REPRODUCTIVE ECOLOGY AND HABITAT PREFERENCE OF THE LEOPARD DARTER, *PERCINA PANTHERINA*

By

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REPRODUCTIVE ECOLOGY AND HABITAT

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PANTHERINA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

Figure		Page

Figure Page

Figure Page

Figure Page

Figure | Page

CHAPTER I

INTRODUCTION

The leopard darter, *Percina pantherina*, is a small fish endemic to streams in the Little River drainage of Oklahoma and Arkansas (Fig. 1) (Miller and Robison 1973). It is a relatively rare species with a very restricted distribution. Recent impoundments in the Little River system have destroyed suitable habitat and decreased the distribution of *P. pantherina* (Hubbs and Pigg 1976). Several water development projects (including impoundments) currently being proposed in the Little River system threaten to further restrict suitable habitat of *P. pantherina*. Very little information concerning *P. pantherina*'s life history and specific habitat requirements existed prior to this study (see chapter II). Life history data on *P. pantherina* are necessary for any conservation or management efforts to succeed. The continued existence of *P. pantherina* (as with any organism) ultimately depends on the survival of future generations of offspring. Reproduction is therefore the most important activity in its life history, and an understanding of this activity is crucial for its management and preservation.

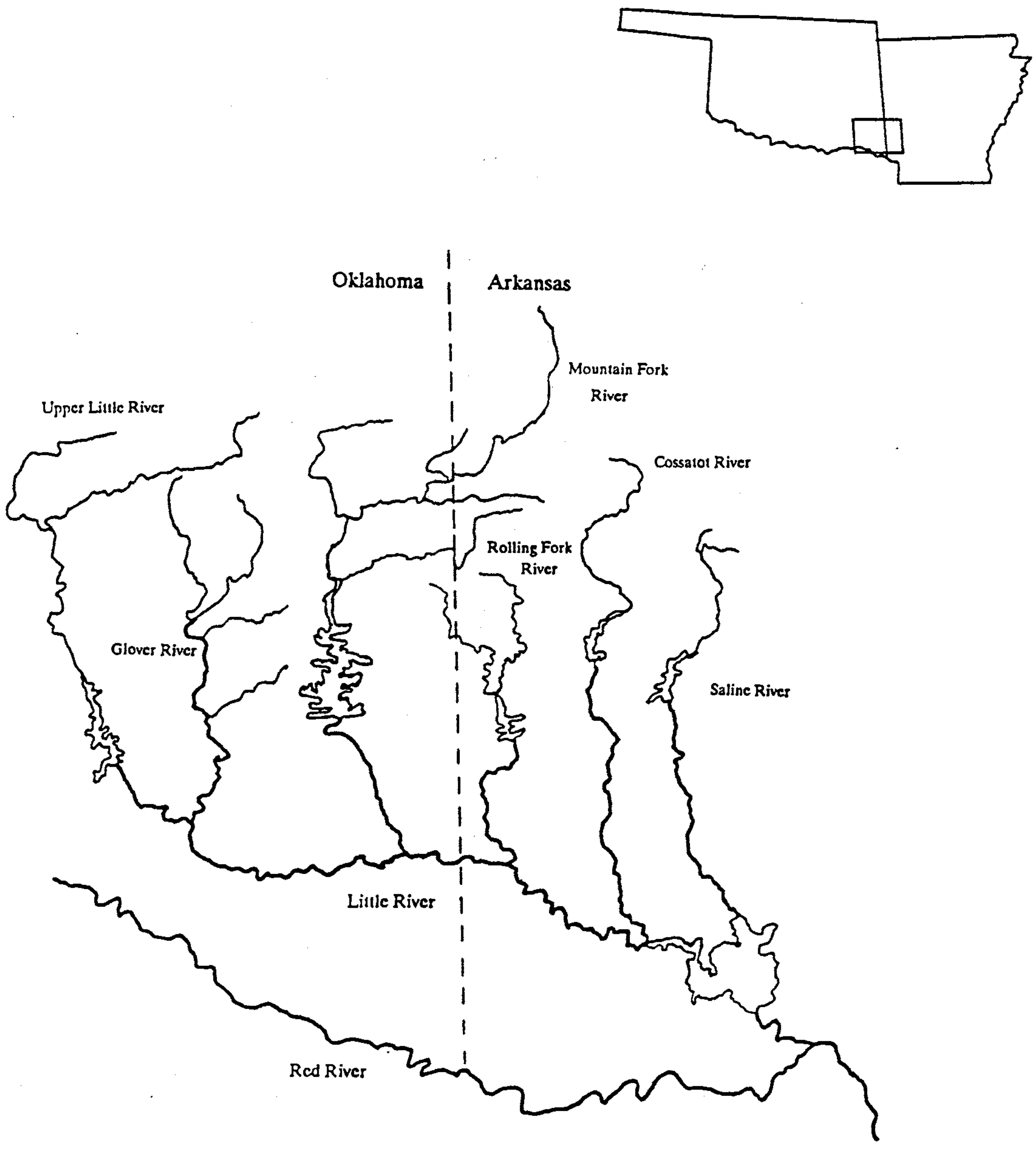

Figure 1. Little River drainage in Oklahoma and Arkansas.

Species that have extremely restricted distributions or highly specific habitat requirements are particularly vulnerable to changes in habitat. The major threat to most species of fish classified as threatened or endangered is loss of habitat (Miller 1972). Currently, 73 fishes in the United States are legally protected nationwide (Johnson 1987). Detailed habitat information for most of these species is lacking (Ono et al. 1983). Most of the available habitat information on endangered fishes is descriptive and lacks quantitative measurements. A quantitative determination of *P. pantherina*'s habitat requirements is necessary before accurate predictions can be made concerning the effects of habitat changes on its populations.

The collection and identification of *P. pantherina* individuals is a labor-intensive and difficult procedure (see chapter IV). Simple methods for evaluating the suitability of areas for *P. pantherina* and estimating the likelihood of occurrence of the species would therefore be useful to management biologists. Methods that could predict possible habitat changes due to altered stream flows would also be useful in the management and preservation of *P. pantherina*.

The objectives of this study were to: 1) describe the reproductive ecology and life history of *P. pantherina*, 2) quantify the habitat preferences of all life stages of *P. pantherina*, 3) determine the suitability of specific areas for _P. pantherina_ habitation and spawning, and 4) determine the effects of altered stream flows on the preferred habitat of _P. pantherina_.

CHAPTER II

LITERATURE REVIEW

Historical Background

O. P. Hay made the first collection of *Percina pantherina* in 1884, but these specimens were not recognized as being *P. pantherina* until about 1970 (Jim Williams, USFWS Gainesville National Fisheries Research Center; personal communication). In 1927, Hubbs and Ortenburger (1929) provisionally identified a single specimen from the Mountain Fork River, Arkansas, as an aberrant *Hadropterus macrocephalus*. This specimen had the cheek scalation and body coloration that are currently recognized as defining *P. pantherina*. As more collections were made in the Little River drainage of Oklahoma and Arkansas, it became apparent that a new species of darter occupied these areas. The species was formally described as *Hadropterus pantherinus* by Moore and Reeves (1955). Bailey et al. (1954) synonymized *Hadropterus* with *Percina*, and thus assigned the name *Percina pantherina* to the leopard darter.

Only 109 specimens of *P. pantherina* were collected prior to 1975 (Eley et al. 1975). Its rarity in collections caused several researchers and collectors to recommend that *P. pantherina* be given special protection (Miller and Robison 1973; Buchanan 1974; Cloutman and Olmsted 1974; Robison et al. 1974; Hubbs and Pigg 1976). In 1978, the U.S. Fish and Wildlife Service listed *P. pantherina* as threatened and designated critical habitat in the upper Little River, Glover River, and the upper Mountain Fork River (U.S. Fish and Wildlife Service 1978) (Fig. 2).

Description of *Percina pantherina*

The following description of *P. pantherina* is taken from Page (1983).

Along the midline of the olive dorsum are 11-13 rectangular dusky blotches. Along the midside is a series of 10-14 round black spots. Between the dorsal and mid-lateral blotches are scattered many oval or round black or dusky spots. The venter is white. The head is dark above, light below, and has a bold preorbital stripe and suborbital bar. The suborbital bar extends slightly posteriad ventrally. There is a discrete basicaudal spot, somewhat elongated vertically. The first dorsal fin is black basally with a large concentration of pigment anteriorly and has scattered melanophores elsewhere, as do the second dorsal and caudal fins. The other fins are usually clear.

The cheek is fully or partially scaled; the opercle is fully scaled. Nape squamation is variable; the breast is usually unscaled but may have a few scales; the belly is scaled except anteriorly. The male has an incomplete row of 11-15 modified scales on the midline of the belly.

Lateral scales 81-96; no pored scales on caudal fin; scales above lateral line 9-13; scales below lateral line 14-19; transverse scales 25-30; scales around caudal peduncle 28-33; dorsal spines 12-16; dorsal rays 10-14; pectoral rays 13-14; anal spines 2; anal rays 8-11; branchiostegal rays 6.

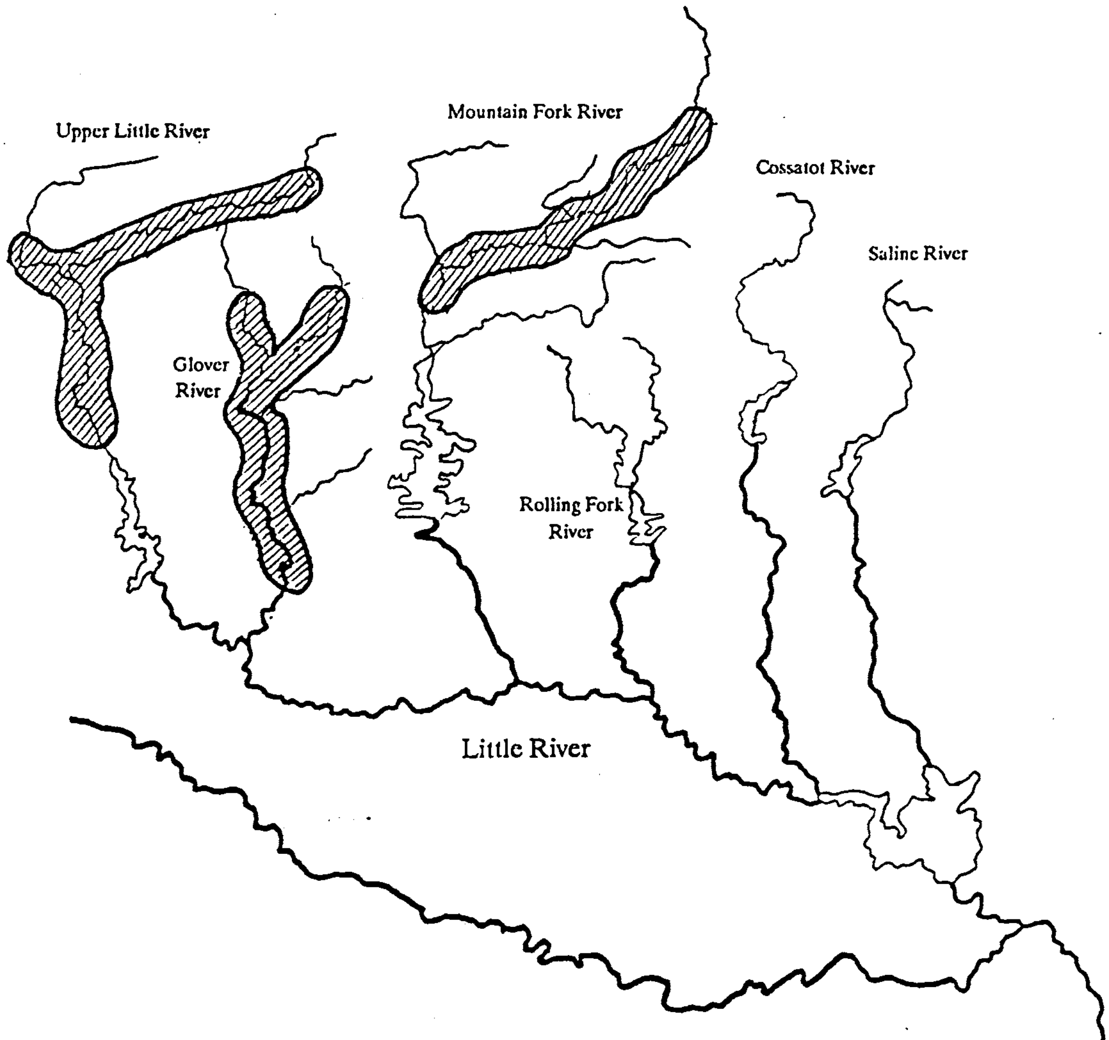

Figure 2. Critical habitat of P. pantherina in the Little River drainage.

Taxonomy

Percina pantherina has been assigned to the subgenus *Alvordius* by Collette (1967) and Page (1974). Other species placed in this subgenus include *P. maculata* (blackside darter), *P. macrocephala* (longhead darter), *P. peltata* (shield darter), *P. crassa* (piedmont darter), *P. roanoka* (roanoke darter), *P. nottogramma* (stripeback darter), and *P. gymnocephala* (Appalachia darter). All members of subgenus *Alvordius* have the following characteristics: an incomplete row of scales on the midline of the belly of the male; branchiostegal membranes separate; no breeding tubercles or sexual dichromism; unscaled breast; anterior portion of belly of male usually unscaled. According to phylogenies constructed by Page (1974, 1981), *P. maculata*, the blackside darter, appears to be the species most closely related to *P. pantherina*. The two species have a similar appearance but can be easily distinguished because *P. pantherina* has smaller scales, 10-14 round or square dark blotches along the lateral band, and a well-defined reticulated pattern on the dorsum.

Zoogeography

Moore and Reeves (1955) hypothesized that a population of *P. maculata* that inhabited the lower Little River drainage became isolated in the upper Little River tributaries and evolved into *P. pantherina*. Mayden (1985) proposed that the Kiamichi, Little, and Ouachita rivers once shared a common Ouachita Highland drainage and hypothesized that a P. maculata-like ancestor inhabited these highland streams. Presumably, the Ouachita Highland streams served as an effective isolating mechanism between highland and lowland populations and eventually the highland form became P. pantherina. Currently, populations of P. maculata surrounding the Ouachita Highlands are generally confined to lowland streams (Mayden 1985).

Distribution

Populations of P. pantherina are known to occur in the Little River upstream from Pine Creek Reservoir, Glover River upstream from Oklahoma Highway 3 and 7 bridge, Mountain Fork River upstream from Broken Bow Reservoir, Robinson Fork upstream from its confluence with Rolling Fork River, and Cossatot River upstream from Gillham Reservoir (Fig. 3). Populations have also been found in some of the larger tributaries of these rivers (Leon et al. 1987; Lechner et al. 1987). The downstream limits of the distributions of P. pantherina can be clearly defined in all of the rivers except the Glover as the free-flowing area immediately upstream from reservoir headwaters. Historically, populations were known to inhabit the lower Mountain Fork and Cossatot rivers (Eley et al. 1975), but these populations have apparently been extirpated since the

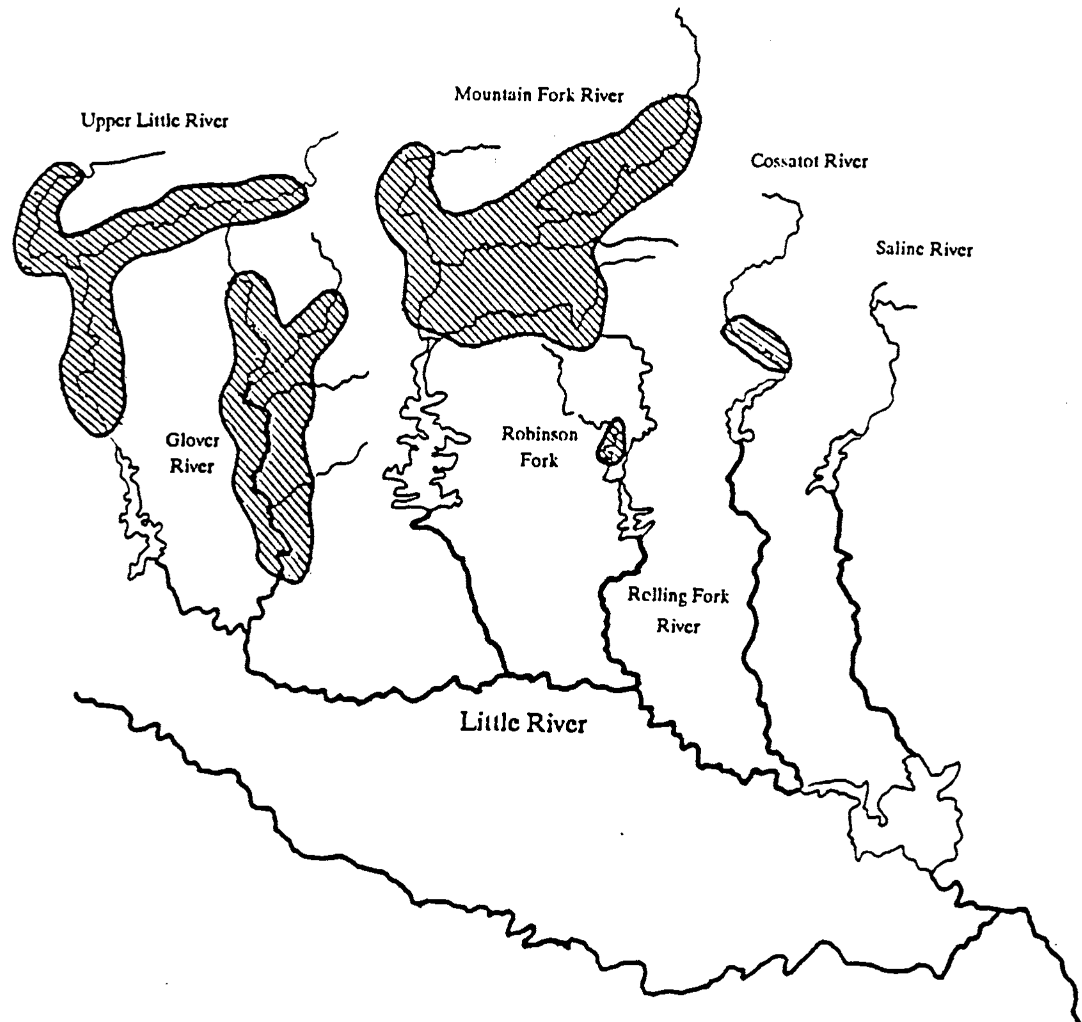

Figure 3. Distribution of P. pantherina in the Little River drainage.

construction of Broken Bow and Gillham reservoirs, respectively. Population abundances in Cossatot River and Robinson Fork River are low and confined to small sections (Leon et al. 1987). Population abundances in Mountain Fork, Glover, and Little rivers are higher than those in Cossatot and Robinson Fork rivers, but the most abundant populations are found in the section of Glover River upstream from Carter Creek to the town of Battiest, Oklahoma (personal observations) (Fig. 4). Glover River was chosen as the study area for this project because it supports the most abundant populations of P. pantherina and is the only natural, free-flowing river in the Little River drainage.

Habitat Description

Prior to the study by Jones et al. (1984), P. pantherina was generally believed to inhabit gravel and cobble riffles with moderately-swift current velocity at water depths of 25-100 cm (Moore and Reeves 1955; Taylor and Wade 1972; Miller and Robison 1973; Buchanan 1974; Cloutman and Olmsted 1974; Eley et al. 1975). Jones et al. (1984) found P. pantherina to be predominantly a pool-dweller that generally inhabited areas where water depths were 20 to 80 cm with little or no detectable current over rubble and boulder substrates.

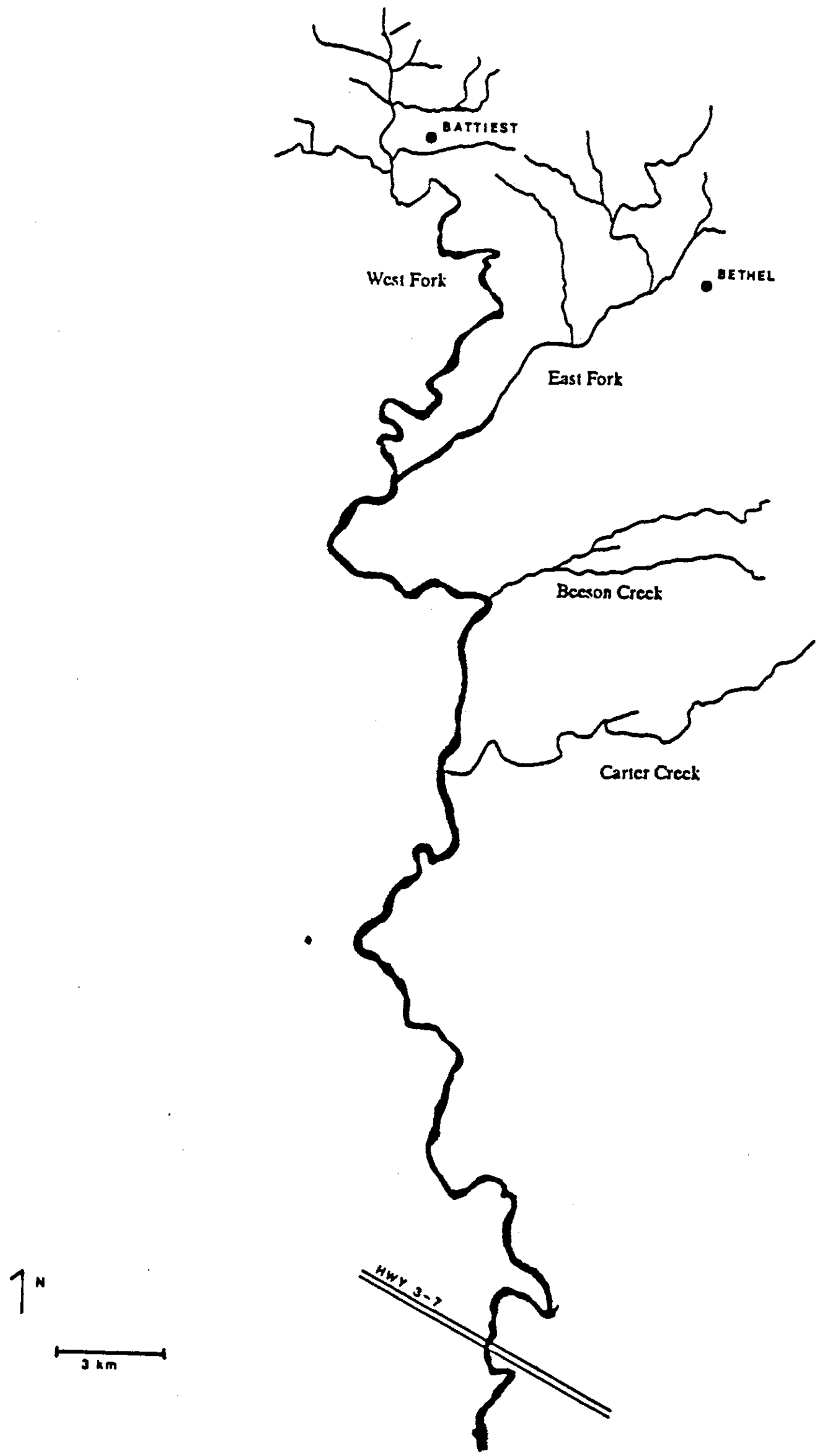

Figure 4. Glover River in McCurtain County, Oklahoma.

Life History

Robison (1978) and Jones et al. (1984) summarized their understanding of the life history of P. pantherina from collection records, museum specimens, and general observations. Robison (1978) concluded that P. pantherina had a 1:1 sex ratio, a longevity of 3+ years, and attained a maximum size of about 77 mm SL. He concluded that the species was a spring spawner because mature and immature ova counts during spring months were 260 to 418 and 510 to 2302, respectively, and both sexes had enlarged genital papillae. Black fly larvae (Simuliidae) and mayfly nymphs (Baetidae) were the most common food items (Robison 1978). Jones et al. (1984) confirmed Robison's estimate of the longevity of P. pantherina from length-frequency distributions and scale annuli. Jones et al. (1984) also concluded that spawning occurred in the spring because of increased densities of P. pantherina in riffle areas during that period, however, no observations of spawning activity were made. Robison (1978) and Jones et al. (1984) were unable to describe the spawning behavior and spawning habitat of P. pantherina, but predicted that it was probably similar to that of its nearest relative, P. maculata which spawns on riffles and buries its eggs in sand and gravel (Petravicz 1938; Winn 1958).

CHAPTER III

STUDY AREA

Glover River is a major tributary in the Little River drainage of southeastern Oklahoma and southwestern Arkansas. The river originates in the Beaver's Bend Hills subsection of the Ouachita Mountains in northern McCurtain County, Oklahoma, and flows south toward the Little River (Fig. 1). The drainage basin is 56.3 km long, 32.2 km wide, and drains about 876 km^2. The mainstem is 53 km long and the East and West forks are 35 and 33 km long, respectively. The mean gradient is 2.3 m/km, and ranges from 19 m/km near the source to 1 m/km at the mouth (U. S. Army Corps of Engineers 1975). The basin is composed largely of sandstone and shale sedimentary rocks of Cambrian or Ordovician to Pennsylvanian origin (Thornbury 1965). The river bed is composed predominantly of Pennsylvanian and Mississippian Stanley Shale (Flawn et al. 1961).

The upper reaches of the Glover drainage are characterized by heavily forested (oaks and pines) mountainous ridges with steep slopes. Commercial timber harvesting and poultry farming are the principal economic activities in this area. The lower reaches flow through fertile lowlands and the floodplain of the Gulf Coastal Plain. These areas are devoted principally to livestock grazing.

Stream habitat of Glover River upstream from Carter Creek (Fig. 4), consists of shallow, wide pools with bedrock, boulder, and rubble substrates separated by riffles, chutes, and low falls over bedrock and boulders. Stream habitat below Carter Creek consists of long, deep pools, separated by shallow riffles of rubble and gravel substrates. Periodic flooding in all areas keeps the stream well scoured and results in substrates dominated by bedrock, boulders, and rubble. During summer, extensive growths of water willow (*Justicia americana*) develop in shallow, slow-current areas, and cattail (*Typha* sp.) grow along the shorelines of some pools. Six sites in Glover River (Table I) with relatively high densities of leopard darters were selected for study. The study sites were distributed as follows: sites 1 and 2 on mainstem Glover, sites 3, 4 and 5 on the West Fork, and site 6 on the East Fork (Fig. 5). Sites 1, 2, and 3 were pool habitats and sites 4, 5, and 6 each contained riffle and pool habitats (Table I).

