I. Identification of nine larval cyprinids inhabiting small northern rivers

II. Spatial and temporal patterns of larval fish drift in the upper Skunk River

by

Lance Galen Perry

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INTRODUCTION

The biology of early life stages of North American freshwater fishes, including taxonomy, ecology, and behavior, was, until recently, a conspicuously neglected area of fishery research. Recent emphasis on this subject has tended to focus on taxonomy (Boreman 1976) since the lack of methodologies for species identification of larvae precludes investigations of their habitat requirements and behavior in nature. Elucidating the ecological characteristics of fishes during early life stages is essential in gaining a more complete understanding of the environmental factors that regulate population dynamics and interactions at the adult level (Balon 1975a).

This investigation deals with identification and ecology of larval fishes of the upper Skunk River. The study area supports a permanent ichthyofauna as evidenced by the consistent occurrence of the same species over the last 25 years; however, little is known of the early life histories of these fishes.

Explanation of thesis format: This manuscript was written in standard scientific format according to guidelines established by the Council of Biological Editors Style Manual, 3rd ed., and by the Iowa Agriculture and Home Economics Experiment Station.

PART I: IDENTIFICATION OF NINE LARVAL CYPRINIDS INHABITING SMALL NORTHERN RIVERS[1]

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[1] Paper to be published in the proceedings of the Tennessee Valley Authority larval fish workshop, Knoxville, Tenn., 21-22 Feb., 1978.

ABSTRACT

Taxonomic descriptions are given for larvae of nine species: Campostoma anomalum, Hybognathus hankinsoni, Notropis cornutus, N. dorsalis, N. lutrensis, N. stramineus, Pimephales notatus, P. promelus, and Semotilus atromaculatus. Study material was collected in the upper Skunk River, Story County, Iowa. Identification criteria emphasize characters that are useful for distinguishing between morphologically similar species.

INTRODUCTION

Species identification of North American cyprinid larvae presently is hindered by a paucity of published descriptions and keys and by the general morphological, ecological, and reproductive similarities of many species. Identification of undescribed larvae may be accomplished by comparison with series of reference specimens produced from controlled matings; however, few such reference collections are available. Alternatively, identification may be made by field collection of sequential size series of conspecific larvae. Characters of greatest diagnostic utility are initially determined through examination of a life stage that can be positively identified. Recognition of progressively smaller-sized conspecifies then proceeds according to the presence of shared characteristics. For distinguishing between morphologically similar forms, characters must be selected that are species specific and relatively invariable during larval development. Ideally, complete developmental series of larvae of all species occurring in the study area should be available for comparative purposes.

In this study, extensive field collection of larvae resulted in identification of nine species of the genera Campostoma, Hybognathus, Notropis, Pimephales, and Semotilus. Larvae of several of these species are described here for the first time. All of the taxa discussed range widely throughout the north-central United States and are common inhabitants of streams and small rivers.

METHODS AND MATERIALS

Specimens were obtained from the upper Skunk River between Story City and Cambridge, Story County, central Iowa. Collections were made with stationary drift nets and dip nets from 25 April to 11 July, 1977. Identification of each species was based upon a combination of characters including melanophore distribution, lengths at selected developmental stages, myomere and fin ray counts and several morphometric measurements. Available literature descriptions were utilized where applicable. The presence of identifiable juveniles in the collections and knowledge of the local adult populations also aided in species determinations. All specimens were field preserved in 5-10% formalin. Observations and measurements were made with a stereoscopic microscope equipped with an ocular micrometer. The characters of greatest diagnostic value were determined empirically with the aid of guidelines in Berry and Richards (1973) and Lippson (1976a). Total length (TL), standard length (SL), and snout-vent length measurements were made according to the methods of Mansueti and Hardy (1967). The predorsal length measurement was made from the tip of the snout to the origin of the dorsal finfold (when present) or to the dorsal fin origin. The method of Siefert (1969) was utilized to distinguish preanal and postanal myomeres. Principal anal rays were counted in standard fashion (Hubbs and Lagler 1964). Photography was accomplished with a Leitz macro-dia utilizing a circular reflected-light system and Kodak Plus-X 35-mm film. Common and scientific names

of fishes follow Bailey et al. (1970). The use of the descriptive terms larva, protolarva, mesolarva, metalarva, and juvenile are in accordance with the definitions of Snyder (1976). The term stage is defined as "a just observed, immediate moment of development" (Balon 1975b).

The sequence of ontogenetic developmental events is generally similar within the Cyprinidae (Balinsky 1948). Interspecific differences were apparent, however, in the relative lengths at which comparable developmental stages were reached. Accordingly, the lengths (TL mm) of each species at initial caudal fin ray formation (i.e., beginning of mesolarval phase of development) and initial pelvic fin bud appearance were recorded for comparative purposes.

RESULTS AND DISCUSSION

The features that are useful for distinguishing cyprinid larvae are summarzied in Lippson and Moran (1974) and Lippson (1976b) as follows. The vent (anus) position generally is posterior to the midpoint of the body. The yolk sac is typically spherical anteriorly and more cylindrical near the vent. Although pigmentation is variable, several series of melanophores are usually evident: dorsally on the head and body, laterally along the horizontal septum, on the ventral surface anterior to the vent, and ventrally on the myomeres behind the vent. The latter series is also continuous internally above the body cavity. As development progresses, a single dorsal fin and two-chambered gas bladder appear. The anal fin origin is usually below or just behind the insertion of the dorsal fin, and the pelvic fins develop below or slightly in advance of the dorsal fin origin.

A summary of key characters is presented on the following page. These features, plus data presented in Table 1 and Fig. 1, allow for initial separation of the nine species into four groups on the basis of morphological similarities. Each group is subsequently treated in more detail for species identification. The descriptions follow a "dynamic" approach (Berry and Richards 1973) and are comparative; i.e., the distinguishing features of each species are described as they develop. Although there is frequent reference to melanophore distributions, newly hatched individuals may lack pigment entirely. As a result, caution should be exercised when utilizing these descriptions for identifying early protolarvae.

Group Descriptions

Group I

Preanal myomeres usually 27-28. Midventral surface between origin of preanal finfold and vent unpigmented or only a few scattered melanophores present.

Semotilus atromaculatus - creek chub
Campostoma anomalum - stoneroller

Group II

Preanal myomeres usually 25-26. A prominent midventral series of melanophores present between heart region and vent.

Notropis cornutus - common shiner
Hybognathus hankinsoni - brassy minnow

Group III

Preanal myomeres usually 24-25. Some yolk usually persists in size range 5.0 - 6.5 mm TL. Distinct linear series or aggregation of melanophores on each side of midline immediately behind heart region. Midventral surface from behind heart region to origin of preanal finfold usually unpigmented. Scattered melanophores ventrally below intestine.

Pimephales promelus - fathead minnow
Pimephales notatus - bluntnose minnow

Group IV

Preanal myomeres usually 21-22. Yolk completely assimilated by 5.0 mm TL. Entire midventral surface between heart region and vent with scattered melanophores or unpigmented.

Notropis dorsalis - bigmouth shiner
Notropis stramineus - sand shiner
Notropis lutrensis - red shiner

Species Descriptions

Group I *Semotilus atromaculatus* - creek chub (Plates 1-2)
Campostoma anomalum - stoneroller (Plates 3-4)

The only published description of the larval creek chub is that of a 14 mm TL speciment by Fish (1932). Creek chub larvae are characterized by a high number of preanal myomeres, usually 28 (Table 1). Protolarvae are large, ranging 7.0 - 8.5 mm TL. A substantial amount of yolk may persist early in the mesolarval phase. Various stages in the larval development of the stoneroller are described in Fish (1932), Reed (1958), Hogue et al. (1976), and are included in the key of May and Gasaway (1967). Length at hatching has been recorded as 5.7 mm SL (Reed 1958) and 6.3 - 6.9 mm (Hogue et al. 1976). The usual preanal myomere count for this species is 27 (Table 1).

Although larvae of the creek chub and stoneroller are morphologically similar, several characters serve to separate them. Stoneroller larvae develop more precociously, generally acquiring caudal fin rays and pelvic fin buds at a smaller size (Fig. 1). In creek chub larvae, the "ventro-visceral" pigmentation (Balinsky 1948) branches anterior to the gas bladder and extends anteriorly under each auditory vesicle. A dense, continuous line of internal pigment is thus evident above the body cavity from immediately behind the eye to the vent (Plate 1). On stoneroller larvae, the internal melanophores above the intestine and anterior to the gas bladder are sparse and scattered, the ventro-visceral pigment line appearing discontinuous and less dense than that of the creek chub larvae. Protolarval creek chubs have scattered melanophores on the

ventral surface of the yolk sac immediately behind the heart region. As the yolk is absorbed, midventral pigment is confined to the region anterior to the preanal finfold. The midventral surface between the origin of the preanal finfold and the vent remains unpigmented throughout larval development (Plate 2). Protolarval stonerollers have scattered melanophores on the ventral surface below the intestine. The midventral surface anterior to the preanal finfold usually remains unpigmented, although a few melanophores may occur in this region (Plate 4).

Early in the mesolarval phase, creek chubs acquire a concentration of melanophores on the ventral surface of the operculum (Plate 2). The ventral opercular surface remains unpigmented on mesolarval stonerollers (Plate 4). As metalarvae, the ratio of predorsal length to TL is greater in creek chubs relative to stonerollers (Table 1). Juvenile creek chubs have a large, terminal mouth. The tip of the upper jaw is on a level with the lower margin of the pupil, and the maxillary extends posteriorly to a point below the eye. A small, subterminal mouth is characteristic of juvenile stonerollers. The upper jaw is entirely below the eye, and the maxillary is short, its posterior margin not extending under the eye.

Group II — Notropis cornutus - common shiner (Plates 5-6)
Hybognathus hankinsoni - brassy minnow (Plates 7-8)

The description of newly hatched and 2-day old larvae of Notropis cornutus chrysocephalus by Fish (1932) includes several features that are inconsistent with the distinguishing characteristics of cyprinid larvae as given by Lippson and Moran (1974) and Lippson (1976b). Specifically, an apparent midbody location of the vent and the presence of an oil

globule in the yolk sac are not typical features of the family. The preanal and postanal myomere counts (14 and 19, respectively) additionally conflict with the findings of the present study. Accordingly, certain portions of that description are unreliable for identification purposes. There is no other published description of common shiner larvae. It is controversial whether the chrysocephalus form of the common shiner group represents a distinct species or a subspecies of Notropis cornutus (Gilbert 1961, Miller 1968, Menzel 1976). Our study material represents Notropis cornutus cornutus in the nomenclatural arrangement recommended by Menzel (1976). The larval development of the brassy minnow has not been described previously.

Common shiner larvae are characterized by the presence of three diverging, ventral lines of melanophores which emanate from a common origin behind the heart region. One line extends along the midventral surface to the vent. The others extend obliquely across the body cavity (Plate 6). In contrast, brassy minnow larvae possess only a single line of melanophores anterior to the vent (Plate 8). An additional feature of this species is the acquisition of a prominent melanophore on the pectoral fin base early in the mesolarval phase (Plate 8). The pectoral fin base of the common shiner remains unpigmented during larval development.

Late in the metalarval phase, common shiners acquire a longitudinal band of melanophores on the midlateral body surface. In brassy minnow metalarvae, surface melanophores on the epaxial myomeres are evenly distributed so that no lateral pigment band is evident. The relatively

smaller sizes at which brassy minnow larvae complete yolk absorption (ca. 5.2 mm TL compared to ca. 6.5 mm TL in common shiner larvae) and acquire caudal fin rays and pelvic fin buds also are diagnostic for distinguishing between these two species (Fig. 1).

Group III Pimephales promelus - fathead minnow (Plates 9-10)
Pimephales notatus - bluntnose minnow (Plates 11-12)

Characters useful for identifying fathead minnow larvae are given in Fish (1932), Hogue et al. (1976), and Snyder et al. (1977). Hatching length has been recorded as 4 mm TL (Hogue et al. 1976, Snyder et al. 1977). Fish (1932) described the larval development of the bluntnose minnow from hatching (4.6 mm TL) to the "young adult" stage (17.75 mm TL). Hogue et al. (1976) provided a photograph of a 6 mm TL specimen, which they indicated may be a larval Pimephales. Separating species of Pimephales as protolarvae is difficult, but two features were useful for distinguishing bluntnose and fathead minnows among our collections. Fathead minnow protolarvae of 5.0 - 5.5 mm TL acquire heavy pigmentation dorsally on the head and body (Plate 10), while pigment on the dorsal surface of bluntnose minnow protolarvae is restricted to a few late-developing melanophores in the occipital region and nape (Plate 12). The eye of bluntnose minnow protolarvae is distinctly flattened dorso-ventrally, whereas that of the protolarval fathead minnow is more round (Plates 9, 11).

As the yolk is absorbed and the position of the mouth becomes established, bluntnose minnow larvae can be distinguished by the conspicuously decurved snout and subterminal mouth, the upper jaw placed

well below the center of the eye (Plate 11). In contrast, the snout of the fathead minnow larvae is not noticeably decurved, the mouth is terminal, and the tip of the upper jaw is level with the center of the eye (Plate 9). Late in the metalarval phase, bluntnose minnows acquire a concentration of melanophores at the base of the dorsal fin and a dark spot at the base of the caudal fin. These characters are not evident on fathead minnow metalarvae.

Group IV — Notropis dorsalis - bigmouth shiner (Plates 13-14)
Notropis stramineus - sand shiner (Plates 15-16)
Notropis lutrensis - red shiner (Plates 17-18)

Larval features of the bigmouth shiner have not been recorded previously. Fish (1932) described the larval development of Notropis deliciosus stramineus (Cope) from 5 mm TL to 28.6 mm TL. Descriptions and illustrations of red shiner larvae are provided in Saksena (1962) and Taber (1969). Hatching length for the bigmouth shiner and sand shiner evidently is less than 3.5 mm TL, as indicated by the frequent occurrence of protolarvae in our collections ranging 3.5 - 4.0 mm TL. The eye and entire body of early protolarvae of these species may lack pigment, thus making their separation tentative at this stage (see Plate 15, specimen A). The smallest red shiner observed (4.3 mm TL) had a small cylindrical yolk sac, pigmented eye, and a series of melanophores on the lateral surface of the yolk (Plate 17). Larvae of all three species usually complete assimilation of yolk material by 5.0 mm TL.

Bigmouth shiner protolarvae (greater than ca. 3.8 mm TL) have melanophores scattered on the dorsal surface of the head and body. After

yolk absorption, the entire dorsal surface is densely pigmented, and scattered melanophores are present ventrally between the heart region and vent (Plate 14). On sand shiner protolarvae (less than ca. 5.0 mm TL), dorsal pigmentation is restricted to the occipital region. After yolk absorption, two irregular rows of melanophores appear on the dorsal surface of the body (Plate 16). This dorsal pigment remains less dense than that of the bigmouth shiner, however, i.e., the melanophores are consistently smaller and more widely spaced along the body axis. Pigment on the ventral surface of sand shiner larvae is essentially similar to that of the bigmouth shiner.

