%	avg	%	avg	%	avg	%	avg	%	avg	%	avg	%	avg
Copepoda	64	1.24	52	1.48	80	2.20	52	1.52	20	0.40	--	----	4	0.04	--	----
Cladocera	96	5.76	56	4.72	72	4.76	36	0.76	12	0.20	--	----	--	----	--	----
Ostracoda	--	----	8	1.00	8	0.12	16	0.32	20	0.72	32	1.28	28	0.72	12	0.16
Ephemeridae	--	----	8	0.08	--	----	24	0.84	72	2.00	60	2.08	92	3.28	84	2.08
Dipteran larvae	24	0.20	40	0.60	40	0.56	72	3.00	84	3.12	88	4.56	68	2.36	72	4.08
Hydropsychidae	--	----	--	----	--	----	12	0.24	12	0.32	52	0.96	20	0.28	36	0.64
Baetidae	--	----	--	----	--	----	12	0.12	4	0.04	20	0.52	28	0.36	24	0.28
Leptoceridae	--	----	--	----	4	0.04	--	----	--	----	--	----	--	----	--	----
Corydalidae	--	----	--	----	--	----	--	----	--	----	4	0.04	--	----	--	----
Pyralididae	--	----	--	----	--	----	--	----	--	----	--	----	--	----	4	0.04
Amphipoda	--	----	--	----	--	----	--	----	--	----	4	0.04	--	----	--	----
Planariidae	--	----	--	----	--	----	--	----	--	----	--	----	4	0.04	4	0.04
Hydracarina	4	0.04	--	----	--	----	--	----	4	0.04	4	0.04	4	0.04	--	----
Elmidae	--	----	--	----	--	----	--	----	--	----	--	----	4	0.04	4	0.04
Filamentous algae	4	0.04	--	----	--	----	4	0.04	--	----	--	----	--	----	--	----

There were three possible reasons why the fish changed their food habits as they increased in size. The first was that of preference for particular food organisms because of their particle size. Fish less than 16 mm total length may have fed primarily on copepods and cladocerans because the sizes of these food items were such that they lent themselves to greater utilization. As the fish increased in size, larger food items such as ephemerids, dipteran larvae, baetids, and hydropsychids were used to a greater extent, possibly because of their larger particle sizes. This heavy utilization of small food organisms first, followed by the use of larger organisms as the fish increased in size, is a commonly encountered phenomenon in fishes.

The second possible reason for a change in food habits may have been that of availability. Fish of less than 16 mm total length were found in the quiet water areas of the stream where copepods and cladocerans abounded. As the fish increased in size to over 16 mm total length, they moved to the protected edges of the raceway where ephemerids, hydropsychids, baetids, and dipteran larvae were more numerous than copepods and cladocerans. Whether the smaller fish were found in the pool areas because they could not maintain their positions in the more rapid current of the raceway edge is not known. The same could be said of the larger juveniles--were they in the raceway edge because their preferred food was there or because they could now swim strongly enough to maintain a position in the raceway edge?

The third possibility was that of vulnerability of forage organisms. Most of the food organisms eaten are adapted in some way to life in the lotic environment. Various forms of adaptation, such as burrowing, clinging, etc., may make some of these organisms more or less vulnerable to predation by the darters. This may affect a change in the food habits of the fish, although it would be difficult to ascertain the various degrees of vulnerability of the different food organisms present. It was probable that all factors, i.e., preferability, availability, and vulnerability, influenced the food habits of these postlarval and juvenile darters.

Adult Food Habits

In order to determine the relative volumes of food items for adult darters, an alcohol displacement method was used. A graduated vial was filled with a known amount of ethyl alcohol. Representatives of a food organism were then placed in the vial and the relative volume for an individual was calculated. This procedure was done numerous times and an average was taken. Some types of food organisms which had large ranges in size were arbitrarily divided into size classes so that the volume figures would be more accurate. Baetids and ephemerids were divided into small and large size classes, while hydropsychids were divided into five size classes with the largest individuals designated as size-class 1 and the smallest as size-class 5.

The main source of food of adult darters consisted of the aquatic larvae or naiads of five families of insects: Tendipedidae, Baetidae, Ephemeridae, Hydropsychidae, and Simuliidae. These five families represented 97.3% of the total food number and 95.0% of the total food volume utilized by the 459 adult orangebelly darters examined. Other food organisms used to lesser degrees were leptocerids, corydalids, pyralidids, agrionids, rhagionids, planariids, hydracarinids, elmids, crayfish, and fish eggs (Table 4).

The numbers, volumes, and kinds of food organisms utilized changed as the darters increased in size. The larger fish were divided into four age groups (See Age and Growth). The stomach contents of age-group 0 showed 65.3% of the total food number to be tendipedids with a volume of 25.7%. This use of tendipedids decreased as the fish increased in size until in age-group III only 16.7% of the total food number and 1.7% of the total food volume consisted of these aquatic dipterans. Tendipedids represented 48.1% of the total number of food items eaten by all age groups, with a total volume of 11.2%.

The use of baetids followed an opposite pattern. As the darters increased in size, the utilization of baetids increased. This was true for both large- and small-sized baetids. The darters in age-group 0 were found to utilize baetids as only 5.3% of their total food number and 11.4% of their total food volume, while age-group III darters used baetids as 25.2% of their total food number and 18.0% of their total food volume. As expected, larger-sized darters tended to utilize large baetids to a greater degree than did the smaller fish. Overall, baetids represented 10.8% of the total food number eaten by all age groups and 14.4% of the total food volume.

Utilization of ephemerids followed a pattern which differed from that of the two previous food organisms. While the percent number of ephemerids remained relatively stable, the percent volume decreased as the size of the darters increased. The food of age-group 0 darters consisted of ephemerids at a rate of 18.3% of the total number and 21.3%

Table 4. Kinds, percent of number (%N), and percent of volume (%V) of food items found in different age groups of the orangebelly darter, Etheostoma radiosum cyanorum, in the Blue River, Oklahoma.

Organism		Age-Group 0 (124 fish)		Age-Group I (154 fish)		Age-Group II (106 fish)		Age-Group III (75 fish)		Total (459 fish)	
		%N	%V	%N	%V	%N	%V	%N	%V	%N	%V
Tendipedidae		65.3	25.7	49.6	14.3	45.3	9.4	16.7	1.7	48.1	11.2
Baetidae	large	1.3	5.2	2.5	4.8	4.2	8.6	10.2	11.3	3.6	7.7
	small	4.0	6.2	6.5	7.4	7.4	6.2	15.0	6.7	7.2	6.7
	total	5.3	11.4	9.0	12.2	11.6	14.8	25.2	18.0	10.8	14.4
Ephemeridae	large	0.8	7.5	1.0	6.9	1.8	8.9	2.4	6.5	1.3	7.3
	small	17.5	13.8	20.8	12.0	16.9	7.0	17.7	3.9	18.7	8.8
	total	18.3	21.3	21.8	18.9	18.7	15.9	20.1	10.4	20.0	16.1
Hydropsychidae	1[a]	---	---	0.1	1.4	0.5	5.6	2.7	17.8	0.5	6.9
	2	0.4	4.7	0.7	5.7	1.5	9.3	6.3	21.0	1.5	10.8
	3	2.4	18.7	2.7	15.8	5.9	24.7	5.8	12.9	3.8	17.6
	4	3.0	9.5	4.3	10.1	4.5	7.4	4.6	4.1	4.1	7.6
	5	2.9	2.3	2.1	1.2	4.0	1.6	3.6	0.8	2.9	1.4
	total	8.7	35.2	9.9	34.2	16.4	48.6	23.0	56.6	12.8	44.3
Simuliidae		0.4	1.1	7.0	14.1	6.2	9.0	9.5	7.4	5.6	9.0
Leptoceridae		0.4	1.1	0.4	0.6	0.5	0.8	0.5	0.3	0.5	0.6
Corydalidae		---	---	0.2	0.7	---	---	---	---	0.1	0.2
Pyralididae		0.5	0.6	0.3	0.2	0.3	0.2	0.5	0.2	0.4	0.3
Agrionidae		---	---	---	---	---	---	0.7	1.6	0.1	0.5
Rhagionidae		0.1	2.1	---	---	---	---	---	---	0.0	0.3
Planariidae		0.3	0.5	---	---	---	---	1.2	0.5	0.2	0.2
Hydracarina		---	---	0.1	0.1	---	---	---	---	0.0	0.0
Elmidae		0.4	0.9	1.3	1.3	1.0	1.3	1.8	1.3	1.1	1.2
Crayfish		---	---	0.2	3.3	---	---	0.3	1.9	0.1	1.6
Fish eggs		0.3	0.1	0.2	0.1	---	---	0.5	0.1	0.2	0.1

[a]Numbers represent size classes of organism, smallest number being largest size.

of the total volume, while age-group III darters contained 20.1% of the total number and only 10.4% of the total volume. Ephemerids represented 20.0% of the total number of food items eaten by all age groups, with a total food volume of 16.1%.

Hydropsychids were more heavily utilized both in number and volume as the fish increased in size. There was also an increased use of larger hydropsychids by larger darters. Age-group 0 darters fed mainly on hydropsychids of size-classes 3, 4, and 5, i.e., the smaller hydropsychids. These smaller hydropsychids represented 8.3% of the total number and 30.5% of the total volume of the food eaten by this age group. In age-group III darters, hydropsychids represented 23.0% of the total number of organisms eaten, with a volume of 56.6%. The fish of age-group III fed mainly on hydropsychids of size-classes 1 and 2, i.e., the larger hydropsychids. Although hydropsychids were not always utilized in greater numbers than some of the other food organisms present, they always represented the greatest volume of food in all age groups. Even in the darters of age-group 0, hydropsychids represented approximately 10% more food volume than the next nearest food organism. Overall, hydropsychids represented 12.8% of the total number and 44.3% of the total volume of the food items eaten by all age groups.

Blackfly larvae, Simuliidae, were utilized by all age groups. Highest utilization of these dipterous larvae was found in darters of age-group I. In this age group, blackfly larvae represented 7.0% of the total number and 14.1% of the total volume of the food organisms eaten.

Riffle beetles from the family Elmidae were used by all age groups of darters. It was interesting to note that only the larvae were utilized as food by the darters. No adult riffle beetles were ever found in the stomach contents of the darters, although these adult beetles were of useable size and were present in the stream.

The other food organisms represented in the stomach content analyses of adult orangebelly darters were of only minor importance. No distinct trends could be shown for their utilization by particular age groups of fish. These other food items represented only 2.7% of the total number and 5.0% of the total volume of food items eaten by the four age groups of adult darters.

Food Habits in Correlation with Stream-Bottom Samples

Throughout the course of one year, bottom samples were taken from the Blue River to ascertain what types of food, their numbers, and volumes, were available to the fish. This was done with a Surber stream-bottom sampler. This sampler, when placed in the stream bottom, sampled a one-square foot area. The sampler was put in place and the encompassed substrate was stirred, scraped, and turned, so that the organisms present were carried by the stream current into the net. After the square foot was thoroughly worked the sampler was lifted from the stream and its contents placed in two-percent formalin. The samples could then be transported back to the laboratory for examination. Four different types of bottom were sampled--gravel areas, small rock areas, large rock areas, and weedy areas. The gravel areas consisted of small rock particles approximately 5 mm in diameter. These areas had no vegetation and were the most unproductive of the areas sampled. The small rock areas consisted of rocks between 20 and 60 mm in diameter. Again, no aquatic vegetation was present, but these areas were more productive than the gravel areas. The large rock areas, which contained rocks from 60 mm to very large sizes, were generally covered with aquatic mosses or filamentous algae. The weedy areas consisted of beds of Myriophyllum heterophyllum. Both the large rock and weedy areas were quite productive. In these areas it was not uncommon to obtain over 1,500 food organisms per square foot. Only food organisms of a size and consistency which could be eaten by the darters were counted.

Each month four stream-bottom samples were taken, one from each of the bottom types. Table 5 represents 48 stream-bottom samples taken in all seasons of the year from the various bottom types where adult darters were present.

In comparing stream-bottom sample data with the stomach analysis data, various trends could be seen. While tendipedids were found to be only 11.7% of the total number and 2.2% of the total volume of the bottom samples, they represented 48.1% of the number and 11.2% of the volume of organisms eaten by the adult darters. Baetids represented only 8.1% of the total number and 7.3% of the total volume of bottom samples but were found to be 10.8% of the number and 14.4% of the volume in the stomach samples. The bottom samples contained ephemerids at a rate of 39.1% of the total number and 17.0% of the total volume while the darters contained ephemerids at 20.0% of the number and 16.1% of the volume. Hydropsychids were found in less numbers in the stomach samples than in the bottom samples, 12.8% to 20.2%, and also in less volumes, 44.3% to 49.8%. Simuliids were found in greater numbers and volumes in the stomach samples than in the bottom samples, 5.6% to 2.9% of the total

Table 5. The kinds, percent numbers, and percent volumes of organisms taken in 48 Surber stream-bottom samples from the Blue River, Oklahoma, over a period of one year.