TABLE I

LOCATIONS OF STUDY SITES IN GLOVER RIVER, MCCURTAIN COUNTY, OKLAHOMA

Site	Location	Description
1	mainstem Glover (R23E T3S Sec. 32)	pool about 75 m upstream from bridge on Weyerhauser Road No. 52000
2	mainstem Glover (R23E T3S Sec. 7)	East Fork-West Fork confluence pool on upstream side of bridge on Weyerhauser Road No. 53000
3	West Fork (R23E T3S Sec. 7)	pool about 100 m upstream from bridge on Weyerhauser Road No. 53100
4	West Fork (R23E T2S Sec. 20)	riffle and pool on downstream side of bridge on Weyerhauser Road No. 74260
5	West Fork (R23E T2S Sec. 6)	riffle and pool on downstream side of bridge on Weyerhauser Road No. 61000
6	East Fork (R23E T2S Sec. 27)	riffle and pool on downstream side of bridge on Weyerhauser Road No. 53100

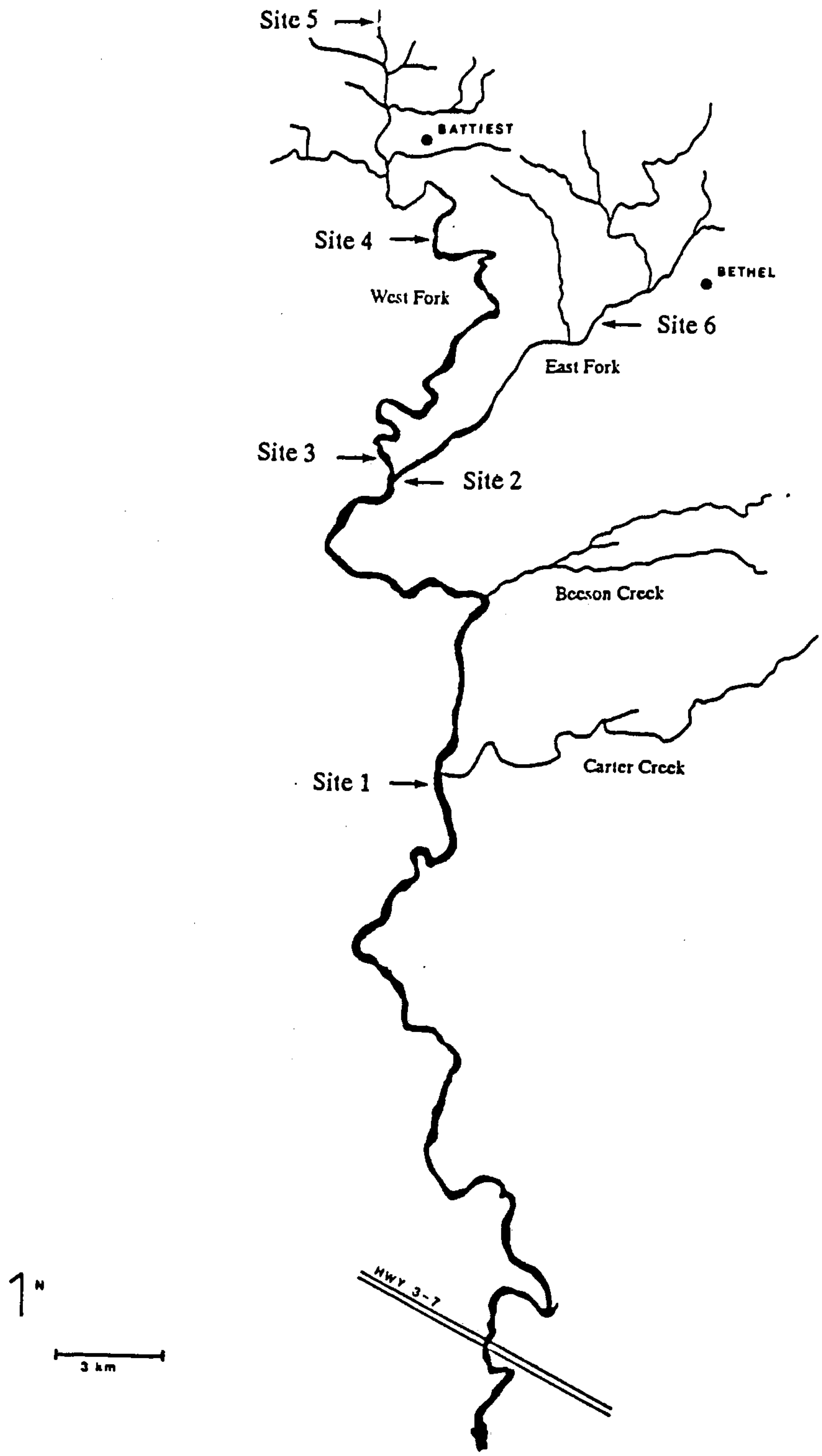

Figure 5. Map of study sites in Glover River, McCurtain County, Oklahoma.

CHAPTER IV

REPRODUCTIVE ECOLOGY AND LIFE HISTORY OF *PERCINA PANTHERINA*

Introduction

Although Robison (1978) summarized available life history information on *P. pantherina* and Jones et al. (1984) determined the habitat and abundance of *P. pantherina*, detailed descriptions and quantitative analyses of *P. pantherina* reproductive ecology, age and growth, and young-of-the-year habitat were unavailable prior to my investigation. I described the reproductive ecology and life history of *P. pantherina* by making underwater observations and habitat measurements throughout the year.

Materials and Methods

Behavior

Underwater observations were made at each site monthly by snorkeling within a 45 m to 75 m-long section of stream delineated by three to five transects established at each site. The transects were perpendicular to stream flow and spaced 15-m apart. Masks and snorkels were used for underwater sampling during summer, but drysuits, hoods, and gloves were required during fall, winter, and spring. Observations of _P. pantherina_ swimming and feeding behaviors and interactions with other species were recorded following each dive during the first several months of the study. Notes were made of any unusual observations or behaviors as they occurred throughout the duration of the study.

Habitat

A diver-operated electrofisher (James et al. 1987) was used during the first year of the study to capture individual fish encountered during underwater observation periods. However, divers were able to trap individual darters using two hand-held dipnets (16x26-cm aquarium nets) after considerable practice. A few _P. pantherina_ were stunned and collected with the use of a backpack electrofisher, but most were captured by divers with dipnets. Repeated electrofishing has been found to have a negative effect on growth rates of some species (Gatz et al. 1986). Underwater capture of individuals by divers using dipnets did not appear to cause physical damage or stress to specimens.

The exact location where a diver first sighted an individual was marked with a small weighted float made of a 10x10x1-cm styrofoam block attached to a 40-g lead weight by a 2-m long section of monofilament fishing line. The microhabitat at each capture location was quantified by measuring water depth, substrate type, and current velocity at the point where the lead weight was placed. Eight additional measurements of depth and substrate were made at 25-cm intervals along imaginary X-Y axes to quantify the microhabitat in a 1-m^2 area (Fig. 6). Water depth was measured to the nearest cm with a meter stick, substrate was coded according to a modified Wentworth Particle Size scale (Table II), and current velocity was measured to the nearest 2 cm/sec with a pygmy-gurley current meter. The mean depth, modal substrate value, and current velocity were used to characterize the microhabitat at each capture location and were used to construct frequency distributions estimating habitat use throughout the year. Seasonal habitat use was determined by grouping data into a winter (December-February), spring (March-May), summer (June-August), or fall (September-November) group.

Spawning Behavior and Habitat

Underwater observations of spawning behavior were made in Glover River during spring of 1986 and 1987; high water and turbid conditions during spring months in 1988 precluded any observations of spawning. Detailed descriptions of male and female behaviors during spawning were recorded immediately following each observation. When spawning acts were observed, a

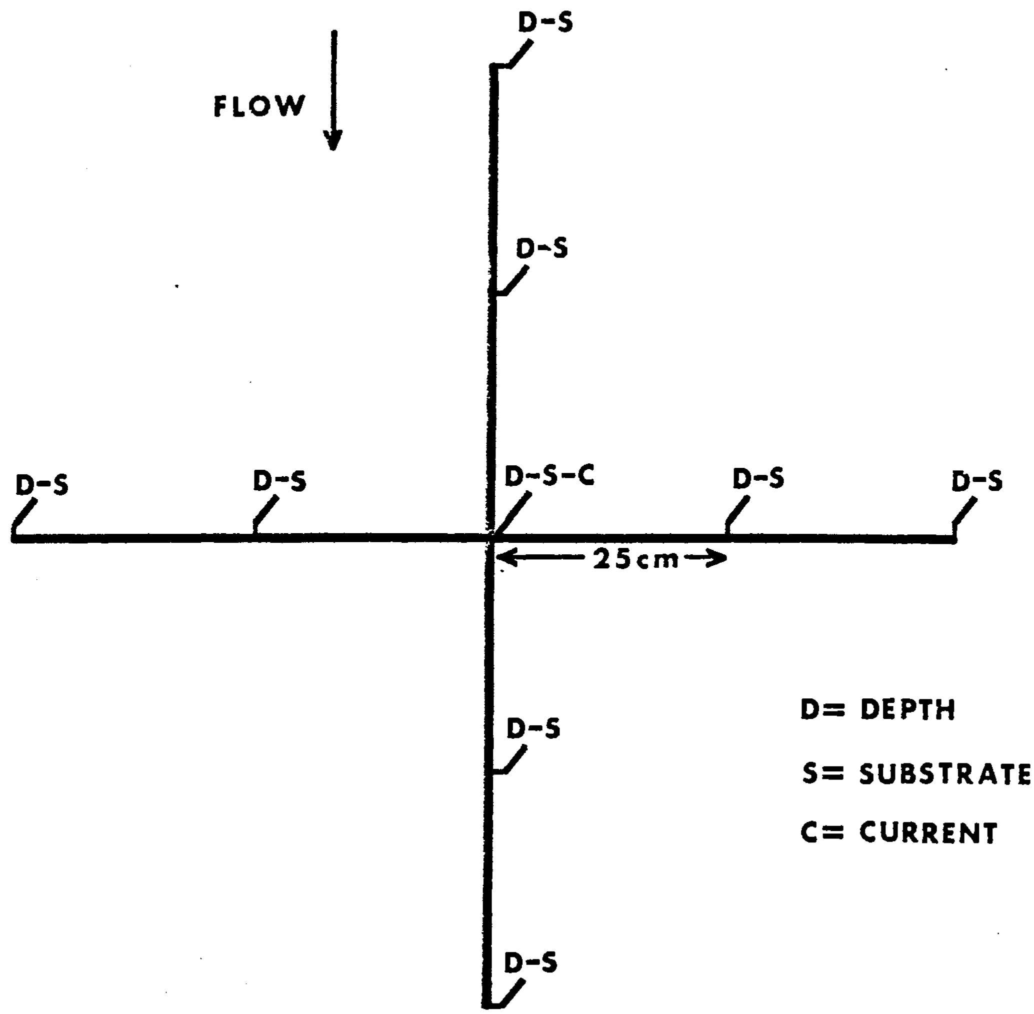

Figure 6. Diagram of measurement points taken at *P. pantherina* capture locations. The intersection of the axes corresponds to the point of initial sighting.

TABLE II

MODIFIED WENTWORTH PARTICLE-SIZE SCALE
FOR CODING SUBSTRATE

Value	Particle Size (mm in diameter)	Description
1	-----	detritus,muck
2	<0.004	mud, clay
3	0.004-0.05	silt
4	0.06-2.00	sand
5	2.00-64.0	gravel
6	65-255	rubble
7	256-1000	boulder
8	>1000	bedrock

fluorescent-yellow, metal washer (8-cm in diameter) was placed at the exact site of egg deposition. Characteristics of spawning sites were quantified using the same procedure described above for habitat use.

Fecundity

Fecundity estimates of other darter species determined from ova counts have been made using two different methods. One method is to count only the large, mature ova (Speare 1965; Page and Smith 1970; Mathur 1973). This method assumes that the immature ova do not mature and instead are retained until the next reproductive period. The other method is to count all distinguishable ova (Fahy, 1954; Winn, 1958b). This method assumes that all immature ova will mature and be spawned. Hubbs (1985) concluded that many darters species can mature and spawn several clutches of eggs. Hubbs and Strawn (1957) were able to keep a female Etheostoma lepidum (greenthroat darter) producing eggs for 251 days, suggesting that ova mature during the spawning season.

An estimate of fecundity was determined by counting all distinguishable ova in five museum specimens that were collected during spring months. The diameter of each ovum in the preserved specimens was measured to the nearest 0.05 mm using an ocular micrometer.

Fecundity was also estimated by collecting and counting eggs spawned by single pairs of *P. pantherina* held in 150-l fiberglass aquaria at 18-20 °C and exposed to a photoperiod of 13L:11D. The substrate in the aquarium (mixture of coarse and fine gravel) was siphoned every 2 days to remove eggs. The eggs collected from the aquarium were counted, measured, and incubated in glass bowls at 18-20 °C.

Age and Growth

Total lengths (TL, mm) and standard lengths (SL, mm) of all captured specimens were measured and used in a length-frequency analysis to determine age and growth (Jearld 1983). Length-frequency histograms were constructed for fish captured during each month. The monthly mean SL of young-of-the-year individuals was used to determine growth rate. Handling stress was reduced by holding specimens in a water-filled graduated cylinder while measurements were made with a small, flexible metric ruler (Litvak 1983). Following measurement, all specimens were released as close to their original capture location as possible. Early growth rates of embryos and larvae were determined by examination of eggs spawned in the laboratory. Sexes of adults were determined by examination of mid-ventral scalation (Page 1976) with a 10x hand lens. Counts and descriptions of specimens having ectoparasites were made to determine the magnitude and effects of parasitism.

Food Habits

Stomachs of nineteen specimens in the Oklahoma State University Collection of Vertebrates were examined to determine general diets. All food items were identified to family using the keys of Merritt and Cummins (1984).

Population Abundance

Population abundance estimates were made at sites 1-5 during the summers of 1987 and 1988. The population at site 6 was sampled during the summers of 1986 and 1988. Population abundance estimates were made from actual counts of captured specimens. Specimens were captured according to methods described above. Repeated depletion samples were made within an area delineated by the habitat transects at each site until no *P. pantherina* were found. The captured darters were measured, sexed, and enumerated, then released as close to their original capture location as possible.

Two important assumptions were made concerning the population abundance estimates. One assumption is that all or nearly all of the specimens of *P. pantherina* at each site were captured during the depletion samples. The other assumption is that the population at each site is closed and stable. Sites 1, 5, and 6 are pools that are naturally enclosed by rock ledges or low-water bridges during the summer months. Sites 2, 3, and 4, however, are either at the head or tail of a long (>0.5 km) open pool. From behavioral observations described below concerning home range and mobility, it did not appear that individuals were moving great distances between or within pools.

Results

Behavior

Throughout the summer and fall, *P. pantherina* were typically observed in calm pools swimming 5-10 cm above the substrate, stopping often to pick prey items from the periphytic growth. Individuals were rarely seen resting on the substrate and appeared to be capable of maintaining position in the water column with minimal effort. Although most individuals were observed swimming constantly, they rarely moved more than a few meters from a specific location. Some individuals that could be specifically identified because of their unusual markings or scars were observed to occupy the same specific location within a pool over several successive sampling dates. *P. pantherina* fled in a burst-swimming behavior when large piscivorous fishes such as *Micropterus dolomieui* (smallmouth bass) and *Lepomis cyanellus* (green sunfish) approached, although no predation was ever observed. Individuals occasionally swam into crevices or under slabs to escape our nets. The few individuals captured during periods of extremely low water temperatures (2-6 ^{o}C) were found under large rocks. During spring months, when P. pantherina moved onto riffles for spawning, individuals were usually observed resting on the gravel/cobble substrate and appeared to have difficulty swimming in the swift currents of riffles. During the spawning season, gravid females were identified by their distended belly and mature ova could occasionally be seen through the body wall. Sexually ripe males were easily identified by the presence of a row of modified scales with tooth-like projections along the midline of the belly. These modified scales were noticeably enlarged during the spawning season.

Benthic fishes that were commonly observed with P. pantherina were (in decreasing order of abundance) Etheostoma radiosum (orangebelly darter), P. copelandi (channel darter), P. caprodes (logperch), and E. nigrum (johnny darter). At a supplemental study site in lower Glover River (R23E T5S Sec. 9) P. pantherina was captured with P. maculata (blackside darter) and P. sciera (dusky darter).

Habitat

P. pantherina inhabited pools exclusively except during the spawning season in March and April when they inhabited riffles. Individuals were captured most often at depths ranging from 30 to 100 cm over rubble and boulder substrates with little or no detectable current velocity (Figs. 7-18 and Appendix A). A detailed analysis of the specific habitat of _P_. _pantherina_ is presented in chapter V.

Spawning Behavior and Habitat

_P_. _pantherina_ occurred exclusively in the tailwaters of riffles in late February or early March of when water temperatures were about 10 °C. The average number of _P_. _pantherina_ collected at sites 5 and 6 during the summer was 2 and 4, respectively. During the spawning season, as many as 10 individuals occurred in the riffle area at site 5 and as many as 18 at site 6. Conversely, no _P_. _pantherina_ spawned on the riffle area immediately downstream from the pool at site 3 where about 15 _P_. _pantherina_ were found during the summer and fall months. _P_. _pantherina_ did not necessarily use the nearest riffle for spawning, but appeared to select specific spawning riffles. The relatively high densities (20-25 individuals) found on some but not all riffles during the spring suggested that _P_. _pantherina_ underwent a migration from pools to specific spawning areas.

Spawning occurred from mid-March through mid-April in 1986-1988. Spawning began on March 9, 1986, at a water temperature of 17 °C, and on March 12, 1987, at a water

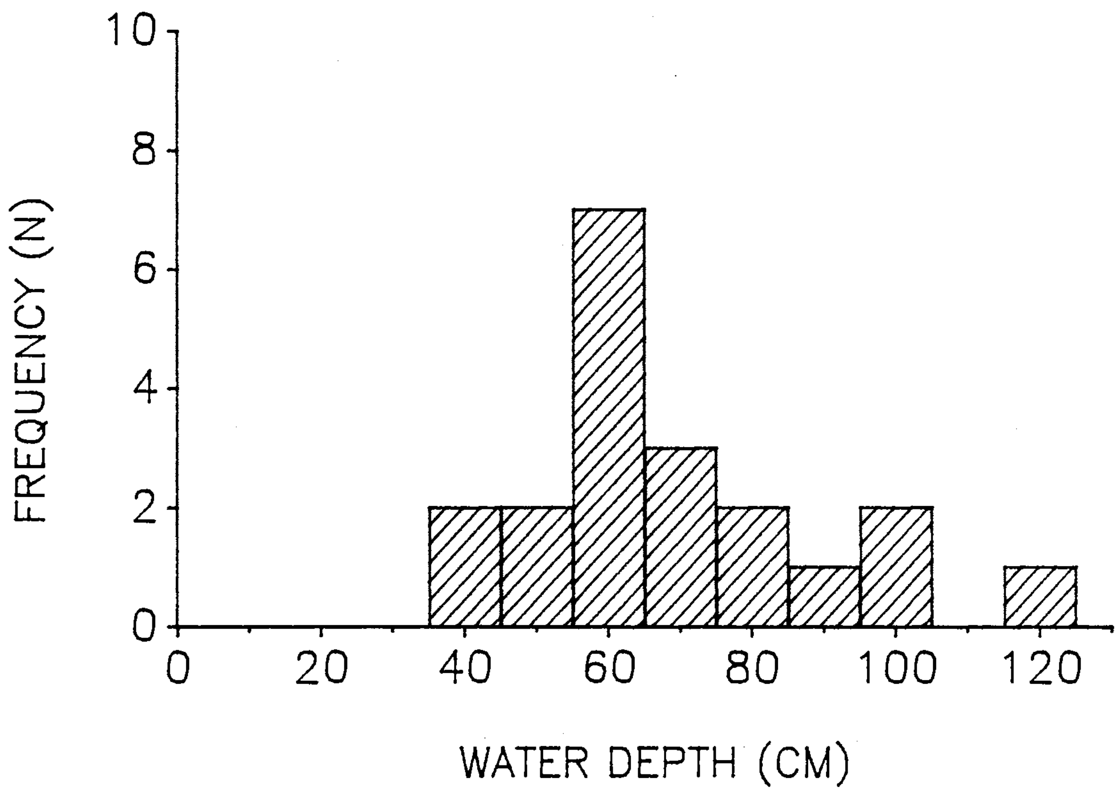

Figure 7. Frequency distribution of water depths measured at _P. pantherina_ capture locations in Glover River during winter months 1986-1988.

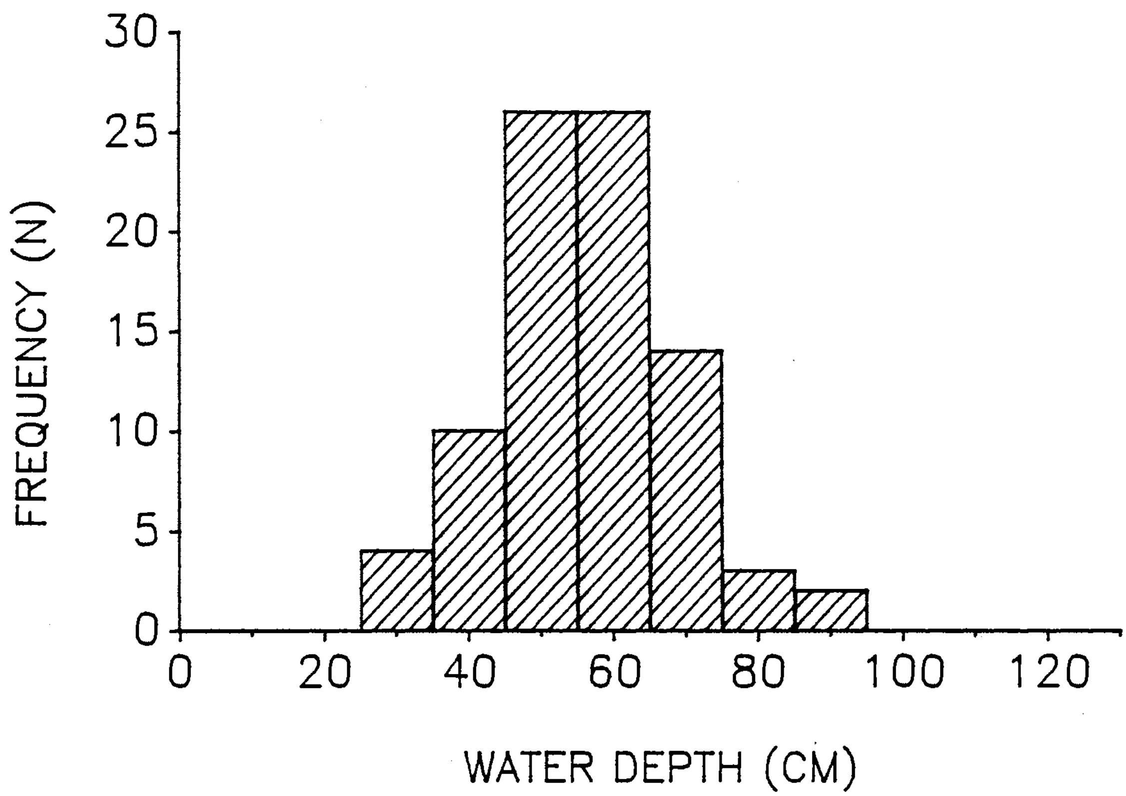

Figure 8. Frequency distribution of water depths measured at _P. pantherina_ capture locations in Glover River during spring months 1986-1988.

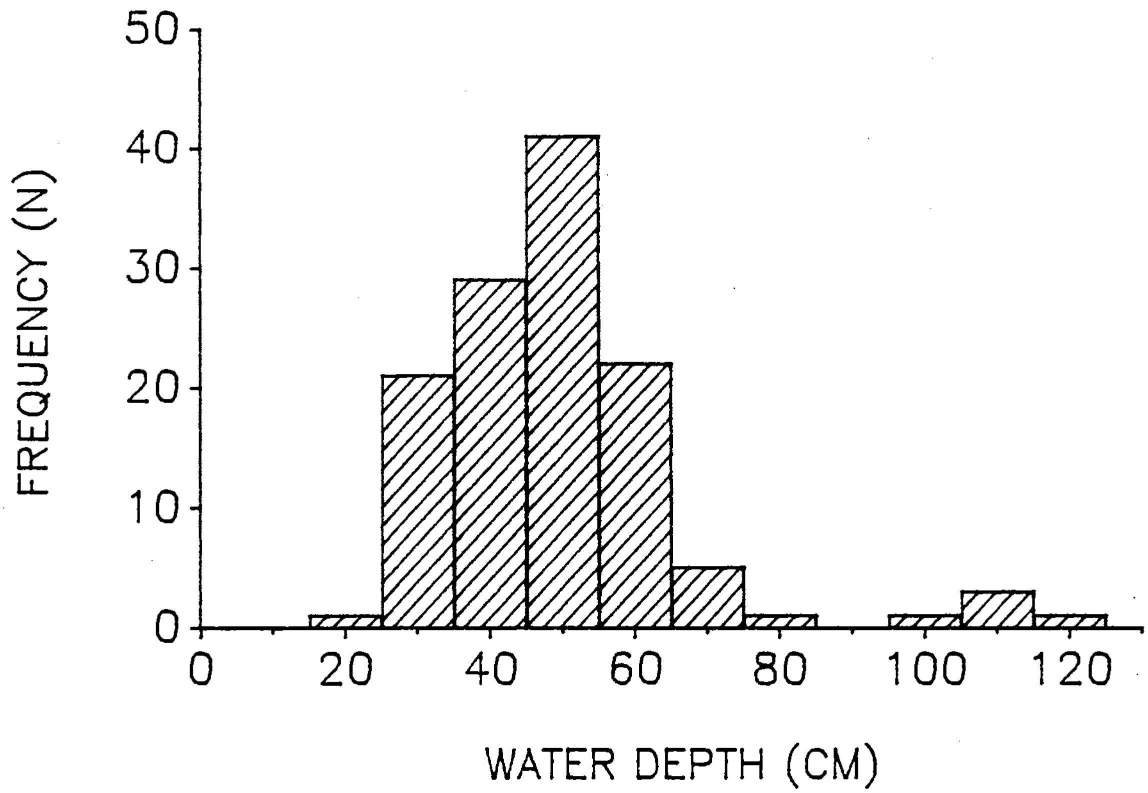

Figure 9. Frequency distribution of water depths measured at *P. pantherina* capture locations in Glover River during summer months 1986-1988.

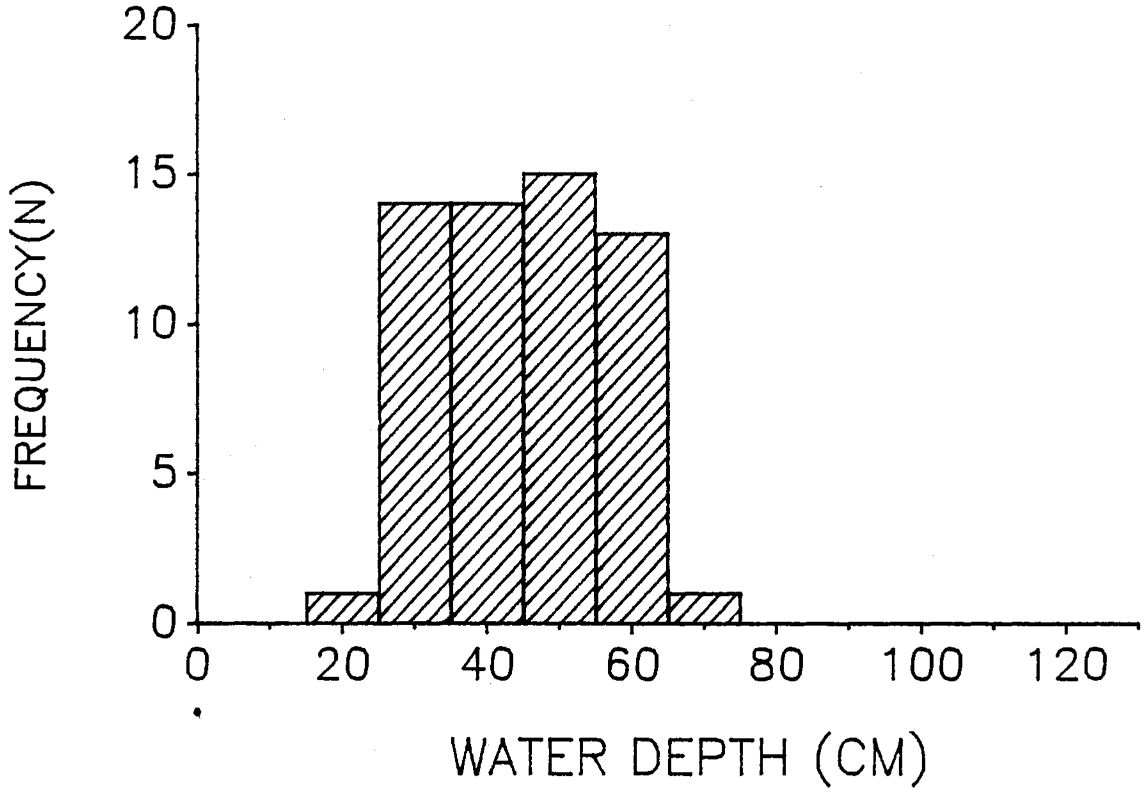

Figure 10. Frequency distribution of water depths measured at P. pantherina capture locations in Glover River during fall months 1986-1988.