Early in the mesolarval phase, bigmouth shiners acquire a prominent melanophore in the nasal pit. The nasal pits of sand shiner larvae remain unpigmented until the late metalarval phase. As metalarvae, sand shiners acquire a concentration of melanophores along the base of the dorsal fin, and a dusky lateral band becomes evident during the juvenile period. Both characters are lacking on bigmouth shiners of comparable development.

Red shiner protolarvae have pigment in the occipital region, and a few melanophores appear dorsally on the body late in the phase. A short, linear series of melanophores is present on each side of the midline immediately behind the heart region. A prominent series also is present on the lateral surface of the intestine from immediately behind the gas bladder to the vent. The midventral surface between the heart region and the vent usually remains unpigmented during larval development (Plate 18). In contrast, melanophores are scattered over the entire ventral region of bigmouth and sand shiner larvae (Plates 14, 16).

Table 1. Selected morphometric and meristic characters of larvae of nine species of cyprinids. Length measurments (means) and myomere counts (modes) are given with ranges below. Data based on five specimens in each developmental phase.

Developmental Phase	TL(mm)	Lengths (%TL)			Myomeres		Principal anal rays
		SL	Snout-vent	Pre-dorsal	Pre-anal	Post-anal	
			Semotilus atromaculatus				
protolarvae	7.7 7.0-8.1	95 94-96	65 64-67	42 40-45	29 28-29	12 12-13	-
mesolarvae	9.1 8.0-10.7	94 91-95	64 62-66	43 41-48	28 28-29	12 12-13	-
metalarvae	13.6 12.3-14.7	88 88-90	63 61-64	47 46-48	28 27-29	12 12-13	8
			Campostoma anomalum				
protolarvae	6.5 5.7-7.0	94 91-95	66 64-68	42 39-44	27 27-28	12 11-12	-
mesolarvae	9.1 8.0-10.7	93 88-95	65 64-66	42 40-44	28 27-28	12 11-12	-
metalarvae	12.7 12.2-13.2	88 87-89	63 61-64	44 43-45	27 26-28	12 11-12	7
			Notropis cornutus				
protolarvae	6.3 5.6-6.8	96 95-96	63 61-65	36 34-38	26 25-26	13 12-14	-
mesolarvae	9.2 7.6-10.9	93 90-95	63 63-64	38 36-40	26 26-27	14 12-15	-
metalarvae	13.7 12.6-14.7	87 85-87	60 58-61	42 40-43	26 25-27	13 12-14	9

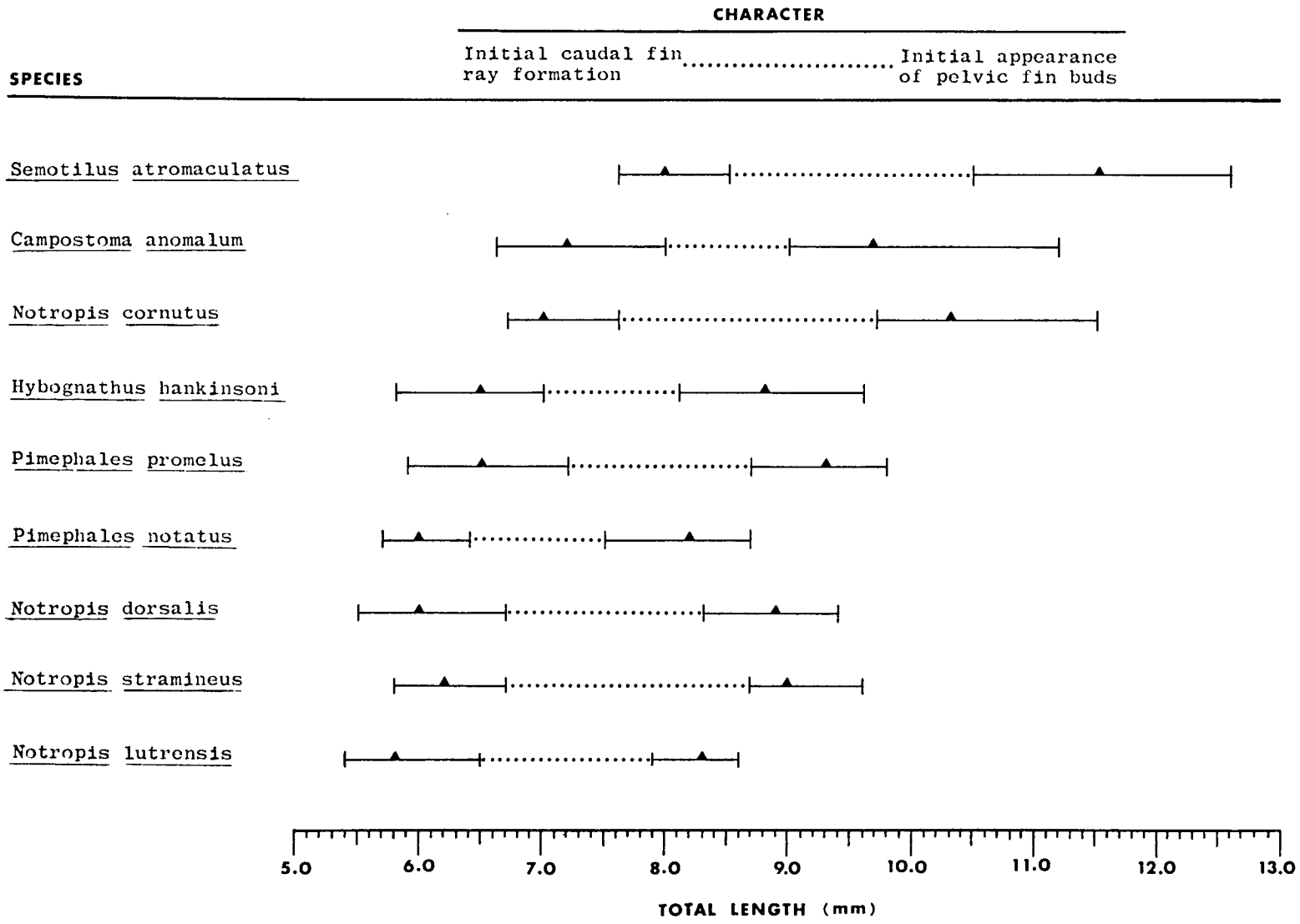
Table 1 (continued)

			Hybognathus hankinsoni				
protolarvae	5.7	95	65	38	25	11	-
	5.1-6.6	95	63-66	36-40	24-25	9-13	
mesolarvae	8.0	93	65	39	26	12	-
	7.0-9.4	87-96	64-66	37-40	25-26	11-13	
metalarvae	10.8	87	62	43	25	12	8
	9.8-12.2	84-88	59-64	41-44	24-26	11-13	
			Pimephales promelus				
protolarvae	5.5	95	61	39	24	14	-
	5.0-6.3	95-96	59-63	37-41	24	13-15	
mesolarvae	8.3	94	61	41	24	13	-
	7.4-8.9	94-95	53-63	40-42	24-25	12-15	
metalarvae	11.4	86	60	44	25	12	7
	9.1-14.0	84-88	59-62	41-47	24-25	11-12	
			Pimephales notatus				
protolarvae	5.6	95	61	40	24	15	-
	5.4-6.1	95-96	58-62	39-41	24-25	14-15	
mesolarvae	7.1	94	63	42	25	14	-
	6.5-7.5	91-95	62-64	40-44	24-25	14-15	
metalarvae	9.2	88	61	45	25	13	7
	8.6-10.6	85-91	60-61	44-46	25	12-14	

Table 1 (continued)

Developmental Phase	TL(mm)	Lengths (%TL) SL	Snout-vent	Pre-dorsal	Myomeres Pre-anal	Post-anal	Principal anal rays
			Notropis dorsalis				
protolarvae	4.1 3.7-4.5	95 95-96	61 59-63	41 38-44	21 20-21	13 13-14	-
mesolarvae	8.2 7.0-9-4	92 89-95	61 59-62	41 40-44	22 21-22	13 12-14	-
metalarvae	11.9 10.2-13.2	87 86-89	58 56-59	44 43-44	21 20-21	13 12-14	8
			Notropis stramineus				
protolarvae	4.6 3.9-5.5	95 93-96	62 59-64	38 36-41	22 22-23	13 13-14	-
mesolarvae	7.7 6.7-9.8	93 90-96	63 62-65	41 39-44	23 22-23	13 12-13	-
metalarvae	10.9 9.9-13.0	87 85-88	60 56-63	44 42-46	22 21-23	12 11-13	7
			Notropis lutrensis				
protolarvae	4.9 4.3-5.5	95 94-97	60 59-62	38 37-39	21 20-22	14 13-15	-
mesolarvae	7.0 6.3-7.8	92 89-95	60 58-63	40 39-41	21 21-22	14 13-15	-
metalarvae	10.0 9.4-10.7	86 85-88	57 56-58	44 41-44	22 21-22	13 12-14	9

Figure 1. Total lengths (mm) at which caudal fin rays and pelvic fin buds are acquired in nine species of cyprinids. Means (▲) and ranges (⊢——⊣) are based upon 10 specimens in each stage of development.

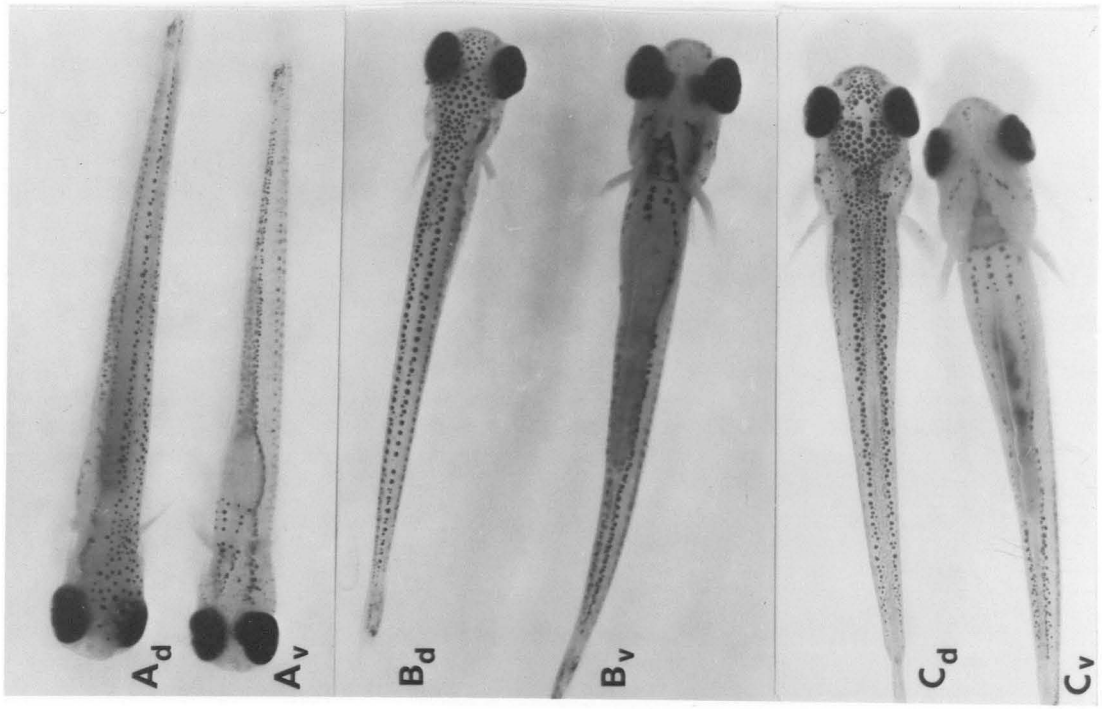

CHARACTER
Initial caudal fin ray formation
Initial appearance of pelvic fin buds
SPECIES
Semotilus atromaculatus
Campostoma anomalum
Notropis cornutus
Hybognathus hankinsoni
Pimephales promelus
Pimephales notatus
Notropis dorsalis
Notropis stramineus
Notropis lutrensis
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
TOTAL LENGTH (mm)

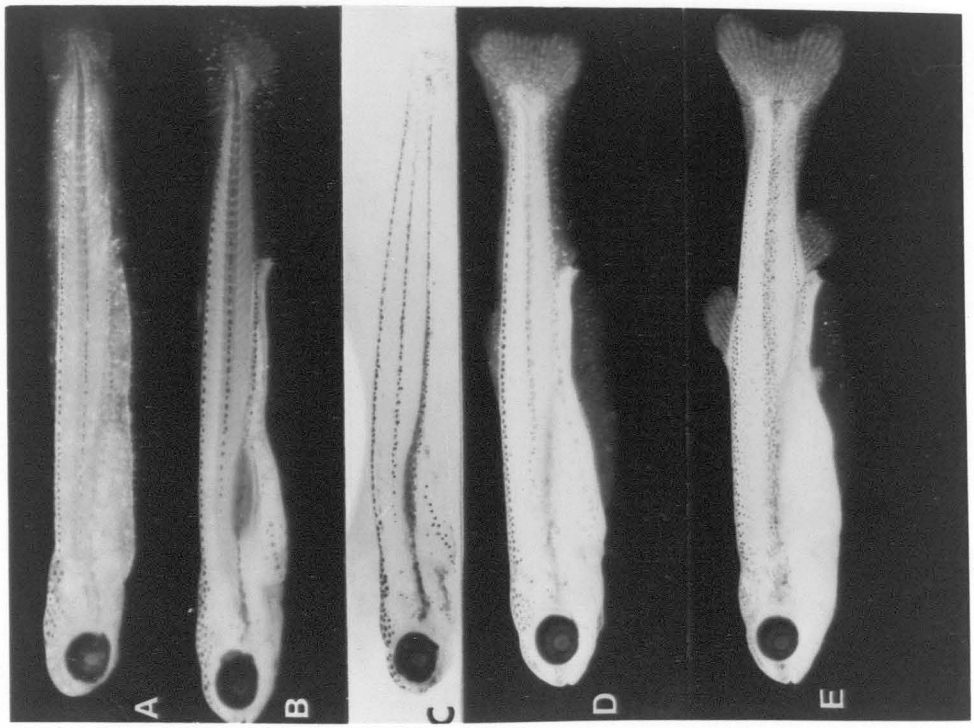
Semotilus atromaculatus - creek chub

Plate 1.
A) protolarva 7.8 mm TL
B) mesolarva 8.2 mm TL
C) mesolarva 9.4 mm TL
D) mesolarva 10.6 mm TL
E) metalarva 14.2 mm TL

Plate 2.

	dorsal	ventral	
A) protolarvae	7.7	7.4	mm TL
B) mesolarvae	8.6	9.3	mm TL
C) metalarvae	13.1	13.7	mm TL