Organism		% number	% volume
Tendipedidae		11.7	2.2
Baetidae	large	2.1	3.2
	small	6.0	4.1
	total	8.1	7.3
Ephemeridae	large	0.8	3.1
	small	38.3	13.9
	total	39.1	17.0
Hydropsychidae	1[a]	1.7	17.1
	2	2.3	11.7
	3	4.0	11.9
	4	5.1	6.8
	5	7.1	2.3
	total	20.2	49.8
Simuliidae		2.9	3.2
Leptoceridae		3.1	2.6
Corydalidae		0.1	0.5
Pyralididae		0.3	3.6
Agrionidae		0.1	0.6
Rhagionidae		0.9	3.7
Tipulidae		0.2	1.0
Helicopsychidae		1.8	0.8
Libellulidae		0.02	0.4
Haliplidae		0.01	0.01
Veliidae		0.02	0.01
Planariidae		1.7	1.7
Oligochaeta		3.3	0.9
Hydracarina		0.01	0.01
Elmidae		5.0	4.1
Gammaridae		0.1	0.1
Crayfish		0.1	0.3
Fish eggs		1.3	0.2

[a]Numbers represent size classes of organism, smallest number being largest size.

number and 9.0% to 3.2% of the total volume. It was also found that numerous organisms present in the bottom samples were used to little or no degree as food items by adult darters. It is possible that the number and volume figures obtained from data using the stream-bottom sampler were slightly inaccurate because of the differences in susceptibility to this type of sampling among the organisms present in the stream.

In the adults, as in the postlarval and juvenile darters, it would appear that a combination of preferability, availability, and vulnerability dictated the food organisms used. Whether a food organism was utilized by the fish because it was of the correct particle size, because it could be easily captured, or because of any other number of reasons is unknown. It seemed clear, however, that some food organisms were not eaten in the same numbers or volumes in which they were present in the stream.

Competition for Food

Interspecific competition for food was found among the stream fishes in the Blue River system. Except for the more piscivorous forms, the orangebelly darter and its stream associates utilized the same food organisms. Many of the stomachs of these associated species contained large numbers of hydropsychids, baetids, and ephemerids.

CHAPTER X

MOVEMENTS

Many stream fishes live in very restricted areas during most, if not all, of their lifetimes. Gerking (1953) studied the concepts of home range and territory of stream fishes and found that the long-ear sunfish, *Lepomis megalotis*; the rock bass, *Ambloplites rupestris*; and the green sunfish, *Lepomis cyanellus*, limited their activities to rather small areas. Larimore (1952) found similar results for the smallmouth bass, *Micropterus dolomieui*, though these fish had larger ranges than did the previously mentioned centrarchids. Reed (1968), while studying the movements of four species of darters, the rainbow darter, *Etheostoma caeruleum*; the greenside darter, *E. blennioides*; the fantail darter, *E. flabellare*; and the banded darter, *E. zonale*, found that the darters remained upon specific riffles during the course of a summer. He reported that only 1.4% of a marked population moved to adjacent riffles and that there was very little movement of darters within the riffle itself.

A portion of the Diamond Spring Branch of the Blue River was chosen to ascertain whether adult *Etheostoma radiosum cyanorum* showed tendencies of stream movement similar to those reported for other stream fishes. A portion of stream was selected where a pool separated two raceway areas. The upstream raceway was designated as raceway 1, while the downstream raceway was designated as raceway 2. The adult darters captured in these raceways were marked so that each could be identified as being from a particular raceway. The fish were also marked so that a darter taken from the upper portion of a raceway could be separated from those taken in the lower portion. The upper portion of each raceway was designated as A, while the lower portion was designated as B (Figure 3). Marking consisted of finclipping the distal one-fourth of the fin in question. Darters captured on the upper portion of the upstream raceway (1A) were marked by clipping the left pectoral fin. Fish from 1B had their right pectoral fin clipped. The left pelvic fin was clipped on fish from 2A, while the right pelvic fin was clipped on darters captured in 2B. By marking the fish in this manner both intra- and inter-raceway movement could be observed.

The effects of finclipping were observed in both the field and the laboratory. This method of marking the fish had no noticeable adverse effects. The fish could maintain their positions on the raceways, and no recaptured fish were observed to be emaciated. Also, none of these fish were observed to develop infection on these clipped areas. The fins were regenerated quite rapidly; this was one of the reasons for the shortness of the two sampling periods.

On July 3, 1969, the stream was seined in the manner described in the previous section (See Food and Feeding). The fins of captured adult fish were clipped to designate in which portion of the stream they had been taken. They were then released at the point of capture. Every week following the initial sampling, the study area was carefully

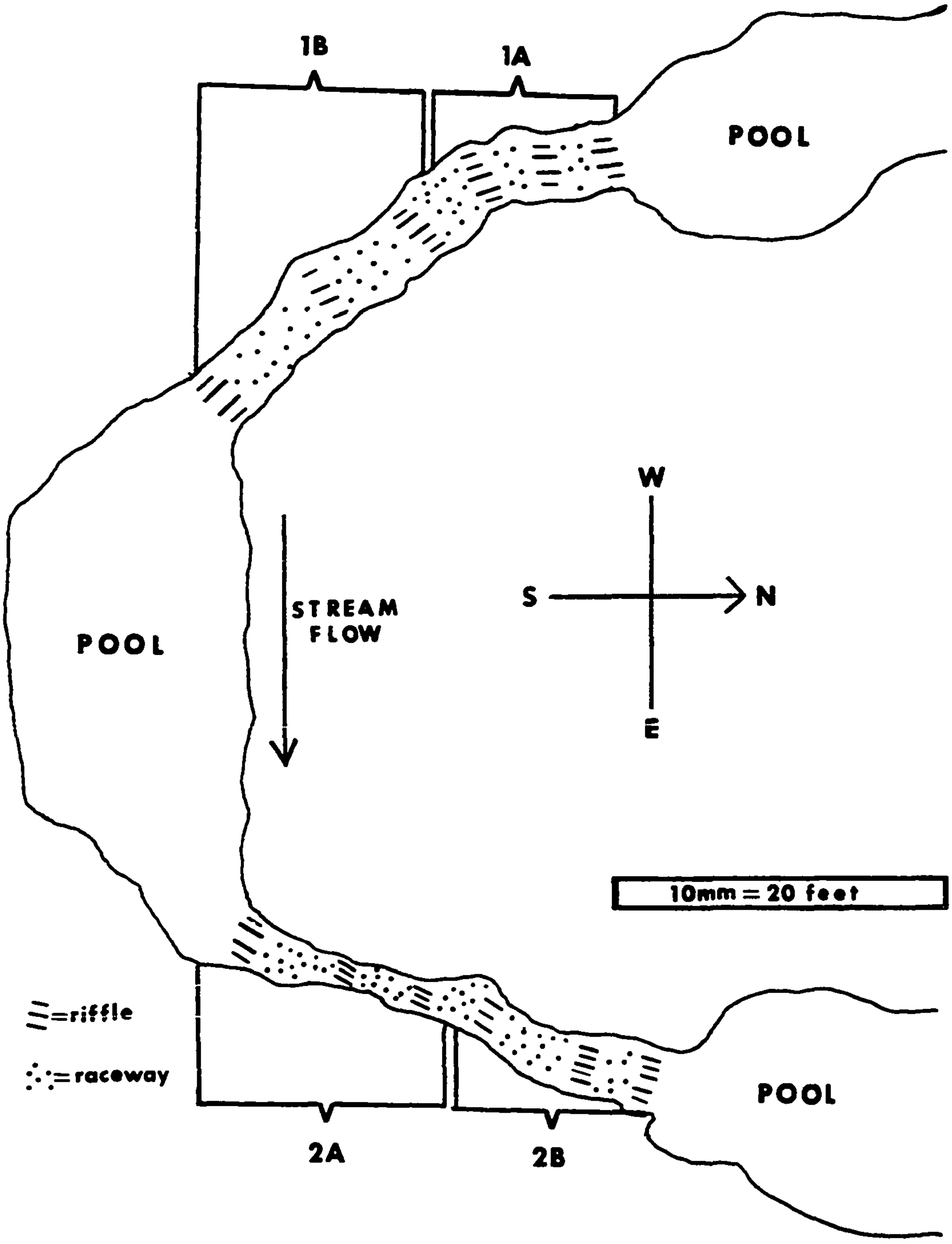


Figure 3. Portion of Diamond Spring Branch of the Blue River, Oklahoma, where stream movements of adult orangebelly darters, <u>Etheostoma radiosum cyanorum</u>, were observed.

sampled so that fish which were marked were not recaptured the same day they were finclipped. The captured fish were examined and if they had already been marked this was recorded as a recapture; if they had not been previously marked they were finclipped. All captured darters were released. This sampling period ended on August 21, 1969.

On March 24, 1970, a new sampling period was started. The same procedures used in the previous experiment were followed, except that the population was sampled every two weeks. The sampling was conducted for a ten-week period, until June 5, 1970, when the experiment was terminated.

In the first study period 242 adult darters were eventually finclipped. During the seven weeks of the study, 69 recaptures were made. Of these recaptures, only two were found to have moved from the area of original capture (Table 6). One which had been finclipped in section 1B was found in section 1A. The other fish which had moved had been marked in 2B and was recaptured in section 2A. Therefore, neither of the fish which moved during this sampling period had crossed the pool to the next raceway. These two fish represented only 2.9% of the recaptured darters.

Table 6. Movements of adult orangebelly darters, _Etheostoma radiosum cyanorum_, based on marked recaptures in the Diamond Spring Branch of the Blue River, Oklahoma.

Sampling period	Number of fish marked	Number of recaptures	Recaptures demonstrating intra-raceway movement	Recaptures demonstrating inter-raceway movement
July 3 - August 21, 1969	242	69	2	0
March 24 - June 5, 1970	316	73	4	0

During the second marking period 316 adult darters were fin-clipped. In this experiment 73 marked fish were recaptured (Table 6). Of these 73 fish, only four were recaptured in areas where they had not been originally taken. Two darters had moved from section 2A to section 2B; the other two darters had moved in the opposite direction, from 2B to 2A. These four fish represented only 5.5% of the recaptured darters. In this study period, as in the first period, only intra-raceway movement was observed.

It was interesting to note that during the second mark and recovery period, numerous fish which appeared to have been marked in the first sampling period were captured. These fish, having fins which seemed to be regenerated, were usually taken in the portion of the raceway where they were originally marked. Only one of these darters appeared to have moved from its original raceway. It was unfortunate that identification of these fish could not have been more positive, but the fins were completely regenerated and the only sign of marking was some disfiguration of the fin-ray elements, and this was not always clearly evident.

On each sampling date, the raceway areas both above and below the study area were sampled. Both of these raceways were separated from the study area by pools. At no time in either of these raceways was a marked fish recaptured. The pool areas between all raceways were also sampled and again no marked fish were found.

It would seem from the results of these experiments that the adult orangebelly darter moved very little within the stream. It may have been that adult darters showed little movement because the pool areas of the stream acted as barriers, but this would not explain the lack of intra-raceway movement. In all probability this general lack of movement was a result of the small home range of the fish. A small home range for this stream fish would not be unexpected since this tendency has been shown for many other stream fishes. It was also possible that the darters may have shown more movement in the fall or winter seasons, but indications were that they did not move even then because the fish were easily collected on the raceways in all seasons.

Winn (1953, 1958b) stated that numerous species of darters exhibited various degrees of migration, but his studies did not include the orangebelly darter. Most darters which have shown large-scale migrations have moved for reproductive reasons. The orangebelly darter lives the year round in its reproductive area so no such movement is necessary. Adult orangebelly darters might migrate out of an area when water levels drop too low, but at no time during the three-year course of this study did low water levels develop in the study areas.

Very little work was done to determine whether the distribution of the orangebelly darter differed between day and night. On a few occasions, however, collections were made during hours of darkness, and on these occasions, just as during daylight hours, the darters were collected in the raceways.

The only movement of adult darters which resembled any type of migration was observed in the Blue River proper. On these occasions, an inordinate number of darters which had just completed spawning activities was found in an area of abundant food. These fish, which were all quite thin, were congregated in an area containing abundant growths of

Myriophyllum heterophyllum. As mentioned previously, these weed beds always had a superabundance of food. Almost all of these darters were completely spent, while darters taken a short distance away, in the spawning areas, were still spawning. It would appear that after completion of spawning, the spent darters had moved a short distance to where a great abundance of food was available.

The larval and juvenile darters were observed to migrate. As eggs or prolarvae, they were carried passively by the water current into the pools or quiet water areas. As they increased in size they moved into the swifter portions of the stream. This movement into the raceway areas was accomplished in stages as the fish increased in size, i.e., first the deeper portions of the pool, then the shallower, faster areas where raceway and pool met, then along the edges of the raceway, and finally into the raceway proper. The distances these postlarval and juvenile forms were forced to migrate depended upon the portion of the river system where they were found. In the Diamond Spring Branch, which had a lineally arranged pool-riffle-raceway situation, this movement depended on the length of the pools and raceways. A fish starting in the middle of a long pool and moving into a raceway might have had to migrate a few hundred feet. The Blue River itself was not so neatly delineated. It was not uncommon to find a riffle and pool situation on one bank of the river and a raceway on the other. Therefore, the young darters in the Blue River proper might have had to move only a few feet to get from quiet water to raceway areas. This distance would be considerably shorter than the distances traveled by darters in a lineally arranged pool-riffle-raceway situation.

CHAPTER XI

TERRITORIALITY

Noble's (1939) definition that a territory is any defended area is a well established and accepted concept. As a group, the darters exhibit marked differences in types and degrees of territoriality. These differences grade from a simple pugnaciousness to a very strong defense of a given area (Winn, 1958a). Of the numerous published reports concerning territorial behavior in fishes, some of the more comprehensive have been done by Breder (1949), Baerends and Baerends-van Roon (1950), Gerking (1953), and Fabricius (1951).

During courtship and spawning the male orangebelly darter had a "moving" territory which surrounded the female. This defended area was rather small and its boundaries were so indefinite that the distance from which intruders provoked attack by the defending male varied considerably.