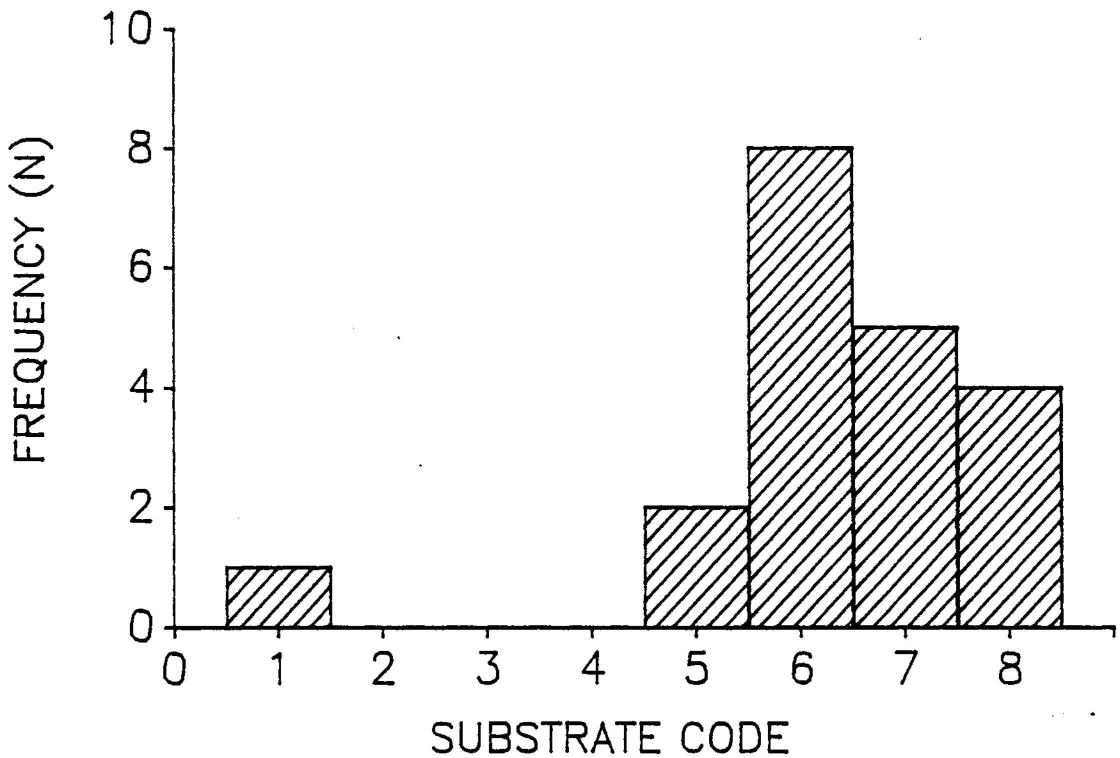

Figure 11. Frequency distribution of substrates measured at *P. pantherina* capture locations in Glover River during winter months 1986-1988.

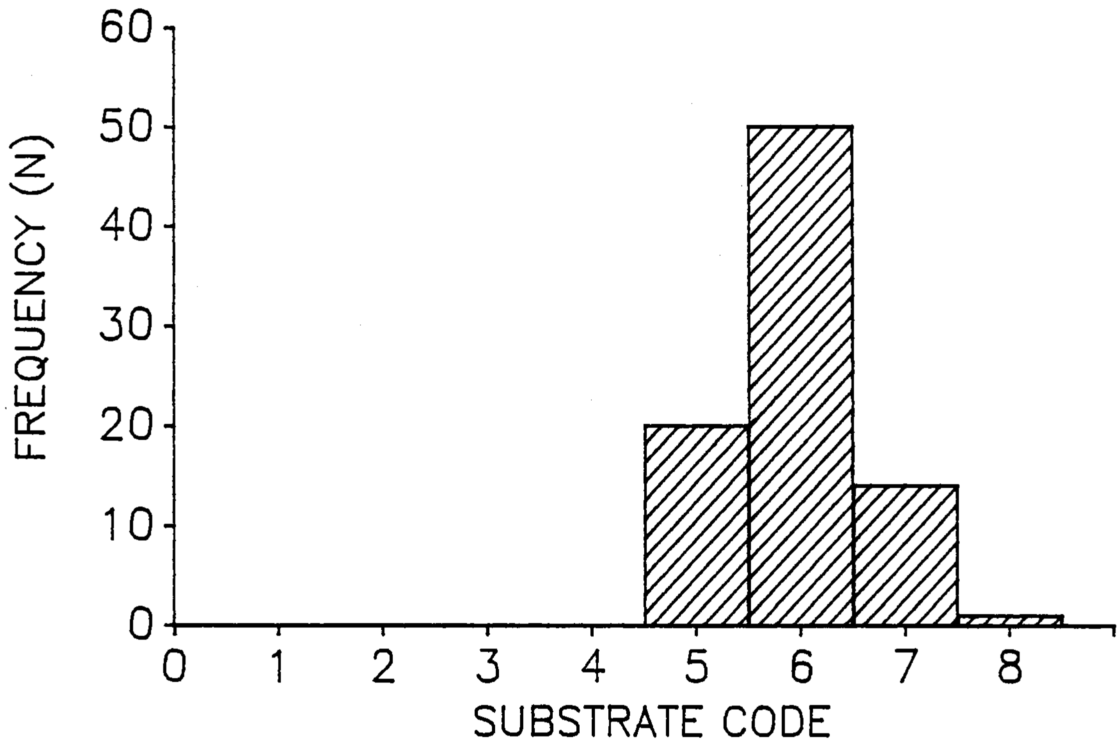

Figure 12. Frequency distribution of substrates measured at *P. pantherina* capture locations in Glover River during spring months 1986-1988.

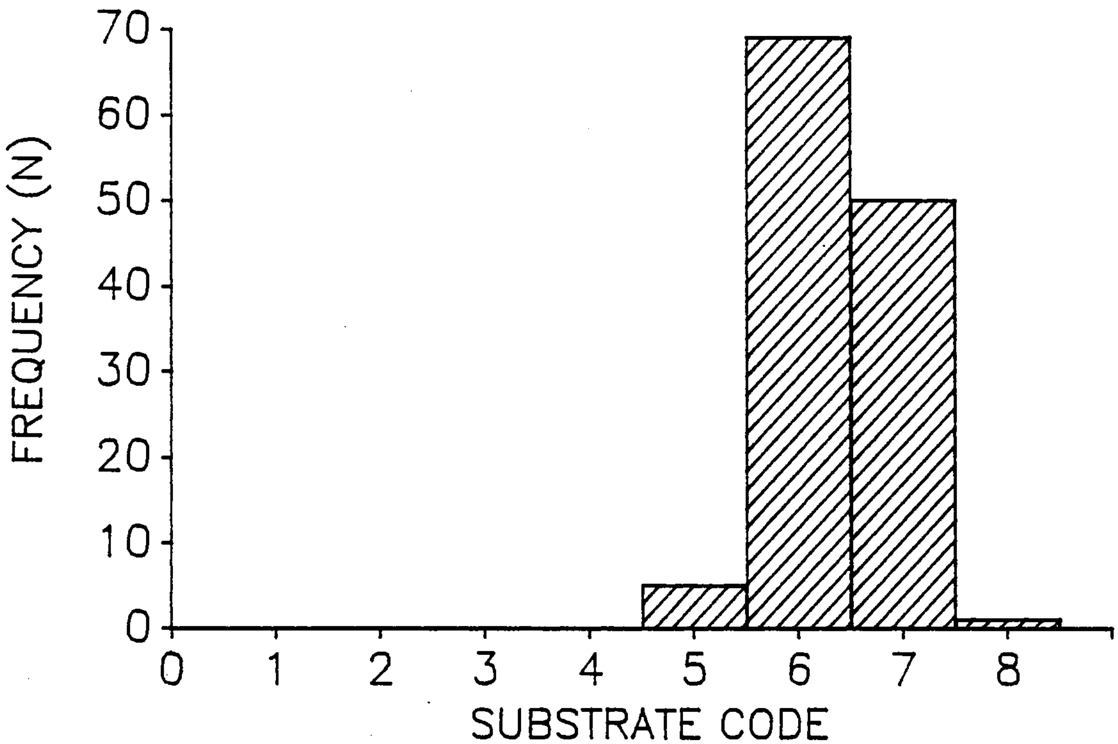

Figure 13. Frequency distribution of substrates measured at P. pantherina capture locations in Glover River during summer months 1986-1988.

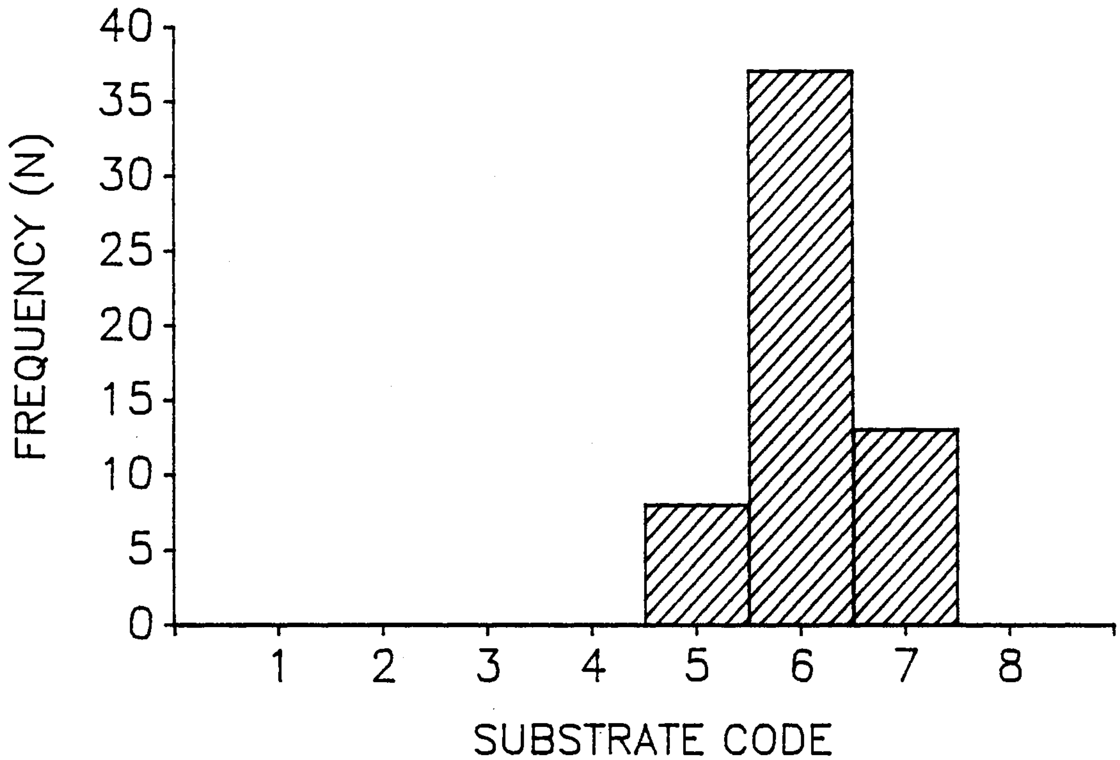

Figure 14. Frequency distribution of substrates measured at P. *pantherina* capture locations in Glover River during fall months 1986-1988.

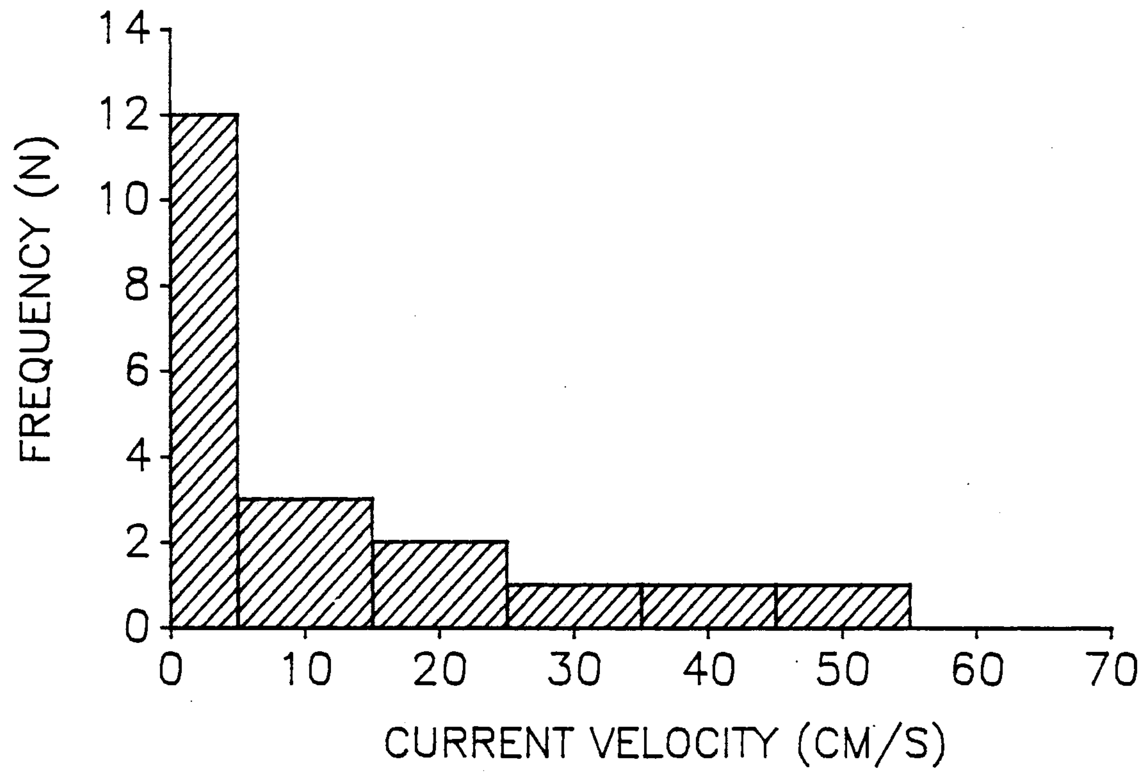

Figure 15. Frequency distribution of current velocities measured at P. pantherina capture locations in Glover River during winter months 1986-1988.

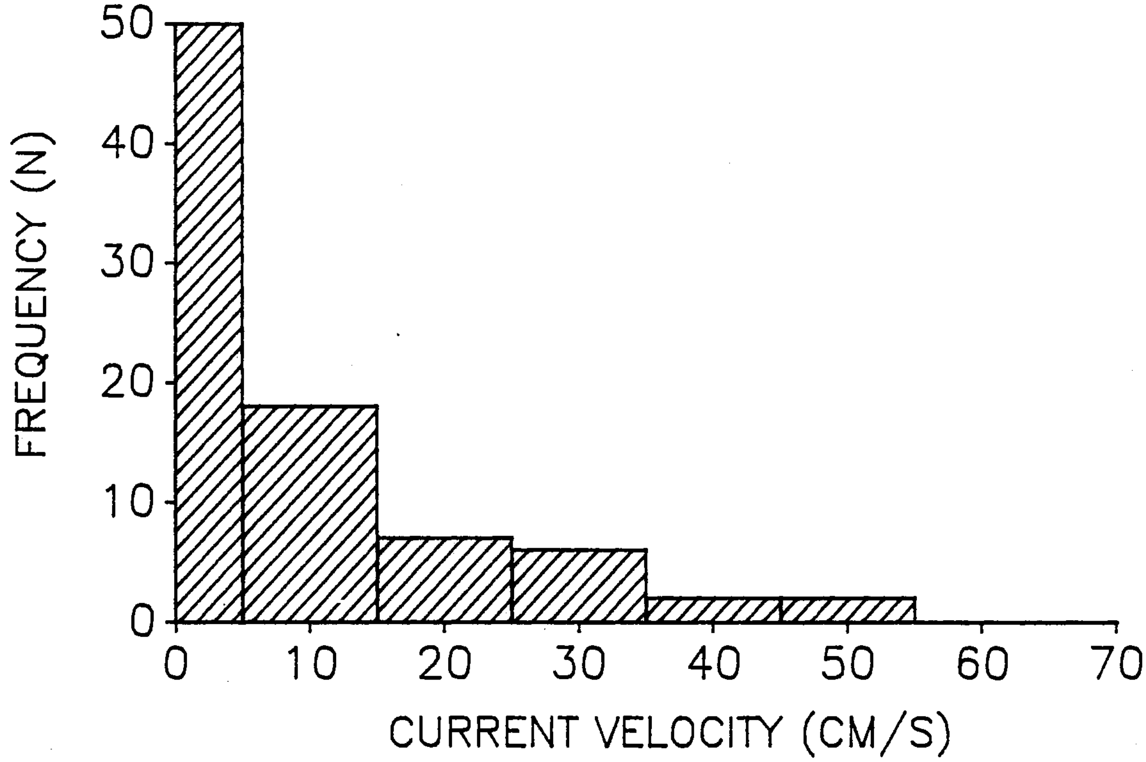

Figure 16. Frequency distribution of current velocities measured at P. *pantherina* capture locations in Glover River during spring months 1986-1988.

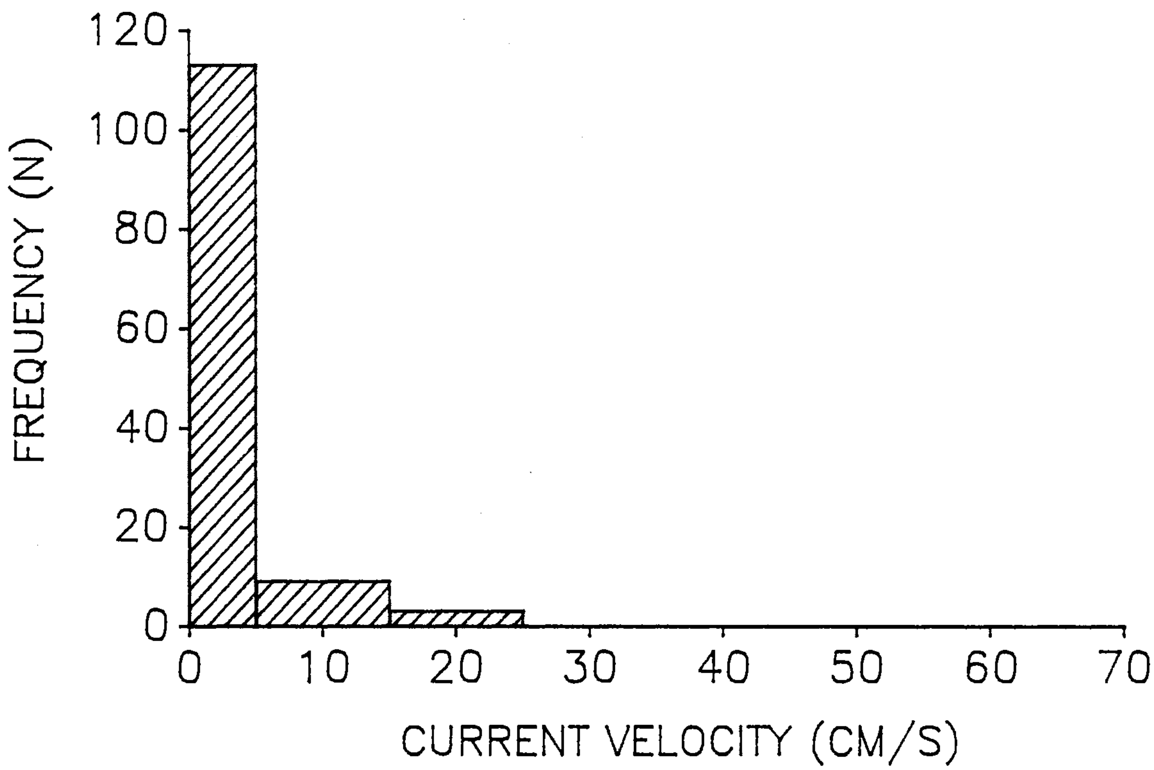

Figure 17. Frequency distribution of current velocities measured at P. *pantherina* capture locations in Glover River during summer months 1986-1988.

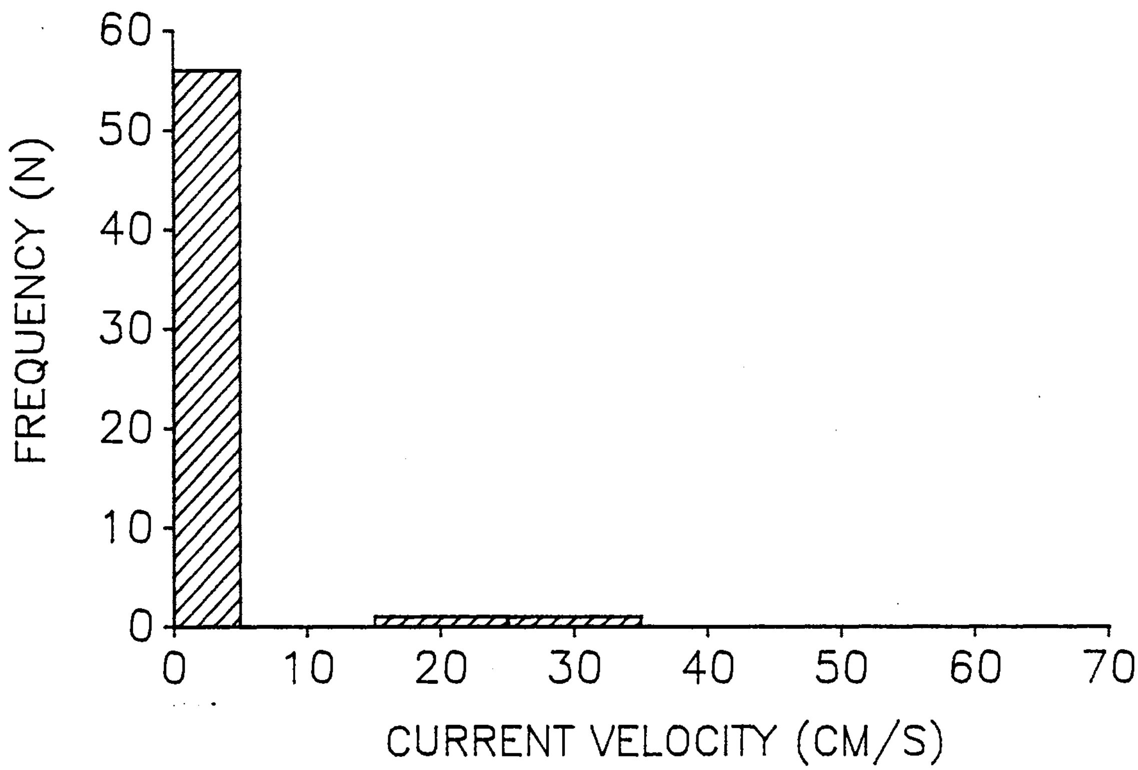

Figure 18. Frequency distribution of current velocities measured at P. *pantherina* capture locations in Glover River during fall months 1986-1988.

temperature of 12 °C. No spawning acts were observed in 1988 but gravid females were found on riffles on 7 March at a water temperature of 13 °C. Individuals were found in riffles as late as 16 April, 1988, at a water temperature of 15 °C. The spawning season in 1988 was probably interrupted because of three heavy rainfall events that caused high flows in Glover River (Fig. 19).

In a typical spawning event, a gravid female, followed by one or more males, moved from the riffle tailwaters upstream into the riffle. The female moved slowly over the gravel and rubble and occasionally settled on the substrate. Males appeared to establish and defend "moving territories" around a gravid female and attempted to chase other males away from the female. One of the males, usually the largest, attempted to position himself directly on top of the female. Unreceptive females immediately swam away with the male or males following. If a female was receptive, a male positioned himself with his pelvic fins on her spinous dorsal fin. With both fish oriented in the same direction, the male curved his body into an S-shape and the pair began to vibrate rapidly, presumably releasing gametes. During the vibrations, the female's genital papilla became buried in the gravel. The male appeared to begin vibrating before the female. Contact with the enlarged midventral scales of males in the genus Percina may provide tactile stimulation to induce females to

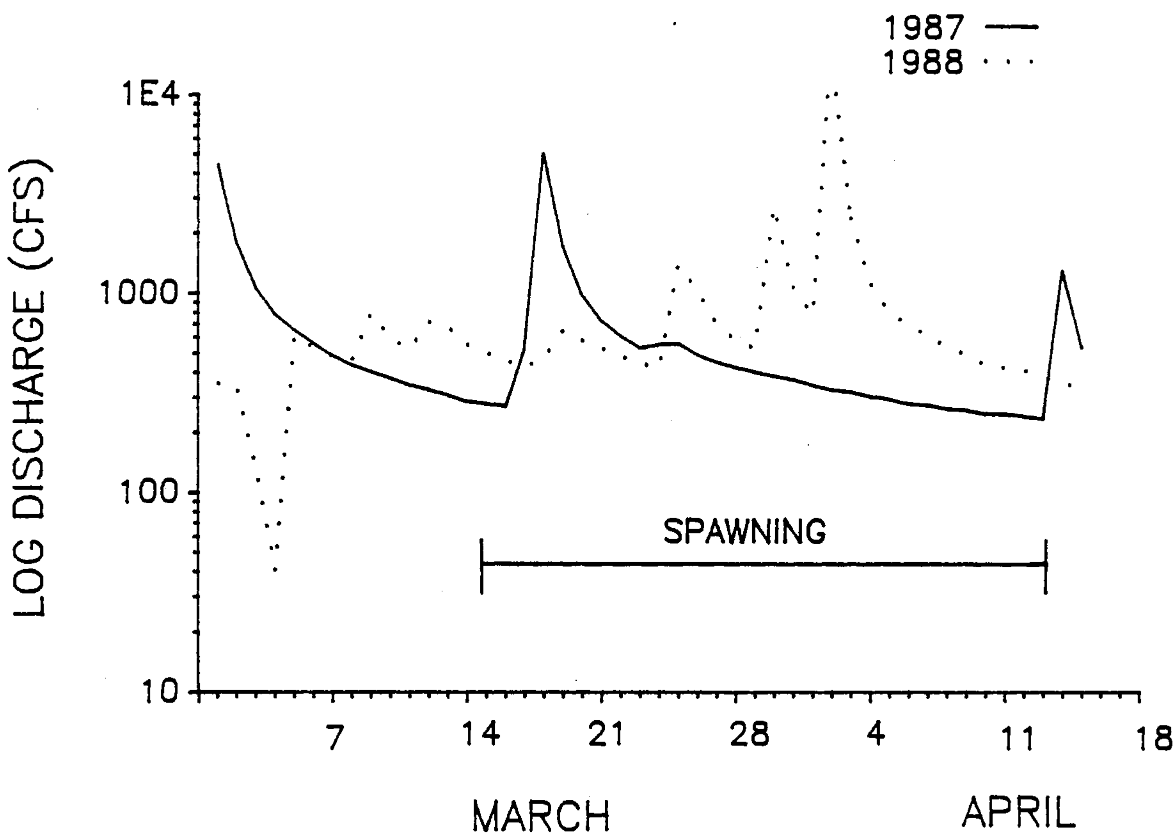

Figure 19. Mean daily discharges from Glover River recorded at Hwy. 3 bridge during March and April 1987-1988.

release eggs (New 1966; Page 1976). The vibrating movements of the pair buried the fertilized eggs in fine gravel. The water-hardened eggs were non-adhesive and demersal. No eggs remained on the surface of the substrate following a spawning act. The vibrations lasted 3-5 sec and were followed by an inactive period of 3-10 min. During the resting phase, both fish remained stationary on the substrate. The female and attendant males then selected another spawning site and repeated the spawning act. Females engaged in as many as six spawning acts during a 30 min period. When multiple spawning acts occurred, the eggs were deposited within a 0.5 m^2 area. Occasionally, one or two additional males joined a pair already engaged in a spawning act. These males, facing in the same direction as the original pair, vibrated while making contact along the side of the female. The supernumerary males were usually smaller than the attendant male and moved away from the original pair immediately following the spawning act. Parental care of eggs or larvae has never been observed in any species of *Percina* (Page 1983) and none was observed in *P. pantherina*. Individuals of *P. caprodes*, *P. copelandi*, and *E. radiosum* were observed on the riffles while *P. pantherina* was spawning, and on two occasions, predation on *P. pantherina* eggs by *P. copelandi* was observed. Immediately following the observation of apparent egg predation, six specimens of

P. copelandi were preserved in 10% formalin. Dissection revealed 1-2 eggs in each of the six stomachs. Although the eggs could not be positively identified as P. pantherina eggs, the eggs were within the size range for P. pantherina eggs and P. pantherina was the only fish observed spawning on the riffle during the observation period.

Spawning sites were located at depths of 30-90 cm over predominantly gravel substrates where current velocities were 0-50 cm/s (Fig. 20-22). Eggs were buried in deposits of fine gravel (3-10 mm in diameter) in the interstices of coarse gravel and rubble. Underwater observations made at several riffles in Glover River revealed that some riffles were not used for spawning, despite habitation of adjacent pools by P. pantherina. In general, the riffles where spawning activities were observed had deposits of fine gravel at water depths of 50-100 cm in the less turbulent (5-30 cm/s current velocity) tailwater areas.