A_d
A_v
B_d
B_v
C_d
C_v

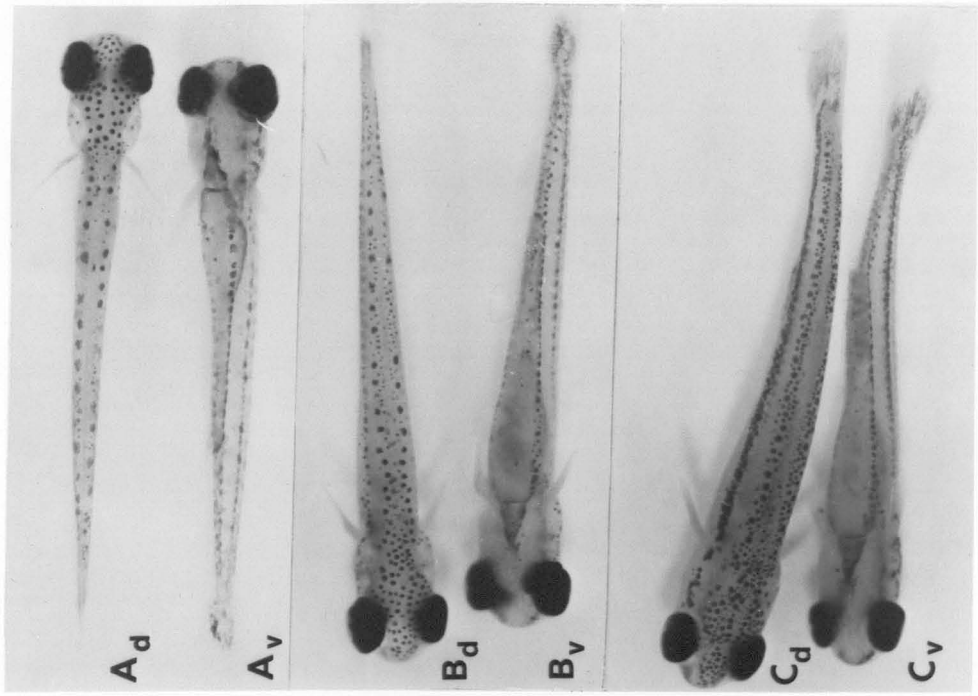

A
B
C
D
E

Campostoma anomalum - stoneroller

Plate 3.
A) protolarva 6.8 mm TL
B) mesolarva 7.5 mm TL
C) mesolarva 8.6 mm TL
D) mesolarva 10.4 mm TL
E) metalarva 10.5 mm TL
F) metalarva 11.8 mm TL

Plate 4.

	dorsal	ventral
A) protolarvae	6.5	6.6 mm TL
B) mesolarvae	8.7	8.4 mm TL
C) metalarvae	11.7	10.1 mm TL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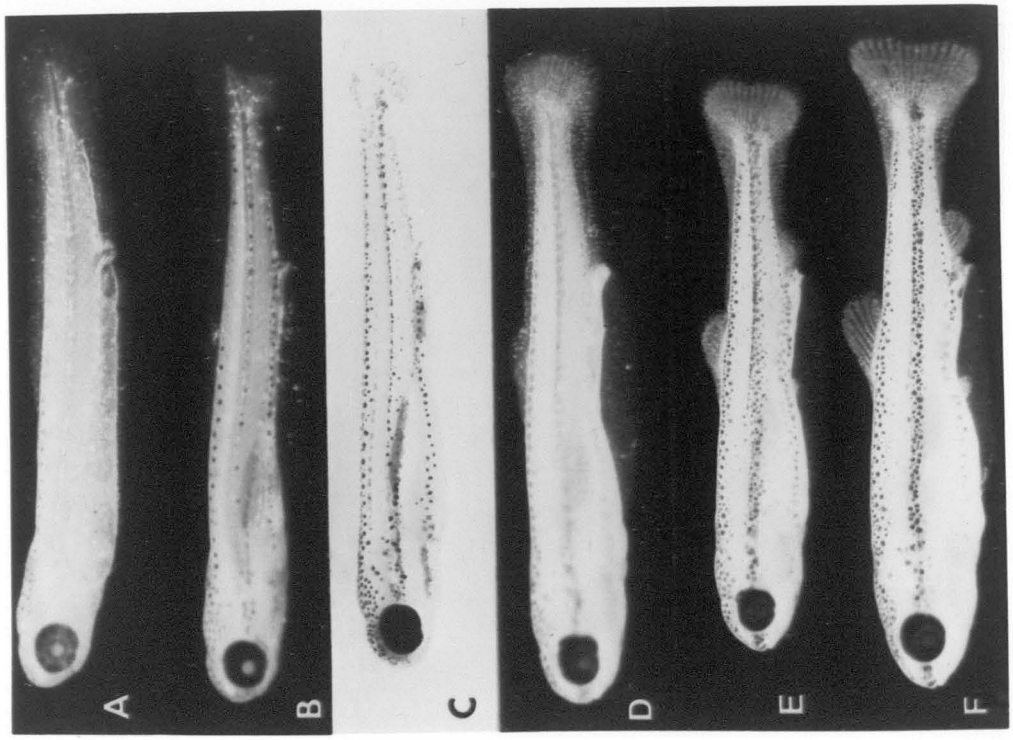
A_v
B_d
B_v
C_d
C_v

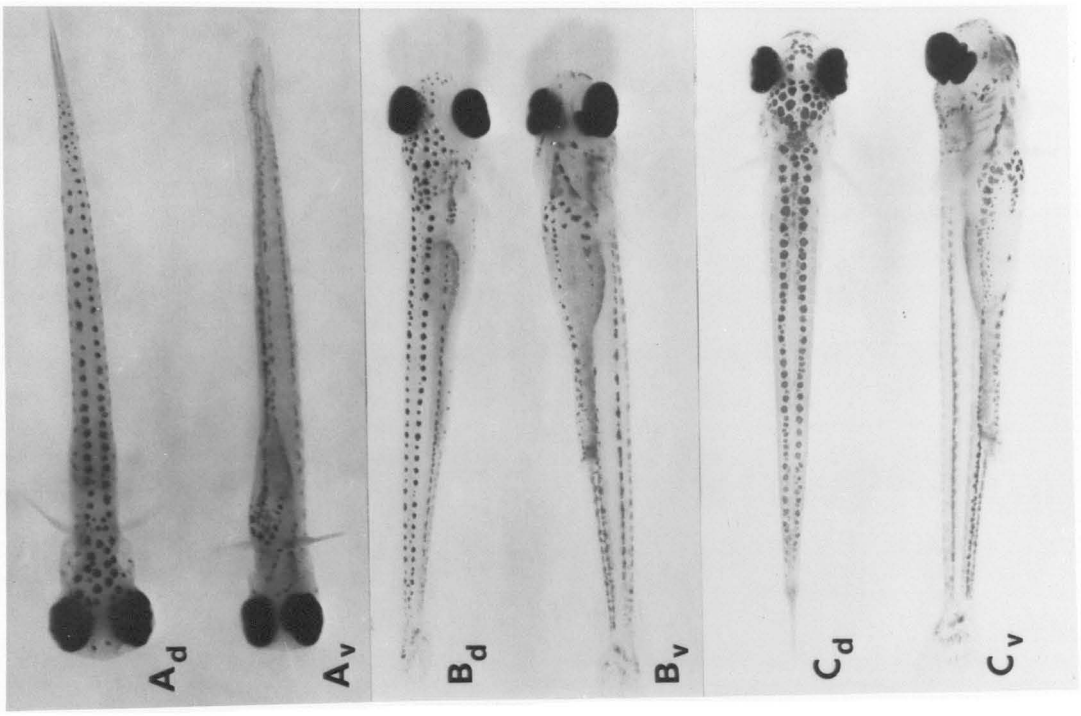

A
B
C
D
E
F

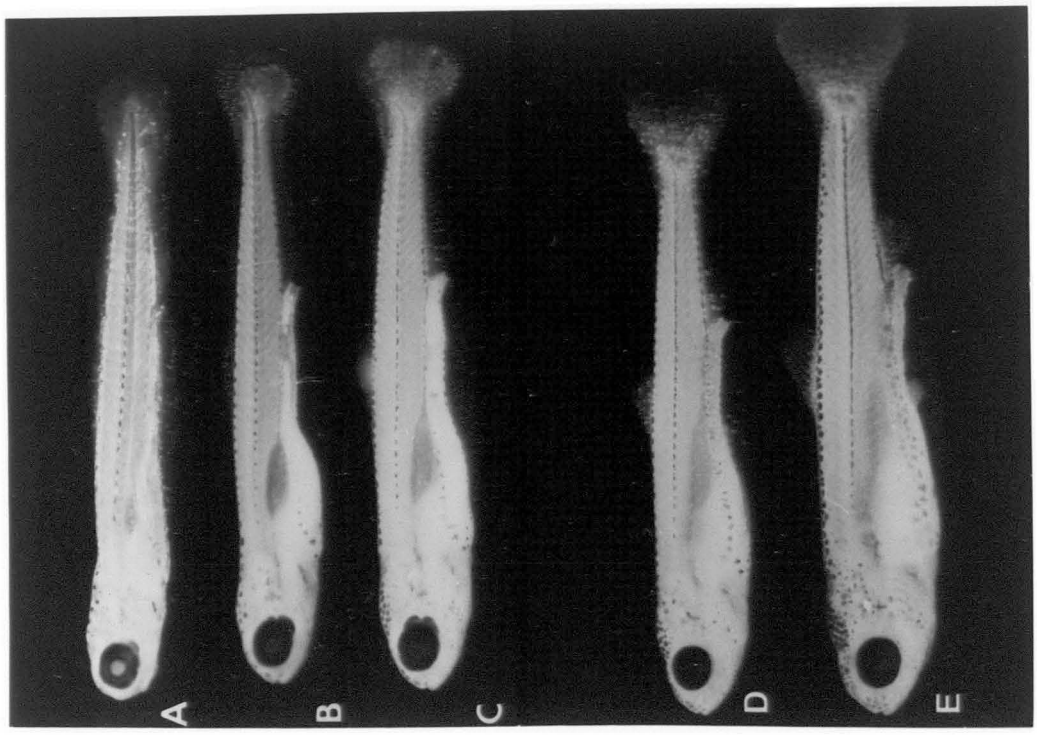
Notropis cornutus - common shiner

Plate 5.
A) protolarva 6.4 mm TL
B) mesolarva 7.8 mm TL
C) mesolarva 9.8 mm TL
D) mesolarva 11.3 mm TL
E) metalarva 12.7 mm TL

Plate 6.

	dorsal	ventral	
A) protolarvae	6.4	6.0	mm TL
B) mesolarvae	8.8	8.4	mm TL
C) metalarvae	10.5	11.2	mm TL


A_d
A_v
B_d
B_v
C_d
C_v

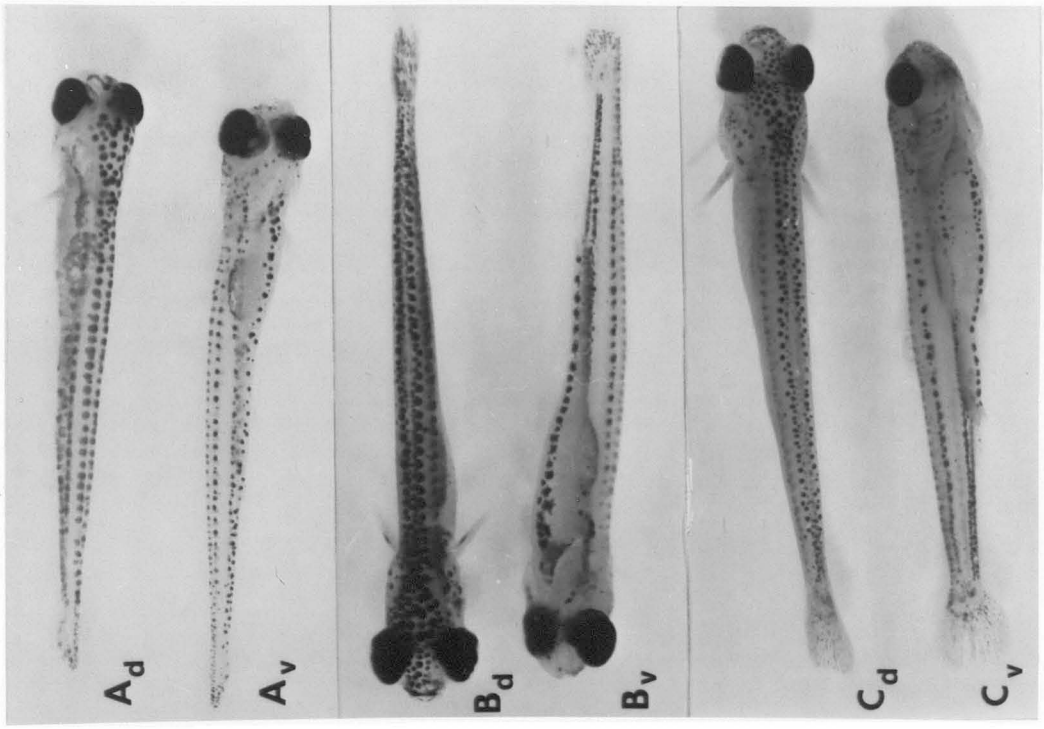

A
B
C
D
E

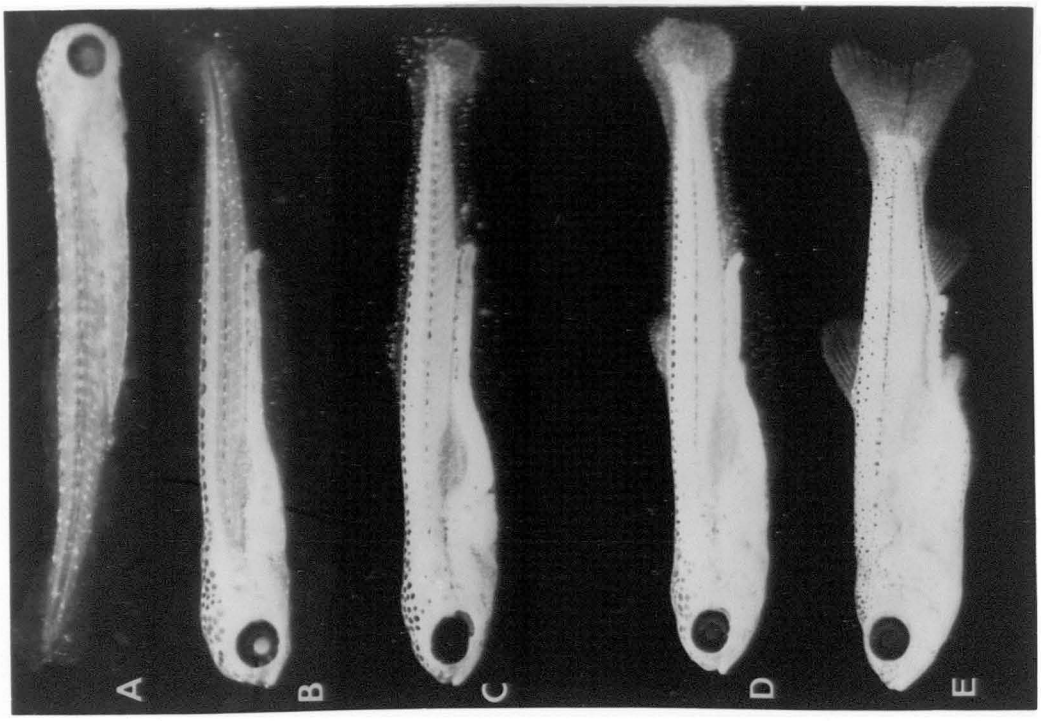
Hybognathus hankinsoni - brassy minnow

Plate 7.
A) protolarva 5.0 mm TL
B) protolarva 5.2 mm TL
C) mesolarva 7.6 mm TL
D) mesolarva 9.6 mm TL
E) metalarva 13.9 mm TL