The exact cues triggering territorial defense are unknown, but it is probable that visual cues are the most important. During the breeding season males were brightly colored compared to the females and the sexes responded differently to each other. Females always remained docile when encountering other orangebelly darters while the reaction of the male to an intruder into its "moving" territory was quite different. Whenever an orangebelly darter entered the "moving" territory of a defending male, the defending male would erect its dorsal fin and swim toward the intruder. If the intruding darter was a female, he would lower his dorsal fin and return to the original female (except in some cases when the male would begin to court the new female). This intruding female could then remain where she was or move even closer to the courting pair without being chased away. If the intruding darter was a male, the courting male would not lower its dorsal fin after swimming toward the interloper but would instead keep his fin erected and chase the intruder from the area. At other times the original male would be chased from the area by the intruder who would then court the female. These encounters between males never involved biting or fighting. In most cases the larger or more highly colored individual won these encounters. This "moving" territory was never observed to be defended against a fish of another species, although it is possible that the orangethroat darter, *Etheostoma spectabile*, might elicit such a reaction because of its morphological similarity to the orangebelly darter (See Hybridization).

Winn (1958a) stated that non-reproductive territories in fishes are more common than published information indicates and that this type of territoriality in fishes is correlated with a reproductive territory. He also reported that many darters possess non-reproductive territories. Defense of a non-reproductive territory by the orangebelly darter was quite weak. The fish exhibited only slight pugnaciousness in defending its territory and this was done by only the large males. It was not uncommon to find four or five intermediate-sized males under a large rock, while a rock of similar size might harbor only one large male. Females appeared to play no role in the maintenance of non-reproductive territories. This non-reproductive territoriality by male darters was interpreted as an indication of the presence of a spacing mechanism in this species of fish. Some evidence for this spacing was observed when an A. C. electric shocker was used as a collecting device. In these instances, the darters were found scattered individually or in small groups throughout the available habitat sites which were acceptable to this species of darter.

CHAPTER XII

REPRODUCTION

Age at Maturity

Lake (1936) stated that the fantail darter, *Etheostoma flabellare*, reached maturity and spawned in the spring of the year following hatching. Raney and Lachner (1943) found that only the fast growing individuals of the johnny darter, *E. nigrum*, attained maturity and spawned when one-year old. Raney and Lachner (1939) also reported that the spotted darter, *E. maculatum*, reached maturity and spawned at the age of two years. Lachner (1950) found that individuals of the banded darter, *E. zonale*; the variegate darter, *E. variatum*; and the greenside darter, *E. blennioides*; matured and spawned when two-years old, with a few of the banded darters maturing and spawning in one year.

Most orangebelly darters were found to reach sexual maturity and to spawn when one-year old. A small number of age-group I individuals was sexually immature, but most of the fish, both male and female, were able to spawn. Evidence of this maturity was found by examination of the gonads of the fish and by actual field observations of spawning fish.

Gonadal Development

Male orangebelly darters had free flowing milt as early as the beginning of February and as late as the end of May, while the female darters had mature ova from the beginning of March to the middle of May. In both sexes a few individual fish were found in breeding condition both earlier and later than the above-mentioned months but these fish were not numerous.

The gonads of 429 fish, collected throughout the year, were removed and weighed on a Mettler Model H balance. The weight of the gonads was then divided by the standard length of the fish and the resulting number was considered to be an index of the state of gonadal development. Monthly comparisons of the states of development of the gonads were made throughout one year (Figure 4). The gonads of both sexes of orangebelly darters reached their maximum sizes in March, April, and May. After these peak months the gonads became progressively smaller until the end of September. After September gonadal development again started and continued steadily until the next spawning season.

At the peak of the spawning season ripe females could easily be distinguished. Their bellies were quite distended and the ovaries of some of the large females weighed over 600 milligrams. At this time the ovaries constituted approximately 10-15% of the total body weight of the fish. In September the ovaries of females comparably sized weighed as little as ten milligrams.

The gonads of male darters were never as large as those of females of a similar size collected during the same month. The testes of a large male weighed as much as 140 milligrams at the peak of gonadal development. This weight for a male of similar size in September was as low as three milligrams.

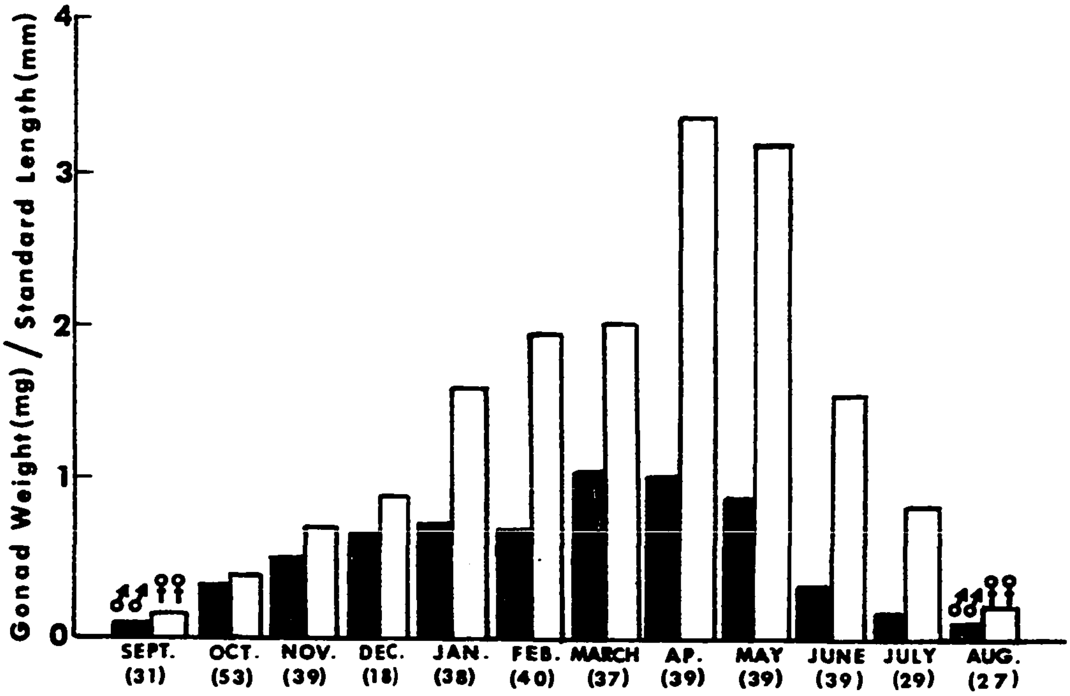


Figure 4. Gonadal development of the orangebelly darter, Etheostoma radiosum cyanorum, in the Blue River, Oklahoma. Males are signified by dark areas and females by light areas. Number of fish sampled is in parentheses.

Sexual Dimorphism

Lachner, Westlake, and Handwerk (1950) stated that the greenside darter, *Etheostoma blennioides*, exhibited various sexually dimorphic traits. They cited such things as longer anal papillae in females, larger body sizes in males, faster growth rates in males, and differences in sizes of the various fins.

Some of these characteristics were exhibited by the orange-belly darter. The anal papillae showed quite distinct differences in adult darters, especially during the spawning season. The females possessed papillae which were rather long, fleshy, pointed, and non-pigmented, while the papillae of the males were rather short, thin, blunt, and pigmented. The male darters also tended to be larger than females of the same age (See Age and Growth).

Various other sexually dimorphic characteristics were exhibited by these fish. During the breeding season the male of the species had conical breeding tubercles located on three rows of ventral scales starting about one-fourth of the way posterior from the pelvic origin and extending to the anal origin. They were slightly raised, circular mounds on the posterior edge of the scales. The tubercles on the ventral-most scales had elongate points on their posterior end. These tubercles functioned primarily in facilitating contact between the male and female during spawning (Collette, 1965).

There were also sexual dimorphic differences in both intensity and pattern of body coloration (See Description).

Juveniles could not be sexed, except by dissection, until six or eight months of age. At this later age, body coloration and papillae shape were such that accurate sexing could be accomplished.

Fecundity

Most darters have rather low reproductive capabilities. Of all darters studied, Winn (1958a) listed the log perch, *Percina caprodes*, as producing the largest number of eggs, approximately 3,000. Raney and Lachner (1939) stated that the spotted darter, *Etheostoma maculatum*, produced between 200 and 400 eggs. Petravicz (1936) found that the least darter, *E. microperca*, produced approximately 500 eggs. Most authors have limited their egg counts to those ova which contained yolk. It has also been found that not all developed ova are spawned. Some are retained by the females and reabsorbed after the spawning season is completed; therefore, the number of eggs which develop is not the same as the number spawned (Fahy, 1954).

Gross examination of the ovaries from specimens of different sizes collected in late February and early March showed them to be full and compact, an indication that spawning had not yet occurred. These gross examinations were made on both preserved and live darters. Various degrees of ova development were present, from ova which were quite minute in size to those which had large amounts of yolk present and appeared ready for spawning. Highly developed ova were usually irregularly shaped and yellowish in color. No differences in the distribution of ova sizes were apparent among the various ovary regions or between ovaries of the same fish. The ova present in spent females were small and poorly developed and were probably being reabsorbed by the fish.

Because of the low total number of ova per female, all ova, rather than a fraction, were counted; consequently, all ova counts represent actual numbers, not projections. The ova counts were made on 11 female darters which ranged in standard length from 35 mm to 55 mm. All ova which contained yolk material were counted. Some ova were quite small and poorly developed, and it was highly unlikely that they would have been spawned. Other ova were large, contained a large oil globule, and appeared to be fully developed. Because of these differences in ova size and development, two counts were made for each female. The first represented all yolked ova, regardless of size, while the second represented only those ova which were highly developed (Table 7).

The number of yolked ova ranged from 377 to 1,222, with the smaller, younger females having fewer ova than the larger, older females. This general trend was also followed in highly developed ova numbers where the smallest female contained only 51 highly developed ova as compared to 270 in the largest female. Thus in both total number of yolked ova and highly developed ova, the larger females possessed greater numbers than did their smaller counterparts.

No direct evidence was found to indicate how many of these ova were actually spawned by the fish, but Linder (1958) stated that he obtained 272 mature ova from one female. This number would roughly correspond to the number of highly developed ova found in the 55 mm female in this study, but unfortunately Linder did not report the size of his female. Indirect evidence for the number of ova spawned was obtained by observing the number of ova present in similarly sized females before and after spawning (Table 7). Of course one would not

Table 7. Direct counts of ova in both ovaries of 11 ripe and 11 spent female orangebelly darters, _Etheostoma radiosum cyanorum_, from the Blue River, Oklahoma.

Standard length of fish (mm)	Total number of ova in ripe female[a]	Number of highly developed ova in ripe female[b]	Number of ova in spent female[c]
35	377	51	320
36	380	58	318
38	446	80	391
40	489	81	404
43	562	112	481
44	640	123	502
47	998	173	641
49	1,048	206	663
51	1,052	210	763
52	1,070	221	712
55	1,222	270	928

[a]All ova which contained yolk.

[b]Large, highly developed ova with prominent oil globule.

[c]Yolked ova present.

expect the exact same number of ova to be originally present in each corresponding pair, but the approximate numbers would probably be quite similar. By comparing the prespawning to the postspawning ova counts, it appeared that the number of highly developed ova present in prespawning fish represented that complement of the ova which was spawned. This method of determining fertility of darters was questioned by Hubbs and Strawn (1957a) based on work they did on the greenthroat darter, _Etheostoma lepidum_. They found that this fish could develop large numbers of eggs but their fish were kept in the laboratory under constant maximum spawning conditions for long periods of time. How these results could be correlated to fish in the natural environment is unknown.

Many authors have correlated fish fecundity with parental care. Allee, _et al_. (1949), stated that fishes which provided parental care produced fewer eggs than those which did not provide parental care. This statement becomes questionable for the various species of darters when one observes the low degrees of parental care and fecundity exhibited by these fishes. The orangebelly darter had a rather low fecundity while exhibiting very little parental care (See Parental Care). Williams (1959) concluded that evolutionary development of parental care did not entail a reduction of fecundity but that other factors were limiting, such as available space in the body cavity. Hubbs and Strawn (1957a) in their work on the greenthroat darter, _Etheostoma lepidum_, stated that temperature affected fecundity. Lack (1954) expressed the opinion that fecundity in fishes was limited mainly by the availability of food reserves. It would appear that fecundity of darters is controlled by a variety of genetic and environmental factors.

Time of Spawning

Observations based upon two successive spawning seasons indicated that the spawning period for *Etheostoma radiosum cyanorum* occurred mainly between the middle of March and the middle of April. The spawning season of the orangebelly darter was delimited during these two years by field observation of spawning darters and by examination of the stream bottom for spawned eggs.

On March 19, 1969, spawned orangebelly darter eggs were found on the stream bottom. These eggs, in early developmental stages, were the earliest found during the two spawning seasons studied. The water temperature was 54°F when the eggs were found. One week prior to the discovery of these eggs no darters had been observed to be spawning and no eggs had been found, but on the date of discovery not only were eggs found, but also spawning darters. In 1970 eggs were first found on March 23. The water temperature was 55°F. In this observation, as in the previous one, no spawning darters or eggs were found the week previous to the initial discovery of eggs.

In 1969 only a few eggs were found after April 15 when the water temperature had risen to 64°F. Similar results were obtained in 1970 when only a few eggs were found after April 21 when the water temperature had risen to 62°F. On only three instances in two years were any darters observed to be actively spawning after April 15, and in these cases only single pairs of fish were involved. It should be noted here, however, that numerous females captured after April 15 still contained mature unspawned eggs. Whether these eggs would have been spawned or reabsorbed is unknown.

Darters actively spawned in all daylight hours. Very little effort was made to observe if the orangebelly darters spawned at night, but in instances where observations were made, no nocturnal spawning was observed. Nocturnal spawning has been reported for some darter species (Fahy, 1954), so nighttime spawning by the orangebelly darter was not an impossibility.