Fecundity

Total numbers of distinguishable ova in preserved specimens ranged from 294 to 757 with a mean of 465 ova per female. Diameter-frequency distributions showed a decrease in the frequency of ova >0.5 mm in diameter after the spawning season (Fig. 23-27). A relationship between standard length and fecundity (Fig. 28) suggests that

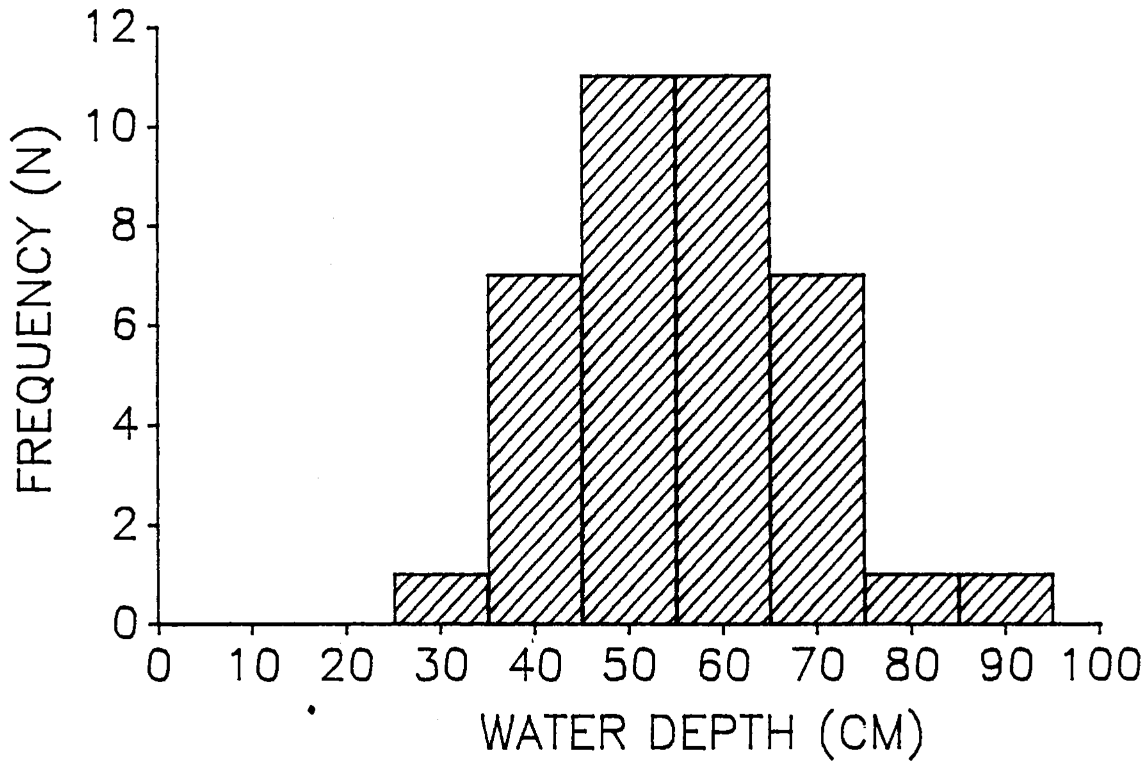

Figure 20. Frequency distribution of water depths measured at *P. pantherina* spawning sites in Glover River 1986-1987.

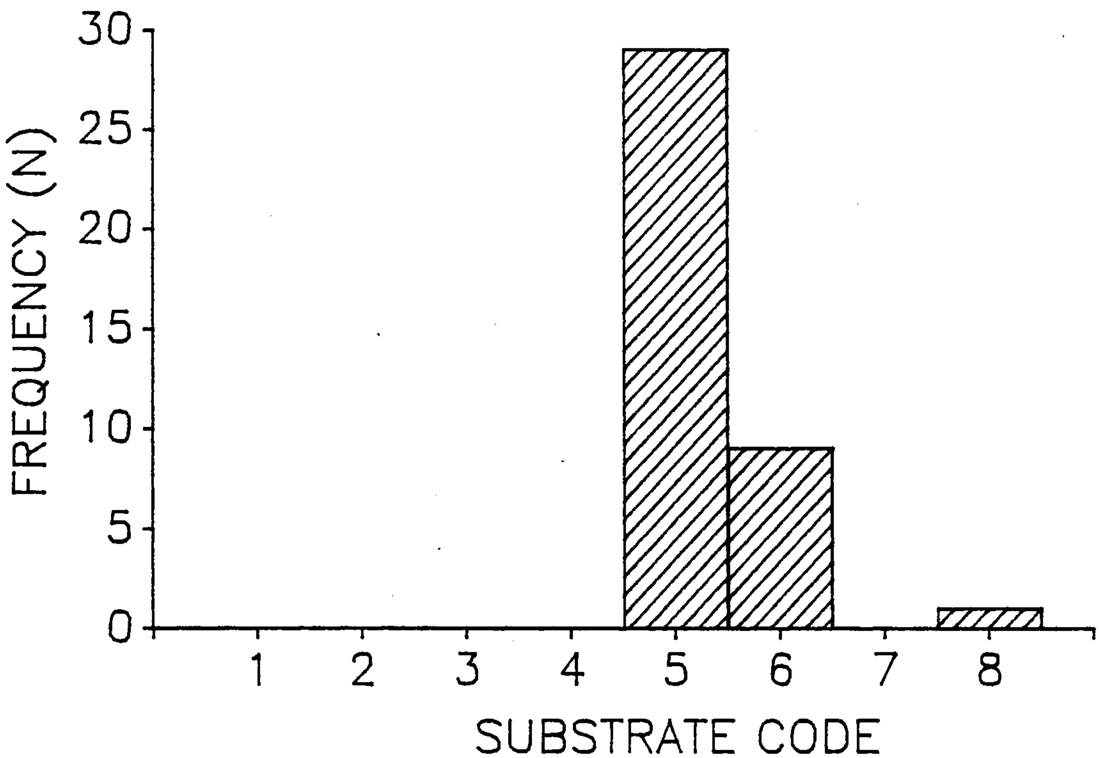

Figure 21. Frequency distribution of substrates measured at *P. pantherina* spawning sites in Glover River 1986-1987.

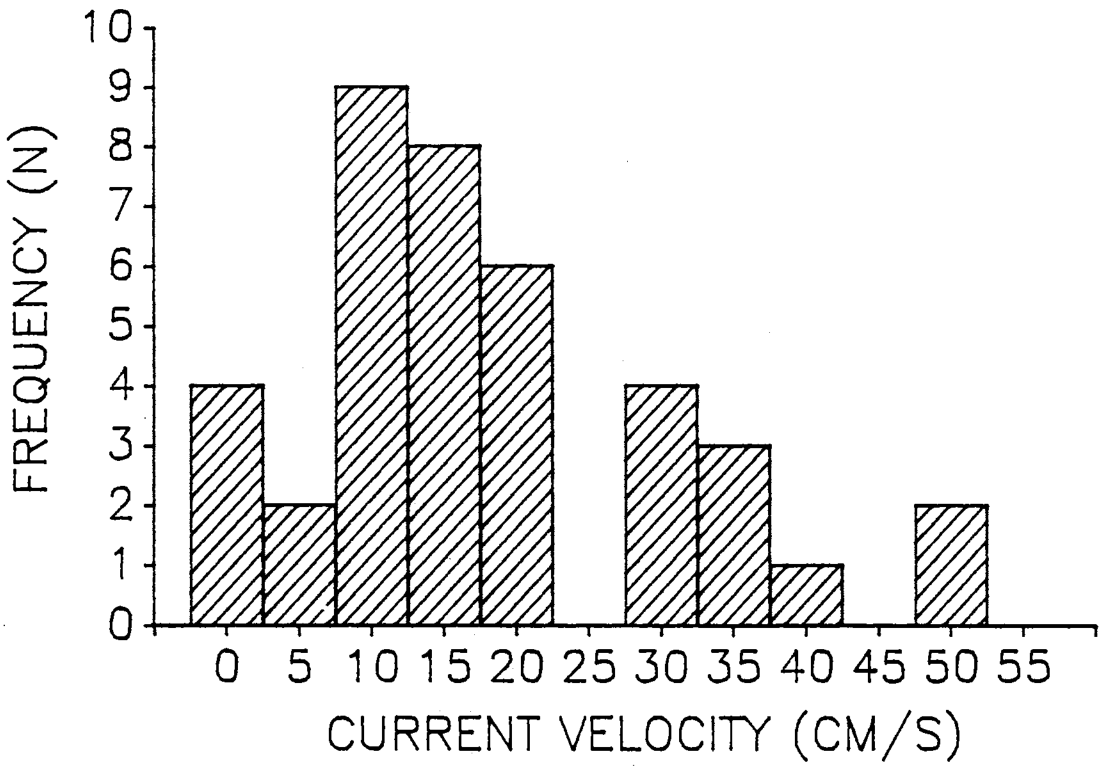

Figure 22. Frequency distribution of current velocities measured at P. *pantherina* spawning sites in Glover River 1986-1987.

larger fish produce more eggs (F=4.89, P=0.11).

The pair held in captivity in 1986 spawned 26 clutches over about 120 days with an average time between spawns of about 4.6 days. In 1987, the pair collected in April spawned only four clutches in captivity, but the female had probably already spawned several clutches in the stream before being captured. Egg clutches from the 1986 pair contained 15-146 eggs with an average of 58.5 eggs per clutch. If female leopard darters spawn 58.5 eggs every 4.6 days in natural systems, an individual female could potentially spawn 6-7 times and produce about 350-410 eggs over a 30-day spawning season. This prediction is relatively close to the actual ova counts made from museum specimens.

Age and Growth

Fertilized, water-hardened eggs from spawning events in aquaria had a mean diameter of 1.37 mm (range 1.25-1.5) and hatched in about seven days at 20 ^{o}C. Total lengths of larvae were about 5.0 mm TL at hatching. The larvae exhibited a distinctive swimming-up behavior in the glass bowls. Several unsuccessful attempts were made to rear larvae. Although a variety of food items was presented to the larvae (e.g., infusoria, liquid larval fish food, brine shrimp nauplii, rotifers, small copepods), none of the larvae lived for more than about six days.

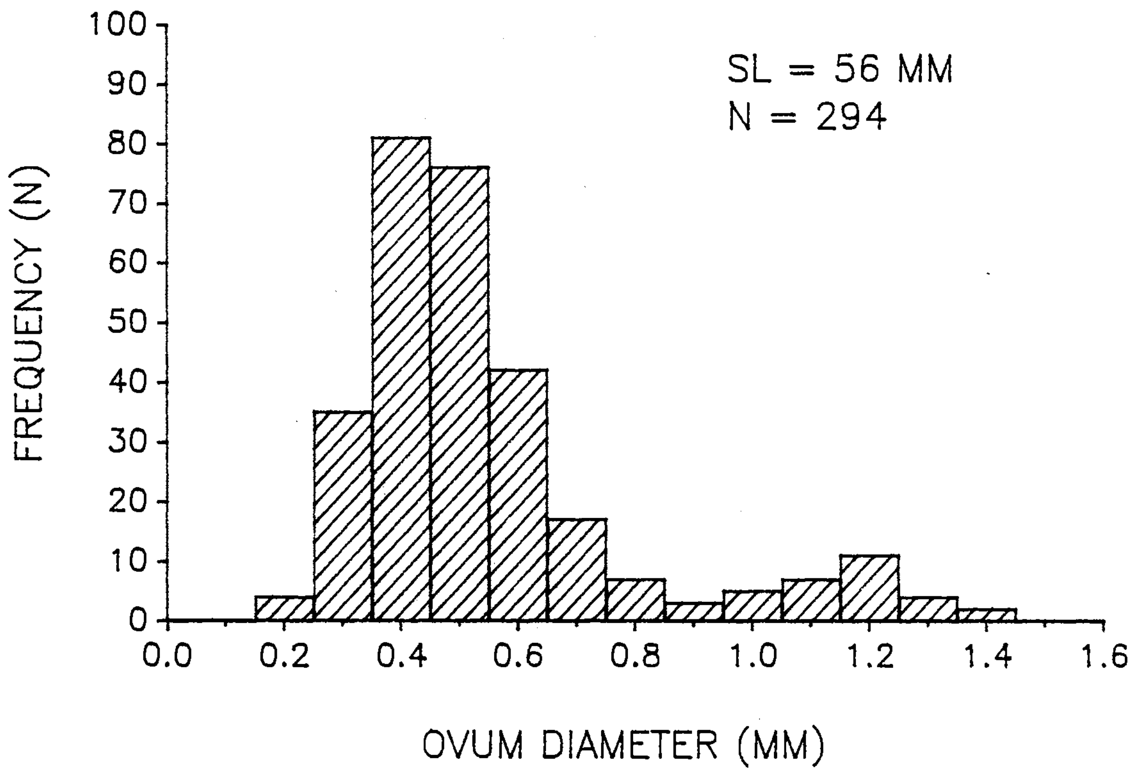

Figure 23. Frequency distribution of ova from a P. pantherina museum specimen collected on 9 March.

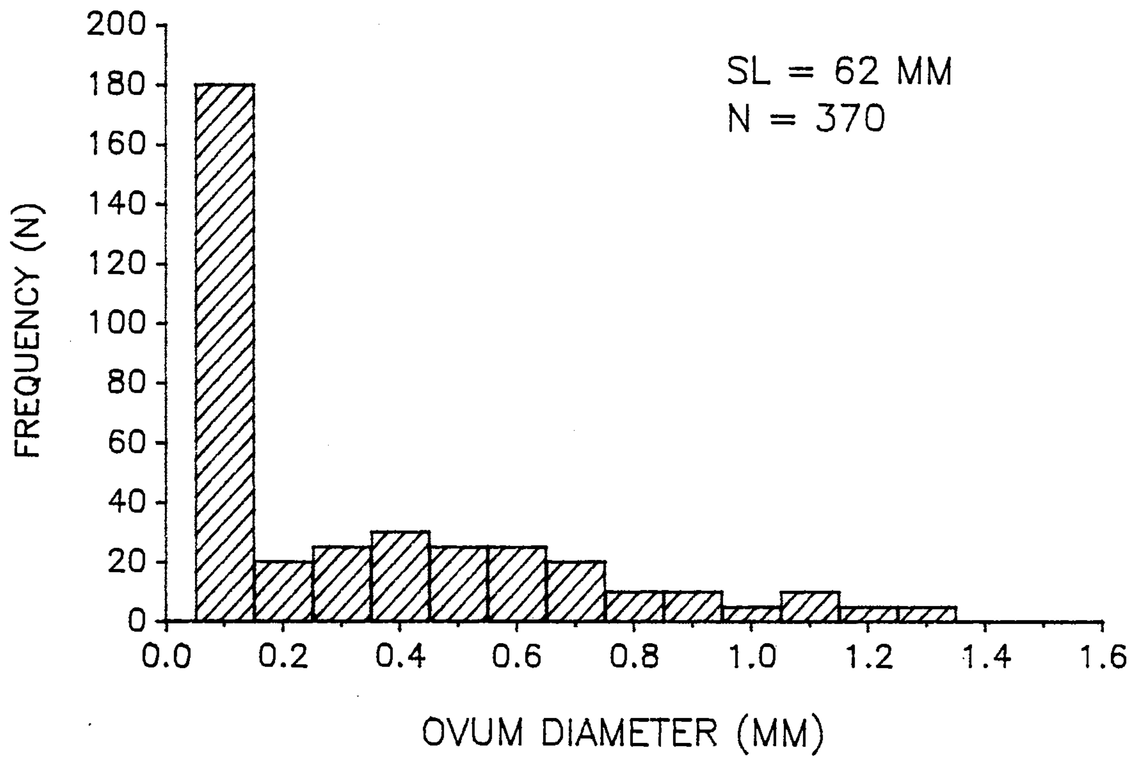

Figure 24. Frequency distribution of ova from a *P. pantherina* museum specimen collected on 25 March.

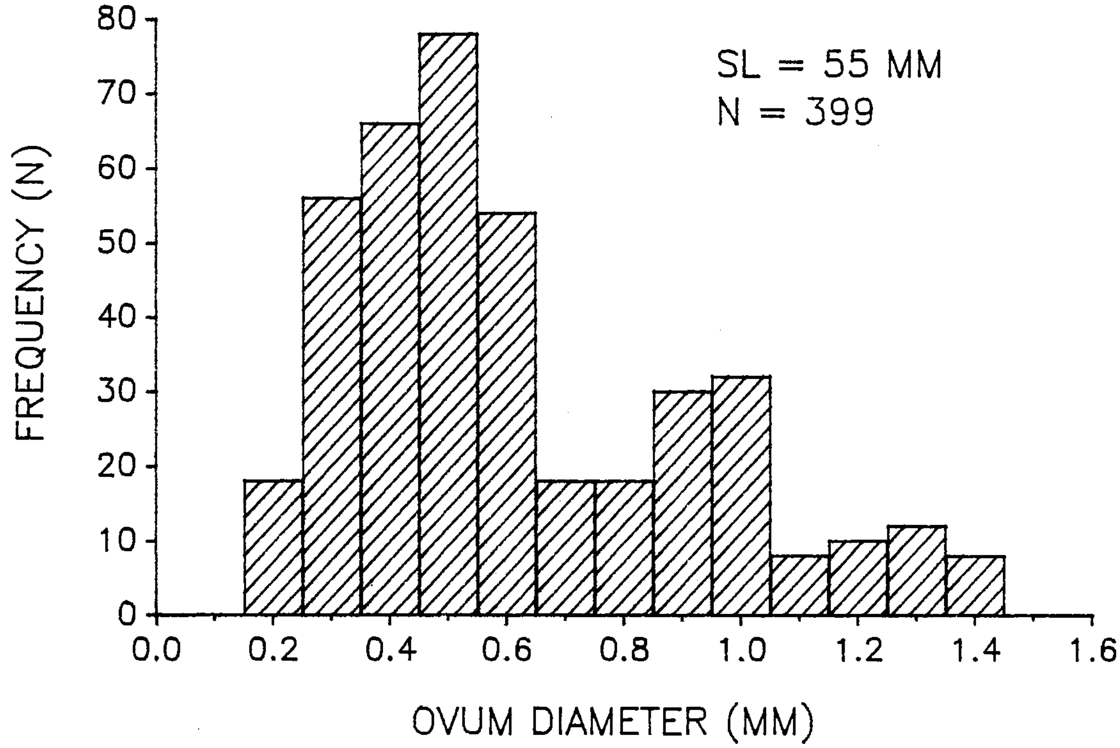

Figure 25. Frequency distribution of ova from a P. pantherina museum specimen collected on 25 March.

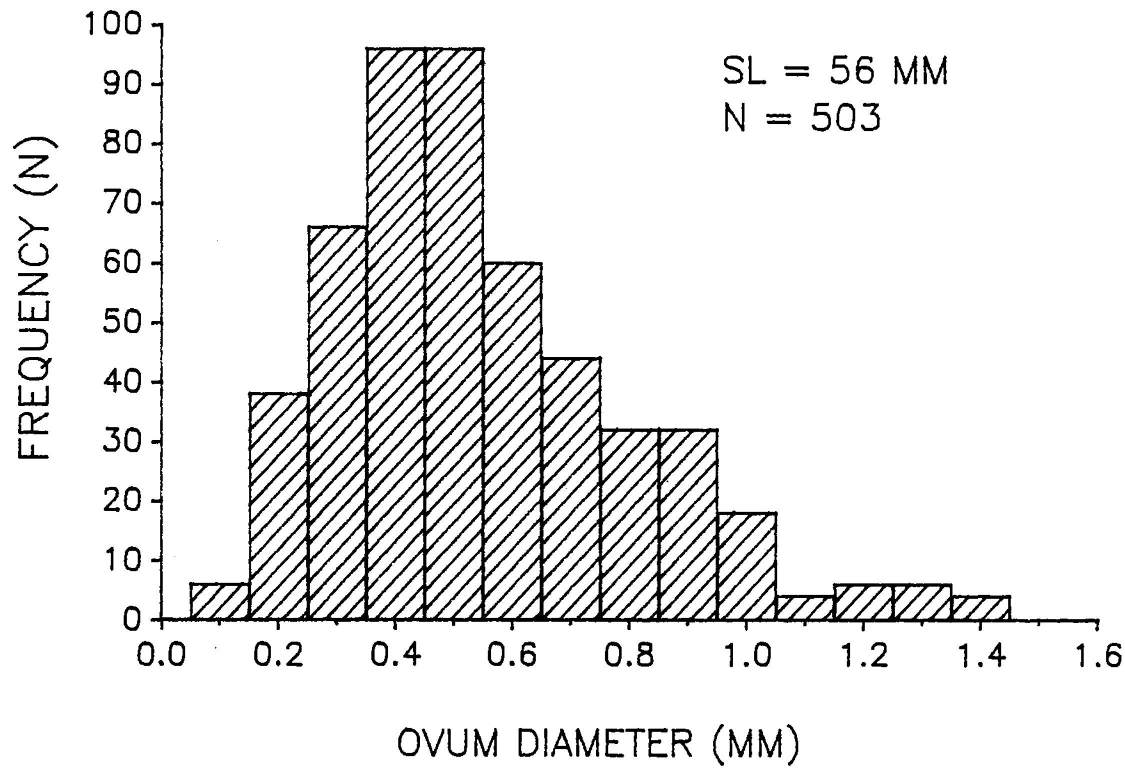

Figure 26. Frequency distribution of ova from a P. pantherina museum specimen collected on 29 April.

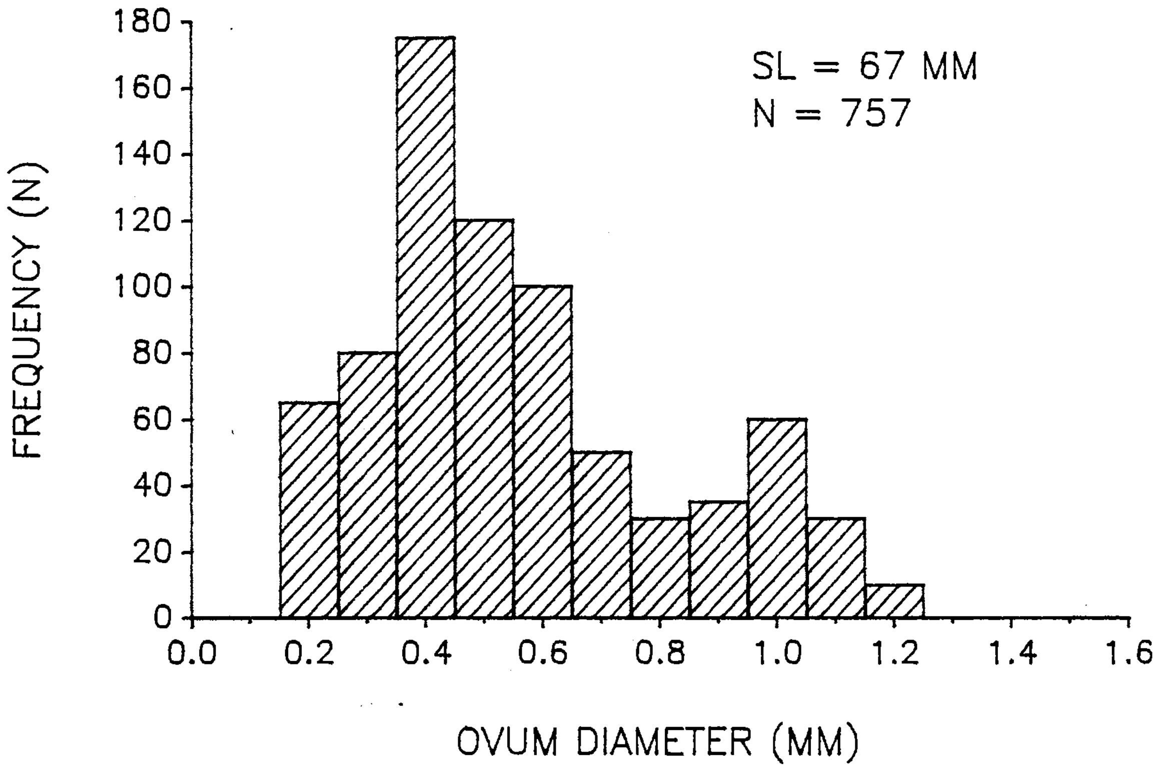

Figure 27. Frequency distribution of ova from a P. pantherina museum specimen collected on 13 April.

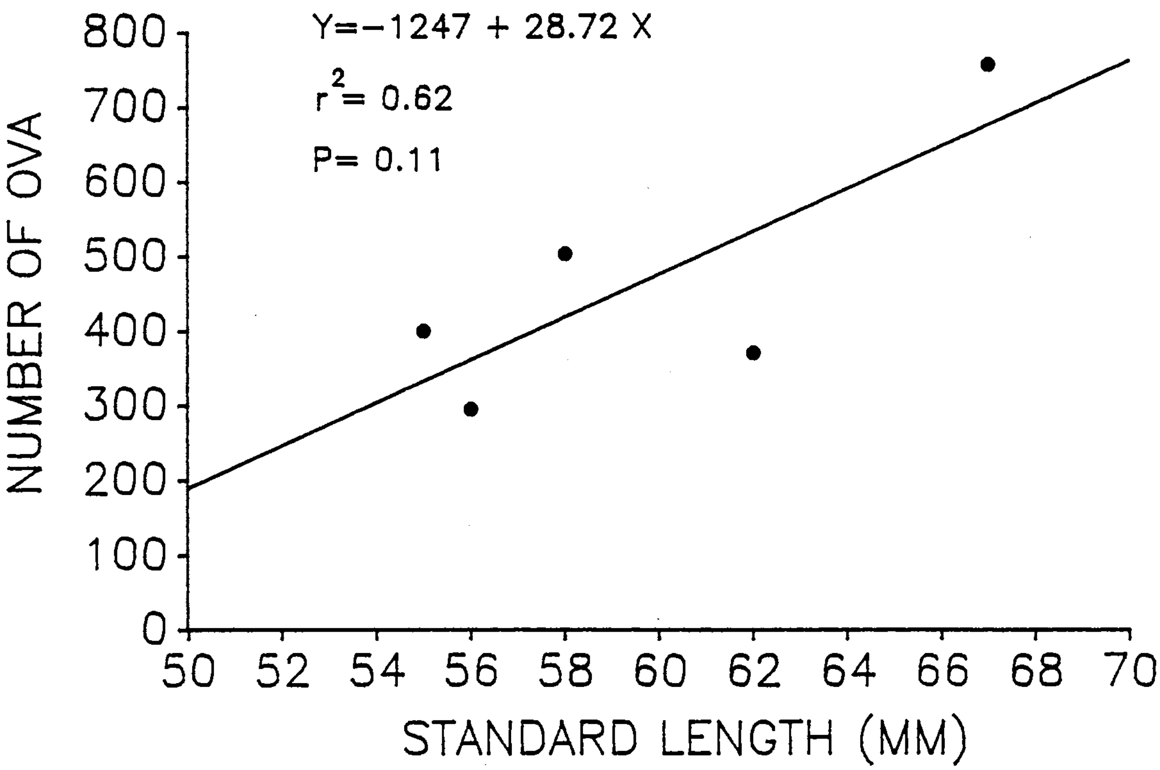

Figure 28. Relationship between P. *pantherina* standard length and total number of ova in five museum specimens.

Young-of-the-year P. pantherina were first captured in May and averaged 26 mm SL. By late July, adults were 75-85 mm SL and juveniles were 35-55 mm SL (Fig. 29-31 and Appendix B). No large adults (>80 mm SL) were found after the end of September and young-of-the-year attained adult size (55-70 mm SL) by September (Fig. 29-31 and Appendix B). During winter and spring months, adults ranged from 55 to 80 mm SL (Fig. 29-31 and Appendix B). Populations were dominated by young-of-the-year from September through the next spawning season in March. The sex ratio did not deviate significantly from a 1:1 ratio (276 males, 286 females, χ^2=0.178, P>0.25).

Monthly mean growth rates of juvenile P. pantherina approximated 10-15 mm SL from May through August (Fig. 32-34). Growth rates decreased to about 10 mm SL for the period September through April (Fig. 32-34).

P. pantherina individuals were occasionally found with parasitic copepods (Lernaea sp.) attached to the base of either their dorsal fins or their pectoral fins. Small leeches were occasionally attached to either the pectoral fins or the caudal fin. The leeches did not appear to cause any noticeable damage to their hosts; however, the copepods caused large wounds at attachment sites. Parasites were found on 30 individuals from 1986-1988. Except for two individuals captured in November, all parasitized individuals were captured during the summer.