Plate 8.

	dorsal	ventral
A) protolarvae	5.0	5.2 mm TL
B) mesolarvae	7.7	7.6 mm TL
C) metalarvae	10.6	10.2 mm TL


A_d
A_v
B_d
B_v
C_d
C_v

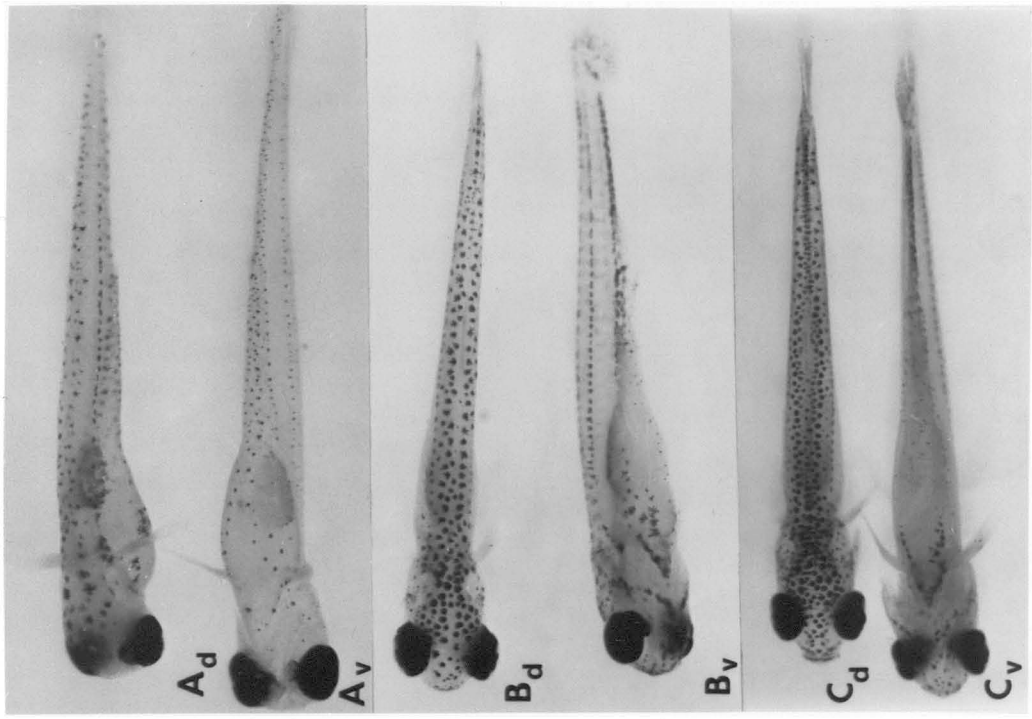

A
B
C
D
E

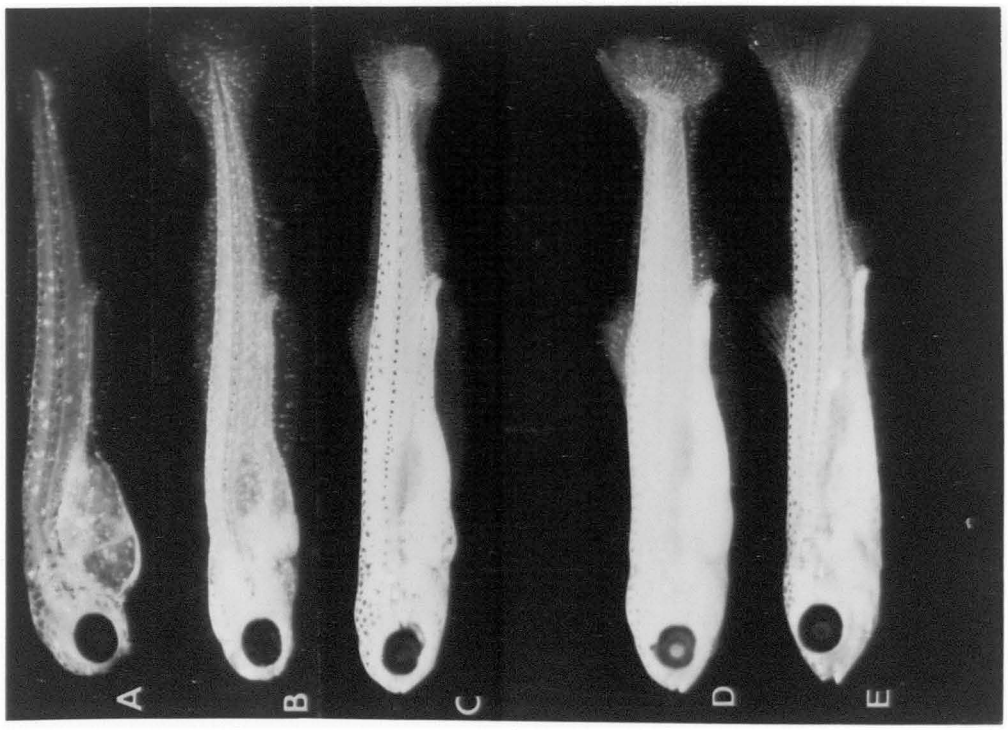
Pimephales promelus - fathead minnow

Plate 9.
A) protolarva 5.3 mm TL
B) protolarva 5.7 mm TL
C) mesolarva 9.0 mm TL
D) mesolarva 9.9 mm TL
E) metalarva 10.2 mm TL

Plate 10.

	dorsal	ventral
A) protolarvae	5.3	5.6 mm TL
B) mesolarvae	9.0	9.0 mm TL
C) metalarvae	10.2	10.5 mm TL


A_d
A_v
B_d
B_v
C_d
C_v

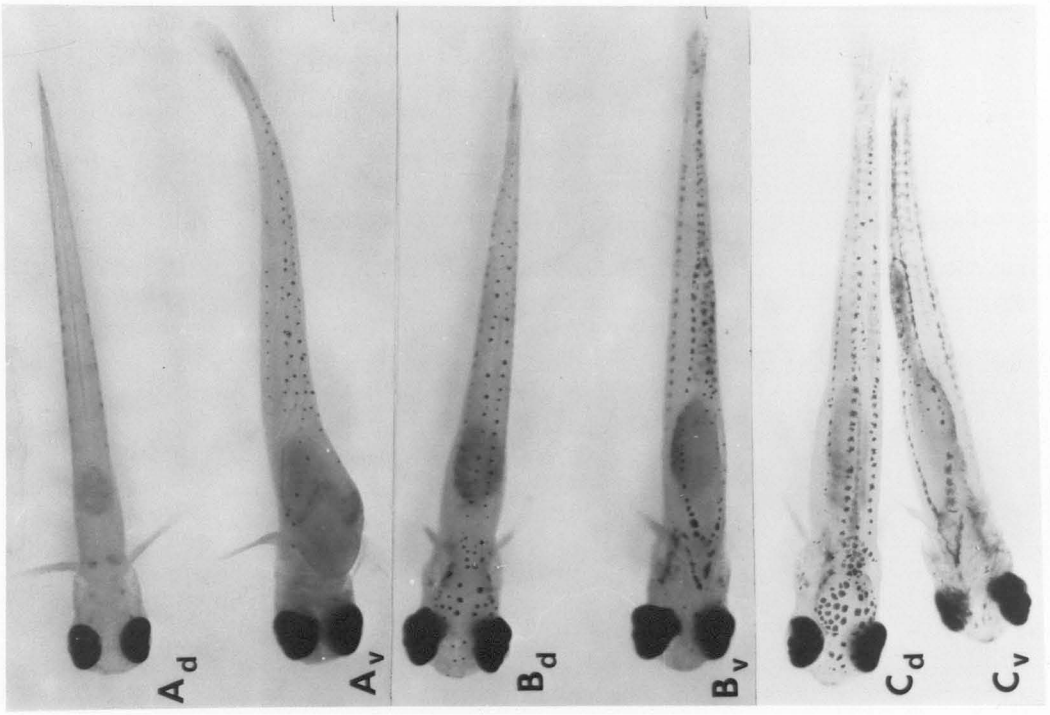

A
B
C
D
E

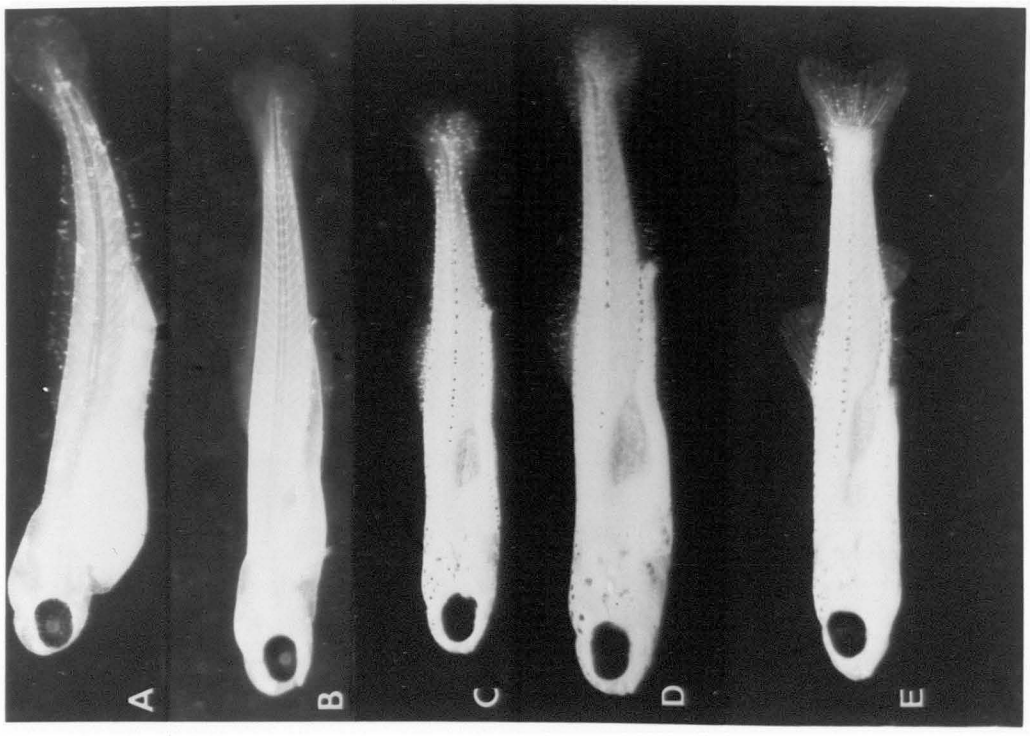
Pimephales notatus - bluntnose minnow

Plate 11.
A) protolarva 5.9 mm TL
B) protolarva 6.0 mm TL
C) mesolarva 6.9 mm TL
D) mesolarva 8.0 mm TL
E) metalarva 9.8 mm TL

Plate 12.

	dorsal	ventral
A) protolarvae	5.9	6.2 mm TL
B) mesolarvae	6.9	7.2 mm TL
C) metalarvae	9.3	9.8 mm TL


A_d
A_v
B_d
B_v
C_d
C_v

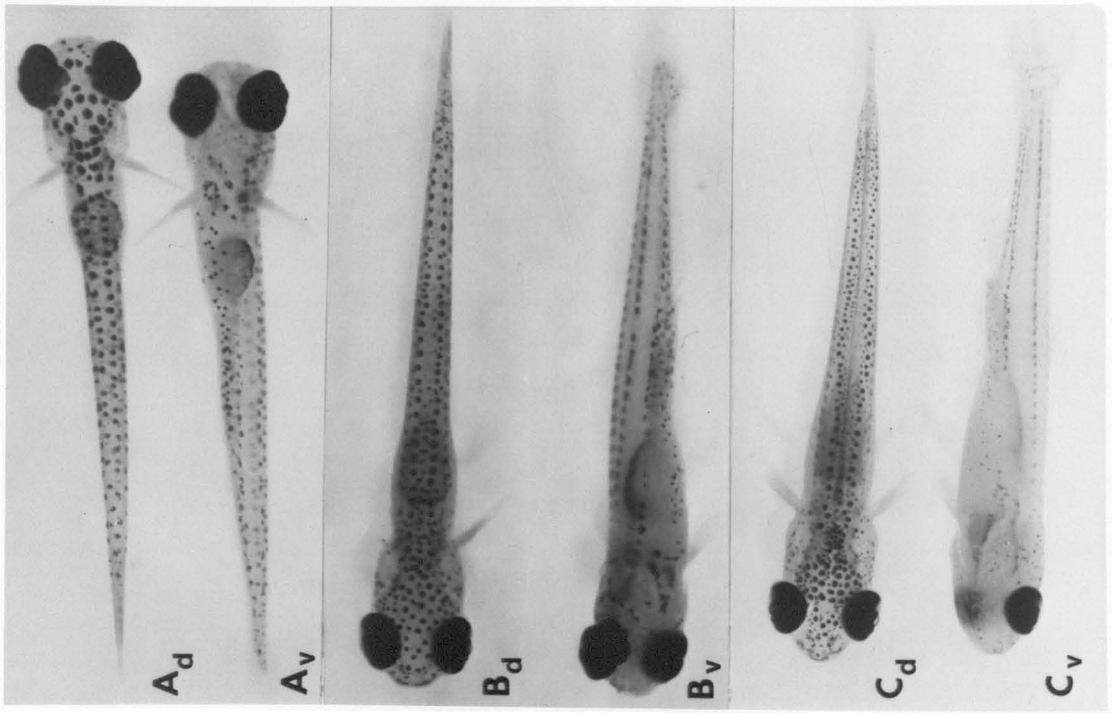

A
B
C
D
E

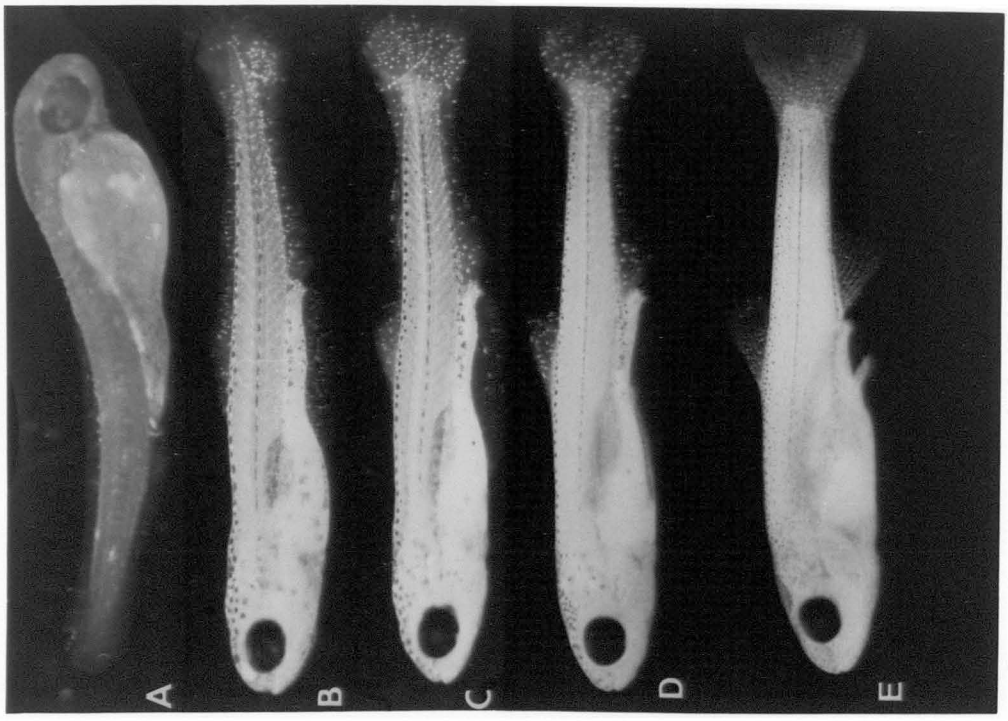
Notropis dorsalis - bigmouth shiner

Plate 13.
A) protolarva 3.8 mm TL
B) mesolarva 5.7 mm TL
C) mesolarva 7.8 mm TL
D) mesolarva 10.1 mm TL
E) metalarva 14.0 mm TL