Location of Spawning Site

The orangebelly darter is quite specific in its selection of spawning sites. The spawning site is usually located in the moderate current portions of the raceway section of the stream. The actual spawning sites are patches of small-diameter (3-5 mm) gravel. These patches are commonly found in low spots in the stream bed or downstream from large rocks. Gravel deposits tend to accumulate in these more protected areas due to the change in water-current velocity. The gravel areas range in size from large patches covering approximately 25 square feet to smaller ones of less than one square foot. The large patches are generally found downstream from exposed bedrock areas or weedbeds, while the small patches are usually found behind large rocks. These accumulations of gravel are always free of silt and vegetative litter.

During the two breeding seasons studied, searches were made for spawning sites other than the areas mentioned above. These searches included the inspection of the pool, raceway, and riffle portions of the stream and the materials found in them. Aquatic vegetation, sand, large rocks, sticks, logs, and mud were all examined for orangebelly darter eggs. No eggs were found except in the gravel bottom areas of the raceway or in areas where the water current had carried this gravel.

Darters are known to deposit their eggs on a variety of objects in various portions of the stream. Seal (1892) stated that the johnny darter, _E. nigrum_, deposits its eggs on the undersides of stones. Petravicz (1938) stated that the blackside darter, _Percina maculata_, lays its eggs in shallow depressions of sand and gravel. Winn (1958b) stated that the least darter, _E. microperca_, deposits its eggs on aquatic vegetation. Some darters, such as the greenside darter, _E. blennioides_, prefer the swift riffle portions of streams for egg laying (Winn, 1957) while others, like the slough darter, _E. gracile_, utilize quiet water areas (Braasch and Smith, 1967).

Darters appear to be quite specific in their selection of spawning sites. Winn (1957) found that the orangethroat darter, _E. spectabile_, and the rainbow darter, _E. caeruleum_, both spawn in the same stream at the same time, but he found that the two darters utilize different spawning niches. Both spawn on fine gravel in the riffle portions of the stream, but the two species select slightly different sizes of gravel. The gravel which the rainbow darter uses is coarser than that utilized by the orangethroat darter; thus, gravel size aids in the maintenance of separate spawning niches on the same riffle for these two species.

In the Blue River, five species of darters are commonly found, but the spawning sites utilized by these fishes are usually different. _Etheostoma radiosum cyanorum_ utilizes the gravel areas in the raceway portions of the stream; _E. spectabile_ uses the gravel in the riffle portions of the stream; _E. microperca_ utilizes aquatic vegetation in somewhat less turbulent areas. The channel darter, _Percina copelandi_, uses gravel in the deeper water areas, and the logperch, *P. caprodes*, utilizes sandier areas. The only species which exhibit much overlap in spawning areas are the orangethroat and orangebelly darters (See Hybridization). Most of these species of darters also differ in their times of spawning.

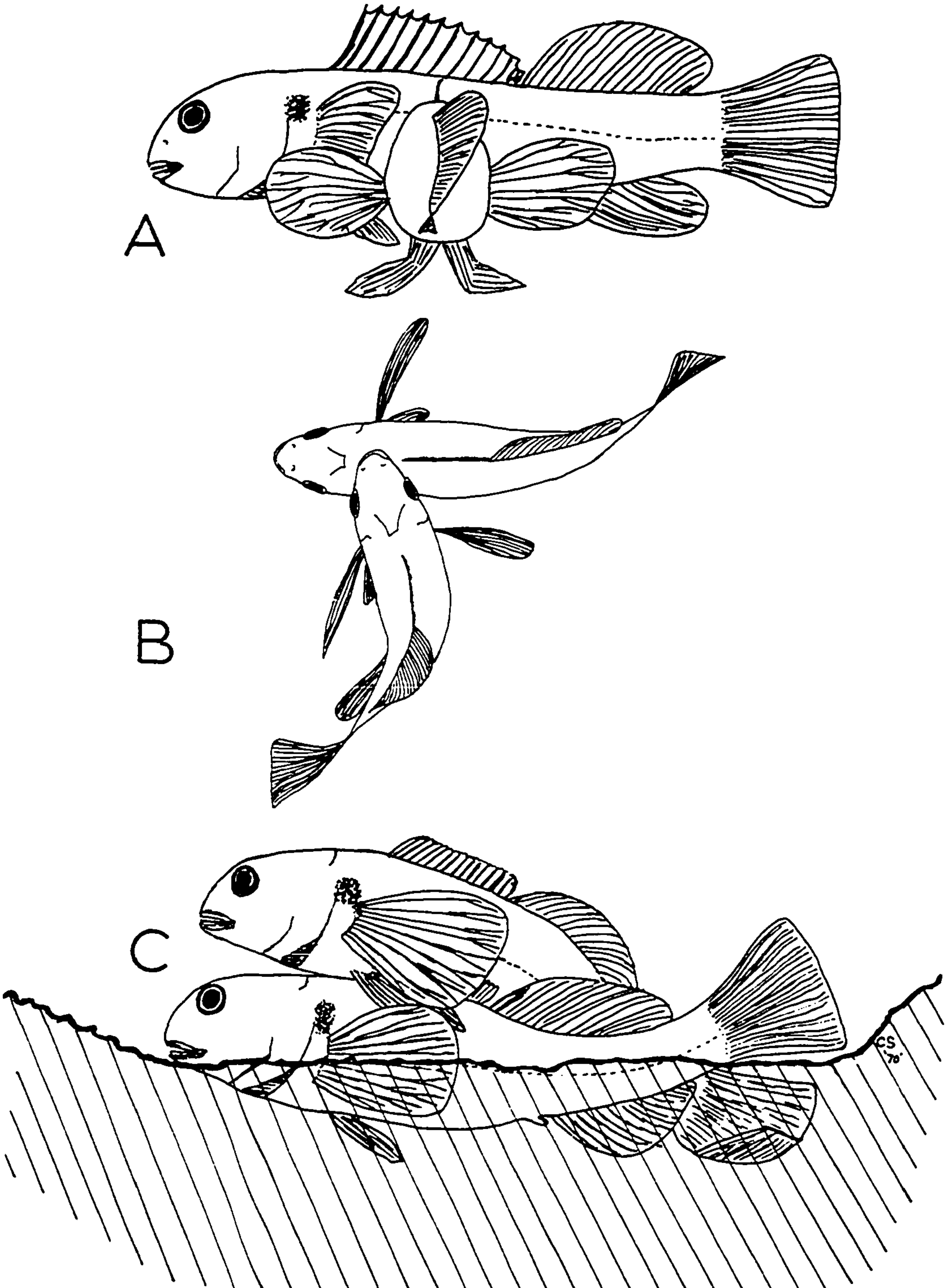
Courtship and Spawning Behavior

The courtship and spawning behavior phases of the life histories of many darters have been recorded. Winn (1958a) published a comprehensive work encompassing the comparative reproductive behavior of 14 species of darters. Fahy (1954) described the reproductive behavior of the greenside darter, *Etheostoma blennioides*. Other excellent papers dealing with reproductive behavior and breeding habits of darters have been published by Atz (1940), Braasch and Smith (1967), Lake (1936), Mount (1959), New (1966), Petravicz (1936), Petravicz (1938), Reeves (1907), Reighard (1913), Winn (1953), and Winn and Picciolo (1960). Linder (1958) described the spawning behavior of the orangebelly darter, *Etheostoma radiosum*, but his observations were made only under laboratory conditions. Field observations of the courtship and spawning behavior of the orangebelly darter have not previously been reported.

A glass-bottom, underwater viewer was utilized to observe the breeding behavior of the orangebelly darter. Without this device observation was impossible because of a combination of surface reflection and water turbulence. It was possible to sit in the middle of the stream and use the underwater viewer without observably affecting the behavior of the darters. The presence of two human legs, four wooden legs of a campstool, and an aluminum tube six inches in diameter was virtually ignored by the fish. It was not uncommon to have darters actively spawning within an inch of any one of these six legs, and frequently the downstream sides of these obstacles were used by the darters as convenient resting places. It was also possible to move around in the spawning area following a particular pair of courting or spawning fish without disturbing their activity. The reason for this obliviousness may be explained by the fact that the adult fish have relatively few, or no, predators (See Predators). Throughout the year, not just during the breeding season, these fish were easily observed in the field.

Courtship behavior began when a female entered the spawning area. This area was usually occupied by a varying number of males, the number depending upon the size of the males and the size of the area. Small areas might have only one or two males while some of the larger areas contained dozens of males. While swimming through the spawning area the female would be confronted by a male. The male would attempt to get directly in front of the female and stop her from swimming further. If she stopped he would swim so that he was in front of and perpendicular to her. He would then erect his brightly colored dorsal and anal fins and very rapidly fan his pectoral fins (Figure 5A). This fanning was usually accompanied by a vibration or trembling of his whole body and at times these movements were no more than a series of quick jerks. The female would then swim on and the same procedure would be repeated. The male often appeared to nip at or nudge the body of the female as he chased after her. During this chasing phase of courtship, four possible occurrences could result. First, the female could ignore

Figure 5. Courtship and spawning postures of the orangebelly darter, *Etheostoma radiosum cyanorum*, in the Blue River, Oklahoma.
A. Male darter (laterally oriented fish) confronting female.
B. Top view of male darter resting head on back of female.
C. Lateral view of spawning act (female on bottom).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the male and keep swimming until she was out of the spawning area; second, the male could cease chasing the female; third, another male could replace the original male and continue the same courtship behavior; or finally, the two fish could continue courtship and consummate it by spawning.

Most females swimming through the area would stop when confronted by a male; however, sometimes a female darter would not stay in the area but instead would swim away until the male ceased his chase. This non-receptive female would be ignored by all males once she had left the spawning area.

At times males would begin courtship behavior only to stop after the female appeared to be receptive. Why this particular reaction was exhibited is unknown. No discernible difference in the reaction of the female to courtship could be observed. It was possible that a particular action by either the male or female triggered this cessation of courtship.

It was common for numerous males to attempt to court one female. When the female entered the spawning area a male would try to stop her and give his courtship display. While he was doing this another male could swim up to the female and try to get between her and the original courting male. At this time one of the males would chase the other male from the area. Most often the larger or more colorful male would be successful in this encounter. The male which was successful would then begin courting the female again. This procedure was done by as many as five males before one was successful in actually spawning with the female.

Quite often during this courtship behavior the male would swim up to the female and rest his head on her back (Figure 5B). No female was ever seen to swim away from a male when the fish were in this position. The effect of this behavior is not known, but it could have a stimulating effect on the fish.

During the courtship behavior the female could do one of two things. After she stopped and the male had erected his fins, fanned, and vibrated, she could either swim away or she, too, could fan her pectoral fins and vibrate her body. If she swam away without displaying, the male would chase her and begin the courtship display again. This could happen numerous times until she either swam out of the spawning area or began to display herself. If she was receptive she would then initiate the beginning of the actual spawning act. She would swim slightly off the stream bottom and then dive headlong into the gravel in an attempt to bury herself. Her caudal fin was used for propulsion in this burying procedure. Sometimes she would just poke her head into the gravel and go no further. She would then rise from the stream bottom and dive again. Some females were observed to bury themselves on the first try, but in one instance a female dived six times before burying herself. It was possible that on the abortive attempts to bury some requirement was not met by the patch of gravel selected. After burying herself deep enough so that she was completely covered by the gravel, she would begin to fan and vibrate until she formed a small depression in the stream bottom with her back exposed to the male. The male then mounted her to consummate the spawning act. He did not have to move any gravel prior to mounting. He would clasp the female with his pelvic fins and press his tail close to the tail of the female. At this time the female appeared to arch the posterior part of her body upward toward the male while he appeared to arch the posterior part of his body downward toward her (Figure 5C). Both fish would then rapidly fan and vibrate their pectoral fins and bodies for approximately two to five seconds until the spawning act was completed. This spawning act was very rapid and intense. Gravel surrounding the mating pair was thrown several centimeters in all directions. Both fish then remained motionless for a short period of time. The number of spawning acts performed varied with different females; some spawned numerous times in succession while others spawned only once before leaving the area. It was not observed how many times any particular female spawned during the course of the spawning season, but from data available on the number of eggs spawned per spawning act compared to the number of mature ova produced, it would seem that each female spawned many times.

Slight variations were observed in this breeding behavior. On one occasion a female was observed to begin and end the actual spawning act with her head completely buried in the gravel. In another instance, two males were observed to spawn simultaneously with a single female. The second male had entered the area, had swum to a position alongside the female, and had completed his portion of the spawning act, while she and a mounted male were completing their spawning act. This second male was chased away by the original male after spawning was completed. In another instance, a male courted a female and after she buried herself the male swam away and did not return. This female remained buried in the gravel for approximately three minutes and then swam away to be courted by another male who eventually spawned with her.

The exact reasons for the female burying herself and her eggs are unknown. Winn (1958a) stated that this buried position enabled the pair to remain stationary. In his experiments utilizing darters which buried themselves during spawning, the fish shot forward when they began the fanning and vibration part of the spawning act on a smooth surface. Winn (1957) also mentioned that the gravel could aid in the extrusion of eggs by placing extra pressure on the abdomen of the female. It was also probable that greater survival of eggs was accomplished by this burying behavior since it was not uncommon to find many other species of fishes in the spawning area and these fishes could prey upon exposed darter eggs (See Predators). It was interesting to note that in no way did these other fish species interfere with the darter spawning.

This description of courtship and spawning behavior of the orangebelly darter is similar to that made by Linder (1958) under laboratory conditions. In Linder's study, however, inter- and intra-specific reactions were lacking because of the paucity of space, and, therefore, fish numbers available, in an aquarium situation.