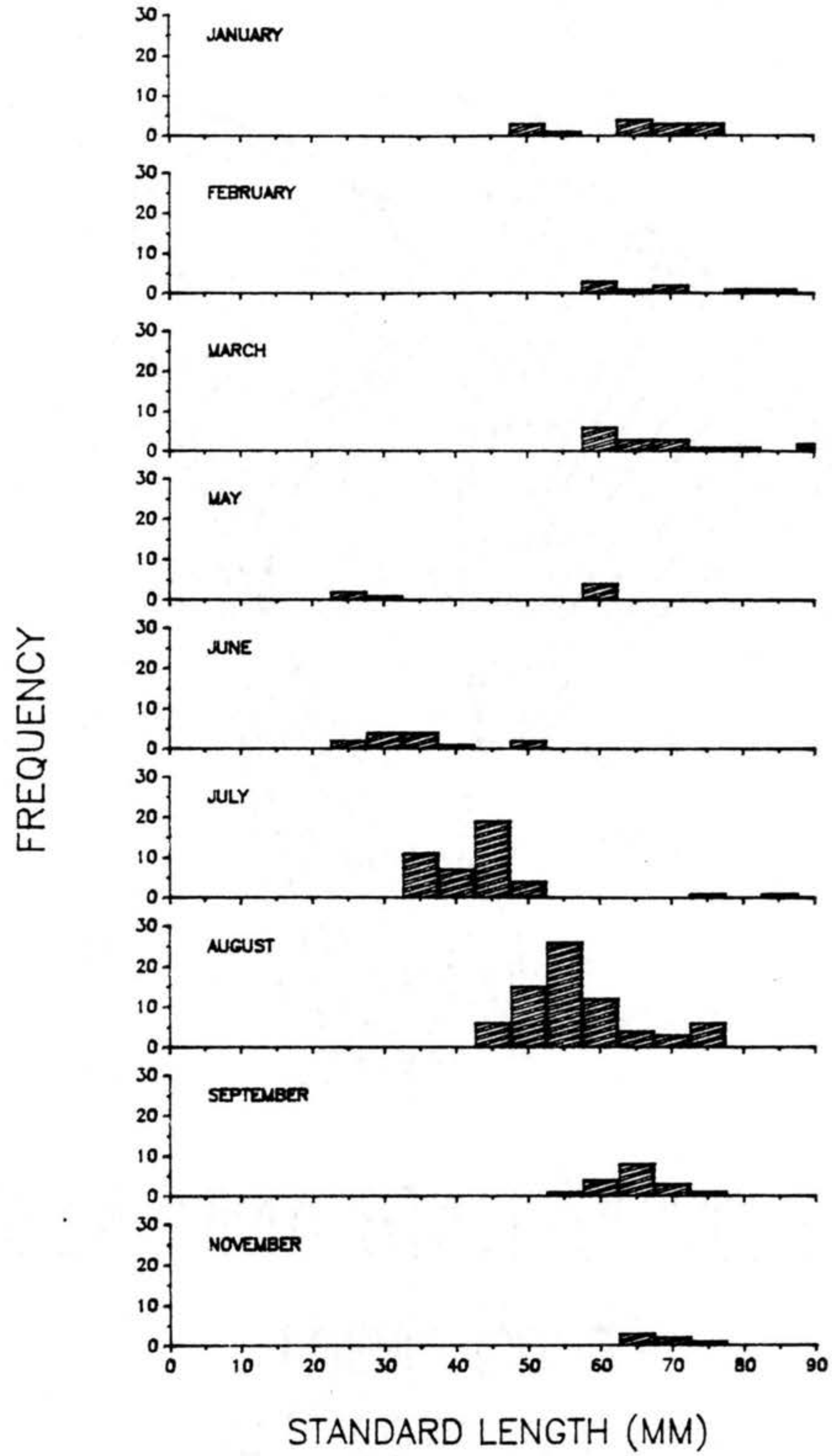

Figure 29. Monthly length-frequency distributions of _P. pantherina_ captured in Glover River during 1986.

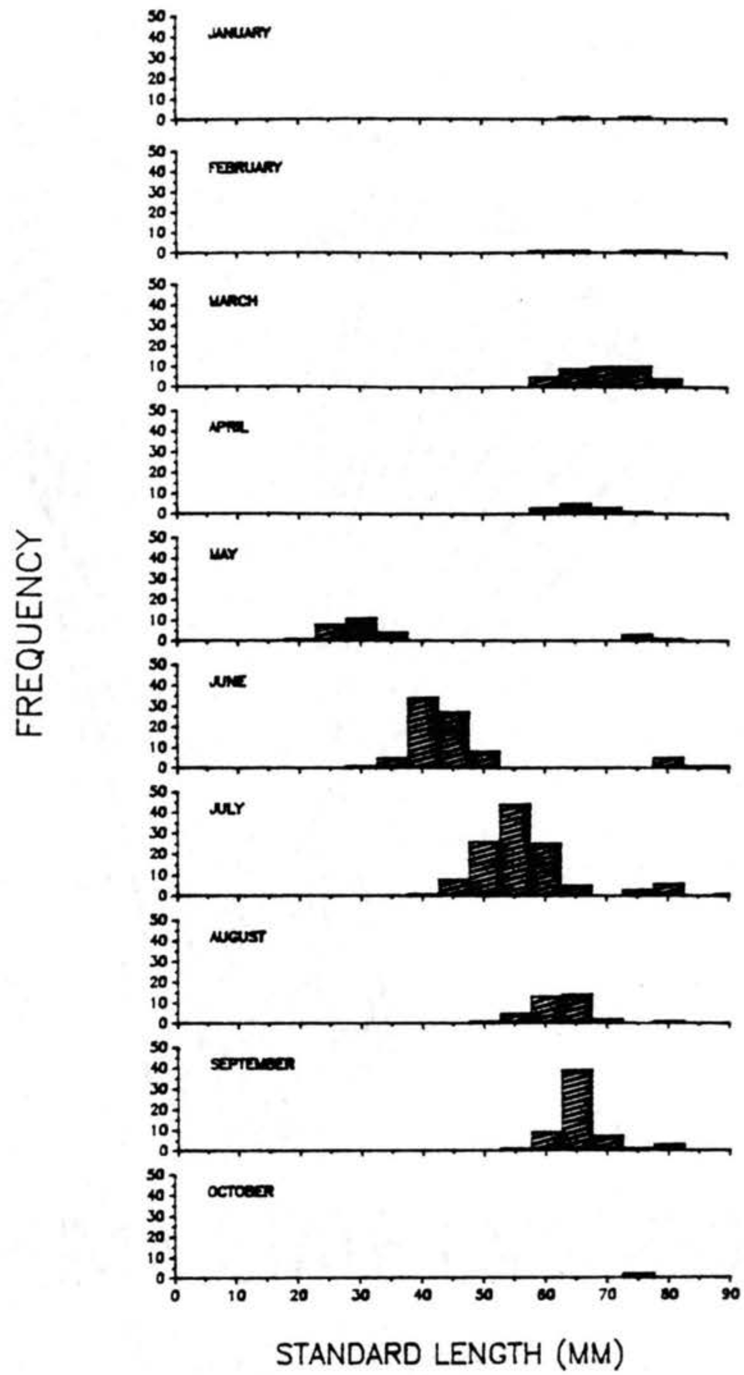

Figure 30. Monthly length-frequency distributions of P. pantherina captured in Glover River during 1987.

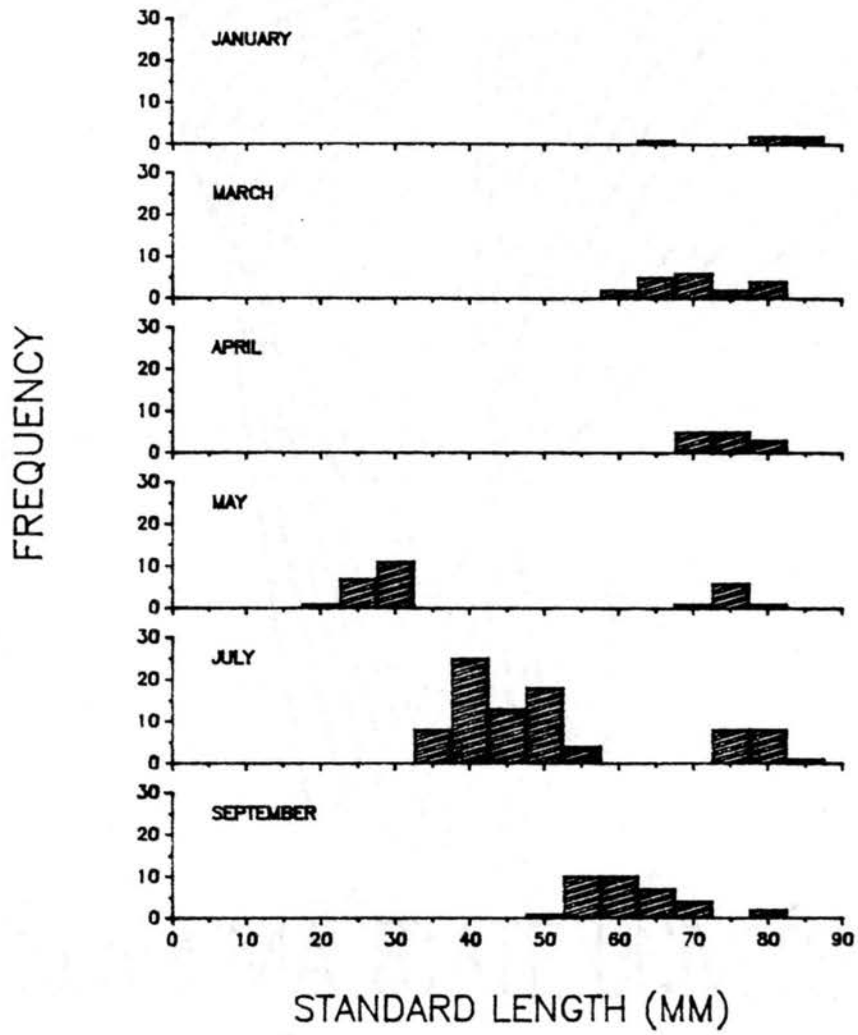

Figure 31. Monthly length-frequency distributions of P. pantherina captured in Glover River during 1988.

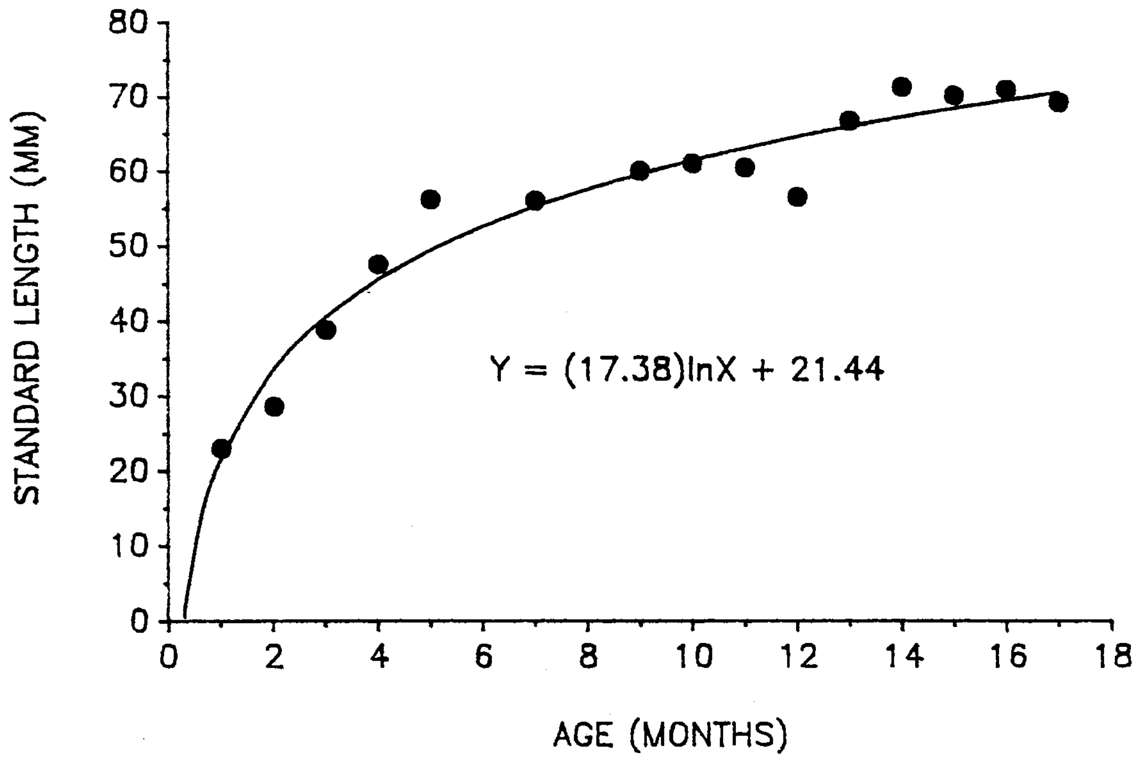

Figure 32. Growth curve of 1986 cohort of P. pantherina in Glover River.

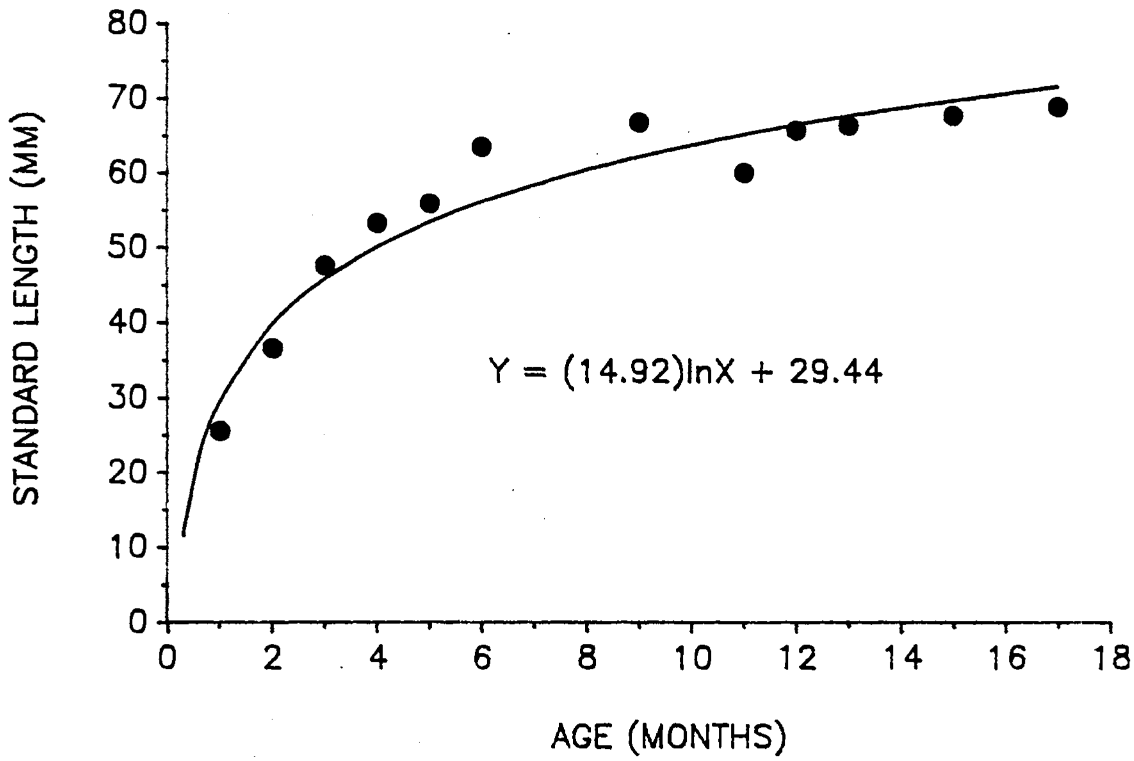

Figure 33. Growth curve of 1987 cohort of P. pantherina in Glover River.

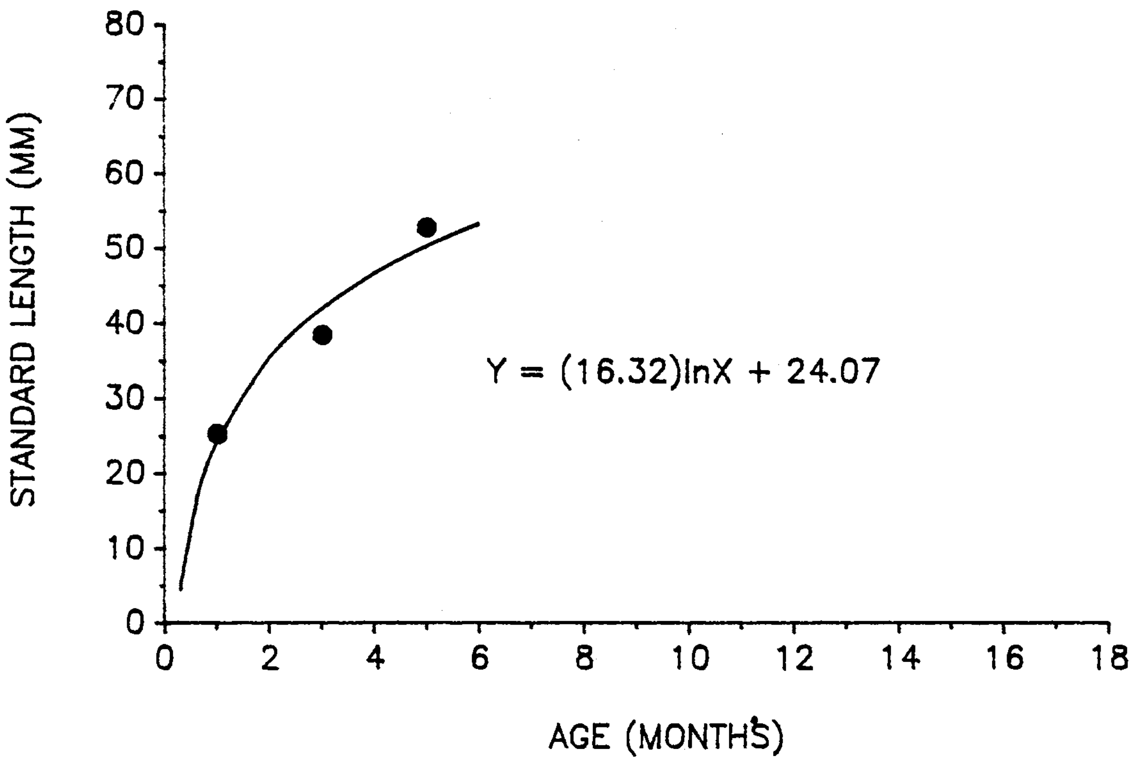

Figure 34. Growth curve of 1988 cohort of P. pantherina in Glover River.

The frequency of individuals having parasites averaged 28.55% (3-100%) at sites where at least one individual had parasites.

Food Habits

Mayfly nymphs (Ephemeroptera: Baetidae and Heptageniidae), blackfly larvae (Diptera: Simuliidae), and midge larvae (Diptera: Chiromonidae) were the only food items in stomachs of 19 *P. pantherina* examined (Table III). Blackfly larvae and mayfly nymphs were the major food items in 13 *P. pantherina* stomachs examined by Robison (1978).

Population Abundance

Population abundance estimates ranged from 1 individual at site 5 in September 1987 and 1988 to 90 individuals at site 1 in June 1987. Mortality rates at the study sites from July to September averaged 60.5% (23.4-85.7%) in 1987 and 58.3% (35.7-77.7%) in 1988. The highest mortality rates were found at site 6 (85.7% in 1987 and 77.7% in 1988), a headwater site on the East Fork. Population abundances at all sites throughout summer months were lower in 1988 than in 1987 (Fig. 35-40). Stream discharges during the spawning season from mid-March through early April were relatively stable in 1987, whereas in 1988 the same time interval was marked by three periods

TABLE III

FREQUENCY (%) AND MEAN NUMBER OF FOOD ITEMS IN STOMACHS OF 19 *PERCINA PANTHERINA* MUSEUM SPECIMENS

Taxon	Frequency	Mean	Range
Ephemeroptera			
Heptageniidae	47.4%	2.0	1-6
Baetidae	52.6%	15.5	1-51
Diptera			
Simuliidae	5.3%	17.0	17
Chironomidae	26.3%	1.6	1-3

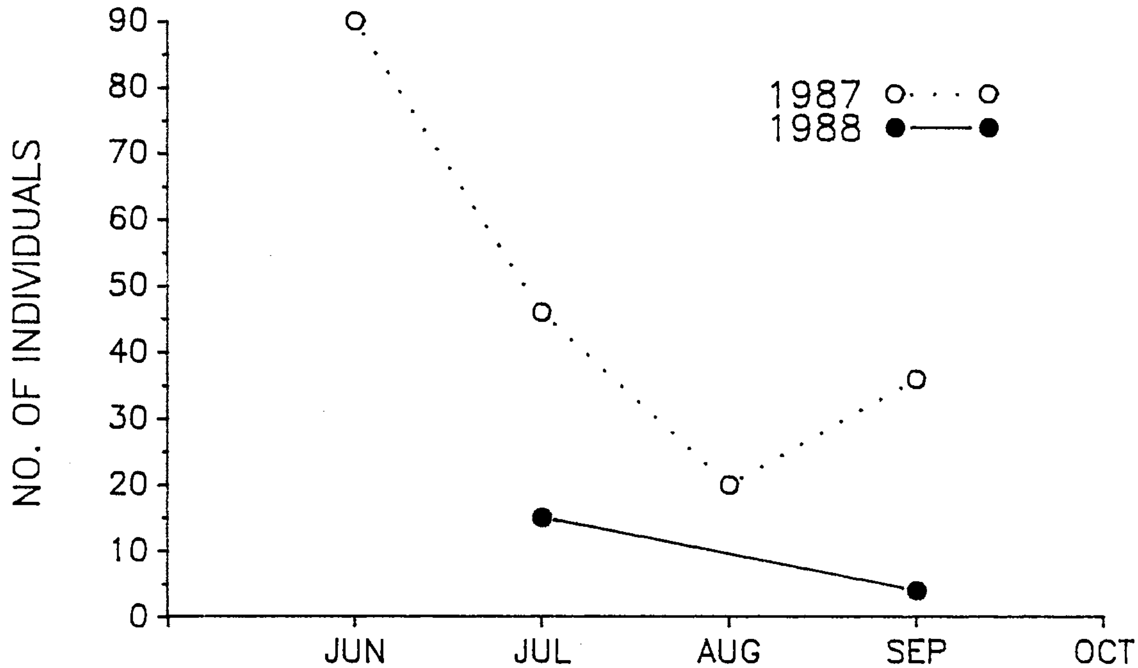

Figure 35. Population abundance of P. pantherina at site 1 during 1987-1988.

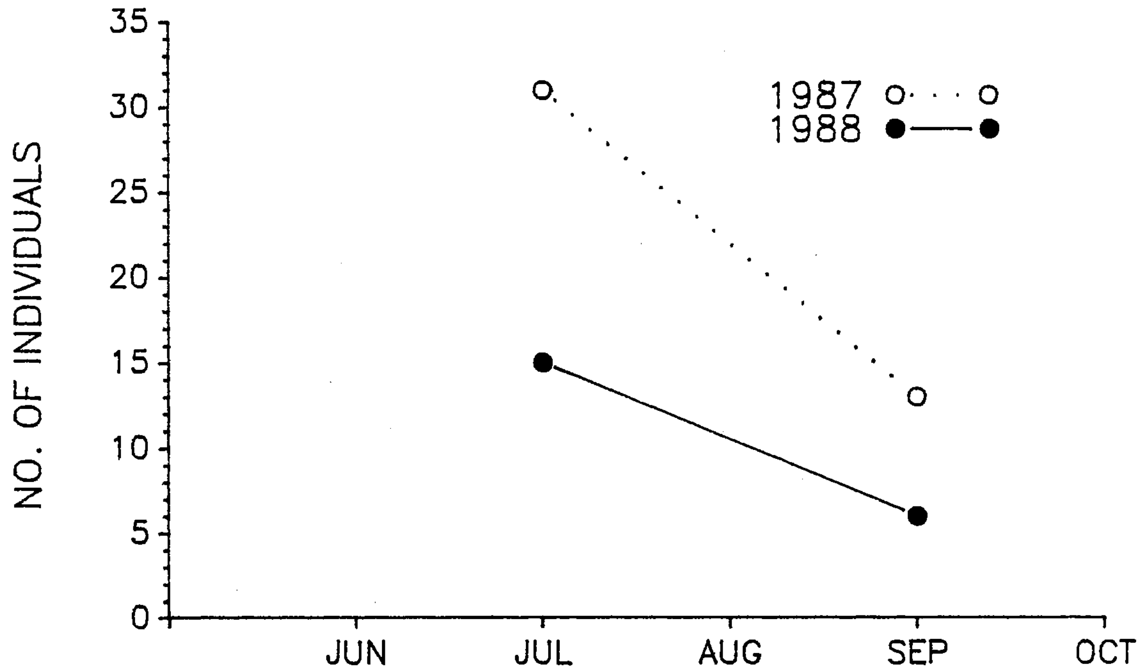

Figure 36. Population abundance of P. pantherina at site 2 during 1987-1988.

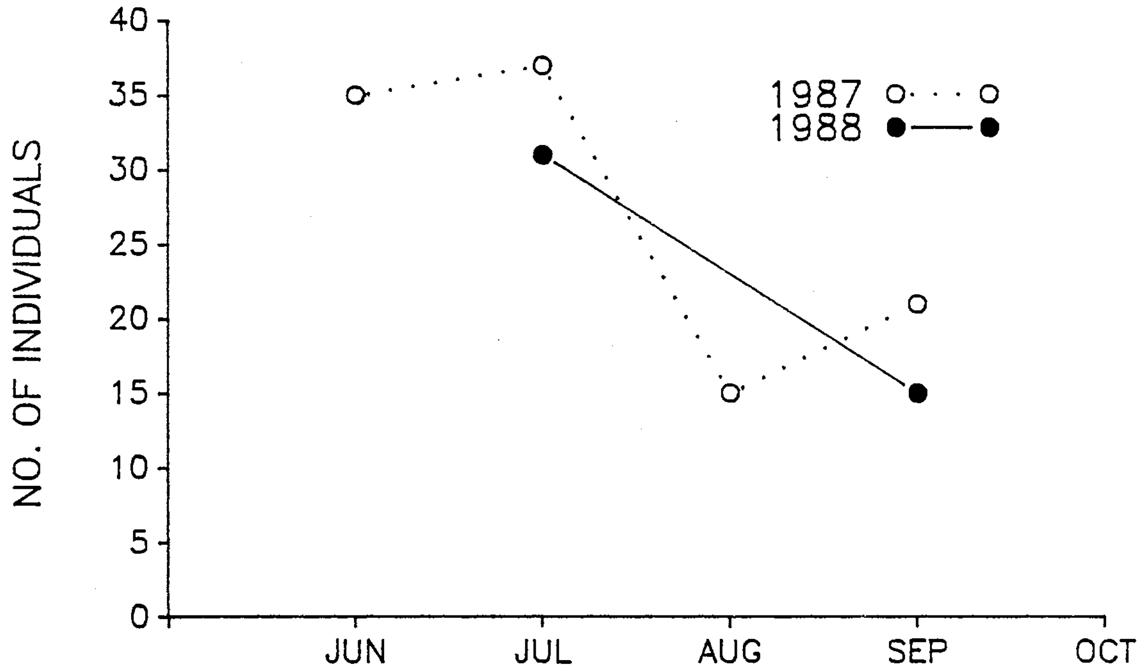

Figure 37. Population abundance of P. pantherina at site 3 during 1987-1988.

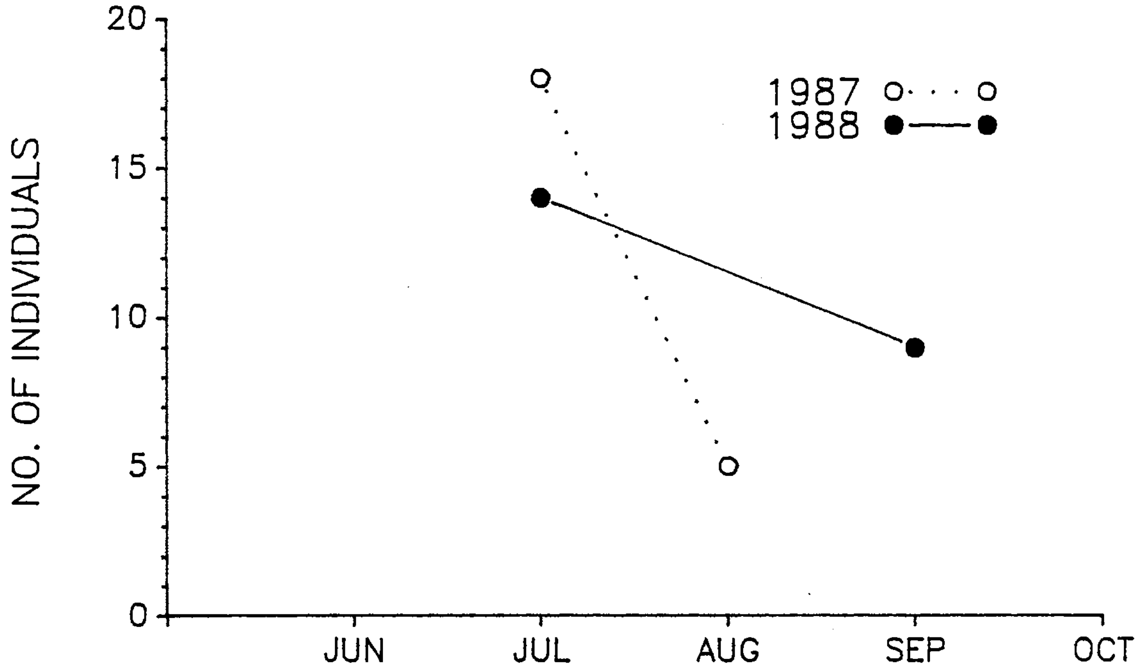

Figure 38. Population abundance of P. pantherina at site 4 during 1987-1988.