Plate 14.

	dorsal	ventral	
A) protolarvae	4.3	4.3	mm TL
B) mesolarvae	6.9	6.6	mm TL
C) metalarvae	10.1	9.9	mm TL


A_d
A_v
B_d
B_v
C_d
C_v


A
B
C
D
E

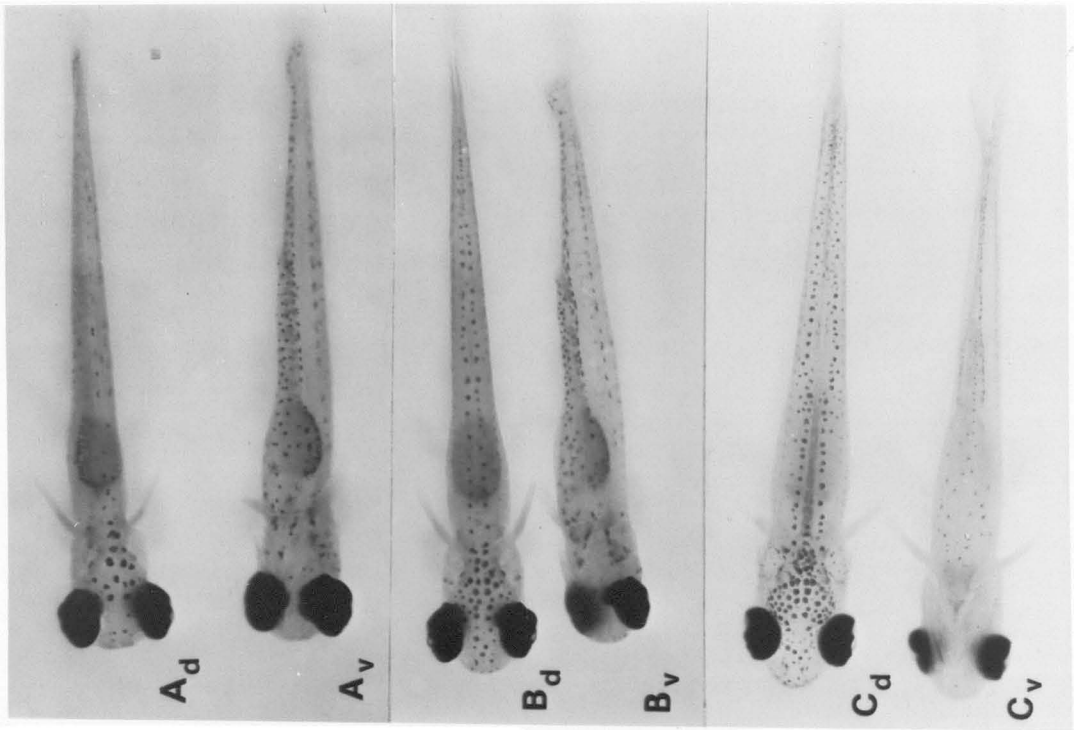
Notropis stramineus - sand shiner

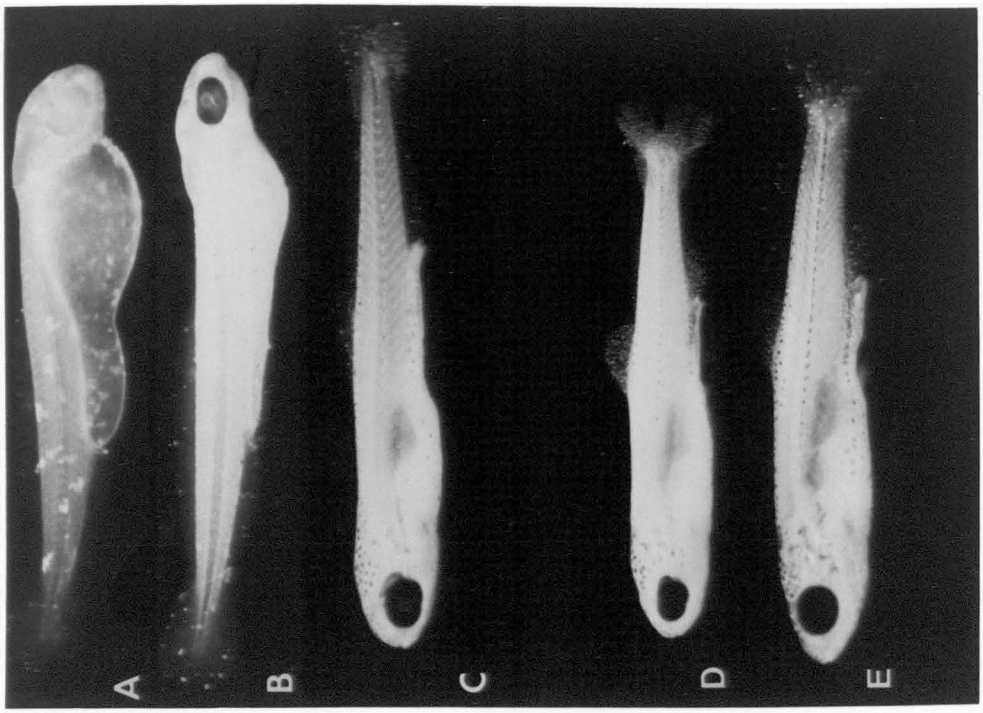
Plate 15.
A) protolarva 3.6 mm TL*
B) protolarva 4.2 mm TL
C) mesolarva 7.0 mm TL
D) mesolarva 9.1 mm TL
E) metalarva 10.8 mm TL

Plate 16.

	dorsal	ventral	
A) protolarvae	5.3	5.3	mm TL
B) mesolarvae	7.0	6.6	mm TL
C) metalarvae	10.6	9.7	mm TL

* Identity uncertain, may be either Notropis stramineus or N. dorsalis.


A_d
A_v
B_d
B_v
C_d
C_v

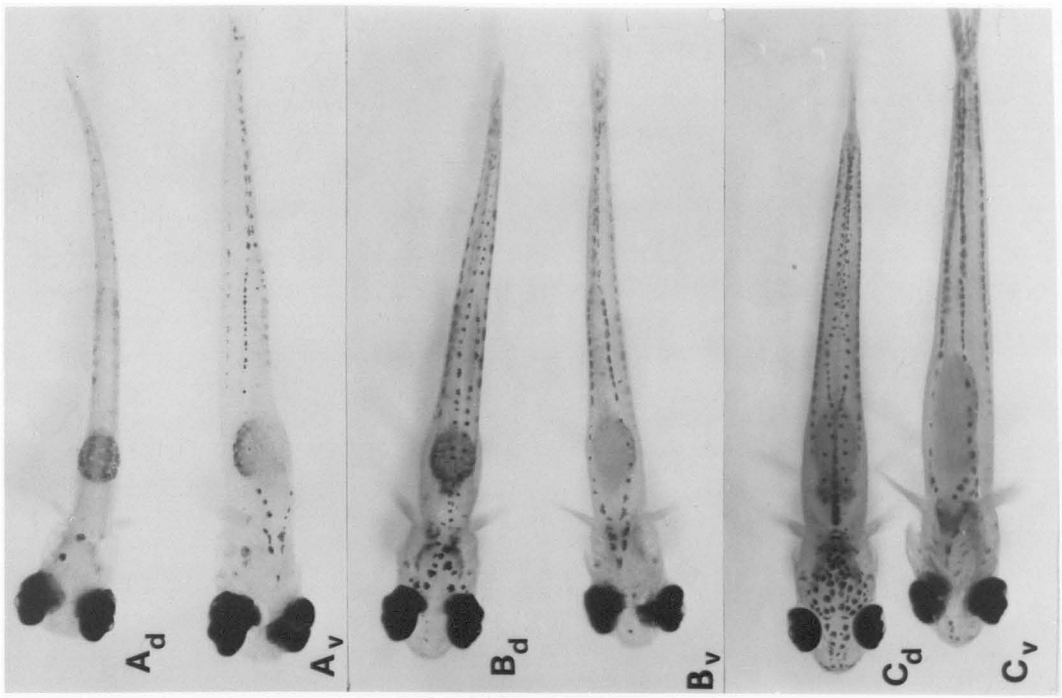

A
B
C
D
E

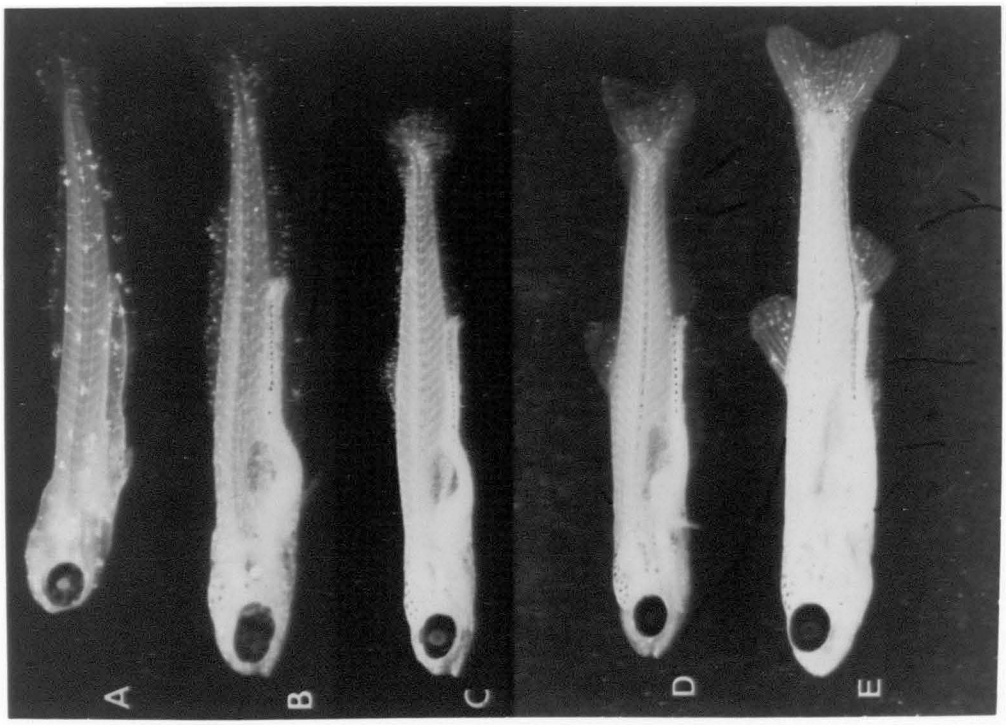
Notropis lutrensis - red shiner

Plate 17.
A) protolarva 4.3 mm TL
B) protolarva 4.7 mm TL
C) mesolarva 6.6 mm TL
D) mesolarva 8.1 mm TL
E) metalarva 9.2 mm TL

Plate 18.

	dorsal	ventral	
A) protolarvae	4.3	4.7	mm TL
B) mesolarvae	7.0	7.0	mm TL
C) metalarvae	9.7	9.5	mm TL


A_d
A_v
B_d
B_v
C_d
C_v


A
B
C
D
E

PART II: SPATIAL AND TEMPORAL PATTERNS OF LARVAL FISH DRIFT IN THE UPPER SKUNK RIVER[1]

[1] Paper to be published in the Iowa State Journal of Research.

ABSTRACT

Larval fish drift was greatest at night and consisted primarily of prolarval and early postlarval stages. Numbers of drifting larvae were not associated with either river discharge or turbidity. Occurrence and abundance of larvae was judged to be similar throughout the study area and was not related to local habitat characteristics. Phenological patterns of occurrence and abundance of larvae in the drift exhibited a close correlation with the known spawning periodicities of Skunk River fishes. It is suggested that drift may serve to transport larvae from low order spawning streams to higher order rivers where planktonic food organisms are more abundant.

INTRODUCTION

The larval forms of many riverine fishes seasonally contribute to the meroplanktonic component of lotic communities in a fashion similar to the drift of aquatic stages of insects (Hynes 1970, Waters 1972). The phenomenon of larval fish drift represents a common element among taxonomically diverse groups of fishes that otherwise exhibit a wide range of early life history strategies. The mechanism and ecological significance of downstream movements among newly-emerged salmonids have been well documented (Reimers 1973, Erman and Leidy 1975, Thorpe and Morgan 1978). Comparatively little is known, however, of the drifting activities of warmwater fish larvae. Several investigators have found a pronounced peak in the diel periodicity of drift, numbers of drifting larvae invariably increasing at night. Furthermore, early larval stages (prolarvae of Hubbs 1943) were encountered most frequently, usually near the surface in midchannel areas of high current velocity (Teraguchi 1962, Lindsey and Northcote 1963, Geen et al. 1966, Sorokin 1968, Priegel 1970, Clifford 1972, Larimore 1972, Gale and Mohr 1978).

The ecological significance of larval fish drift remains largely speculative. In general, the literature suggests two contrasting phenomena as possible causal factors. On the one hand, drift may merely represent involuntary downstream displacement resulting from locally extreme or unfavorable environmental conditions, factors that may disrupt locomotive capabilities or positive rheotaxis in larvae.

Alternatively, larvae may undergo periodic drifting or downstream swimming movements as an innate mode of behavior, regulated either by environmental stimuli or an intrinsic regulatory mechanism, and presumably offering selective advantages.