Parental Care

The orangebelly darter did not actively protect its eggs. Burying of the eggs during spawning did afford some protection, but when other fishes seemed to be feeding in areas where eggs had just been spawned, the darters paid no heed to them. This general lack of parental care of eggs coincides with Winn's (1958a) statement that species which have no, or only a "moving," territory protect their eggs only by burying them.

The larval and young-of-year stages were also not protected by the parents. After hatching, these developmental stages were found in a different part of the stream than that area inhabited by most adults. Thus the parents were not in a position where they could protect their offspring.

Hybridization

It has long been known that closely related species can produce hybrids. In recent years numerous papers concerning hybridization of etheostomatine fishes have been published: Branson and Campbell (1969), Hubbs (1958), Hubbs (1959), Hubbs (1967), Hubbs and Laritz (1961a), Hubbs and Laritz (1961b), Hubbs and Strawn (1957b), Hubbs and Strawn (1957c), Linder (1955), Linder (1958), and Loos and Woolcott (1969). These papers concern both natural and laboratory hybridization of darters.

During the present study, little work concerning hybridization of *Etheostoma radiosum cyanorum* was done. This darter has been reported to hybridize under both natural and laboratory conditions with the orangethroat darter, *E. spectabile* (Hubbs, 1967; Linder, 1958). These fishes are closely related phylogenetically and natural hybrids of the two darters are found in the Blue River system. Examination of chromosome preparations, made using the technique described by Denton and Howell (1969), revealed that both species of darters and their hybrids possessed 48 chromosomes.

How these darters hybridize has been a topic of much discussion. Linder (1955) first suspected that the hybrids resulted from sperm drift, i.e., the sperm of one species of darter being carried downstream by water currents to the eggs of a different species. In 1958, Linder revised his earlier conclusions and stated that the two species actively spawned together in nature. Branson and Campbell (1969) also implied that the two species actively spawned together, but neither these workers nor the previous one had ever observed the two species spawning together under natural conditions. During the present study, many hours were spent in the field observing darter spawnings, but never were the two species seen to reciprocally spawn.

If active inter-specific spawning does take place, it is possible that only small areas of the stream are utilized for such activity. Natural hybridization of these fishes may occur only where man has disrupted the habitat or where natural phenomena have caused change. Blair (1951) stated that species are prevented from interbreeding only by complexes of isolating mechanisms and that hybridization involves the breakdown of some of these mechanisms. These two fishes spawn in different habitats, _E. radiosum_ spawning in the raceway areas and _E. spectabile_ in the riffle areas, but there is some overlapping of spawning sites. This overlap plus changing conditions could break down reproductive isolating mechanisms between the two species.

Hybridization may serve an important function in nature in that occasional crossings, accompanied by backcrossings, might cause an introduction of new genes into the species concerned, thereby bringing about greater variability, thus adaptability, within the species. Hubbs (1955) stated that where the environment is in a state of flux, increased premium may be inherent in the genetic variability that hybridization produces.

Branson and Campbell (1969) suspected that introgression was occurring between the orangebelly and orangethroat darters, but they were unable to substantiate this hypothesis because of their inability to locate a population of hybrid-like E. spectabile in the absence of E. radiosum. Whether introgression is occurring between these two fishes can only be resolved by more study.

That natural hybrids of orangebelly and orangethroat do occur is known. Whether these hybrids produce viable sperm or eggs is not known. Linder (1958) was unable to obtain offspring from crosses involving hybrid parents. In the present study, laboratory experiments utilizing artificially stripped hybrid sperm and eggs were also unsuccessful. Numerous crosses were made and none resulted in developing eggs, but this can not be construed as proof of non-viability. Many such artificial crosses during the present study resulted in failure, even those involving sperm and eggs of the same species.

CHAPTER XIII

EGGS AND OFFSPRING

Materials and Methods for Development Studies

The egg and offspring phases of the life history of the orangebelly darter were conducted in both the laboratory and field. Eggs were obtained from ripe female darters using techniques described by Strawn and Hubbs (1956). Eggs were allowed to develop in one-gallon plastic aquaria. These aquaria were aerated and maintained at a constant temperature. After hatching and absorption of the yolk sac, larval stages were fed with zooplankton obtained in the field and with brine shrimp hatched in the laboratory. Some eggs and various larval stages were obtained in the field, although in most cases these fish were not used because of their unknown age and parentage.

The development of the egg and larval stages was observed under a Bausch and Lomb dissecting microscope. This scope, with magnification up to 30X, was also used as an aid while making freehand drawings of the developmental stages of the darter. Developmental stage terminology was taken from Lagler (1956).

Description of the Egg

The fertilized egg of the orangebelly darter was spherical, demersal, transparent, and adhesive. Eggs were laid singly or in clusters of up to ten. A large prominent yellow oil globule, sometimes surrounded by several smaller globules, imparted a distinct yellow color to the egg although the cytoplasmic material was colorless. The eggs, which adhered to small pieces of gravel, were usually slightly flattened on the side of attachment, and since the eggs were buried they often had two or three of these flattened sides. The diameters of fertilized eggs ranged in size from 1.2 to 1.5 mm. The eggs water-hardened and became less yellowish in color approximately ten minutes after fertilization.

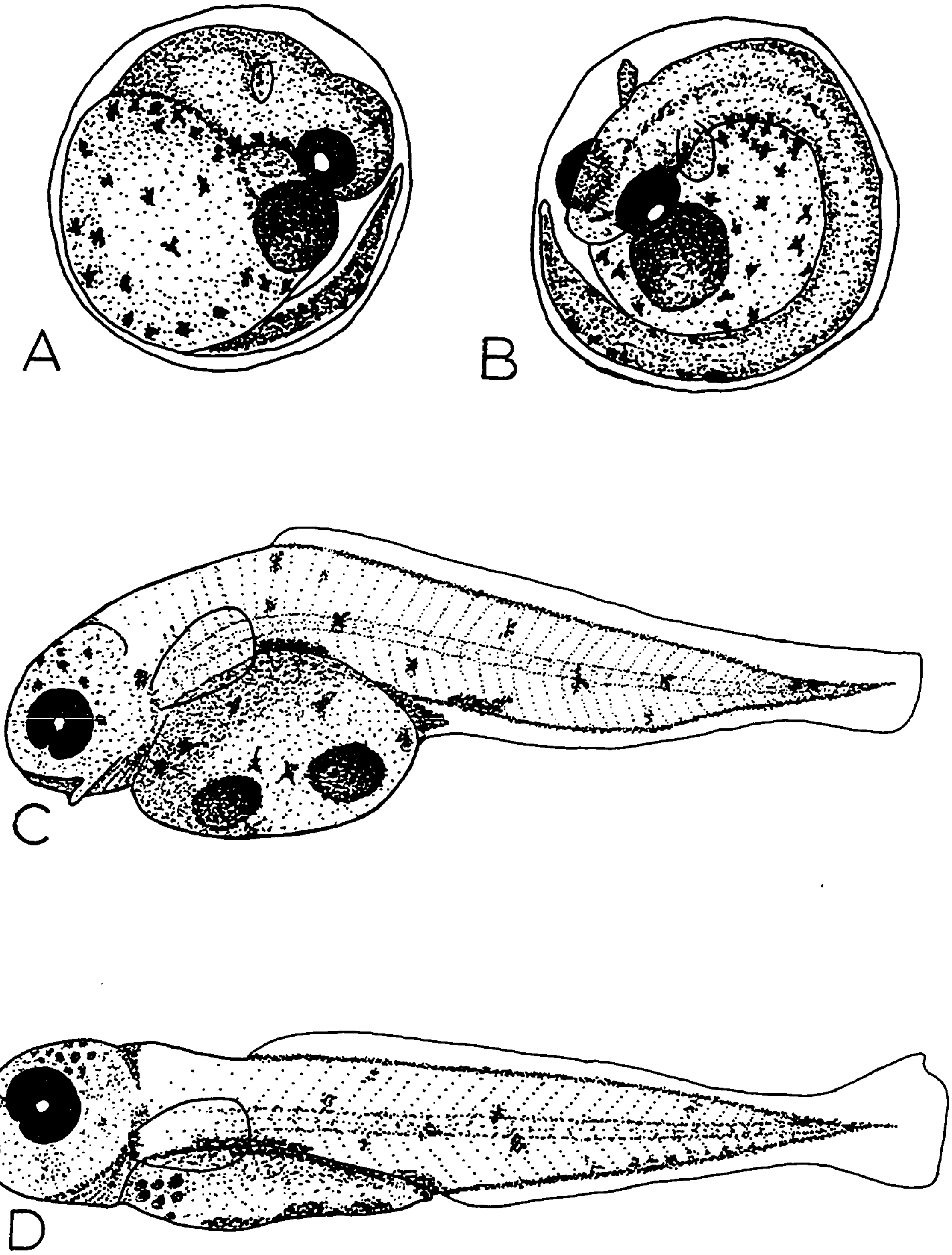
Embryogeny

The time required for complete development of the embryos varied with temperature. Eggs kept at 50°F took 26 days to hatch; those kept at 55°F took ten days to hatch, while those kept at 60°F required eight days to hatch.

In the eggs developed at 55°F the two-cell stage was observable one hour after fertilization. The four-cell stage was reached in an additional twenty minutes. This development continued until the embryo, at approximately 96 hours, had recognizable head, trunk, and tail regions (Figure 6A). At this time the tail was free from the yolk sac and was free moving. The optic cups were clearly visible and melanophores were present, especially in the tail and yolk sac regions. The heartbeat and other embryonic movements could also be observed at this stage.

At 144 hours (Figure 6B) the optic cups were well developed and circulation through the dorsal aorta and vitelline vessels was apparent. The egg capsule at this time had almost completely lost its adhesiveness.

Figure 6. Embryonic and prolarva stages of the orangebelly darter, *Etheostoma radiosum cyanorum*. A. 96-hour embryo at 55°F. B. 144-hour embryo at 55°F. C. Prolarva, 5.4 mm total length. D. Prolarva, 6.1 mm total length.


A
B
C
D

The pectoral fins had appeared and were fan shaped but contained no evident fin-ray elements. The gut was present as a straight tube running from the region of the esophagus to the posterio-ventral attachment of the yolk sac. The fin-fold in the tail region was continuous both ventrally and dorsally. No fin-ray elements were evident anywhere in the fold. The lower jaw appeared to be weakly formed. The oil globule was still large and prominent. At this time the embryo was very active and frequently rotated within the egg capsule.

Hatching

For approximately one day before hatching there was intensely vigorous and almost continuous movement by the embryo. The egg was completely free from attachment to gravel at this time. In all cases observed the darters hatched tail first. After the tail had broken through the egg capsule, vigorous movement was needed to free the head and pectoral fins. Some fish were unsuccessful in extricating their heads from the capsule and this eventually led to their deaths. After freeing themselves the larvae remained motionless on the bottom of the aquaria, but if disturbed they were able to swim.

Tail-first hatching has been observed for numerous species of darters. Fahy (1954) stated that most greenside darters, *E. blennioides*, hatched tail first. Linder (1958) found that some *E. radiosum* X *E. spectabile* hybrids hatched tail first while others hatched head first; unfortunately, his experiments using purebred *E. radiosum* were unsuccessful. Fahy (1954) reported that some of his fish failed to extricate their heads from the egg capsules and died. These fish which appeared to be unable to cast off the capsule would struggle up to five hours before dying. In such cases, removal of the egg capsules with forceps before death often resulted in prolarvae which appeared to be normal.

It was possible that death due to the inability of a fish to remove itself from its egg case was atypical. In the laboratory the struggling embryos were in an aquarium with no water movement, while in the stream situation, moving water is available. This action of moving water could aid the fish in their escape from the egg capsule.

Prolarva

The newly hatched prolarvae were between 4.8 and 5.6 mm in total length (Figure 6C). The yolk sac was still very evident and the oil globule or globules were still quite large. The pectoral fins showed only slight development of fin-ray elements. No differentiation was present in the dorsal or ventral portions of the fin-folds, but the fish had developed a weakly diphycercal tail. Melanophores were concentrated on the head region and on the periphery of the yolk sac. The mouth, though weakly formed, was open and some opercular movement was exhibited, although development of the opercula was incomplete. The heartbeat was evident and circulation throughout the body could be seen.

In the late stages of prolarval development the head region of the fish was well differentiated (Figure 6D). The yolk sac was almost completely absorbed and only small remnants of the oil globules were present. No fin-ray elements, with the exception of those weakly developed on the pectoral fins, were present.

Postlarva

The orangebelly darter reached the early postlarval stage of its life history approximately ten days after hatching (Figure 7A). They were about 6.9 mm in total length at this time. The yolk sac and oil globules were absorbed. Fin-ray elements began to appear on the ventral portion of the caudal region and in the second dorsal region. The dorsal and ventral fin-folds began to show differentiation. The mouth was terminal and both jaws were markedly developed.

The 8.0 mm postlarval stage (Figure 7B) exhibited fin-ray element development on the second dorsal, ventral caudal, and anal fins. As in previous stages, fin-ray development on the pectoral fins was present but weak.

The 9.1 mm postlarval stage (Figure 7C) showed great development of all fins. Observable fin-ray elements were present on both portions of the dorsal fin and on both the dorsal and ventral portions of the caudal fin. Fin-ray development on the anal and pectoral fins was also advanced. This stage also exhibited the presence of small rudiments of the pelvic fins. The fin-folds were much reduced, especially on the ventral portion of the fish.

The 10.1 mm postlarval stage (Figure 8A) exhibited almost complete development of the fin-ray elements. Only small portions of the fin-folds were present, primarily on the dorsal portion of the fish. Pigmentation was quite heavy, especially on the anterior portions of the fish. The mouth was well developed as were the opercula. The digestive tract was still a straight tube and quite transparent. The fish possessed a modified homocercal type tail.