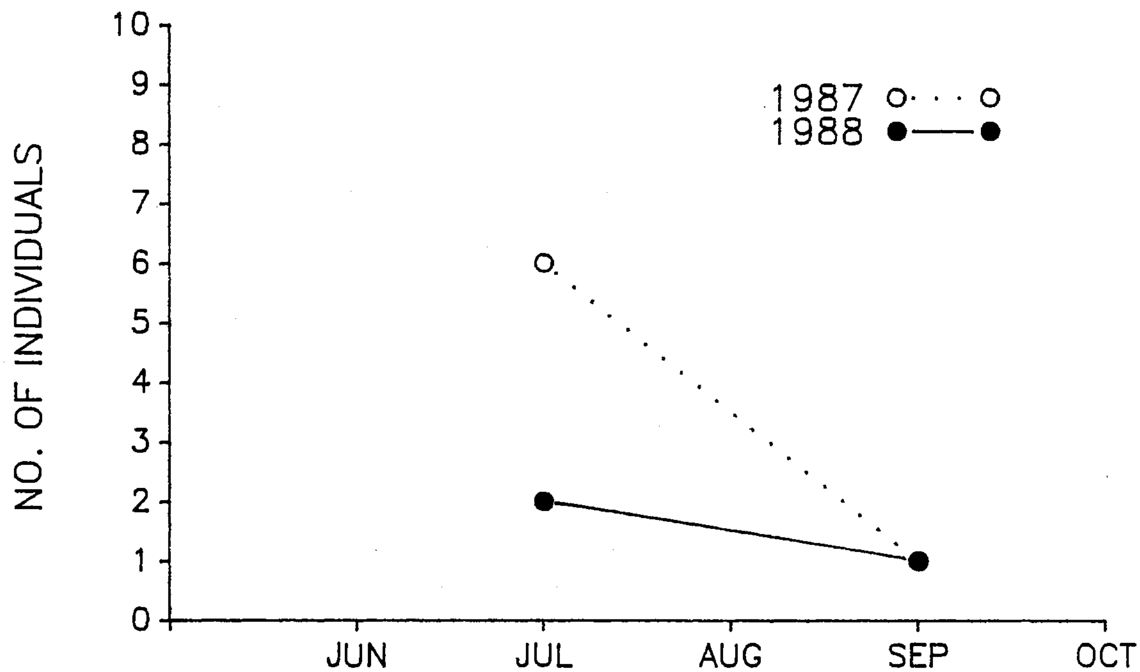

Figure 39. Population abundance of P. pantherina at site 5 during 1987-1988.

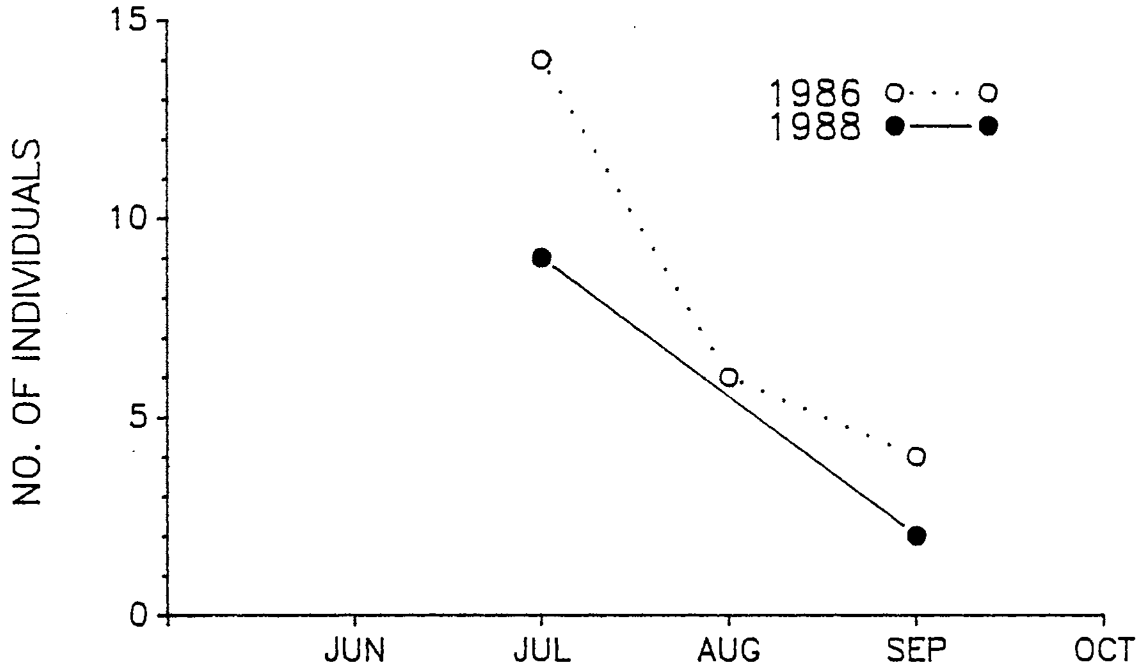

Figure 40. Population abundance of P. pantherina at site 6 during 1986 and 1988.

of high flow (Fig. 19). Flooding events following spawning can destroy eggs and larvae and have caused complete year-class failures in salmonids (Elwood and Waters 1969; Seegrist and Gard 1972). Reduced recruitment in 1988 may have been the result of high flows that may have interrupted spawning or destroyed eggs and larvae.

Discussion

Both juvenile and adult P. pantherina were exclusively pool-dwellers except during the spawning season. My observations corroborate the findings of Jones et al. (1984). The earlier descriptions of the habitat of P. pantherina as being moderately-swift, gravel-bottomed riffles were probably due to a disproportionate amount of sampling in these areas during spring months. Kuehne and Barbour (1983) stated that the distributions of P. maculata and P. pantherina are probably allopatric; however, the supplemental study site in lower Glover River (R23E T5S Sec. 9) represents an area of sympatry. Further studies are needed to determine if hybridization occurs between these closely related species in this area.

Young-of-the-year P. pantherina as small as 16 mm SL were found in the same areas of pools as adults. No larval P. pantherina were collected during this study and their specific habitat preferences are not known. However, if newly-hatched larvae in the stream exhibit the same swimming-up behavior observed in the laboratory rearing bowls, they could easily drift downstream into pools and complete their early life history.

P. pantherina selected specific spawning habitat and did not use all available riffles for spawning. The observation of higher numbers of individuals on a riffle than were believed to inhabit adjacent pools suggests that P. pantherina migrated to specific riffles for spawning. Prespawning migrations from pools to riffles occur in several darter species (Trautman 1957; Stevenson 1971; Pflieger 1981; Page 1983) and are usually followed by a postspawning migration back into pools. Spawning in P. pantherina occurred on riffles from mid-March through mid-April at water temperatures of about 12-20 ^{o}C. Initiation of spawning at different temperatures on about the same date in the two years may indicate that day length was more important than water temperature in inducing spawning. Spawning ended in mid-April when water temperature was about 21 ^{o}C. Hubbs (1985) found water temperature to be an important factor in determining the termination of spawning in darters. The size of the eggs of P. pantherina and their incubation time are both within ranges reported for other egg-burying darters (Page 1983).

Length-frequency distributions (Fig. 29-31) suggest that P. pantherina had a maximum longevity of about 18 months. Although no Age-I darters were captured after

September, it is possible that a few individuals survived to reproduce a second time at Age-II. However, all spawning individuals appeared to be Age-I darters. Mortality rates of Age-I darters following spawning appear to be high, but rapid growth of Age-0 darters allows achievement of adult size in about 5-6 months. The growth rates for P. pantherina (Fig. 32-34) are higher than those that have been reported for any other darter species (Page 1983).

The mortality rate of P. pantherina from July to September was about 59% in both 1987 and 1988. Mortality rates of each life history stage was not estimated, but at least some egg mortality was due to predation by channel darters. Predation on juvenile and adult darters was not observed. Parasitism by copepods caused relatively large wounds on P. pantherina and although they are common parasites of darters (Page 1983), the mortality rate directly or indirectly attributable to parasites could not be determined.

P. pantherina is a member of a relatively primitive group of darters (Page 1981) but appears to exhibit some life history traits that are characteristic of more advanced darter species (Page 1985). The egg-burying behavior observed in P. pantherina is considered to be the most primitive form of spawning in darters and all species of Percina for which spawning data is available exhibit this type of spawning behavior (Page 1985). However, the behavior of "sneaker males" spawning adjacent to spawning pairs is unusual and has been observed only in E. caeruleum (rainbow darter) (Reeves 1907) and P. peltata (shield darter) (New 1966). Page (1985) stated that the most advanced darters such as E. microperca (least darter), E. proeliare (cypress darter), and E. striatulum (striated darter) have small body size, mature at one year, reproduce, and die before a second spawning season. P. pantherina appears to be unique among primitive darters because they are relatively large darters with a short longevity, have extremely rapid growth to maturity, spawn at one year of age, and apparently die before reaching a second year of age.

The life history of P. pantherina is characterized by rapid growth to maturity, short longevity, and high mortality of postspawning and young-of-the-year individuals. In addition, populations of P. pantherina are apparently dependent on successful annual recruitment for maintenance. These characteristics, as well as stochastic environmental effects, cause population abundances to fluctuate drastically from year to year. Any management plans designed to protect populations of P. pantherina should include plans to identify and protect important spawning riffles and rearing pools to ensure successful annual recruitment.

CHAPTER V

HABITAT ANALYSIS OF *PERCINA PANTHERINA*

Introduction

One of the initial observations made in this study was that *P. pantherina* were usually restricted to specific pool areas. The physical characteristics of these areas did not change from August 1985 through September 1988. Therefore, individual *P. pantherina* were commonly found inhabiting the same areas throughout the duration of the study. An attempt was made to quantitatively describe these preferred areas in order to allow testable predictions concerning *P. pantherina* habitat requirements. Seasonal changes in habitat preference and specific habitat preferences of males, females, adults, and juveniles were investigated.

Another initial observation was that *P. pantherina* were restricted to certain pools. Although many other pools had a similar appearance, closer inspection revealed that they differed in water depth, substrate, and current velocity characteristics. An attempt was made to determine the specific characteristics of the pools selected for occupation by *P. pantherina*. An estimate of the minimum amount of suitable habitat required to support a viable population was also made.

In the pools where P. pantherina occurred, population abundances varied greatly. This observation led me to investigate the relationships between P. pantherina population abundance and habitat availability.

Finally, P. pantherina spawned on only certain riffles. In order to understand this affinity for certain riffles, an investigation into the specific habitat requirements for spawning was made.

The working hypotheses for the analyses in this chapter are:

1) No differences in habitat preference exist among seasons, males and females, or adults and juveniles.

2) P. pantherina inhabit all pools within the Little River drainage.

3) P. pantherina spawn on all available riffles within the Little River drainage.

Materials and Methods

Habitat Preference

Habitat preference was determined from depth, substrate, and current velocity measurements made at capture locations at each site. Habitat availability was determined at each site by measuring water depth, substrate, and current velocity at 1-m intervals along three to five habitat transects spaced 15-m apart and perpendicular to stream flow. Frequency distributions of depth, substrate, and current velocity values from capture locations and from transect points at each site were compared by Kolomorogov-Smirnov two sample tests (Sokal and Rohlf 1981). This comparison allowed me to determine if P. pantherina occupied areas of depth, substrate, and current velocity in proportion to their availability. In addition, analysis of variance tests were used to determine if P. pantherina occupied similar depths at all six study sites. Nonparametric Kruskal-Wallis tests were used to analyze substrate and current velocity data for the same relationship. Analysis of variance was not used because the substrate and current velocity data did not conform to the test's assumptions (Sokal and Rohlf 1981). The point transect measurements were used in analysis of variance and Kruskal-Wallis tests to determine if habitat availability differed between sites.

Water depth preferences among males and females and among adults and juveniles were analyzed with t-tests (Sokal and Rohlf 1981). Substrate and current velocity preferences were analyzed with Wilcoxon Rank Sums tests (Sokal and Rohlf 1981).

Seasonal differences in the water depth, substrate type, and current velocity at capture locations were analyzed by grouping the pooled data from all six sites into a winter (December-February), spring (March-May), summer (June-August), or fall (September-November) group. Duncan's test (Sokal and Rohlf 1981) was used with the analysis of variance to determine seasonal differences in water depth preference. Dunn's procedure (Hollander and Wolfe 1973) was used with the Kruskal-Wallis tests to determine seasonal differences in substrate and current velocity preference.

Analysis of *Percina pantherina* Occurrence

Summer 1986 habitat data from the six Glover River study sites and from 34 potential *P. pantherina* habitat sites (Eley et al. 1975) in the Saline, Cossatot, and Rolling Fork rivers in Arkansas (Leon et al. 1987) were used in this analysis. Habitat characteristics at each site were determined by measuring water depth, substrate type, and current velocity at 1-m intervals along three transects spaced 15-m apart. The point measurements were intended to represent average values of depth, substrate, and current velocity for a segment 1-m wide extending 7.5 m upstream and downstream from the transect for a total segment area of 15 m^2 (Fig. 41). Five transects were originally established at Glover sites 1 and 4, but data from the lowermost and uppermost transects were deleted for this analysis in order to standardize the area sampled at each site. The following variables were used to characterize the habitat at each site:

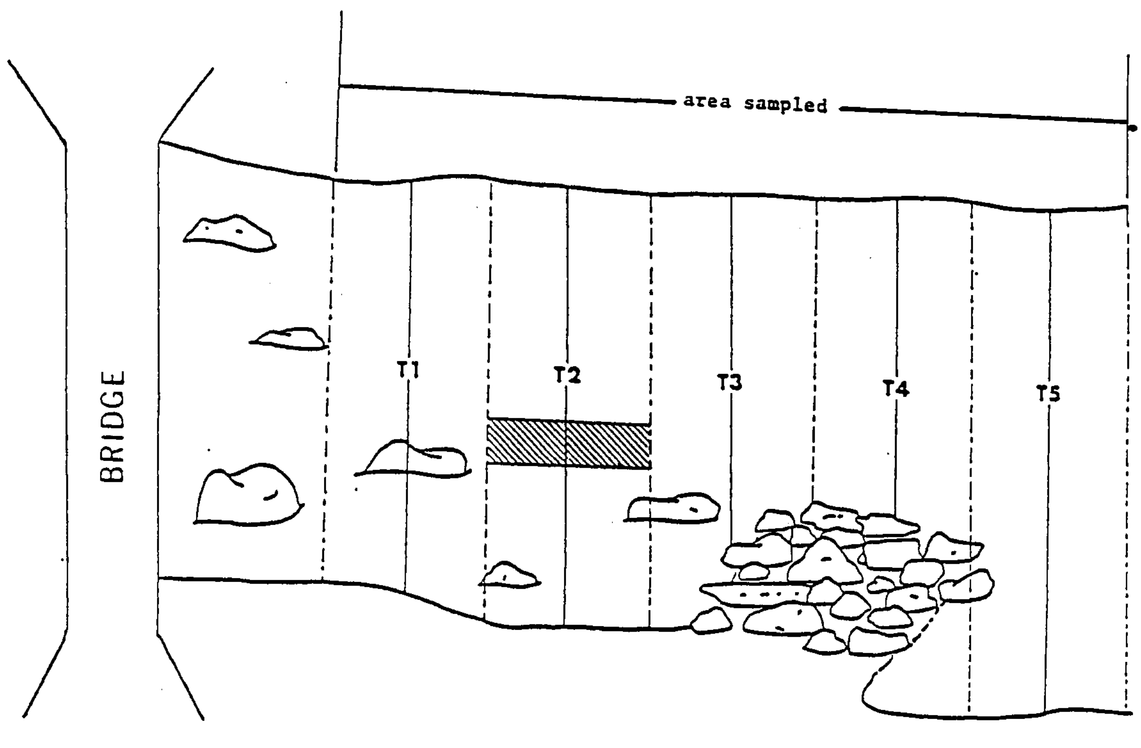

Figure 41. Diagram of a typical study site showing habitat transects (T1-T5), example of an area represented by a point measurement (shaded), and total area sampled.

MD = mean depth (cm)

SD = standard deviation of depth

MS = mean substrate value

SS = standard deviation of substrate value

MC = mean current velocity (cm/s)

SC = standard deviation of current velocity

EL = elevation above mean sea level (m)

GR = stream gradient (m/km)

SW = maximum stream width (m)

PH = amount of preferred habitat (m^2)

Values of PH were calculated by summing all 15 m^2 segments that had a water depth of 25-75 cm, a substrate of rubble or boulder, and no detectable current velocity. These values were considered to be within the preferred range of *P. pantherina* habitat as determined from frequency distributions of water depth, substrate, and current velocity at capture locations (Figs. 7-18). Various combinations of variable ranges were initially used to calculate PH values. However, the value ranges of water depth, substrate, and current velocity listed above appeared to be the most accurate measure of PH.

Habitat data from the 40 sites (Table IV) were used in an exploratory multivariate cluster analysis. This analysis was used to identify similarities among sites where *P. pantherina* was found. The method of clustering used in this analysis was the centroid method (Pielou

1984). A high degree of similarity among sites would indicate that they had similar physical characteristics.

The 40 sites were divided into two groups based on presence or absence of P. pantherina and used in a stepwise discriminant function analysis to determine which variables were most important in distinguishing between presence and absence. This analysis results in an equation that identifies the combination of variables that best separate the two groups. This equation may then be used to classify future observations (Johnson and Wichern 1982). The resulting discriminant function was used predictively to classify 29 sites in Mountain Fork, Glover, and Little rivers (Lechner et al. 1987) that were not used in the original analysis. The major assumption in this analysis is that P. pantherina occurrence at any site is determined by the physical habitat.

Analysis of Percina pantherina Spawning Habitat

Fifteen riffles in the Mountain Fork, Glover, and Little rivers were sampled during the spawning season for the presence or absence of spawning individuals. Habitat characteristics of riffles were quantified using procedures described above for the presence/absence analysis. The three transects across riffles in this analysis were only 5-m apart. All riffles were within areas that supported P. pantherina populations. The variables MD, SD, MS, SS, MC,

TABLE IV

HABITAT DATA FROM POOLS IN LITTLE RIVER DRAINAGE, JUNE-SEPTEMBER 1986. (SA=SALINE, CO=COSSATOT, RL=ROLLING FORK, RB=ROBINSON FORK, GL=GLOVER)

SITE	MD	MC	MS	SD	SC	SS	EL	GR	SW	PH
SA1	58.06	0.89	4.88	15.64	1.05	0.78	253	5.97	9	0
SA2	23.71	5.76	6.76	19.40	5.91	1.20	241	3.13	10	0
SA3	33.06	4.25	5.50	18.04	4.71	0.76	232	3.13	10	15
SA4	50.92	10.56	5.86	25.68	7.42	1.27	218	4.27	34	30
SA5	52.50	10.40	5.80	27.03	7.88	0.63	210	4.27	14	0
SA6	43.21	8.47	5.56	25.85	6.02	0.56	180	2.67	17	15
SA7	37.15	0.53	5.43	19.47	1.50	0.76	176	5.71	14	165
SA8	64.75	4.76	5.87	29.07	5.32	1.12	123	2.34	30	75
SA9	62.18	4.98	5.39	31.89	8.39	1.08	109	1.85	32	45
CO3	34.82	9.76	5.88	23.58	27.71	1.03	261	3.40	26	75
CO4	43.17	5.00	5.81	27.96	13.34	0.82	238	4.04	23	150
CO5	59.15	9.58	6.31	35.74	15.07	1.50	215	6.31	25	60
CO6	73.49	2.63	7.24	43.51	8.46	1.01	195	6.89	22	45
CO7	63.04	0.21	6.75	43.24	0.81	1.15	175	3.84	39	510
CO8	74.30	1.41	5.93	26.53	2.40	1.04	168	1.79	31	225
CO9	63.60	1.41	7.03	40.35	3.48	1.15	159	1.79	43	270
CO10	62.98	4.49	6.30	27.27	5.77	1.28	131	1.22	33	105
CO11	45.87	7.70	5.79	27.08	8.66	1.17	128	1.70	34	165
CO12	43.73	7.46	5.44	17.24	9.18	0.59	119	0.96	34	120
CO13	53.60	5.73	5.65	16.64	6.63	0.77	113	1.16	24	90
CO14	61.14	5.86	5.07	37.54	10.58	0.92	93	0.72	31	210
CO15	36.79	6.12	4.73	25.82	5.29	0.66	88	0.35	36	15
CO16	70.54	6.91	4.79	55.87	13.73	0.81	85	0.35	44	75
RB3	59.11	0.00	6.33	26.77	0.00	1.29	250	6.73	20	225
RB4	39.04	1.10	6.19	25.13	4.37	1.08	236	4.44	17	255
RB5	35.29	0.33	6.08	25.26	1.27	1.10	245	5.55	11	60
RB6	61.22	0.00	6.55	27.92	0.00	1.25	198	4.94	46	630
RB7	59.01	0.48	6.68	25.30	1.25	1.11	161	3.13	27	255
RL1	80.11	0.00	5.97	32.65	0.00	1.12	152	4.12	26	150
RL2	24.08	0.38	6.75	17.73	1.07	1.24	275	4.55	11	30
RL3	44.49	0.00	5.45	35.16	0.00	0.95	252	12.12	24	225
RL4	35.72	0.00	5.84	16.25	0.00	0.95	218	3.96	17	330
RL5	28.63	1.83	6.21	13.92	2.76	0.66	207	4.35	12	105
RL6	42.31	0.40	6.20	21.86	1.63	1.06	153	6.56	19	375
GL1	56.69	3.02	6.38	26.66	7.16	0.93	163	1.96	48	975
GL2	59.18	0.02	6.20	24.98	0.27	0.88	186	2.05	58	915

TABLE IV (Continued)

SITE	MD	MC	MS	SD	SC	SS	EL	GR	SW	PH
GL3	51.68	0.00	6.21	27.90	0.00	1.33	187	2.05	46	1275
GL4	42.01	3.41	6.07	17.76	6.87	0.83	213	2.12	32	915
GL5	49.09	0.64	6.30	16.10	3.27	1.21	235	2.42	31	300
GL6	48.90	1.40	6.03	23.04	3.61	1.20	201	1.26	26	270

and SC were used to characterize each riffle (Table V). Riffles were grouped according to the presence or absence of spawning individuals and a discriminant function analysis was used to determine which variables were most important in distinguishing riffles that were used for spawning from those that were not.

Percina pantherina Population Abundance and Habitat Relationships

The amount of preferred habitat (PH) and population abundance at each study site were used in a linear regression analysis (Sokal and Rohlf 1981) to determine the relationship between preferred habitat area and the abundance of P. pantherina. One assumption of this analysis is that preferred habitat is defined by water depth, substrate type, and current velocity. Another assumption is that P. pantherina population abundance at any site is limited by the amount of preferred habitat available.

The method of measuring the preferred habitat area (m^2) is described in the preceding section. Measurements of preferred habitat area were made during periods of normal flow based on discharge data from a U. S. Geological Survey gauge on Glover River (U. S. Geological Survey 1986). Population abundance estimates were also made during periods of normal flow to alleviate flow-related

TABLE V

HABITAT DATA FROM RIFFLES IN THE LITTLE RIVER DRAINAGE, MARCH-APRIL 1987 (GL=GLOVER RIVER, MF=MOUNTAIN FORK RIVER, LT=LITTLE RIVER).

SITE	MD	MS	MC	SD	SS	SC
GL5	37.08	5.67	0.13	20.55	0.76	0.17
GL6	49.56	5.76	0.21	16.06	0.59	0.20
GL7	31.47	4.63	0.35	15.12	0.59	0.25
GL8	30.54	5.51	0.48	11.71	0.64	0.23
GL9	28.69	6.09	0.25	9.70	2.02	0.24
GL10	23.69	7.13	0.34	12.81	1.04	0.22
LT1	15.56	5.84	0.28	7.42	1.07	0.19
LT2	15.00	6.36	0.17	10.67	0.64	0.15
LT3	23.65	6.26	0.45	11.44	0.75	0.27
GL11	31.90	6.40	0.23	13.62	0.84	0.17
GL12	31.41	5.51	0.28	18.40	0.73	0.19
GL13	25.35	5.87	0.57	11.03	0.55	0.33
MF1	23.00	6.68	0.43	15.17	0.89	0.32
MF2	29.89	6.50	0.35	19.10	0.79	0.27
MF3	26.65	6.82	0.39	15.91	1.24	0.38

biases. Only the population abundance estimates made in August 1986, July 1987, July 1988, and September 1988 were used in this analysis. These estimates were made at each site under similar stream conditions over a two or three day period.

Results

Habitat Preference

Individuals were found at significantly greater depths (ANOVA F=16.6, P<0.001) in winter and spring than in summer and fall (Fig. 7-10, Table VI, and Appendix A). Substrate types at capture locations also differed significantly among seasons (Kruskal-Wallis H=24.5, P<0.001), with rubble/boulder preferred during summer and winter and gravel/rubble preferred during spring and fall (Fig. 11-14, Table VII, and Appendix A). There was also a significant difference in seasonal current velocities used (Kruskal-Wallis H=51.5, P<0.001), with increased use of areas with detectable current velocity during winter and spring (Fig. 15-18, Table VIII, and Appendix A).

Young-of-the-year P. pantherina as small as 18 mm SL inhabited the same pool areas as adults; no significant differences existed between depths (t=0.45, P>0.66), substrates (Wilcoxon Z=0.65, P>0.50) or current velocities (Wilcoxon Z=1.01, P>0.31) inhabited by juveniles and adults. No significant differences existed between depths

TABLE VI

DUNCAN'S MULTIPLE RANGE COMPARISONS OF *PERCINA PANTHERINA* MEAN DEPTH AT CAPTURE LOCATIONS BY SEASON

Season	Mean Depth	Comparison*
Winter	69.44	A
Spring	56.24	B
Summer	49.38	C
Fall	44.97	C

* Seasons with the same letters are not significantly different at the 0.05 level.

TABLE VII

MULTIPLE COMPARISONS OF *PERCINA PANTHERINA* SEASONAL SUBSTRATE USE BASED ON MEAN RANK SUM SCORES (WI=WINTER, SP=SPRING, SU=SUMMER, FA=FALL)

Comparison	Result	Probability
WI vs. SP	unequal	<0.10
WI vs. SU	equal	n.s.*
WI vs. FA	equal	n.s.
SP vs. SU	unequal	<0.10
SP vs. FA	equal	n.s.
SU vs. FA	unequal	<0.10

* n.s. = no significant difference

($t=0.92$, $P>0.36$), substrates (Wilcoxon $Z=0.63$, $P>0.50$), or current velocities (Wilcoxon $Z=0.73$, $P>0.40$) occupied by males and females.

The distribution of depths occupied by _P. pantherina_ differed significantly from the distribution of depths available at each site (Table IX and Appendix C). However, the distributions of substrate and current velocity used did not differ from substrate and current velocity availability at each site (Table IX and Appendix C).

No significant differences existed in mean water depth, mean substrate value, or mean current velocity at _P. pantherina_ capture locations between the six study sites (Table X). However, there were significant differences in availability of mean water depth, mean substrate value, and mean current velocity at the six sites (Table X).

Analysis of _Percina pantherina_ Occurrence

The cluster analysis grouped seven (high density occurrence) of the ten sites where _P. pantherina_ occurred. this group was distinctly different from the clusters of sites where they did not occur (Fig. 42). The remaining three sites where _P. pantherina_ occurred were sites where very few individuals (<5) were found.

The stepwise discriminant function analysis selected the variable PH (m^2 of preferred habitat), as the most important variable distinguishing sites with and without _P._

TABLE VIII

MULTIPLE COMPARISONS OF *PERCINA PANTHERINA* SEASONAL CURRENT VELOCITY USE BASED ON MEAN RANK SUM SCORES (WI=WINTER, SP=SPRING, SU=SUMMER, FA=FALL)

Comparison	Result	Probability
WI vs. SP	equal	n.s.*
WI vs. SU	unequal	<0.10
WI vs. FA	unequal	<0.10
SP vs. SU	unequal	<0.10
SP vs. FA	unequal	<0.10
SU vs. FA	equal	n.s.

* n.s. = no significant difference

TABLE IX

RESULTS OF KOLMOGOROV-SMIRNOV TESTS BETWEEN DISTRIBUTIONS OF DEPTH, SUBSTRATE, AND CURRENT VELOCITY AVAILABILITY AND ACTUAL USE BY *PERCINA PANTHERINA*

Site	Variable	D	P
1	DEPTH	0.3204	<0.01
	SUBSTRATE	0.0873	n.s.*
	CURRENT	0.0274	n.s.
2	DEPTH	0.3695	<0.01
	SUBSTRATE	0.1317	n.s.
	CURRENT	0.0000	n.s.
3	DEPTH	0.2519	<0.05
	SUBSTRATE	0.1481	n.s.
	CURRENT	0.0667	n.s.
4	DEPTH	0.3985	<0.01
	SUBSTRATE	0.1242	n.s.
	CURRENT	0.0564	n.s.
5	DEPTH	0.5692	<0.01
	SUBSTRATE	0.3205	n.s.
	CURRENT	0.0000	n.s.