The objectives of the present study were A) to determine the species composition and spatial and temporal patterns of larval fish drift in the upper Skunk River, and B) to determine the influence of various environmental variables on the magnitude and periodicity of drifting movements. The period of study (spring 1977) represented the last three months of a record drought, consequently, an opportunity was provided to assess the impact of low water levels on reproductive success of resident fishes through observations of species occurrence and abundance of larvae in the drift.

THE STUDY AREA

Larval fish drift was sampled at eight locations on the upper Skunk River between Story City and Cambridge, Story County, central Iowa (Fig. 1). Drainage area at the southernmost station was approximately 1515 km^2. The Skunk River originates in Hamilton County and flows southeast across the state to the Mississippi River. From Story City to Ames, the river meanders in a narrow, postglacial valley and exhibits alternate riffle-pool sequences and a wide range of substrate types. The southern reach of the study area, beginning approximately 1 km north of Ames, flows through a preglacial valley which widens into a broad floodplain below Ames. Substrate materials throughout this region are primarily shifting sand. The abrupt change in substrate composition immediately above Ames (geologic change in Fig. 1) is attributed to a drop in elevation of the bedrock at that location. In the early 1900's. various reaches of the river channel below Ames were channelized by dredging in order to facilitate drainage of agricultural lands (Fig. 1). Consequently, the river in this region is uniformly wide and straight with few riffle areas or meanders. Secondarily treated municipal sewage is released into the study area at Story City and just south of Ames (Fig. 1).

The resident ichthyofauna of the upper Skunk River and associated tributaries has been recorded by Meek (1892), Paloumpis (1958), Zack (1968), Harlan and Speaker (1969), Laser et al. (1969), and Coon (1971). Jones et al. (1974) concluded that this reach of the river supports a

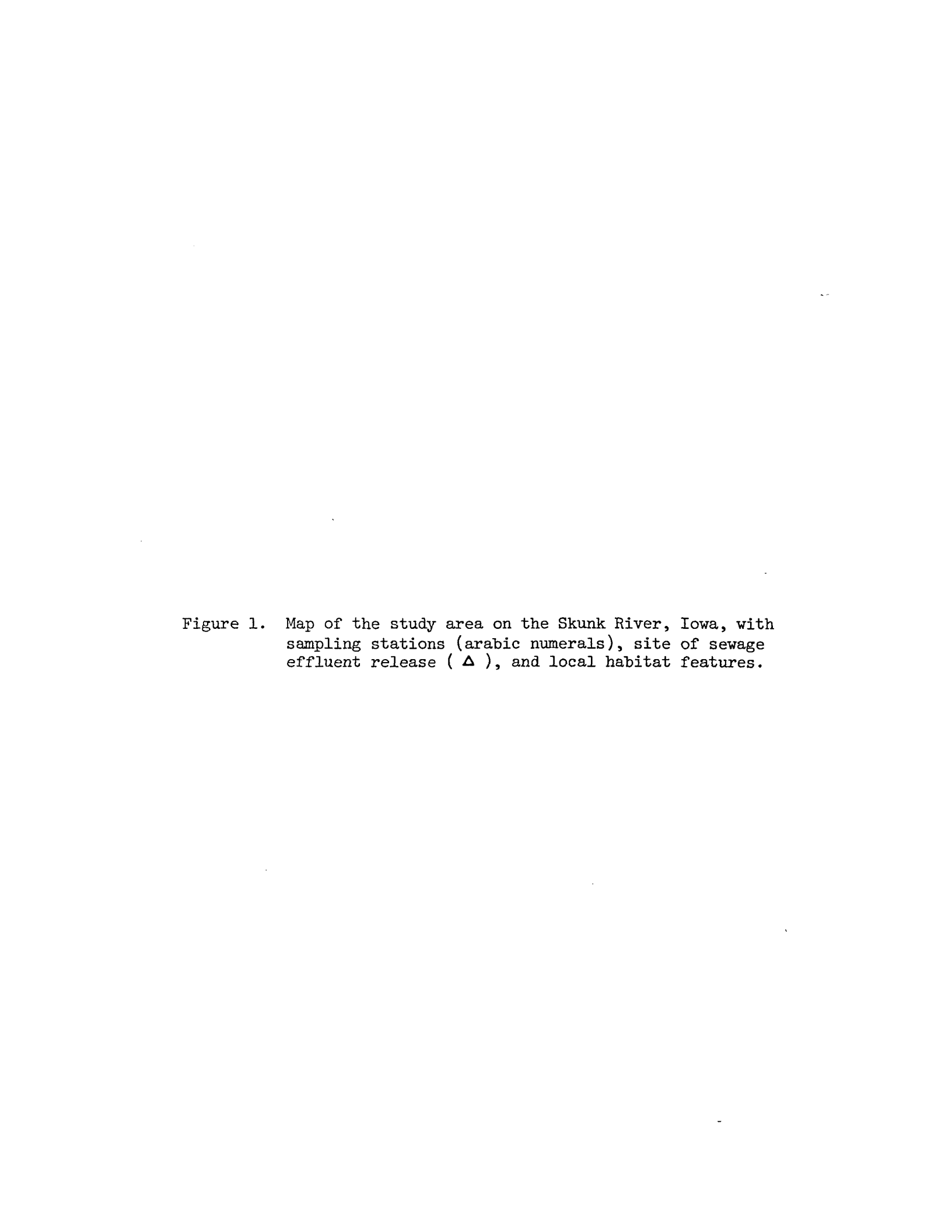
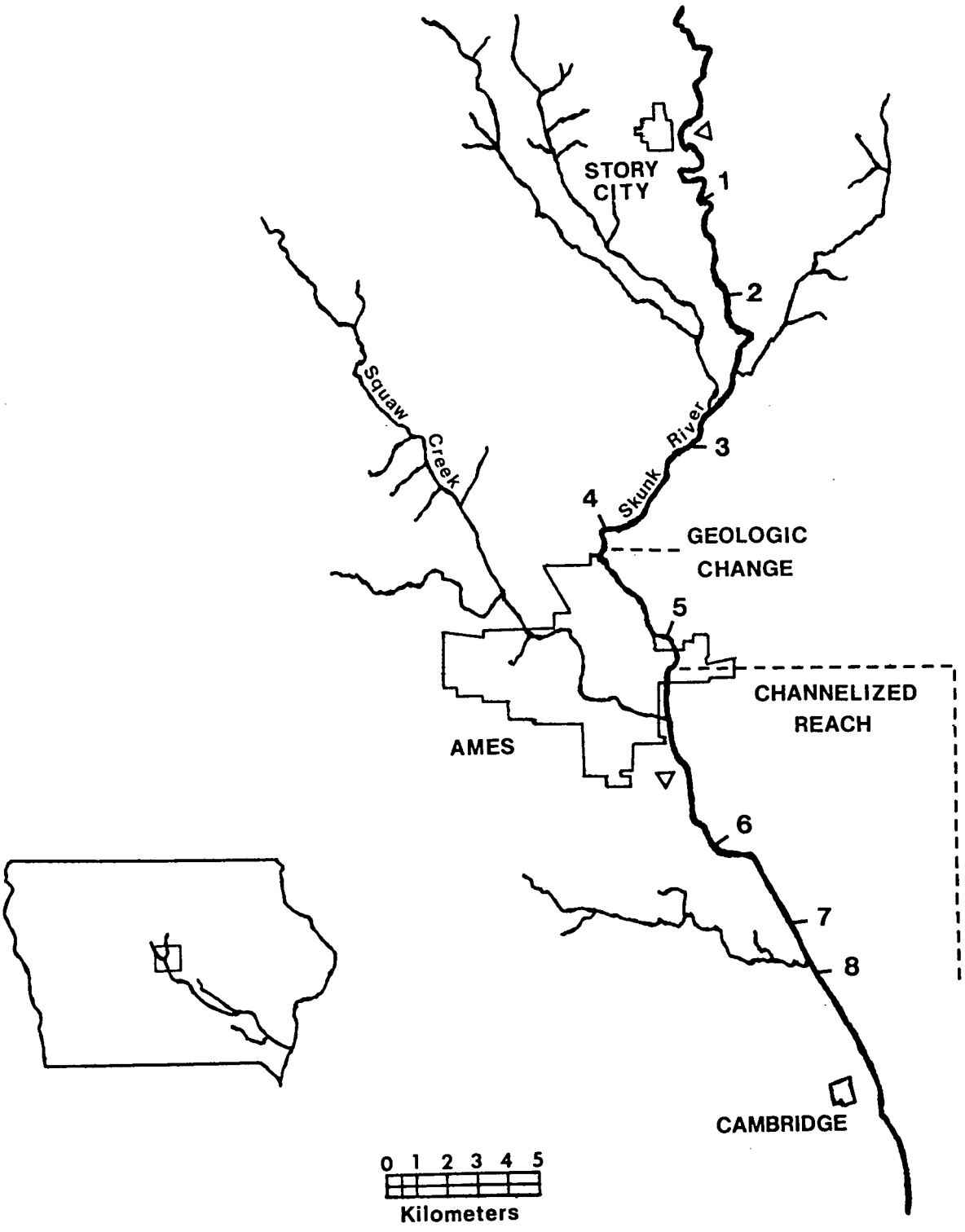


Figure 1. Map of the study area on the Skunk River, Iowa, with sampling stations (arabic numerals), site of sewage effluent release (Δ), and local habitat features.


STORY CITY
1
2
Squaw Creek
Skunk River
3
4
GEOLOGIC CHANGE
5
CHANNELIZED REACH
AMES
6
7
8
CAMBRIDGE
0 1 2 3 4 5
Kilometers

permanent ichthyofauna as evidenced by the consistent occurrence of the same species over the last 25 years.

METHODS AND MATERIALS

Drifting larval fishes were collected with stationary nets constructed of lumite seran screen, 1/32 in square mesh (Chicopee Mfg., Cornelia, GA). Nets were 1.3 m in length and tapered from 30 cm at the mouth to 15 cm at the cod end. Each net was attached to a tapered plexiglass hood which reduced the effective sampling area to a rectangular opening 30 cm high and 10 cm wide. The entire apparatus was supported by a rectangular steel frame with attached steel posts which were driven into the substrate. In operation, nets were adjusted to sample the surface stratum to a depth of 8-12 cm.

Two nets were utilized at each station for 24 h sampling periods. Contents of the nets were combined and preserved (10%) formalin) at the end of 12 h, approximating daytime (0800 - 1200h) and nighttime (1200 - 0800h) periods. To facilitate comparisons between habitat types, the eight sampling stations (Fig. 1) were divided into three groups representing upper stations (1,2,3), middle stations (4,5,6), and lower stations (7,8). Sampling was conducted simultaneously at the stations within each group. An attempt was made to visit each group at least once per week from 25 April to 1 June, 1977. However, extremely low water levels caused abandonment of effort at some stations in late May.

Morning and evening water temperatures were recorded during each sampling period. Water samples for turbidity measurements were held in the dark and analyzed with a Hach model 2100 turbidimeter within 10 days. Stream discharge data was supplied by the U. S. Geological Survey, Iowa City, Iowa. Values recorded at the gauging station

4.02 km north of Ames, the approximate midpoint of the study area, were utilized as flow values for all stations.

In the laboratory, drift samples were stained with rose bengal to facilitate separation of larvae from other animal and plant material. Approximately 10% of the specimens recovered could not be identified because of extensive damage and, consequently, are not included in the data presented herein. The presence of juveniles and an occasional adult in drift samples suggested that considerable numbers of individuals may have been caught accidentally in drift nets. As a result, only prolarvae and early postlarvae (i.e., individuals with yolk or within the prolarva-postlarva transition size range depicted in Fig. 1) are included in Figs. 3, 4, and 5 in order to more accurately represent the true drifting element.

Usage of common and scientific names of fishes follows Bailey et al. (1970). Terminology of early life stages of fishes is in accordance with Hubbs (1943).

IDENTIFICATION OF FISHES

Identification of larval fishes to the family level was based upon distinguishing features presented in Lippson (1976a). Methods for identification of Campostoma, Hybognathus, Pimephales, Notropis, and Semotilus spp. larvae are given in Perry and Menzel (in press). The major references that aided in recognition of additional genera and species included Fish (1932), Lake (1936), Petravicz (1938), Mansueti and Hardy (1967), Siefert (1969), Meyer (1970), Lippson and Moran (1974), Hogue et al. (1976) and Taubert (1977). Diagnostic features that were useful for identification of early stages of sucker-mouth minnow (Phenacobius mirabilis) larvae are presented in the appendix. Only two groups of suckers were recognized initially: Carpiodes spp. (carpsuckers) and Catostominae spp.. The subsequent availability of methods for species identification within the latter group (Fuiman 1978) permitted its separation into white sucker (Catostomus commersoni), northern hogsucker (Hypentelium nigricans), and shorthead redhorse (Moxostoma macrolepidotum) in the ratio 42:11:1. However, the Catostominae spp. group was merely recorded as sucker spp. in the present study (see Figs. 2,4, and 5).

RESULTS

A total of 2832 larval, juvenile, and adult fishes, representing four families, 15 genera, and 20 or more species were obtained in drift samples. Minnows (Cyprinidae) were most important numerically, accounting for 88% of the total, while suckers (Catostomidae), sunfishes (Centrarchidae), and darters (Percidae) represented 8%, 3%, and 1% respectively. Species encountered most frequently included carp (Cyprinus carpio 30% of total), fathead minnow (Pimephales promelus 17%), and common shiner (Notropis cornutus 14%). Prolarvae predominated in the drift (84% of total) and were encountered in greatest numbers at night (Fig. 2). In contrast, postlarvae and juveniles were encountered less frequently, represented a wide range of sizes, and were present in approximately equal numbers in daytime and nighttime samples. It is suggested, therefore, that the occurrence of these larger, more advanced individuals in drift samples may have been incidental, i.e., due to accidental entrainment rather than actual drifting movements. Thus, the true drifting element apparently consisted of early larval stages exclusively, and drifting activities were primarily limited to nighttime periods.

A greater nighttime drift generally persisted throughout the study period and was recorded at all stations (Fig. 3). It is conceivable that current velocity and turbidity could influence the magnitude of drift, but, although fluctuations in discharge were limited, there was no apparent correlation between numbers of drifting larvae and either river discharge or turbidity in the present study. Drift samples obtained while the river was high and turbid (May 5 and 6)

Figure 2. Abundance and length frequencies (up to 25 mm TL) of fishes collected in drift nets during daytime (□) and nighttime (■) periods. Size range at which yolk sac absorption is completed is depicted (▭) for each species.