Figure 7. Postlarval stages of the orangebelly darter, *Etheostoma radiosum cyanorum*. A. Postlarva, 6.9 mm total length. B. Postlarva, 8.0 mm total length. C. Postlarva, 9.1 mm total length.

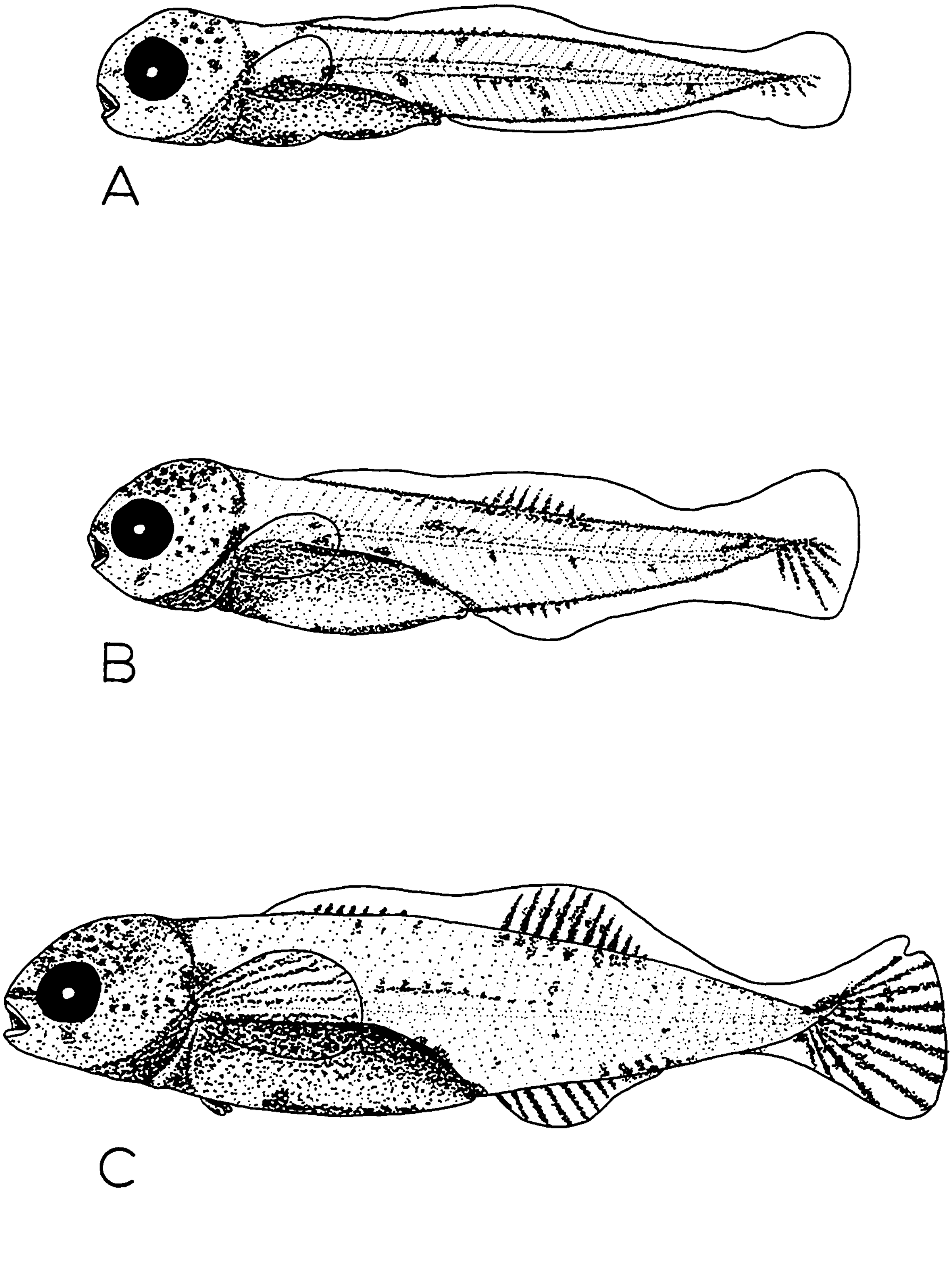
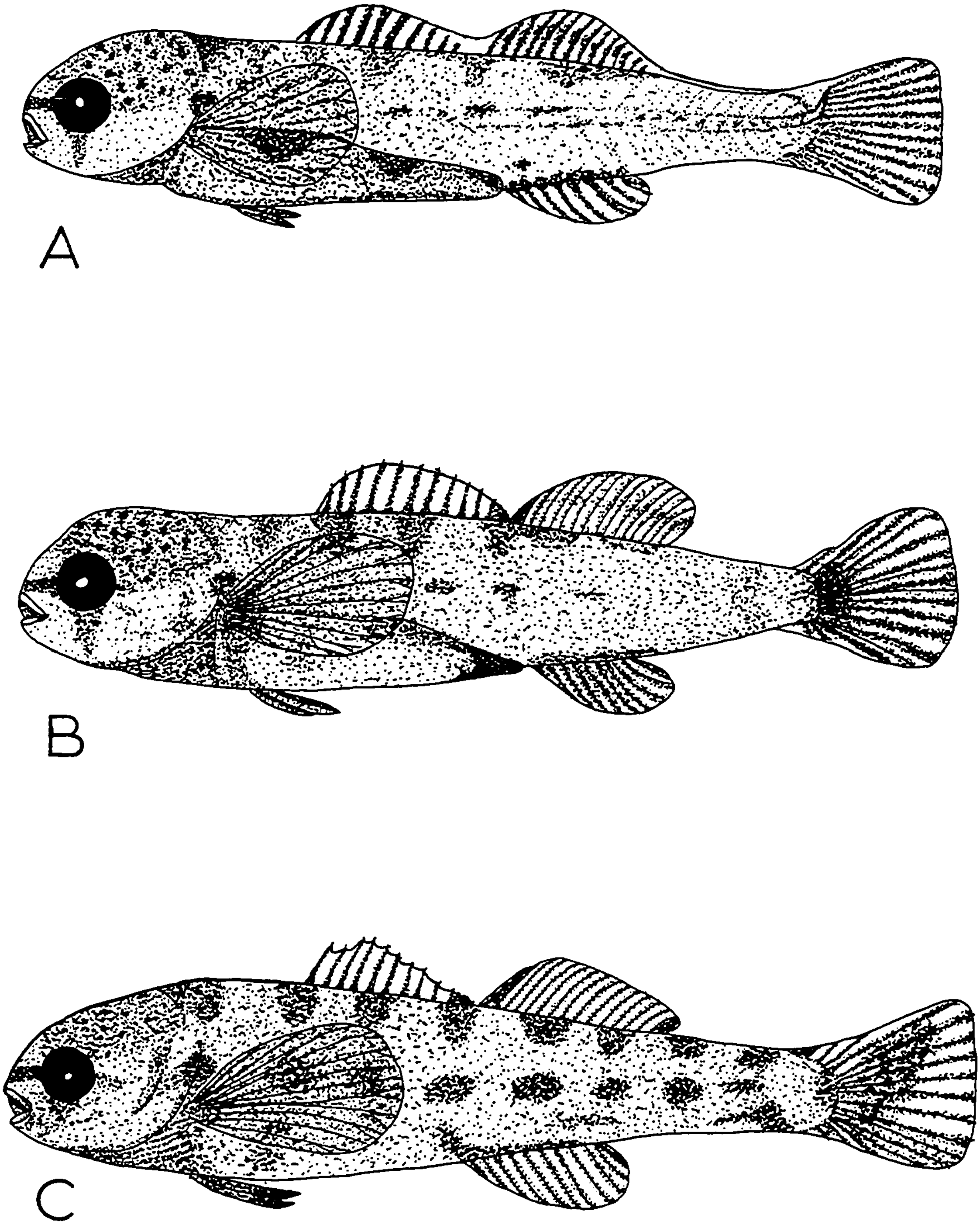

A
B
C

Figure 8. Postlarval and young-of-year stages of the orangebelly darter, Etheostoma radiosum cyanorum. A. Postlarva, 10.1 mm total length. B. Postlarva, 11.5 mm total length. C. Young-of-year, 17.7 mm total length.



A

B

C

The 11.5 mm fish (Figure 8B) represented the late postlarval stage in the life history of the orangebelly darter. The fish was almost completely developed. Young-of-year pigmentation patterns were beginning to become evident and the development of the gut was more advanced. The fish had attained enough pigmentation and size so that the myomeres were no longer visible.

Young-of-Year

The 17.7 mm darter (Figure 8C) represented an early phase of the young-of-year stage of the orangebelly darter. All fins and fin-ray elements were completely developed, the mouth and opercular regions were complete, pigmentation was well advanced, and the fish could be considered a miniature adult. This stage in development was reached approximately one and one-half months after spawning. This complete developmental series was conducted at a temperature of 55°F.

How long it took darters in the wild to reach these various stages of life was unknown. Development of wild fish could not be correlated to that of laboratory fish because of a combination of differential temperatures, spawning times, food availabilities, and innumerable other factors. These factors all contributed to differences in developmental rates exhibited by wild fish and their laboratory counterparts. One month after fish were observed to begin spawning in the middle of April, various developmental stages could be found in the wild. These stages ranged from eggs to fish over 18 mm in total length.

Laboratory fish actively fed on plankters one day after hatching. These same fish would also eat brine shrimp raised in the laboratory.

This activity of eating soon after hatching was also observed in wild fish (See Postlarval and Juvenile Food Habits).

CHAPTER XIV

AGE AND GROWTH

Determination of Age by the Scale Method

The scale method of age determination has been used successfully for many percid fishes. Deason (1933) studied the age and growth of the walleye, *Stizostedion vitreum*, with this method. The age and growth of the yellow perch, *Perca flavescens*, were studied utilizing the scale method by Hile (1931), Hile and Jobes (1940), and Jobes (1933). Numerous species of darters have also been studied by this method. Fahy (1954); Karr (1963); Lachner, Westlake, and Handwerk (1950); Raney and Lachner (1943); and Speare (1960) all used the scale method for age and growth determination of darters.

Scales of the orangebelly darter were taken from the right side of the body, above the lateral line in the vertical scale row immediately anterior to the origin of the first dorsal fin. These scales were then placed on microscope slides and observed under a Bausch and Lomb dissecting microscope. Scale formation in the orangebelly darter was such that circuli formed during the summer months, when rapid growth was prevalent, were far apart; those formed in the winter months, when little growth took place, were close together. An annulus was considered present if cutting over was observable in the lateral fields of the scale. Annuli were formed during the time between the slowing down of growth in the fall and speeding up of growth in the spring, probably right after completion of spawning. This knowledge was useful in identifying false annuli formed during the summer months.

Fish which exhibited no annuli were designated as age-group 0. Age-group I darters were those which possessed one annulus while age-groups II, III, and IV represented darters possessing two, three, and four annuli, respectively.

Age and Sex Length-Frequency Distribution

Fish collected over a one-year period (August, 1968-August, 1969) were aged by the scale method. These fish were collected approximately every two weeks throughout the year. Only fish which were 30 mm or more in standard length were utilized. During the course of the study 463 darters were aged. Table 8 represents a length-frequency distribution according to the age and sex of these fish. It was apparent that the age groups showed considerable overlap in their size ranges. Age-group 0, which ranged in standard length from 30 to 41 mm, overlapped considerably with age-group I, which ranged in size from 30-57 mm. The size range of age-group II overlapped with all age groups. The fish in this age group ranged from 38 to 69 mm in standard length. Age-group III fish ranged in size from 49-69 mm in standard length, which overlapped with age-groups I, II, and IV. Age-group IV, which was a sample of only five fish, ranged in size from 58-69 mm and overlapped with age-groups II and III. Because of these great overlaps in size ranges it was difficult to delineate the age groups into definite

Table 8. Length-frequency distribution according to age and sex of 463 orangebelly darters, Etheostoma radiosum cyanorum, collected from the Blue River, Oklahoma, August, 1968 through August, 1969.

Standard length in mm	Age-group										Totals for all age groups		
	0		I		II		III		IV				
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂&♀
30-33	10	20	5	16	--	--	--	--	--	--	15	36	51
34-37	7	16	16	23	--	--	--	--	--	--	23	39	62
38-41	1	3	21	39	6	13	--	--	--	--	28	55	83
42-45	--	--	24	17	26	11	--	1	--	--	50	29	79
46-49	--	--	12	2	29	14	6	--	--	--	47	16	63
50-53	--	--	1	--	17	13	7	9	--	--	25	22	47
54-57	--	--	1	--	7	4	15	6	--	--	23	10	33
58-61	--	--	--	--	2	3	7	6	1	1	10	10	20
62-65	--	--	--	--	2	--	8	3	1	1	11	4	15
66-69	--	--	--	--	1	--	7	1	1	--	9	1	10
Total	18	39	80	97	90	58	50	26	3	2	241	222	463

size ranges. Thus, in some cases, such as in the food and feeding portion of this paper, where the sizes of the fish involved were more important than their actual age, arbitrary ranges had to be used for delineating age groups. In that situation 30-37 mm fish represented age-group 0, 38-45 mm fish represented age-group I, 46-53 mm fish represented age-group II, and 53-69 mm fish represented age-group III.

Fahy (1954) and Raney and Lachner (1943) in their works on the age and growth of other species of darters stated that although there was overlap in size ranges of various age groups, age-group 0 specimens could be completely separated from the other age groups because of their size. This was not the case with the orangebelly darter where age-group 0 overlapped with both age-groups I and II. These previous authors also stated that it was possible for more than one age group to have the same mode. This situation also was not found in the orangebelly darter, in which each age group had a different mode.