TABLE IX (Continued)

Site	Variable	D	P
6	DEPTH	0.6600	<0.01
	SUBSTRATE	0.2150	n.s.
	CURRENT	0.1200	n.s.

* n.s. = no significant difference

TABLE X

RESULTS OF ANALYSIS OF VARIANCE (F) AND KRUSKAL-WALLIS (H) TESTS OF PERCINA PANTHERINA HABITAT PREFERENCE AMONG THE SIX STUDY SITES AND HABITAT AVAILABILITY AMONG THE SIX STUDY SITES

Variable	F	H	P
Habitat Preference			
Depth	0.88		>0.5
Substrate		8.49	>0.1
Current Velocity		10.43	>0.05
Habitat Availability			
Depth	23.81		<0.001
Substrate		16.06	<0.01
Current Velocity		42.59	<0.001

pantherina. The analysis resulted in a canonical correlation of 0.746. The calculated canonical variable values for the two groups using the formula:

Canonical Variable = 1.2035 - (0.0049 x PH)

were -1.89 for sites with P. pantherina and 0.63 for sites without P. pantherina. The above formula correctly assigned 36 of the 40 sites (90%) in the test data set to their proper group (Fig. 43). The canonical midpoint value between the two groups -0.00000125, was used as a critical value to classify new observations between the two groups. Sites with a calculated canonical value less than -0.00000125 were predicted to have P. pantherina present and those with values greater than -0.00000125 were predicted to have no P. pantherina. According to the discriminant function, sites with a PH value of 240 m^2 or greater were predicted to have P. pantherina whereas those with less than 240 m^2 were predicted not to have P. pantherina. A test of the predictive accuracy of the above formula was performed with data from 23 sites in Mountain Fork River, 5 sites in Little River, and 1 site in lower Glover River. These sites were not randomly chosen but instead were selected because visual examination revealed them to be potentially suitable for P. pantherina (Lechner et al. 1987). At each of these sites, a value for PH was calculated and used to produce a canonical value. The discriminant function correctly predicted the presence or

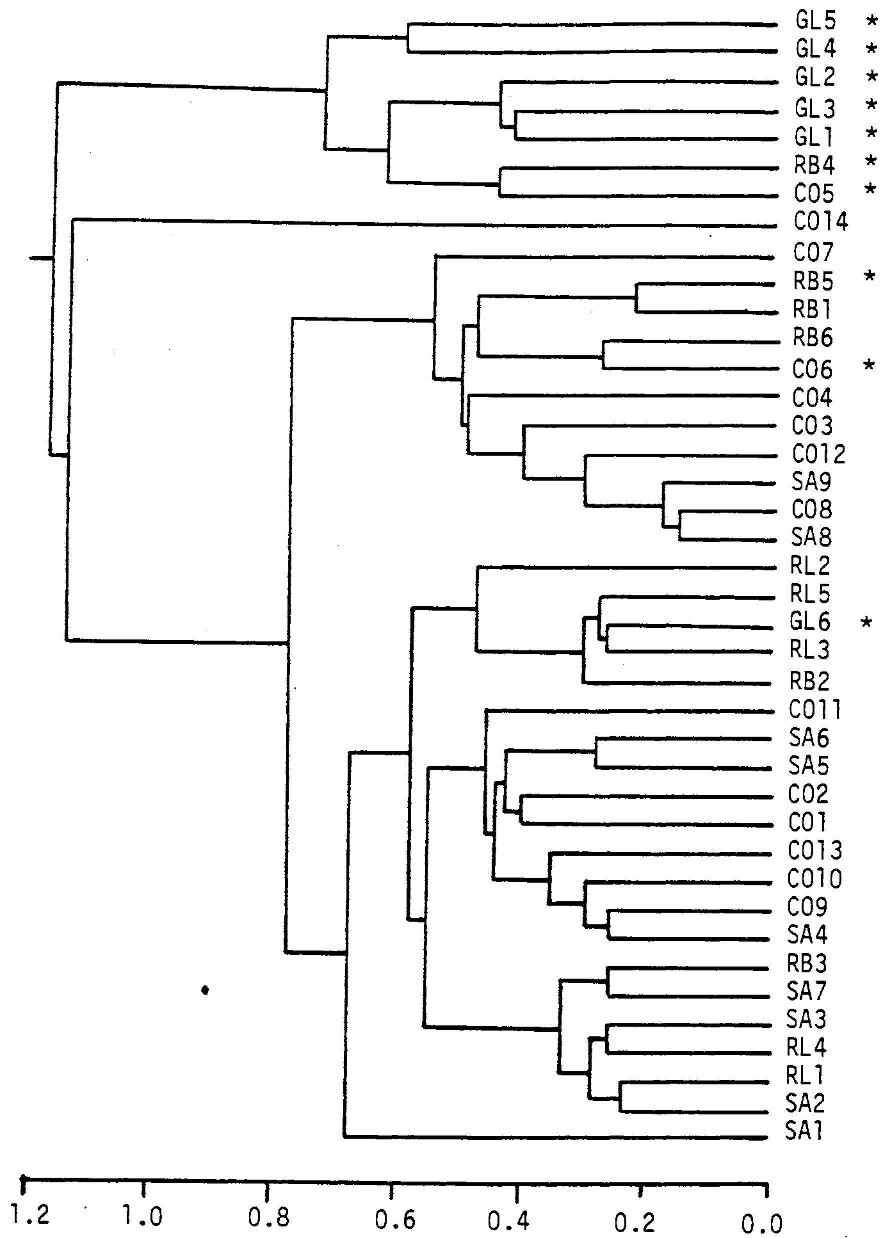

Figure 42. Dendrogram from cluster analysis of 40 sample sites in Little River drainage, Oklahoma in 1986. Sites indicated by an asterisk (*) are sites where P. pantherina was found. (SA=Saline, CO=Cossatot, RL=Rolling Fork, RB=Robinson Fork, GL=Glover)

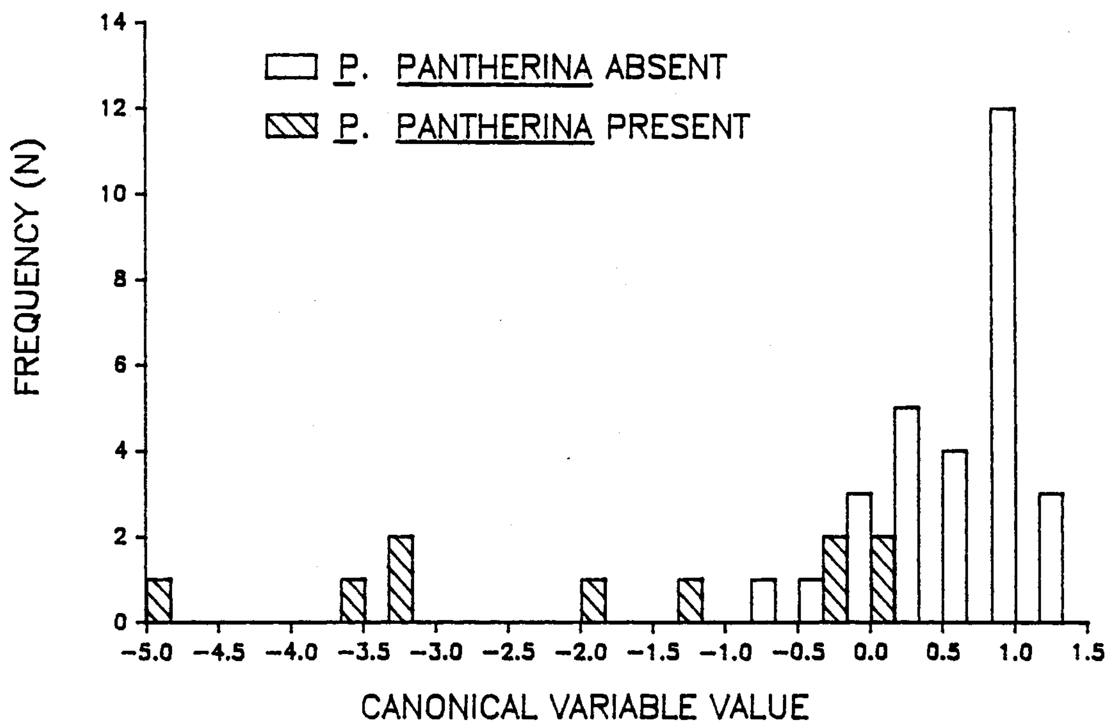

Figure 43. Frequency distribution of canonical variable values from discriminant function analysis of 40 sites in the Little River drainage.

absence of P. pantherina at 23 of 29 sites (79%) (Table XI). Two of the incorrect predictions were at sites where only one individual was found. Another of the incorrect predictions was at a site in lower Mountain Fork River (directly below the Broken Bow Reservoir dam) where P. pantherina have been extirpated.

Analysis of Percina pantherina Spawning Habitat

The variables MD (mean depth) and MS (mean substrate) were the most important in separating riffles used for spawning from those that were not. The formula:

$$\text{Canonical Variable} = -9.6 - (0.13 \times MD) + (2.17 \times MS)$$

was used to classify the riffles into these two groups. The mean canonical variable value for riffles used for spawning was -2.40, whereas 1.20 was the value for riffles with no spawning activity. The analysis correctly classified all 15 riffles to their original group (Fig. 44). According to the discriminant function, any riffle that has a canonical variable value of ≤ 0.0 will be suitable for spawning.

Percina pantherina Population Abundance and Habitat Relationships

A significant relationship existed between amounts of preferred habitat and P. pantherina population abundances at the study sites in August 1986 ($F=13.16$, $P<0.05$), July

TABLE XI

RESULTS OF DISCRIMINANT FUNCTION PREDICTIONS OF *PERCINA PANTHERINA* PRESENCE/ABSENCE AT 29 SITES (M = MOUNTAIN FORK RIVER SITES, L = LITTLE RIVER SITES, G = GLOVER RIVER SITES)

Site	PH (m^2)	*P. pantherina* occurrence	Canonical value	Prediction
M6	360	present	-0.575	Correct
M7	270	present	-0.130	Correct
M11	195	present	0.240	Incorrect
M12	255	present	-0.056	Correct
M17	135	present	0.537	Incorrect
M18	1095	present	-4.206	Correct
M19	240	present	0.018	Incorrect
M20	370	present	-0.624	Correct
M23	315	present	-0.353	Correct
M24	555	present	-1.538	Correct
M28	420	present	-0.871	Correct
M29	465	present	-1.094	Correct
M31	270	present	-0.130	Correct
M32	120	present	0.611	Incorrect
M36	345	present	-0.501	Correct
M38	270	present	-0.130	Correct
M39	285	present	-0.204	Correct
M40	1680	present	-7.096	Correct
M43	75	present	0.833	Incorrect
M45	360	present	-0.575	Correct
M46	560	present	-1.563	Correct
M47	510	present	-1.316	Correct
M48	285	absent	-0.204	Incorrect
L53	300	present	-0.278	Correct
L56	420	present	-0.871	Correct
L57	390	present	-0.723	Correct
L58	855	present	-3.020	Correct
L59	300	present	-0.278	Correct
G7	150	absent	0.463	Correct

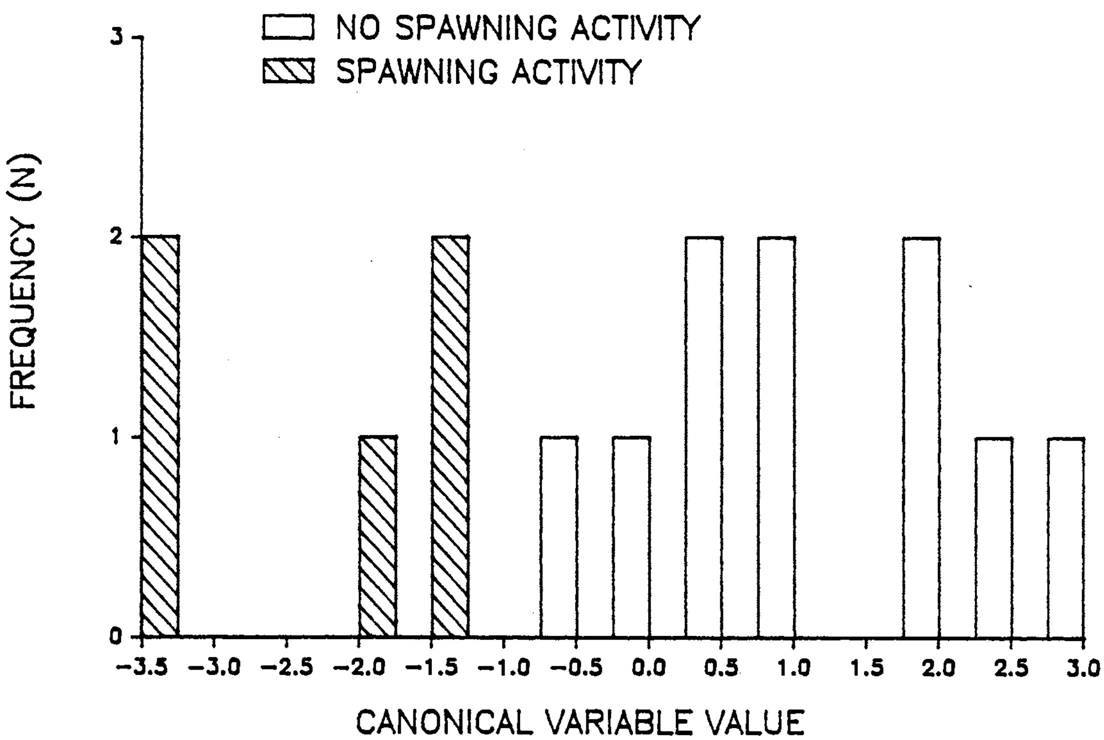

Figure 44. Frequency distribution of canonical variable values from discriminant function analysis of 15 riffles in the Little River drainage.

1987 ($F=11.78$, $P<0.05$), July 1988 ($F=12.12$, $P<0.05$), and September 1988 ($F=10.14$, $P<0.05$) (Fig. 45-48). The linear regression formulas each explained about 75% of the variation in abundance (Fig. 45-48).

Discussion

No significant differences in habitat preference were found between males and females or between adults and juveniles. However, a seasonal shift in water depth, substrate, and current velocity preferences occurred. Individuals occupied deeper water during winter than during any other season. Deep areas may have been chosen to avoid freezing conditions that occasionally occur in the shallow areas of pools. P. pantherina preferred smaller substrates during spring and fall than they did during summer and winter. They preferred slightly flowing water during winter and spring and stagnant areas during other seasons. The affinity for areas with gravel substrate and flowing water in spring is probably indicative of a habitat shift towards riffle tailwaters for spawning. These areas were preferred from late winter through spring even though pools with rubble and boulder substrates and no detectable flow were available. P. pantherina is an egg-burying species and requires flowing water to ensure adequate aeration of the eggs (Page 1985).

Many of the pools in Glover River upstream from the

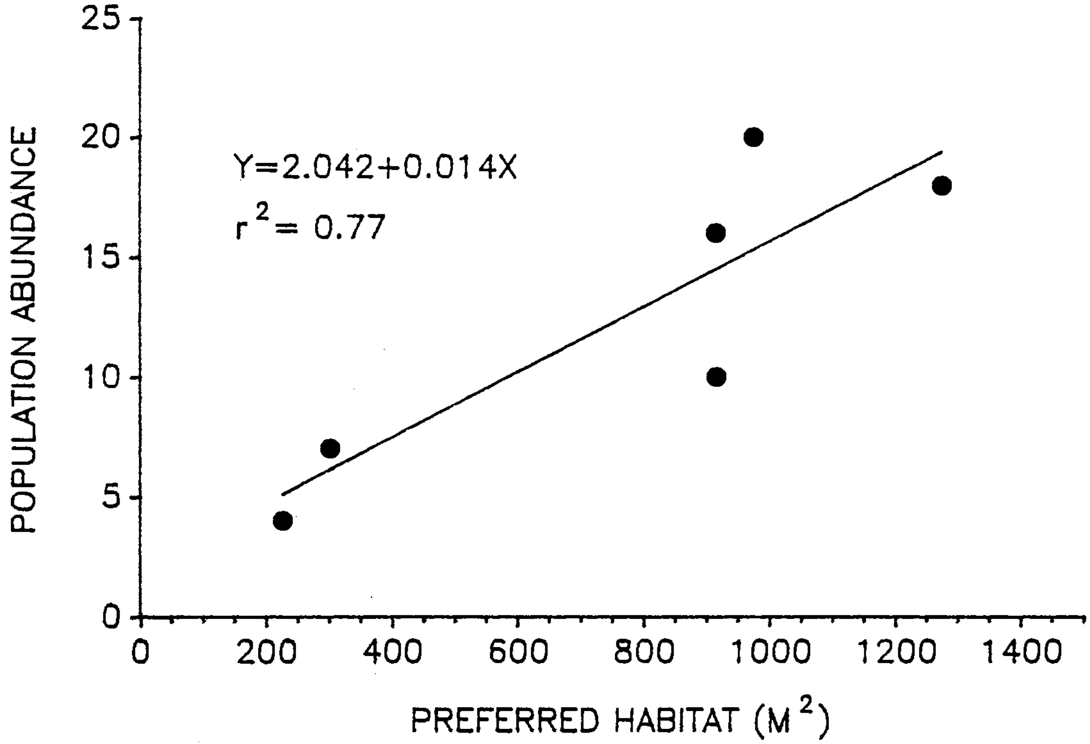

Figure 45. Relationship between the amount of preferred habitat and the abundance of P. pantherina in August 1986 at six study sites in Glover River.

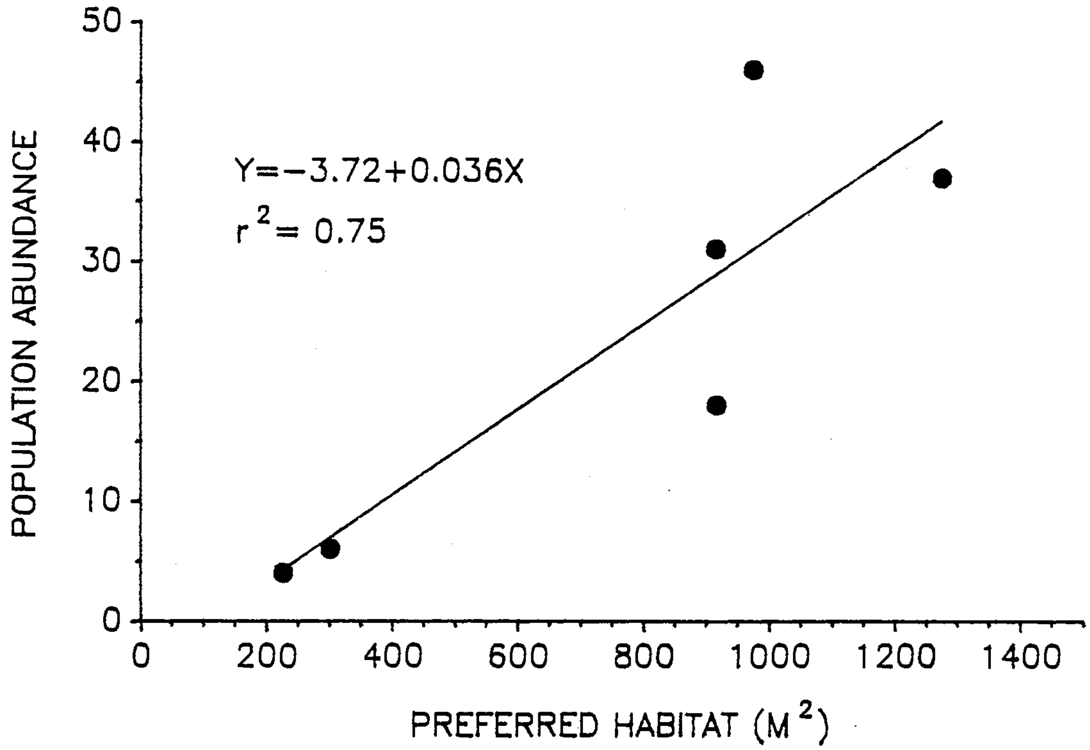

Figure 46. Relationship between the amount of preferred habitat and the abundance of P. pantherina in July 1987 at six study sites in Glover River.

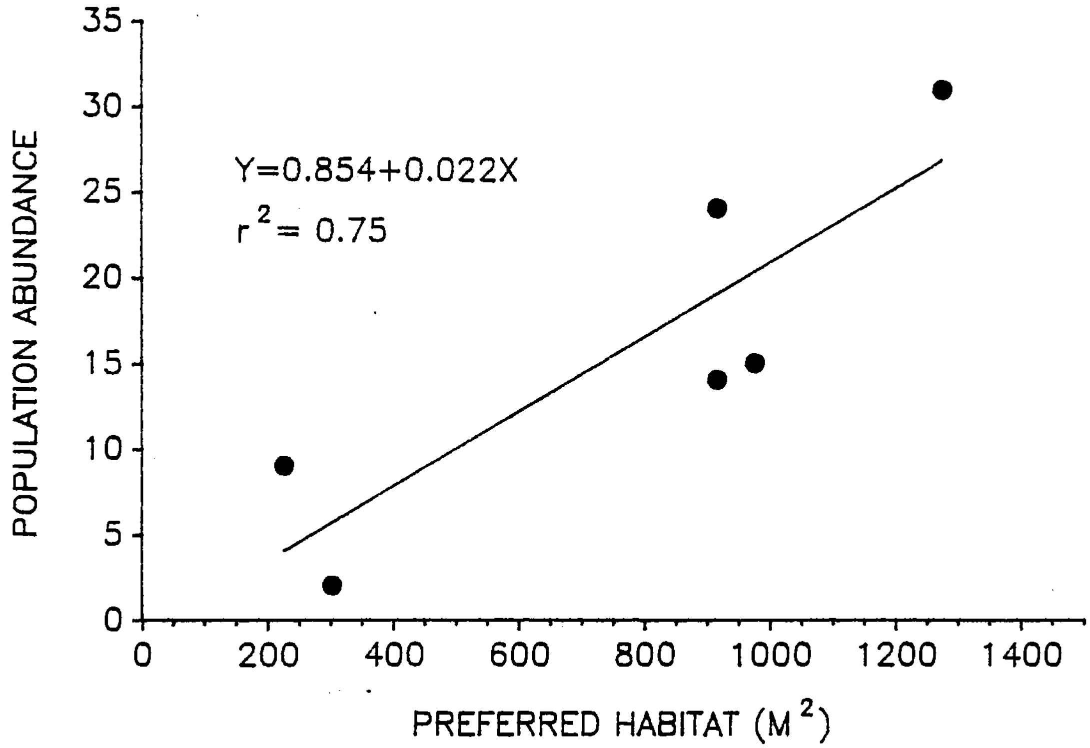

Figure 47. Relationship between the amount of preferred habitat and the abundance of P. pantherina in July 1988 at six study sites in Glover River.

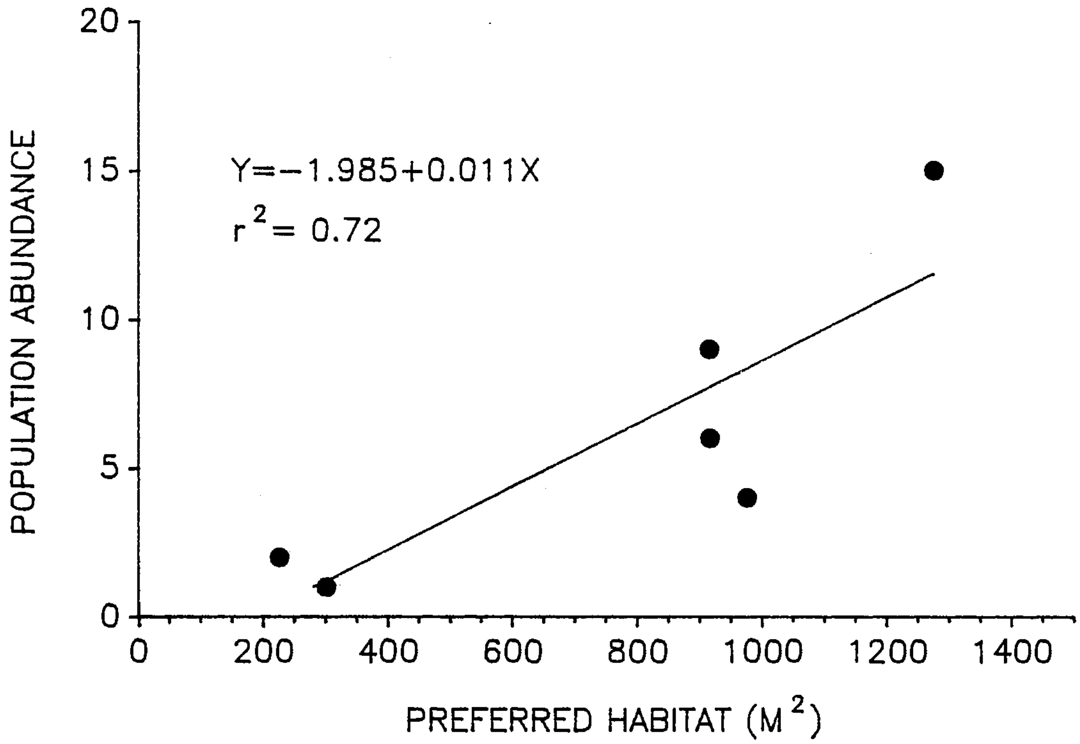

Figure 48. Relationship between the amount of preferred habitat and the abundance of P. pantherina in September 1988 at six study sites in Glover River.

Highway 3 bridge (Fig. 4) have a substrate composed of rubble and boulders, contain little or no detectable current velocity, and have water depths to about two meters. Within these pools the preference for substrates and current velocities based on capture locations was not significantly different from the distribution of substrates and current velocities available in the pools. However, *P. pantherina* preference for water depths was significantly different from the distribution of depths found in the pools. Within pools composed of rubble and boulder substrate *P. pantherina* apparently sought only water depths of 25-75 cm. Water depth is probably the single most important factor determining the amount of preferred habitat.

P. pantherina habitat preference within pools appears to be very specific and well defined regardless of the diversity of habitats available. Individuals exhibited similar preferences for water depth, substrate, and current velocity at all study sites even though the study sites were significantly different with respect to the availability of these variables (Tables IX AND X).

The cluster analysis showed a high degree of similarity among sites that supported populations of *P. pantherina*. Therefore, areas suitable for *P. pantherina* can be identified by their physical habitat characteristics (Table IV).

Results of the discriminant function analysis for predicting occurrence of P. pantherina demonstrated that: 1) P. pantherina occurrence was strongly related to the amount of preferred habitat available at a site, 2) measurement of the amount of preferred habitat could provide an accurate prediction of P. pantherina occurrence, and 3) the suitability of physically altered areas could be predicted.

The predictive model was solely dependent on the variable, PH, which was a measure of the amount of preferred habitat available at a site. This variable is a combination of three other variables (water depth, substrate, and current velocity). Another model that is commonly used to predict fish abundance based on the physical habitat is the Instream Flow Incremental Methodology (IFIM). IFIM was originally developed to estimate changes in fish habitat caused by changes in stream discharge (Bovee 1982). The transect method used in the present study to measure habitat availability is similar to that used in IFIM studies and the physical stream variables are also the same. However, the calculation of the amount of preferred habitat is very different. In IFIM studies, the area of the stream segment represented by each point measurement along transects is multiplied by the relative preference value (ranging from 0 to 1) of the fish species. The values for all segments in the sampled area are then summed to determine the Weighted Usable Area (WUA) (Bovee 1982). The calculation of PH in this study is different from WUA in two respects. First, the calculation of WUA requires that each interval of a variable (water depth, substrate, or current velocity) be assigned a preference value from 0 to 1, whereas the model presented here directly uses a range of intervals. Secondly, in the model used here, the habitat is defined as preferred only if all variables measured (depth, substrate, and current velocity) are within the preferred range. In calculating WUA, a large area with a low preference value is equal to a small area with a high preference value.