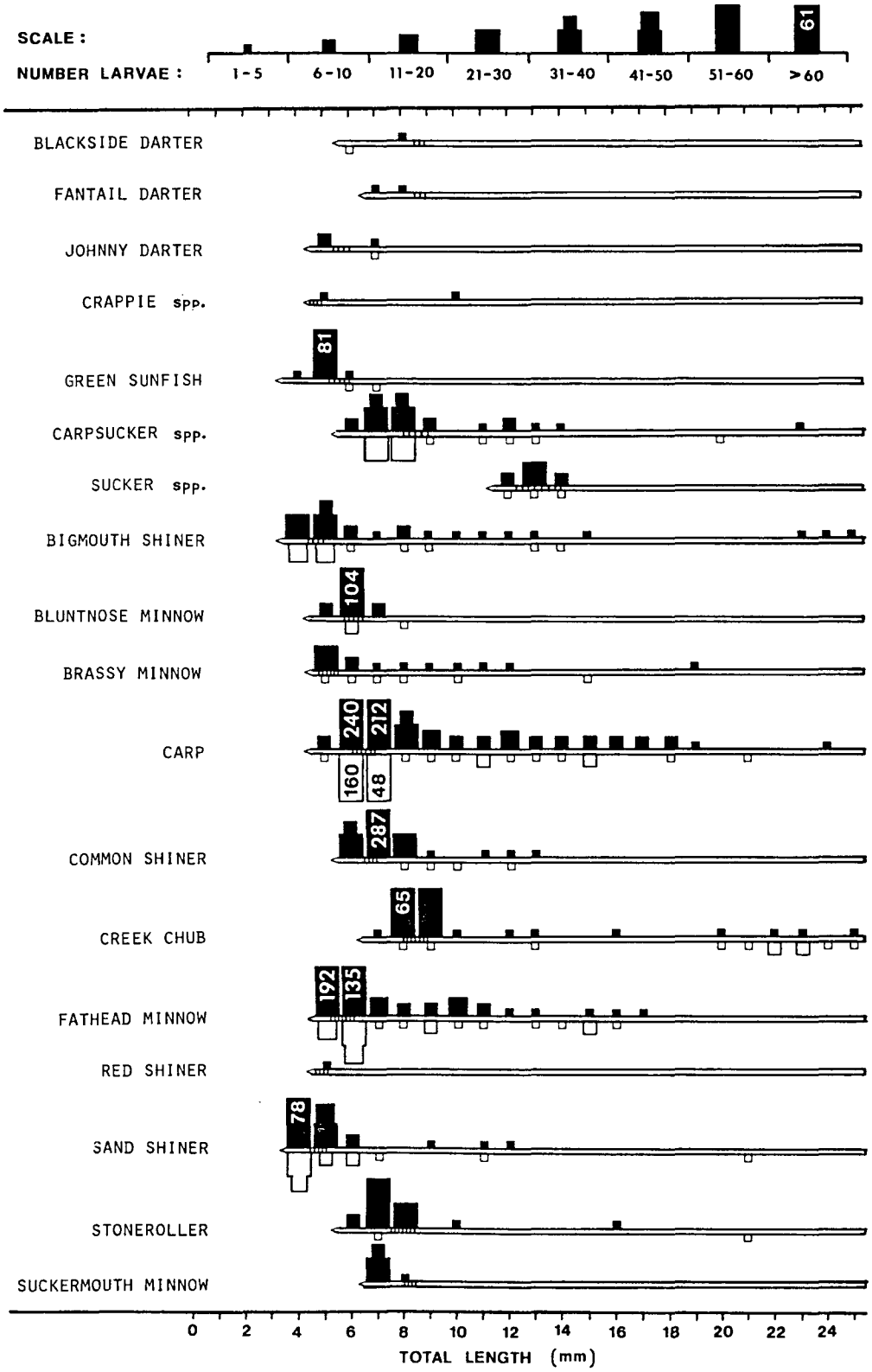
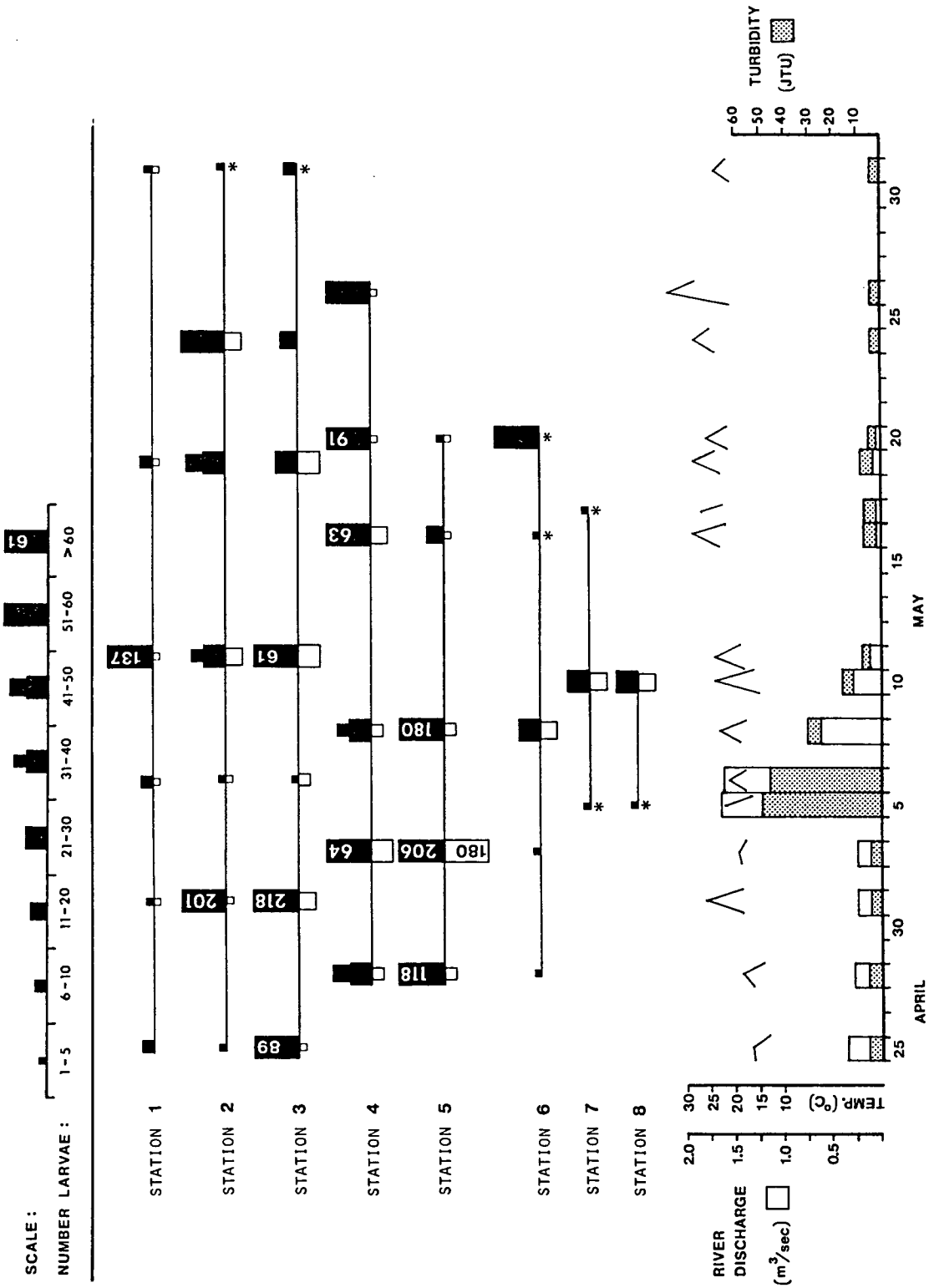

SCALE :
NUMBER LARVAE :
1-5
6-10
11-20
21-30
31-40
41-50
51-60
>60
61
BLACKSIDE DARTER
FANTAIL DARTER
JOHNNY DARTER
CRAPPIE spp.
GREEN SUNFISH
81
CARPSUCKER spp.
SUCKER spp.
BIGMOUTH SHINER
BLUNTNOSE MINNOW
104
BRASSY MINNOW
CARP
240
212
160
48
COMMON SHINER
287
CREEK CHUB
65
FATHEAD MINNOW
192
135
RED SHINER
SAND SHINER
78
STONEROLLER
SUCKERMOUTH MINNOW
0
2
4
6
8
10
12
14
16
18
20
22
24
TOTAL LENGTH (mm)

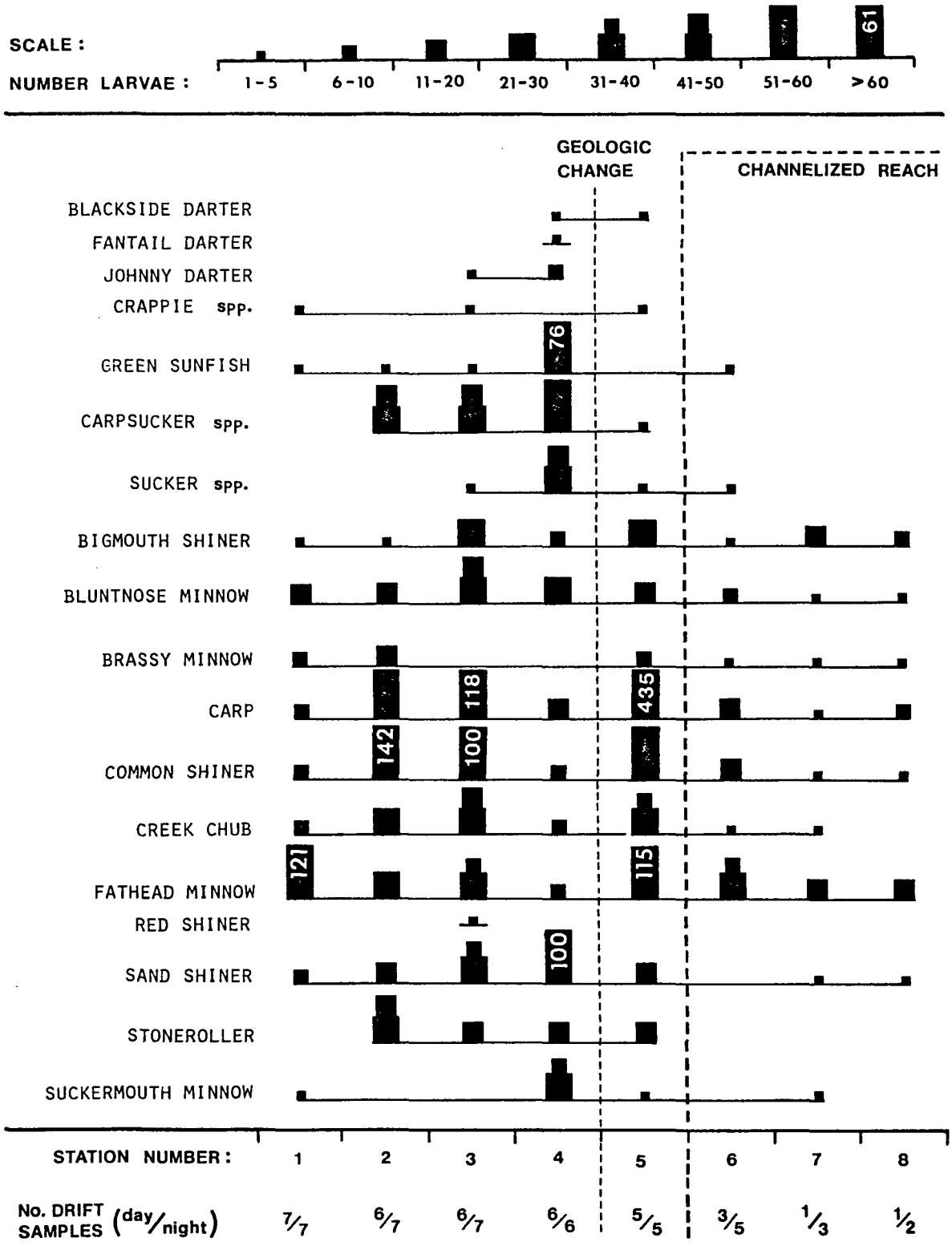
Figure 3. Total numbers of prolarvae collected in drift nets during daytime (□) and nighttime (■) periods in relation to river discharge, turbidity, and water temperature. Daytime drift was not sampled on several occasions (*).


SCALE :
NUMBER LARVAE : 1-5 6-10 11-20 21-30 31-40 41-50 51-60 >60
STATION 1
STATION 2
STATION 3
STATION 4
STATION 5
STATION 6
STATION 7
STATION 8
61
137
89
201
218
61
91
63
64
180
118
180
206
RIVER DISCHARGE (m^3/sec)
TEMP. (°C)
TURBIDITY (JTU)
APRIL
MAY

contained considerably fewer larvae than comparable collections obtained during low water periods. This apparent reduction in numbers of drifting larvae may be an artifact, merely reflecting a greater dispersal of larvae associated with the increased volume of flow, rather than fewer numbers. There was no evidence, however, of an increase in drift attributable to high discharge and turbidity. The relationship between the diel temperature regime and drifting activities was not readily apparent due to the similarity of water temperature fluctuations (diurnal increases, nocturnal decreases) throughout the study (Fig. 3).

Local habitat characteristics had no discernible influence on the distribution of larval fishes as evidenced by the generally uniform occurrence of species throughout the study area (Fig. 4). Although drift sampling at channelized stations yielded fewer species and a lesser overall abundance of larvae, this disparity may have been produced by sampling irregularities. Fewer drift samples were obtained from channelized stations and differences in channel morphometry and volume of flow between upper and lower reaches of the study area may have affected the validity of comparisons between the two regions. In particular, the wide, frequently braided channel and relatively greater discharge (from the release of sewage effluent and confluence of Squaw Creek above station 6) in the channelized section ostensibly reduced drift net efficiency by allowing greater horizontal dispersal of drifting larvae compared to the narrow, well-defined channel in upper reaches. It is probable, therefore, that increased effort at channel-