It should be mentioned here that the length-frequency distribution given in this paper does not represent the relative abundances of all age groups of darters. Age-group 0 was smaller than would be expected in the actual population because only fishes of 30 mm or more in standard length were used, thus eliminating many age-group 0 fish.

Upon initial examination it appeared that male orangebelly darters of each age group, except age-group 0, were larger than their female counterparts. This would have corresponded to results obtained by Fahy (1954) for the greenside darter, Etheostoma blennioides. Unfortunately, this trend could not be shown statistically. Figure 9 is a statistical comparison of the sexes. In a comparison of two

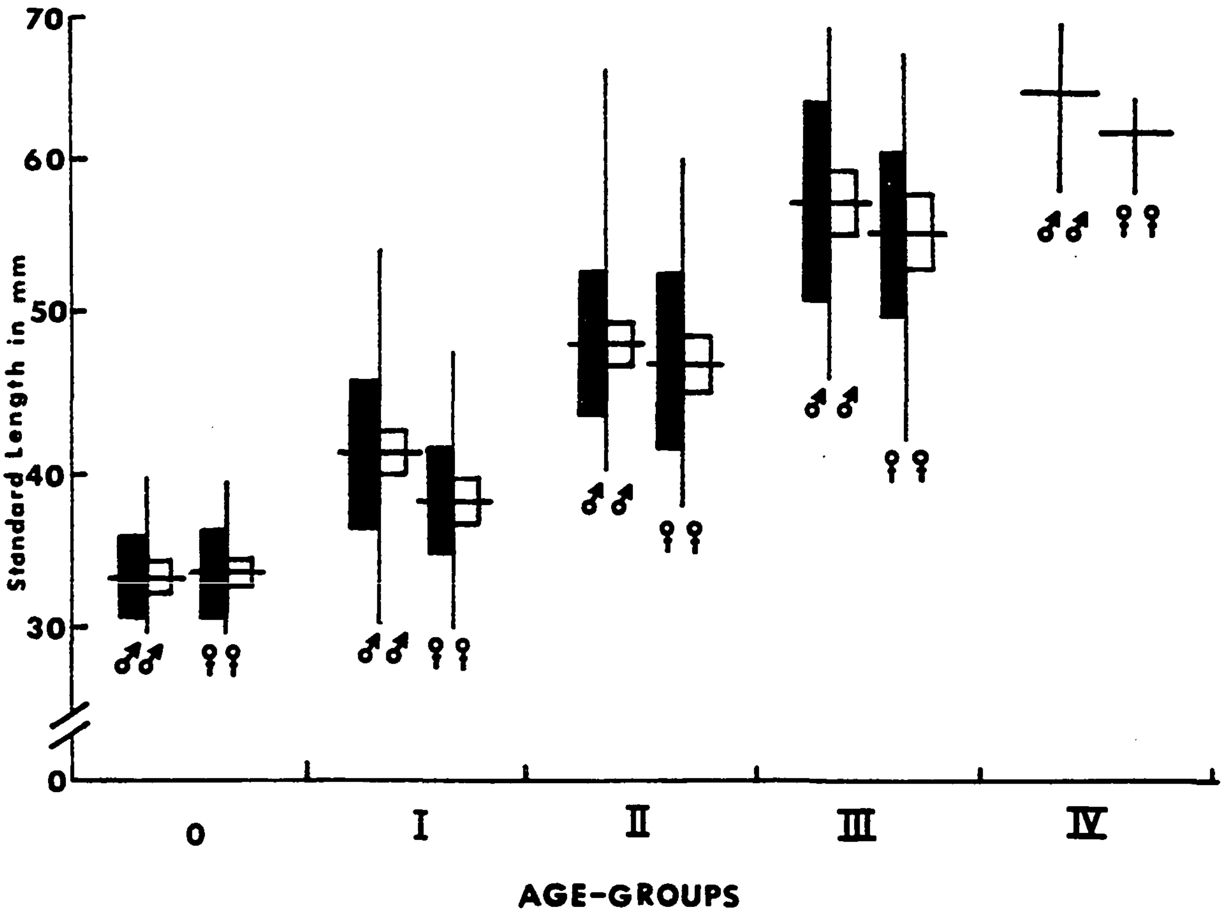


Figure 9. Comparison of the mean standard lengths of the sexes within different age groups of orangebelly darters, <u>Etheostoma radiosum cyanorum</u>, collected in the Blue River, Oklahoma, August, 1968 to August, 1969. In each of the vertical figures the range of variation is indicated by the vertical line; the mean is represented by the single horizontal line; one standard deviation on either side of the mean is marked by the solid rectangle, and twice the standard error on either side of the mean is indicated by the hollow rectangle.

sample means, no significant difference between them was indicated if more than one-third of the length of the shorter of the two hollow rectangles was overlapped by the longer (Fahy, 1954). From Figure 9 it would appear that only those males and females of age-group I were statistically different in body length. All other age-group comparisons showed non-significant results, except in age-group IV of which there were too few samples to make a statistical analysis. Thus, although there appeared to be differential growth of each sex, only one age group showed this difference statistically.

No estimates of sex ratios were made because slight differences in the habitat utilized by the different sexes caused unequal sampling. Greater numbers of females were present in the slower portions of the sampling areas, while males were more prevalent in the swifter portions of the stream. The swifter portions of the sampling areas were more easily sampled; consequently, a preponderance of males was present in the samples.

Longevity

The oldest fish observed were five darters which were in their fifth year of life. The largest of these was a 69 mm male. These five fish represented approximately 1% of all fish studied. Approximately 15% of the fish were found to be in their fourth year of life. Thus only 16% of the fish examined were beyond three years of age. It was concluded that the orangebelly darter in the Blue River had a typical life span of three years or less.

CHAPTER XV

POPULATION STUDIES

Estimates of darter population densities have been made by only a few workers. In these cases the estimates entailed the complete darter population of a stream, not individual darter species. Schwartz (1965), while working on the Allegheny River in Eastern Pennsylvania, reported darter populations of between 0.05 and 0.16 darters per square foot. Lachner, Westlake, and Handwerk (1950) found populations of approximately 0.11 darters per square foot in French Creek in Western Pennsylvania. Reed's 1968 work, also done in Pennsylvania, resulted in darter population estimates of from 0.51 to 1.38 darters per square foot.

It would seem from the disparities in these results that sampling technique affected the population estimates of the fishes. The first two studies used a technique whereby a section of stream was continuously seined until no more darters were captured, while the latter study used a mark and recovery method for its population estimates. Each technique had drawbacks which would result in inaccuracies, but the latter technique, that of mark and recovery, seemed to best lend itself to the present study. With this technique, estimation of seining efficiency was not needed, since only the relative numbers of marked and unmarked fish were important.

It must be remembered in any mark and recovery study that different species of fishes react differently to disturbance and capture. Some completely leave the sampling areas when disturbed while others just move a short distance. Some exhibit more adverse reactions to handling and marking than do others, and some react differently depending upon their stage of development.

The mark and recovery method of population estimate is based on five assumptions: (1) that the marked fish do not lose their identifying marks during the course of the study and that the marks are recognizable upon recapture, (2) that the marked individuals are evenly distributed throughout the population and that sampling is evenly distributed throughout the body of water, (3) that both marked and unmarked fish are susceptible in the same degree to capture, (4) that the number of fish involved in the study is not increased as a result of growth or immigration, and (5) that losses due to death or emigration have the same proportion for both the marked and unmarked fish.

In the present study two different sampling periods were used. One extended from July, 1969, through August, 1969, while the other was conducted from March, 1970, through June, 1970. The marking and sampling methods have already been presented (See Movements). The sampling periods were short, thus fin regeneration was not a factor in identification. From the results of the mark and recovery experiments, it was evident that no inter-raceway movement was present during the study periods, so emigration and immigration were not considered to be factors. The darters were collected and released throughout the study area, thus insuring as even a distribution as possible. Only adult darters were utilized so population estimates were not affected by movement of young-of-year darters into the raceways (See Movements). It could not be ascertained to what degree the finclipping affected mortality or susceptibility of the fish to seining, but observations of finclipped darters in the laboratory and field provided no evidence that finclipping increased mortality or decreased maneuverability.

The population estimates were calculated using the Schumacher-Eschmeyer formula (Lagler, 1956),

$$P = \Sigma m^2(u+r)/\Sigma mr,$$

where m represented the number of marked fish, u represented the number of unmarked fish captured, and r represented the number of marked fish recaptured.

Using the Schumacher-Eschmeyer formula, it was found that approximately 818 adult orangebelly darters inhabited the raceways and riffles of the study area. This area consisted of approximately 3,300 square feet so there were an estimated 0.25 adult orangebelly darters per square foot. This figure was lower than the estimates made by Reed (1968) who also used the mark and recovery method, but in that study all species and sizes of darters were counted. If all darters, regardless of size or species, had been recorded in this study, it was possible that the population estimate would have been similar to those made by Reed, although such a similarity would not necessarily be significant.

The figure of 0.25 adult orangebelly darters per square foot may be deceiving. The study area of approximately 3,300 square feet included areas which were not considered to be good adult orangebelly darter habitat. These areas of shallow riffles and shallow quiet water along the edges of the stream seldom harbored large numbers of adult darters. From field observations with an underwater viewer the adult darters appeared to be more numerous in the raceway areas than the estimated one fish per four square feet. It was probable that some of the more preferred habitat areas harbored as many as three or four adult darters per square foot, while the marginal habitat areas contained only one darter for every ten or 12 square feet.

CHAPTER XVI

SUMMARY

The orangebelly darter, *Etheostoma radiosum cyanorum*, is found only in the Blue River system of South Central Oklahoma. This represents the westernmost subspecies of this species which is found only in Southeastern Oklahoma and South Central Arkansas. Little work has been done on this fish, one of the reasons being its rather small range.

The fish primarily inhabits the raceway portions of the stream, but it is found to some degree in the pool and riffle areas. It was found in association with 51 other species of fishes.

The darters have no apparent predators, but eggs, larval, and adult stages may be preyed upon by other fish species, aquatic invertebrates, or terrestrial vertebrates. It is also possible that the orangebelly darter itself preys upon the eggs.

Some parasites were found to infest the orangebelly darter. Large numbers of a leech, *Illinobdella moorei*, were present, but other parasites were found at only minor levels of infestation.

The feeding responses of the darters were primarily elicited by visual cues. Moving items were actively fed upon while immobile items were shunned. The postlarval and juvenile darters fed primarily on copepods, cladocerans, small ephemerids, dipteran larvae, baetids, and hydropsychids. The smaller of these larval stages fed primarily on the copepods and cladocerans, while the older larval and juvenile stages mainly utilized the latter-mentioned items.

The food of the adults consisted primarily of the aquatic larvae or naiads of five families of insects. These families, Tendipedidae, Baetidae, Ephemeridae, Hydropsychidae, and Simuliidae, represented 97.3% of the total food number and 95.0% of the total food volume of the 459 adult orangebelly darters examined. These food organisms were utilized to differing degrees by the various age groups of darters. Although the percent number of food items used varied with the size of the fish, the greatest volume of food in all size groups consisted of hydropsychids. It appeared from Surber stream-bottom samples that food organism utilization was not directly correlated to the numbers and volumes of food organisms present in the stream. The foods of both the young and adult darters appeared to be dictated by the availability, preferability, and vulnerability of the food organisms present in the stream.

From mark and recovery experiments it was found that adult orangebelly darters had rather small home ranges. No inter-raceway and very little intra-raceway movement was exhibited by adult darters.

Larval and juvenile darters were observed to migrate. The darters spent the early larval stages of their lives in the pool areas of the stream. As the fish increased in size they moved into the faster portions of the stream.

Adult male darters have a "moving" territory during the breeding season. This territory surrounds the female fish which the male is courting. There is only slight non-reproductive territoriality shown by the orangebelly darter and this is exhibited only by larger male fish.

Most orangebelly darters spawn when one-year old. The months of March, April, and May represent the time of greatest gonadal development. At the height of this development the ovaries represent approximately 10-15% of the body weight of the females. The orangebelly darter exhibits a rather low fecundity. By indirect evidence it was concluded that the darters spawned approximately 52 to 270 eggs, depending upon the size of the fish involved.

Spawning takes place in the early spring. Areas of the raceway where small diameter gravel (3-5 mm) is present are utilized as spawning sites. The males actively court the females. After courtship the female buries herself in the gravel, the male mounts her, and the spawning act is consummated. The only mode of parental care which the darters exhibit is the burying of the eggs in gravel.

The eggs are spherical, demersal, transparent, and adhesive. Eggs are laid singly or in clusters of up to ten. Eggs kept at 55°F required ten days for hatching. After hatching tail first, the prolarvae are between 4.8 and 5.6 mm in total length. The darters enter the postlarval stage when approximately 6.9 mm in total length. The young-of-year stage begins at approximately 17.0 mm in total length. In aquaria, it took one and one-half months at 55°F to reach the young-of-year stage.

The orangebelly darter hybridizes with the orangethroat darter, _Etheostoma spectabile_, but it was not ascertained whether these hybrids produced viable sperm and eggs.

The ages of 463 darters were determined by the scale method of age determination. These fish were divided into five age groups. Male darters appeared to have a faster growth rate than female darters but this could not be shown statistically for all age groups. The majority of the darters were in their third year of life or younger; only 16% of the fish examined were older than three years of age. The largest fish examined was a 69 mm (standard length) male which was in its fifth year of life.

Adult orangebelly darters were found to be present at a density of 0.25 darters per square foot. This population estimate was made using the Schumacher-Eschmeyer formula, which required a mark and recovery method of population estimation.

LITERATURE CITED

Allee, W. C., A. E. Emerson, O. Park, T. Park, and K. P. Schmidt. 1949. Principles of Animal Ecology. W. B. Saunders Co., Philadelphia and London. 837 p.

Atz, J. W. 1940. Reproductive behavior in the eastern johnny darter, Boleosoma nigrum olmstedi (Storer). Copeia 1940:100-106.

Baerends, G. P., and J. Baerends-van Roon. 1950. An introduction to the study of the ethology of cichlid fishes. Behaviour supplement 1:1-243.

Bailey, R. M., H. E. Winn, and C. L. Smith. 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. Proc. Acad. Nat. Sci. Phila. 106:109-164.

Blair, W. F. 1951. Interbreeding of natural populations of vertebrates. Amer. Nat. 85:9-30.

Boulenger, G. A. 1895. Catalogue of the perciform fishes in the British Museum. Cat. Fishes Brit. Mus. (2nd ed.) 1:1-394.

Braasch, M. E., and P. W. Smith. 1967. The life history of the slough darter, Etheostoma gracile (Pisces, Percidae). Ill. Nat. Hist. Survey. Biological Notes No. 58:1-12.

Branson, B. A., and J. B. Campbell. 1969. Hybridization in the darters Etheostoma spectabile and Etheostoma radiosum cyanorum. Copeia 1969:70-75.

Breder, C. M. 1924. Respiration as a factor in locomotion of fishes. The Amer. Nat. 58:145-155.

Breder, C. M., Jr. 1949. On the relationship of social behavior to pigmentation in tropical shore fishes. Bull. Amer. Mus. Nat. Hist. 94(2):87-106.

Cockerell, T.D.A. 1913. Observations on fish scales. Bull. U. S. Bur. Fish. 32:117-174.

________. 1927. The scales of the darter Richiella brevispina Coker. Copeia 1927:18-19.

Collette, B. B. 1962. The swamp darters of the subgenus Hololepis (Pisces, Percidae). Tulane Studies in Zoology 9(4):115-211.

_______. 1965. Systematic significance of breeding tubercles in fishes of the family Percidae. Proceedings of the U. S. National Museum 117(3518):567-614.

Deason, H. J. 1933. Preliminary report on the growth rate, dominance, and maturity of the pike-perches (Stizostedion) of Lake Erie. Trans. Amer. Fish. Soc. 63:348-360.

Denton, T. E., and W. M. Howell. 1969. A technique for obtaining chromosomes from the scale epithelium of teleost fishes. Copeia 1969:392-393.

Edmondson, W. T. /ed./ 1959. Freshwater Biology, 2nd ed. Wiley, New York. 1248 p.

Fabricius, E. 1951. The topography of the spawning bottom as a factor influencing the size of the territory in some species of fish. Ann. Report 1950, Inst. Freshwater Res. Drottningholm 32:43-49.

Fahy, W. E. 1954. The life history of the northern greenside darter, Etheostoma blennioides blennioides Rafinesque. Jour. Elisha Mitchell Sci. Soc. 70(2):139-205.

Fowler, H. W. 1904. Notes on fishes from Arkansas, Indian Territory, and Texas. Proc. Acad. Nat. Sci. Phila. 242-249.

Gerking, S. D. 1953. Evidence for concepts of home range and territory in stream fishes. Ecology 34(2):347-365.

Gilbert, C. H. 1887. Descriptions of new and little known etheostomoids. Proceedings of the U. S. National Museum 10:47-64.

Girard, C. 1859. Ichthyological notices. Proc. Acad. Nat. Sci. Phila. 100-104.

Hile, R. 1931. The rate of growth of fishes of Indiana. Indiana State Cons. Dept., Invest. Indiana Lakes and Streams 2(1):7-55.

Hile, R., and F. W. Jobes. 1940. Age, growth, and production of the yellow perch, Perca flavescens (Mitchell), of Saginaw Bay. Trans. Amer. Fish. Soc. 70:102-122.

Hoffman, G. L. 1967. Parasites of North American Freshwater Fishes. U. of Cal. Press, Berkeley and Los Angeles. 486 p.

Hoffman, G. L., and R. E. Putz. 1965. The black-spot (Uvulifer ambloplites: Trematoda: Strigeoidea) of centrarchid fishes. Trans. Amer. Fish. Soc. 94(2):143-151.

Hornuff, L. E. 1957. A survey of four Oklahoma streams with reference to production. Master's Thesis. Univ. Oklahoma. 44 p.

Hubbs, C. 1958. Fertility of F_1 hybrids between the percid fishes, Etheostoma spectabile and Etheostoma lepidum. Copeia 1958:57-59.

________. 1959. Laboratory hybrid combinations among etheostomatine fishes. Texas Journ. Sci. 11:49--56.

________. 1967. Geographic variations in survival of hybrids between etheostomatine fishes. Texas Memorial Mus. Bull. 13:1-72.

Hubbs, C., and C. M. Laritz. 1961a. Occurrence of a natural intergeneric etheostomatine fish hybrid. Copeia 1961:231-232.

________. 1961b. Natural hybridization between Hadropterus scierus and Percina caprodes. Southw. Nat. 6:188-192.

Hubbs, C., and K. Strawn. 1957a. The effects of light and temperature on fecundity of the greenthroat darter, Etheostoma lepidum. Ecology 38:596-602.

________. 1957b. Survival of F_1 hybrids between fishes of the subfamily Etheostominae. Journal Expt. Zool. 134:33-62.

________. 1957c. Relative variability of hybrids between darters Etheostoma spectabile and Percina caprodes. Evolution 11:1-10.

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

Hubbs, C. L., and J. D. Black. 1941. The subspecies of the American percid fish, Poecilichthys whipplii. Occ. Papers Mus. Zool., Univ. Michigan 429:1-27.

Hubbs, C. L., and A. I. Ortenburger. 1929. Fishes collected in Oklahoma and Arkansas in 1927. Univ. Okla. Biol. Survey 1: 45-112.

Jobes, F. W. 1933. Preliminary report on the age and growth of yellow perch, Perca flavescens Mitchell, from Lake Erie as determined from a study of its scales. Pap. Michigan Acad. Sci., Arts and Letters 17:643-652.

Jordan, D. S. 1888. A Manual of the Vertebrate Animals of the Northern United States, including the District North and East of the Ozark Mountains, South of the Laurentian Hills, North of the Southern Boundary of Virginia, and East of the Missouri River. Inclusive of Marine Species. A. C. McClurg and Co., Chicago. 375 p.

________. 1929. Manual of Vertebrate Animals of Northeastern United States. Inclusive of Marine Species. World Book Co., Yonkers, New York. 446 p.

Jordan, D. S., and B. W. Evermann. 1896. The fishes of North and Middle America. Bull. U. S. Nat. Mus. 47:1-1240.

Jordan, D. S., B. W. Evermann, and H. W. Clark. 1930. Check list of fishes and fish-like vertebrates of North and Middle America, north of the northern boundary of Venezuela and Colombia. Rept. U. S. Fish. Comm. 1-670.

Jordan, D. S., and C. H. Gilbert. 1886. List of fishes collected in Arkansas, Indian Territory, and Texas in September, 1884, with notes and descriptions. Proceedings of the U. S. National Museum 9:1-25.

Karr, J. R. 1963. Age, growth, and food habits of the johnny, slenderhead, and blacksided darters of Boone County, Iowa. Iowa Acad. Sci. 70:228-236.

Koster, W. J. 1955. Outline for an ecological life history study of a fish. Ecology 36(1):141-153.

Lachner, E. A. 1950. The comparative food habits of the cyprinid fishes, *Nocomis biguttata* and *Nocomis micropogon*, in Western New York. Jour. Washington Acad. Sci. 40(7):229-236.

Lachner, E. A., E. F. Westlake, and P. S. Handwerk. 1950. Studies on the biology of some percid fishes from Western Pennsylvania. Amer. Midl. Nat. 43:92-111.

Lack, D. 1954. The evolution of reproductive rates, *p*. 143-156. *In* Huxley, J., A. C. Hardy, and E. B. Ford, /eds./, Evolution as a Process. Allen and Unwin, Ltd., London.

Lagler, K. F. 1956. Freshwater Fishery Biology. W. C. Brown Co., Dubuque, Iowa. 421 p.

Lake, C. T. 1936. The life history of the fan-tailed darter, *Catonotus flabellaris flabellaris* (Rafinesque). Amer. Midl. Nat. 17(5): 816-830.

Larimore, R. W. 1952. Home pools and homing behavior of smallmouth black bass in Jordan Creek. Ill. Nat. Hist. Survey Biological Notes No. 28:3-12.

Linder, A. D. 1955. The fishes of the Blue River in Oklahoma, with descriptions of two new percid hybrid combinations. Amer. Midl. Nat. 5:173-191.

________. 1958. Behavior and hybridization of two species of Etheostoma (Percidae). Trans. Kansas Acad. Sci. 61(2):195-202.

Loos, J. J., and W. S. Woolcott. 1969. Hybridization and behavior in two species of Percina (Percidae). Copeia 1969:374-385.

Meek, S. E. 1891. Report of the explorations made in Missouri and Arkansas during 1889, with an account of fishes observed in each of the river basins examined. Bull. U. S. Fish Comm. 9:113-141.

________. 1894a. A catalogue of the fishes of Arkansas. Ann. Rept. Geol. Surv. Ark. 2:215-276.

________. 1894b. Report of investigations respecting the fishes of Arkansas, conducted during 1891, 1892, and 1893, with a synopsis of pervious explorations in the same state. Bull. U. S. Fish Comm. 14:67-94.

________. 1896. A list of fishes and mollusks collected in Arkansas and Indian Territory in 1894. Bull. U. S. Fish Comm. 15:341-349.

Meyer, M. C. 1946. Further notes on the leeches (Piscicolidae) living on fresh-water fishes of North America. Trans. Amer. Micr. Soc. 65(3):237-249.

Miser, H. D. 1954. Geologic map of Oklahoma. U. S. Geological Survey and the Oklahoma Geological Survey.

Moore, G. A., and C. C. Rigney. 1952. Taxonomic status of the percid fish Poecilichthys radiosus in Oklahoma and Arkansas, with descriptions of two new subspecies. Copeia 1952:7-14.

Mount, D. I. 1959. Spawning behavior of the bluebreast darter, Etheostoma camurum (Cope). Copeia 1959:240-243.

New, J. G. 1966. Reproductive behavior of the shield darter, Percina peltata peltata in New York. Copeia 1966:20-28.

Noble, G. K. 1939. The role of dominance in the social life of birds. Auk 59(3):263-273.

Ortenburger, A. I., and C. L. Hubbs. 1927. A report on the fishes of Oklahoma, with descriptions of two new genera and species. Proc. Okla. Acad. Sci. 6:123-141.

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

Petravicz, J. J. 1936. The breeding habits of the least darter, Microperca punctulata Putnam. Copeia 1936:77-82.

Petravicz, W. P. 1938. The breeding habits of the blacksided darter, _Hadropterus maculatus_ Girard. Copeia 1938:40-44.

Raney, E. C., and E. A. Lachner. 1939. Observations on the life history of the spotted darter, _Poecilichthys maculatus_ (Kirkland). Copeia 1939:157-165.

________. 1943. Age and growth of johnny darters, _Boleosoma olmstedi_ (Storer) and _Boleosoma longimanum_ (Jordan). Amer. Midl. Nat. 29:229-238.

Reed, R. J. 1968. Mark and recapture studies of eight species of darters (Pisces: Percidae) in three streams of Northwestern Pennsylvania. Copeia 1968:173-175.

Reeves, C. D. 1907. The breeding habits of the rainbow darter (_Etheostoma coeruleum_ Storer). Biol. Bull. 14:35-59.

Reighard, J. 1913. The breeding habits of the log-perch (_Percina caprodes_). Rept. Michigan Acad. Sci. 15:104-105.

Roberts, N. J., and H. E. Winn. 1962. Utilization of the senses in feeding behavior of the johnny darter, _Etheostoma nigrum_. Copeia 1962:567-570.

Schwartz, F. J. 1965. Densities and ecology of darters of the upper Allegheny River watershed. Pymatuning Lab. Ecol., Univ. Pittsburgh, Spec. Pub. No. 3:95-103.

Seal, W. P. 1892. Observations on the aquaria of the United States Fish Commission Central Station, Washington, D. C. Bull. U. S. Fish Comm. 10:1-12.

Speare, E. B. 1960. Growth of the central johnny darter, _Etheostoma nigrum_ (Rafinesque) in Augusta Creek, Michigan. Copeia 1960: 241-243.

Strawn, K., and C. Hubbs. 1956. Observations on stripping small fishes for experimental purposes. Copeia 1956:114-116.

Turner, C. L. 1921. Food of the common Ohio darters. Ohio Jour. Sci. 22(2):41-62.

Williams, G. C. 1959. Ovary weights of darters; a test of the alleged association of parental care with reduced fecundity of fishes. Copeia 1959:18-24.

Winn, H. E. 1953. Breeding habits of the percid fish _Hadropterus copelandi_ in Michigan. Copeia 1953:26-30.

________. 1957. Egg site selection by three species of darters (Pisces: Percidae). Brit. Jour. Animal Behav. 5(1):25-28.

________. 1958a. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces: Percidae). Ecol. Monogr. 28:155-191.

________. 1958b. Observations on the reproductive habits of darters (Pisces: Percidae). Amer. Midl. Nat. 59(1):190-212.

Winn, H. E., and A. R. Picciolo. 1960. Communal spawning of the glassy darter, _Etheostoma vitreum_ (Cope). Copeia 1960:186-192.