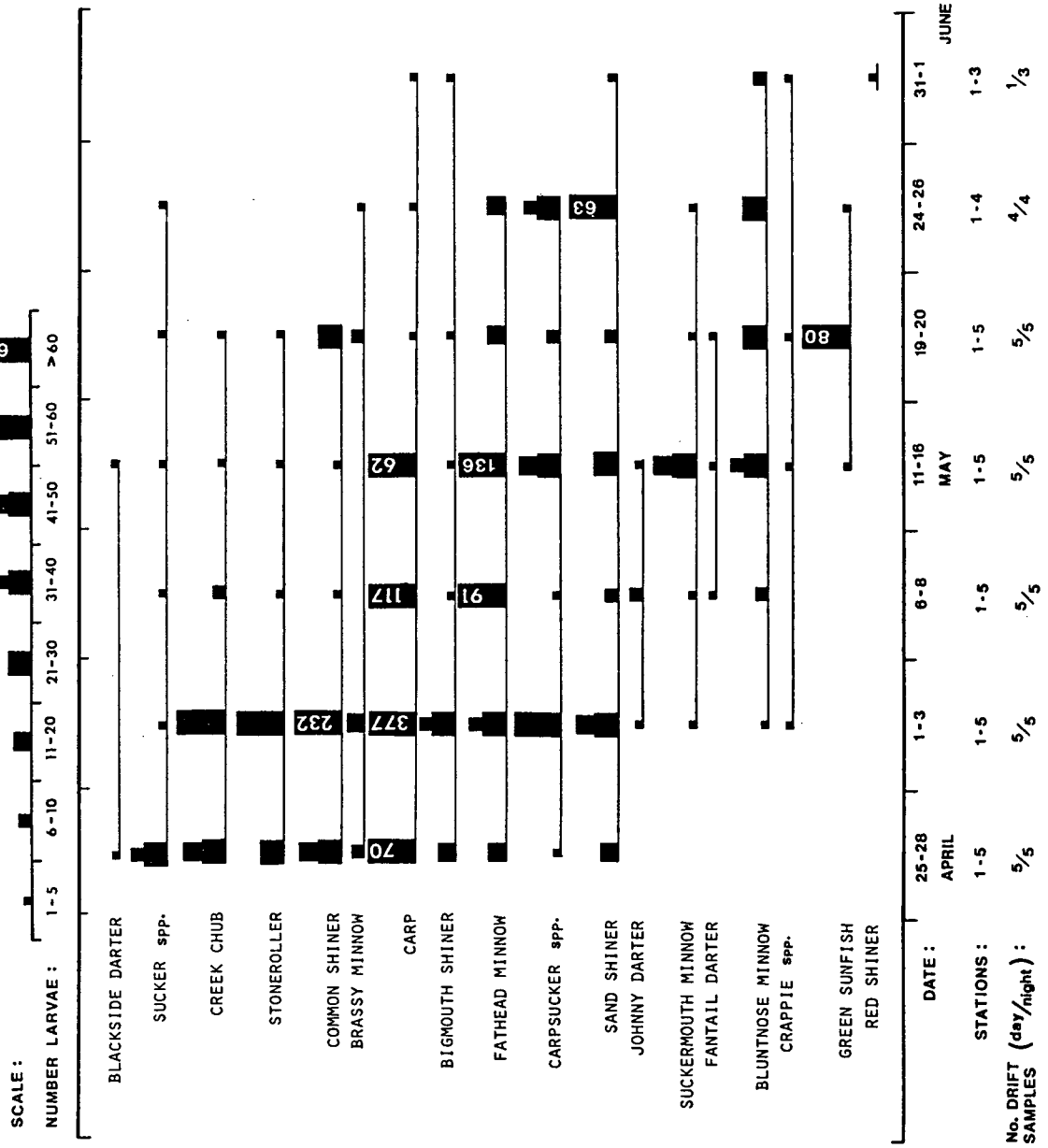
Figure 4. Numbers of prolarvae (combined daytime and nighttime collections from each station) collected in drift nets with habitat characteristics and relative sampling effort at each station.


SCALE :
NUMBER LARVAE :
1-5
6-10
11-20
21-30
31-40
41-50
51-60
>60
61
GEOLOGIC CHANGE
CHANNELIZED REACH
BLACKSIDE DARTER
FANTAIL DARTER
JOHNNY DARTER
CRAPPIE spp.
GREEN SUNFISH
76
CARPSUCKER spp.
SUCKER spp.
BIGMOUTH SHINER
BLUNTNOSE MINNOW
BRASSY MINNOW
CARP
118
435
COMMON SHINER
142
100
CREEK CHUB
FATHEAD MINNOW
121
115
RED SHINER
SAND SHINER
100
STONEROLLER
SUCKERMOUTH MINNOW
STATION NUMBER:
1
2
3
4
5
6
7
8
No. DRIFT SAMPLES (day/night)
7/7
6/7
6/7
6/6
5/5
3/5
1/3
1/2

ized stations, comparable to that at stations 1-5 (Fig. 4), would have revealed the presence of additional species as well as greater numbers of larvae. The larvae collected in the lower reach may have largely emanated from spawning areas above the geologic change, however, since the predominantly sandy substrate in the channelized section provided few suitable spawning areas for resident fishes.

Phenological patterns of occurrence and abundance of larvae in the drift was closely related to the known spawning seasons of Skunk River fishes (Fig. 5). Larvae of early spring spawners such as the white sucker (most or all sucker spp. larvae collected on 25-28 April were white suckers), creek chub (Semotilus atromaculatus), stoneroller (Campostoma anomalum), common shiner, and carp were represented in greatest numbers relatively early in the study period. The more protracted occurrence of fathead minnow, carpsucker, sand shiner (Notropis stramineus), and bluntnose minnow (Pimephales notatus) larvae suggested a fractional mode of spawning, whereas larvae of the green sunfish (Lepomis cyanellus) and red shiner (Notropis lutrensis), presumably relatively late spawners, were only encountered in late May. Eleven species of larval fishes were recorded in the drift in late April, indicating that spawning activities had commenced several weeks earlier than usual for this region. Warm air temperatures in early spring, coupled with persistent low water levels, apparently initiated this early activity. Most of the common resident species successfully reproduced as evidenced by the frequent occurrence of their larvae in drift samples. A few species commonly found in the

Figure 5. Phenological patterns of occurrence and abundance of prolarvae (combined daytime and nighttime collections from selected stations) with relative sampling effort.


SCALE:
NUMBER LARVAE: 1-5 6-10 11-20 21-30 31-40 41-50 51-60 >60
BLACKSIDE DARTER
SUCKER spp.
CREEK CHUB
STONEROLLER
COMMON SHINER
BRASSY MINNOW
CARP
BIGMOUTH SHINER
FATHEAD MINNOW
CARPSUCKER spp.
SAND SHINER
JOHNNY DARTER
SUCKERMOUTH MINNOW
FANTAIL DARTER
BLUNTNOSE MINNOW
CRAPPIE spp.
GREEN SUNFISH
RED SHINER
61
232
377
70
62
117
91
136
63
80
DATE: 25-28 APRIL 1-3 6-8 11-16 MAY 19-20 24-26 31-1 JUNE
STATIONS: 1-5 1-5 1-5 1-5 1-5 1-4 1-3
No. DRIFT SAMPLES (day/night): 5/5 5/5 5/5 5/5 5/5 4/4 1/3

area, especially the catfishes (Ictaluridae) and smallmouth bass (Micropterus dolomieui), were conspicuously absent, whereas the presence of blackside darter (Percina maculata) and crappie (Pomoxis spp.) larvae in the drift was unexpected in view of the rarity of adults in the region. It is possible that the catfish and smallmouth bass populations were reduced or eliminated by winterkill as a result of the unusually cold winter and persistent low water levels that preceded the study. The absence of local species in the drift cannot be regarded as indicative of reproductive failure, however, since a lesser propensity for drifting movements in larvae of these fishes would also account for their absence or infrequent occurrence in drift samples. It follows that interspecific differences in drift tendencies must be considered in making inferences of spawning success based upon the occurrence and relative abundance of larval fishes in the drift.

DISCUSSION

A preponderance of early larval stages in the drift and the persistence of nocturnal increases in the magnitude of drift have been demonstrated here and in previous studies. These findings suggest that drift may result from the inability of newly-hatched larvae to maintain a stationary position in flowing water during periods of darkness. It is noteworthy, however, that nocturnal drift was often of short duration, characterized by an abrupt increase after sunset followed by a rapid decline only a few hours later (Geen et al. 1966, Sheldon 1968, Sorokin 1968, Priegel 1970, Clifford 1972, Gale and Mohr 1978). Consequently, the absence of light cannot be regarded as the only factor producing drift in larval fishes. Hoar (1953) maintained that temporary night blindness accounted for the discrete peak in nocturnal drift of chum salmon (Oncorhynchus keta) alevins. He believed drifting activities ceased as the eye adapted to the reduced illumination, restoring visual orientation. Geen et al. (1966) concluded that larval fish drift was greatest during the period of lowest nocturnal illumination (2300 - 0100 h) and also increased during overcast nights and periods of high water and turbidity. Larimore (1975) noted that conditions that simulate river flood stages, i.e., rapid fluctuations in velocity, turbulence, and turbidity, caused downstream displacement of smallmouth bass black fry as a result of disrupted visual and tactile orientation. Whether downstream displacement is detrimental to larval

fishes has not been established, however. Webster (1954) believed that displacement of smallmouth bass fry during periods of high water and turbidity was beneficial in relieving overcrowding of stream sections used for spawning. Reimers (1973) made a similar suggestion, noting that drift may serve to disperse newly-emerged fall chinook salmon (Oncorhynchus tshawytscha), thereby providing for more efficient utilization of food and space in the nursery stream.

It has also been postulated that larvae may actively drift or swim in search of habitats that are more tolerable or more conducive to development and survival. Gale and Mohr (1978) suggested that newly hatched larvae, presumably incapable of extensive upstream movements, could escape polluted areas by drifting downstream. The utilization of water currents in this manner would require little expenditure of energy yet provide great mobility. Priegel (1970) maintained that the drift response of larval walleyes (Stizostedion vitreum) in the Wolf River, Wisconsin, provided a mechanism for transport into Lake Winnebago where the larvae were able to exploit the abundant zooplankton. Gaining access to the lake prior to the commencement of exogenous feeding appeared to be crucial to survival of the larvae. Dovel (1971) found that larvae in upper Chesapeake Bay tributaries drifted downstream to nursery areas of slightly higher salinity. These areas were characterized by high concentrations of planktonic organisms and were capable of supporting a correspondingly large number of feeding larvae.

A conspicuously common element among teleost larvae is their

dependence upon planktonic organisms of suitable size and accessibility during initial feeding stages. In lotic systems, plankton abundance generally increases towards larger, higher order rivers. Many riverine fishes, however, require rocky substrates and a moderate to strong current for successful incubation of their eggs, environmental characteristics that are typical of low order, headwater areas with relatively high gradients. Consequently, habitats that are optimal for spawning and incubation of eggs may not be most suitable for supporting feeding larvae. Larval fish drift may, therefore, serve as a means of transport from low order spawning streams to higher order rivers where the larvae would encounter a greater density of planktonic food organisms, presumably increasing their chances of successfully transferring to an exogenous food source. Drifting in this fashion could further enhance larval survival by providing an energy-efficient mechanism for dispersal out of small tributary streams that, due to their ephemeral nature, may not be permanently inhabitable. It is conceivable that larvae of all fishes that select low order streams for spawning would derive similar benefits from downstream movements, perhaps accounting for the widespread occurrence of larval fish drift in riverine fish communities.

SUMMARY

Diagnostic features that are most useful for identification of Skunk River larval fishes include myomere counts, melanophore distribution, relative lengths at comparable developmental stages, and several other meristics and morphometrics. Most fishes inhabiting the Skunk River exhibit drifting movements soon after hatching, and these occur primarily at night. Numbers of drifting larvae did not appear to be correlated with either river discharge or turbidity, and the generally uniform occurrence and abundance of larvae throughout the study area suggested that local habitat features did not influence distribution. Phenological patterns of occurrence and abundance of larvae in the drift reflected the relative spawning periodicities of Skunk River fishes and indicated that most of the common resident species successfully reproduced during the study period. Downstream movements of larvae may serve as a means of transport to higher order rivers where survival of feeding larvae may be enhanced by the greater abundance of planktonic food organisms.

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APPENDIX: IDENTIFICATION OF SUCKERMOUTH MINNOW, (*Phenacobius mirabilis*), PROTOLARVAE

Table A1. Selected morphometric and meristic characters of larvae of the suckermouth minnow, (Phenocobius mirabilis). Length measurements (means) and myomere counts (modes) are given with ranges below. Use of terminology and methods for length measurements and myomere counts follows Part I of this document. A summary of general morphology is included.

Developmental Phase	No. Specimens	TL(mm)	Lengths (%TL)			Myomeres	
			SL	Snout-vent	Pre-dorsal	Pre-anal	Post-anal
protolarvae	5	6.9	93	64	37	26	12
		6.6-7.2	92-94	61-65	36-38	25-26	12-13

Morphology: Suckermouth minnow protolarvae have a protruding, shelf-like snout, inferior, horizontal mouth, and a dorso-ventrally flattened eye. A series of internal melanophores is evident immediately above the vertebral column. Dorsal surface pigmentation is limited to a few melanophores in the occipital region. An irregular row of melanophores is present on each side of the ventral midline between the heart region and vent (Plate A2). Yolk absorption is completed by approximately 8.0 mm TL. Late protolarvae and mesolarvae exhibit large pectoral fins, and the dorsal fin anlage develops well anterior to the midpoint of the body (Plate A1).

Phenacobius mirabilis - suckermouth minnow

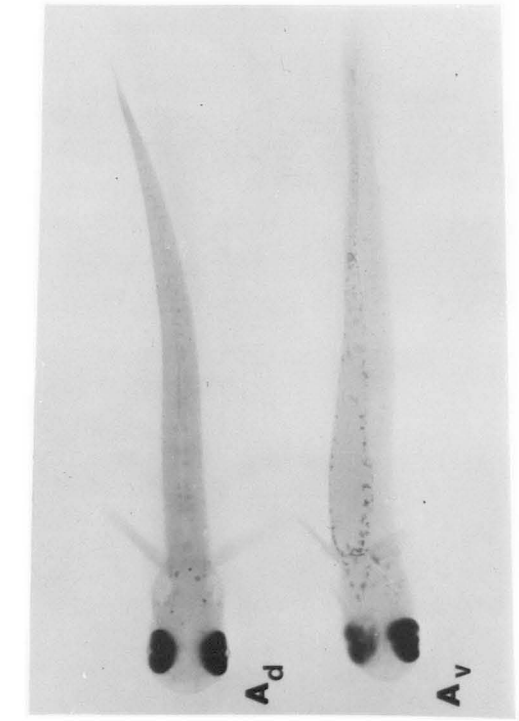
Plate A1. A) protolarva 6.9 mm TL

B) protolarva 7.8 mm TL

C) mesolarva 8.0 mm TL

Plate A2. A) protolarvae

	dorsal	ventral	
	6.9	7.1	mm TL


A_d
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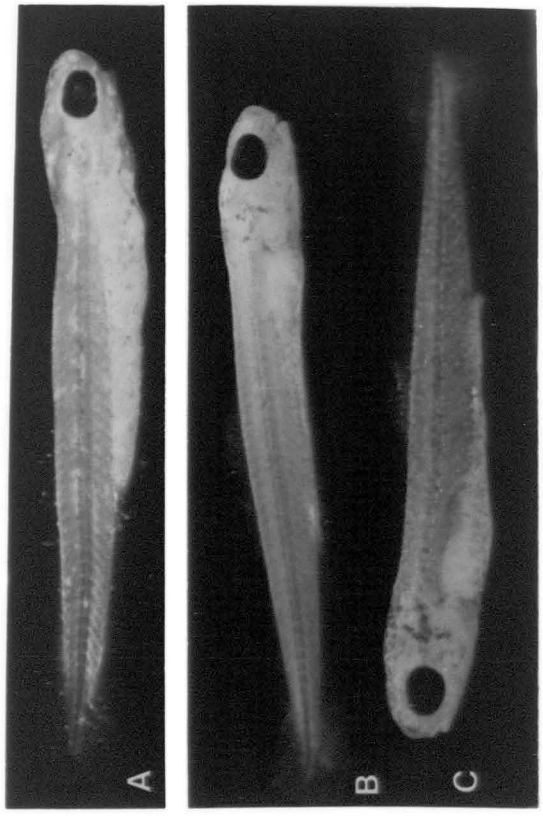
A
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C