Fausch et al. (1988) reviewed models that used WUA to predict fish abundance and found contrasting results. Stalnaker (1979) found WUA accounted for 81 percent of the variation in Salmo trutta (brown trout) abundance in Wyoming streams. In contrast, Orth and Maughan (1982) found no significant correlation between WUA and the abundance of Micropterus dolomieui (smallmouth bass) in Glover River. They also found that many of the IFIM assumptions were violated and that WUA was not always a reliable indicator of fish abundance (Orth and Maughan 1982). PH was calculated from the same type of data as that used to calculate WUA, but appears to be a better measure of habitat availability. PH was highly correlated with P. pantherina occurrence and abundance in Glover

River.

Levins (1966) stated that models used in biology should ideally possess the attributes of realism, precision, and generality. The discriminant function model used here to predict P. pantherina occurrence has generality because it accurately predicted occurrence of P. pantherina in other streams in the drainage. The model is also realistic because it incorporates the functional attributes of P. pantherina's response to habitat availability. The precision of the model cannot be determined because repeatable results have not yet been attempted.

Spawning did not occur on all riffles but only on those with the specific habitat characteristics described in chapter IV. From the results of the discriminant function analysis it appears that suitable spawning riffles are distinctly different from other riffles in the drainage. The two variables used to distinguish between groups of riffles, mean depth (MD) and mean substrate (MS), are significant in that P. pantherina is very specific in its selection of spawning habitat. The eggs are buried in patches of fine gravel (particle size diameter of 3-10 mm). Riffles lacking this substrate are probably not suitable for spawning. Most spawning occurred in riffle tailwaters at the heads of pools. In these areas gravel deposits were found in areas of gradually increasing depth and decreasing current velocity. Riffles such as these were not common in Glover River and spawning activity was observed only on such riffles. Many riffles in the Little River drainage are underlain by bedrock and boulders with shallow, swift-flowing chutes and stair-step ledges.

As many as 15 individuals were observed courting and spawning in areas as small as 6 m^2 (site 5). This tolerance for high density spawning would lead me to conclude that spawning habitat does not limit P. pantherina in areas near suitable spawning habitat. However, over much of the drainage, the number and distribution of riffles suitable for spawning could be an important factor limiting P. pantherina populations.

The significant positive relationship between P. pantherina population abundance and preferred habitat area (PH) revealed in the regression analysis further suggests that this habitat may be limiting. However, the regression analyses were based on small sample sizes (n=6) which artificially increases the coefficient of determination (r^2) (Sokal and Rohlf 1981). The value of r^2 is a measure of the percent of variation in the dependent variable (population abundance) that is accounted for by the regression equation (Sokal and Rohlf 1981). Therefore the regression equations may not explain as much of the variation in population abundance as the r^2 values indicate. Several authors have stated that statistically significant regression analyses do not necessarily imply cause and effect relationships (Sokal and Rohlf 1981; Steel and Torrie 1980; Zar 1974). However, because the habitat preferred by P. pantherina is so specific and limited in abundance, it is reasonable to assume that their populations could be limited by the amount of habitat available. Populations of other threatened or endangered fishes in North America also appear to be limited by the availability of suitable habitat (Ono et al. 1983; Miller 1972).

It appears that the survival of P. pantherina depends largely on the protection of specific areas of preferred habitat and specialized areas of spawning habitat. Water developments such as channelization, impoundment, or diversion that would either obstruct access to or decrease the amount of preferred habitat and spawning habitat would probably result in a decrease in P. pantherina populations.

CHAPTER VI

PERCINA PANTHERINA HABITAT SIMULATION

Introduction

Several authors have stated that a major threat to the survival of *P. pantherina* is loss of habitat (Miller and Robison 1973; Buchanan 1974; Cloutman and Olmsted 1974; Robison et al. 1974; Hubbs and Pigg 1976; Robison 1978; Jones 1984; Ono, et al. 1983). Impoundments in the Little River drainage (Fig. 1) have been cited as the major cause of habitat loss. However, the underlying mechanisms as to how the loss of habitat due to impoundment actually occurs are usually not known. To determine how changes in stream flow affect the preferred habitat of *P. pantherina*, several relationships between water levels in Glover River and habitat availability at the study sites were investigated. Therefore the objectives in this study were to: 1) determine relationships between stream discharges at a permanent recording station and mean water depths at the study sites, 2) determine relationships between mean water depths and the amount of preferred habitat available at each study site, and 3) simulate stream discharges from 0.0 to 15.0 m^3/s and determine their effects on the amount of preferred habitat at each site.

Materials and Methods

Water depths, substrate types, and current velocities were measured at the six Glover River study sites throughout the year using methods described in chapter V. The amount of preferred habitat (m^2) at each site was determined by methods described in chapter V. Water discharge data (m^3/s) from Glover River were obtained from a U. S. Geological Survey recording station at the Hwy. 3 bridge (Fig. 4). Only the discharges on dates when habitat was measured were used.

Linear regression analyses were used to establish relationships between stream discharges at the recording station and mean water depths at the study sites. Non-linear regression analyses (Sokal and Rohlf 1981) were used to determine relationships between mean water depth and the amount of preferred habitat at each site. The major assumption of this analysis is that the amount of preferred habitat at a site will attain a maximum at a certain water level with decreased amounts found at higher and lower water levels. Therefore the shape of the relationship should roughly resemble a parabola. Second order regressions (quadratic) were fitted by including the data point mean depth = 0 and preferred habitat = 0. Although the actual measurement was never made, it was assumed that any site with a mean water depth of 0 will have no preferred habitat available.

A computer simulation that incorporated the linear and non-linear regressions was performed on each site to determine the effects of discharge on the preferred habitat of P. pantherina. A simulation language called SLAM II was used on a personal computer (PC) for the simulations (Fig. 49). SLAM II is an engineering-based computer simulation language originally developed for modeling industrial manufacturing processes (Pritsker 1986) but has recently been used to model ecological systems (Fargo and Woodson 1988).

The simulation for each site was run by creating an entity every 0.5 time units. The first entity was assigned a stream discharge value of 0.0 m^3/s and successive entities were given discharge values increasing in 0.5 m^3/s increments. A mean water depth value (cm) was calculated for each entity moving through the network (Fig. 49). A random error value for the mean depth was drawn from a normal distribution with a mean of zero and a standard deviation of the value of the standard error of the regression (Sokal and Rohlf 1981). The calculated mean depth value for each entity was then used to calculate the preferred habitat area (m^2) from the second order regression equation (Fig. 49). At the end of simulation the discharge, mean depth, and preferred habitat area for

```
GEN, PAUL W. JAMES, GL1 SIMULATION, 4/25/89, 1;
LIMITS,1,10,500;
NETWORK;
      CREATE,.5,0,1,50,1;
      ASSIGN,ATRIB(2)=33.135 + 3.216 * ATRIB(1),
             XX(1)=ATRIB(2)+RNORM(0.0,8.552,9),
             ATRIB(3)=10.44 + 43.402 * XX(1),
             ATRIB(4)=ATRIB(3) - 0.545 * XX(1) * XX(1),
             XX(2)=ATRIB(4);
      TERM;
      ENDNETWORK;
RECORD,TNOW,DISCHARGE,0,B,.5;
      VAR,XX(1),D,MD;
      VAR,XX(2),H,PREF HAB;
INIT,0,15;
FIN;
```

Figure 49. SLAM II computer program statements for habitat simulation at site 1 in Glover River.

each entity were recorded. Each simulation was run for 15 time units resulting in mean depth and preferred habitat output at 30 discharge values.

Results

The regression analyses resulted in significant linear relationships between discharge values from the recording station and mean water depths at the study sites (Figs. 50-55). The non-linear regression analyses between mean water depth and preferred habitat area at a site (Figs. 56-61) resulted in high coefficient of determination (r^2) values. However, due to small sample sizes the r^2 values are probably not statistically valid (Sokal and Rohlf 1981). The simulation output (Figs. 62-67) resulted in increased mean water depths at each site with increased discharges. The amount of preferred habitat at each site was usually maximized at discharges of 1.0 - 7.0 m^3/s (Figs. 62-67).

Discussion

The differences in the slopes of the regressions between discharge and mean depth was probably due to differences in the channel morphometry of the sites. Site 2 was a wide, shallow pool and showed very little increase in mean depth with an increase in discharge (Fig. 63). In contrast, Site 4 was a narrow riffle and pool and showed a rapid increase in mean depth with discharge increase (Fig.

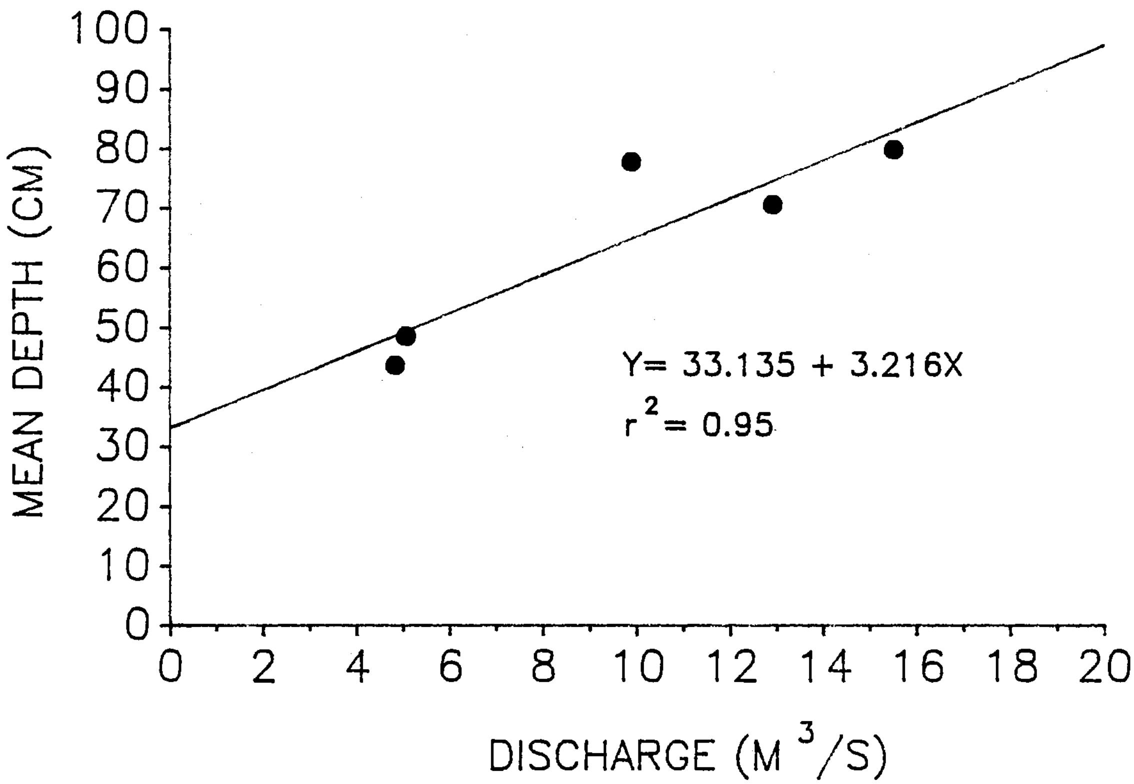

Figure 50. Relationship between stream discharge at Hwy. 3 bridge and mean water depth at site 1 in Glover River 1986-1988.

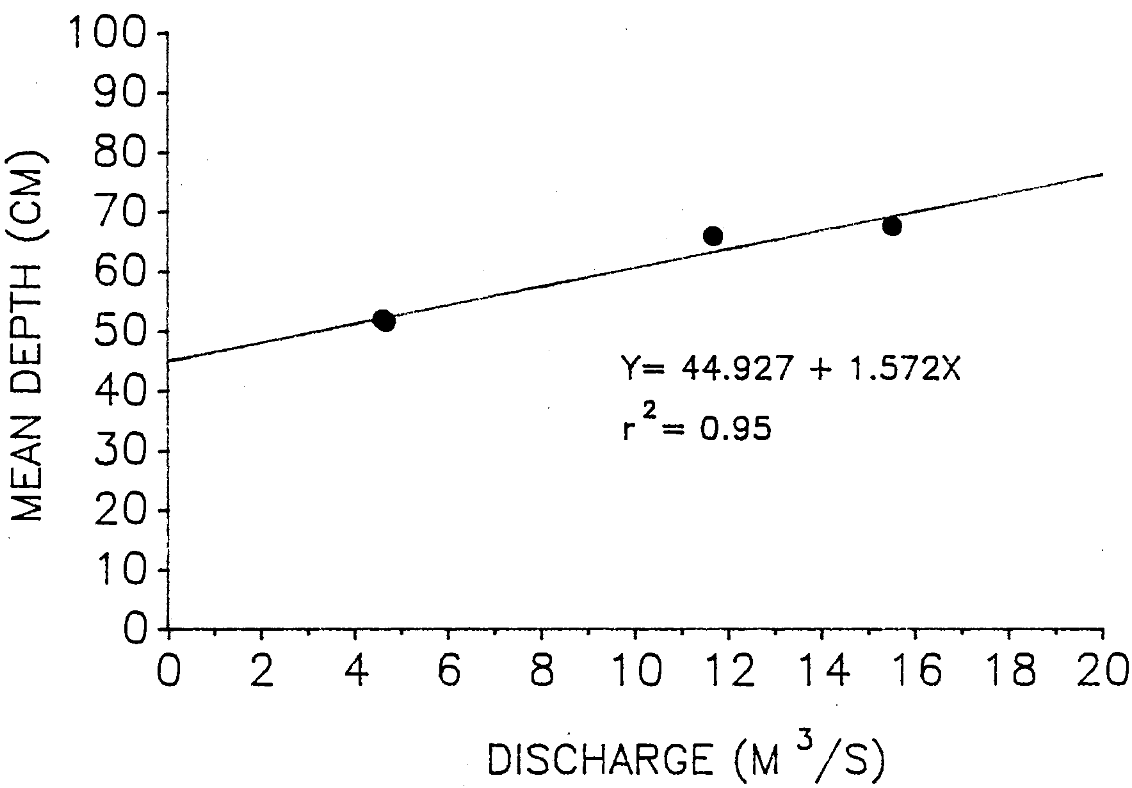

Figure 51. Relationship between stream discharge at Hwy. 3 bridge and mean water depth at site 2 in Glover River 1986-1988.

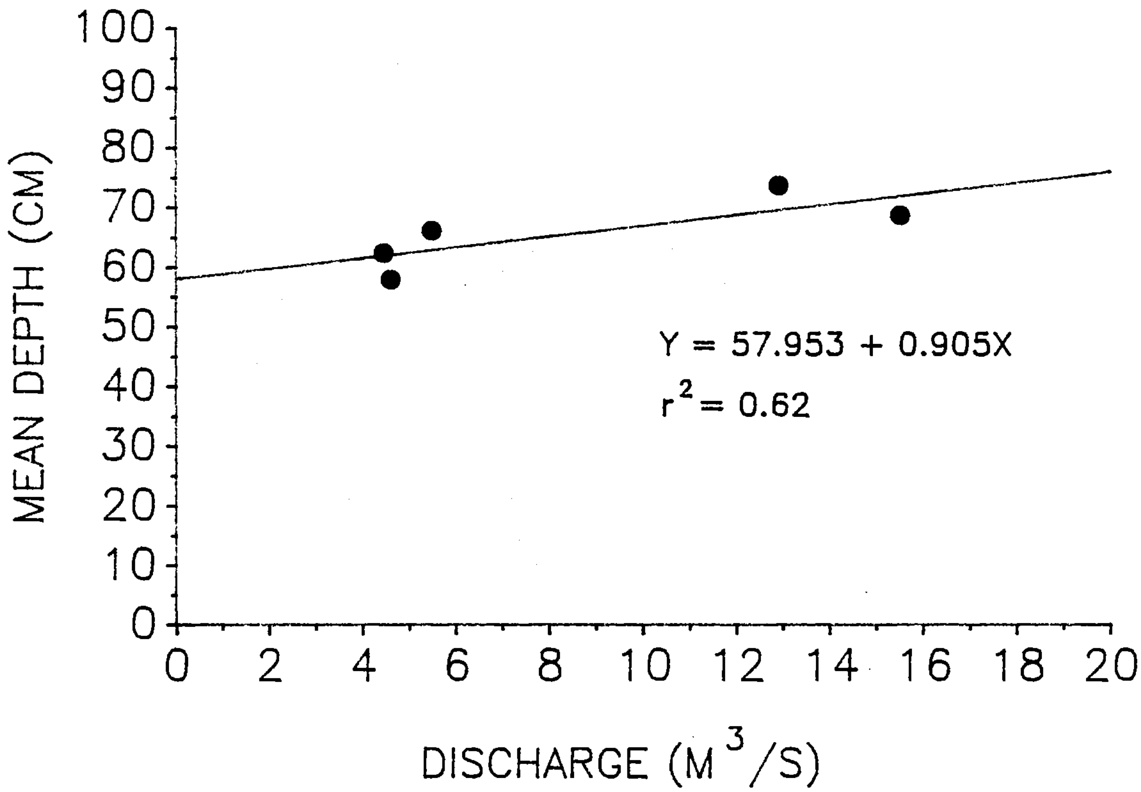

Figure 52. Relationship between stream discharge at Hwy. 3 bridge and mean water depth at site 3 in Glover River 1986-1988.

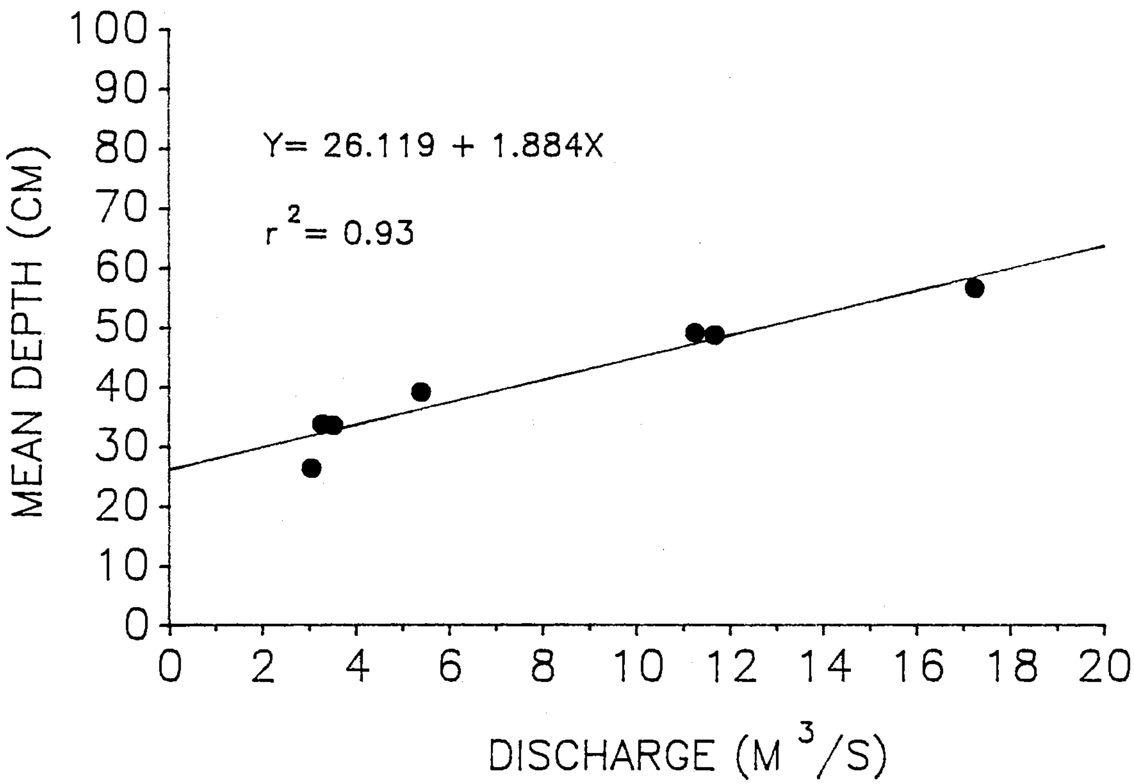

Figure 53. Relationship between stream discharge at Hwy. 3 bridge and mean water depth at site 4 in Glover River 1986-1988.

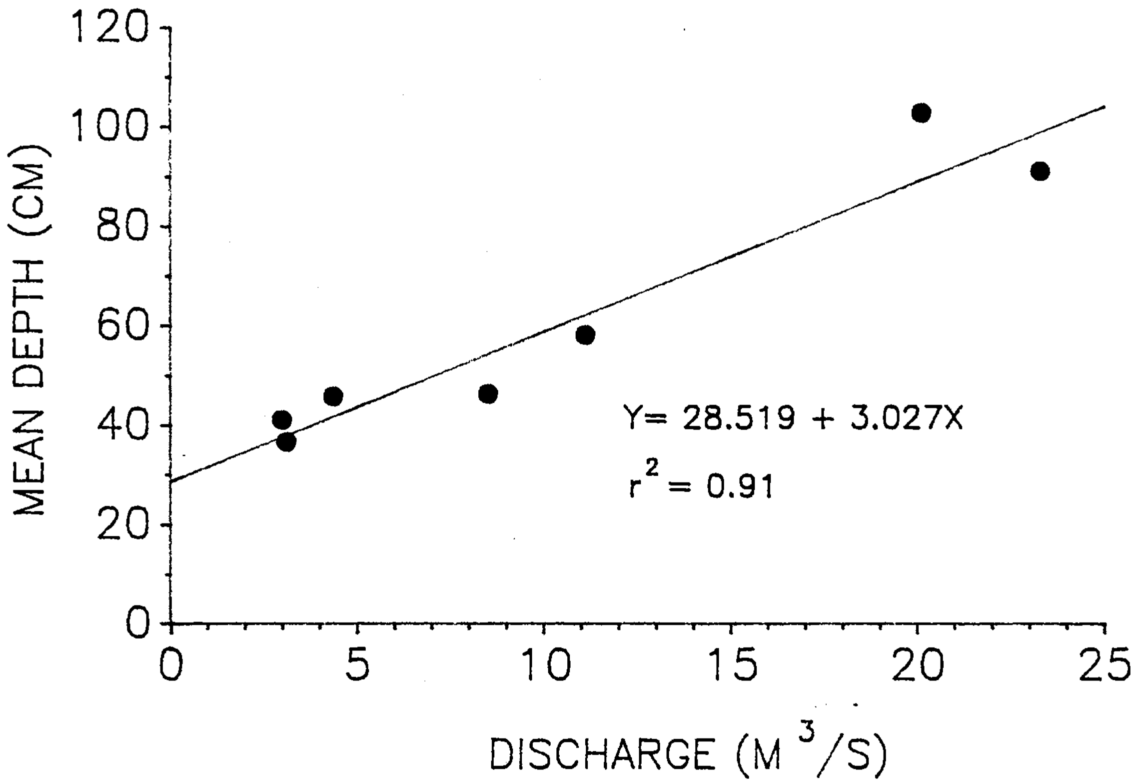

Figure 54. Relationship between stream discharge at Hwy. 3 bridge and mean water depth at site 5 in Glover River 1986-1988.

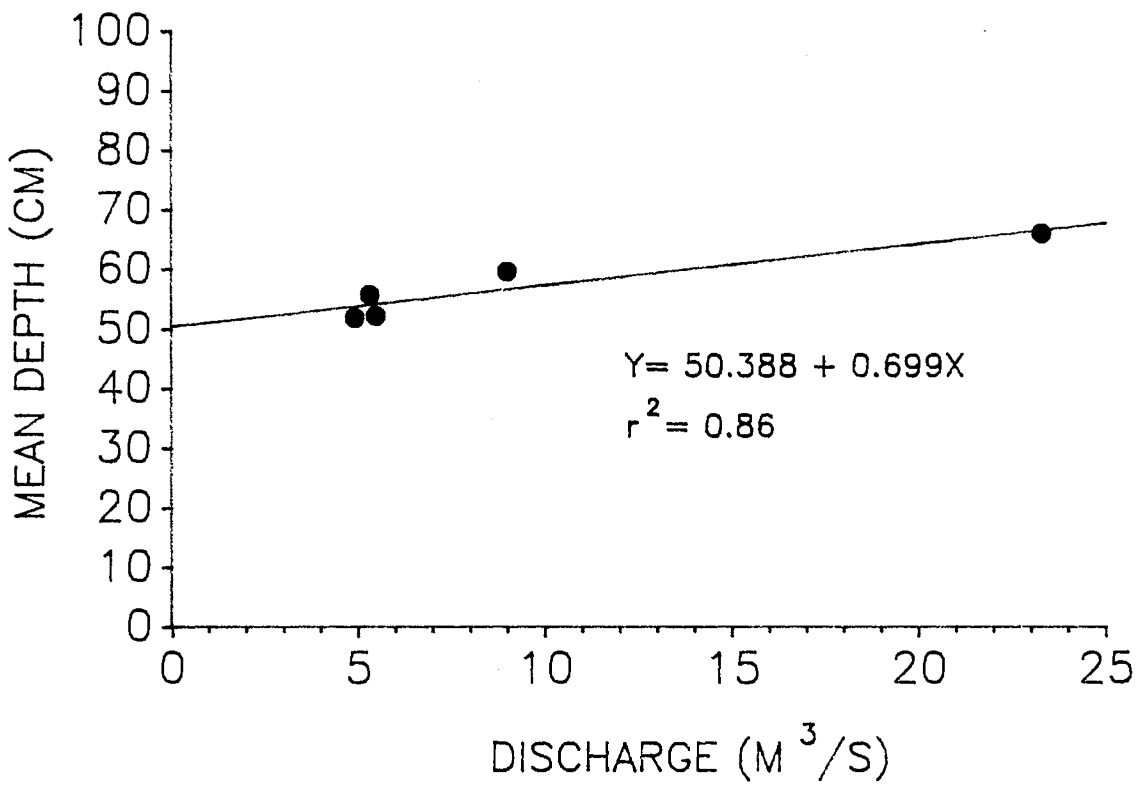

Figure 55. Relationship between stream discharge at Hwy. 3 bridge and mean water depth at site 6 in Glover River 1986-1988.

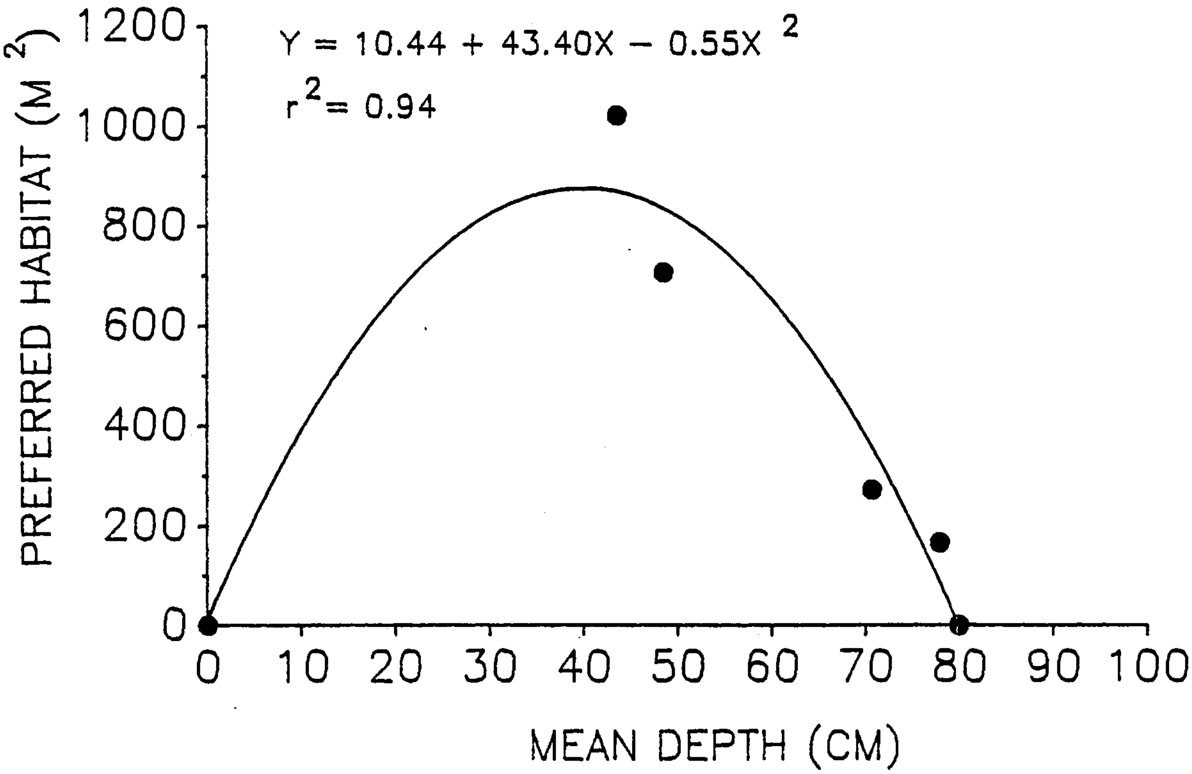

Figure 56. Relationship between mean water depth and preferred habitat area at site 1 in Glover River 1986-1988.

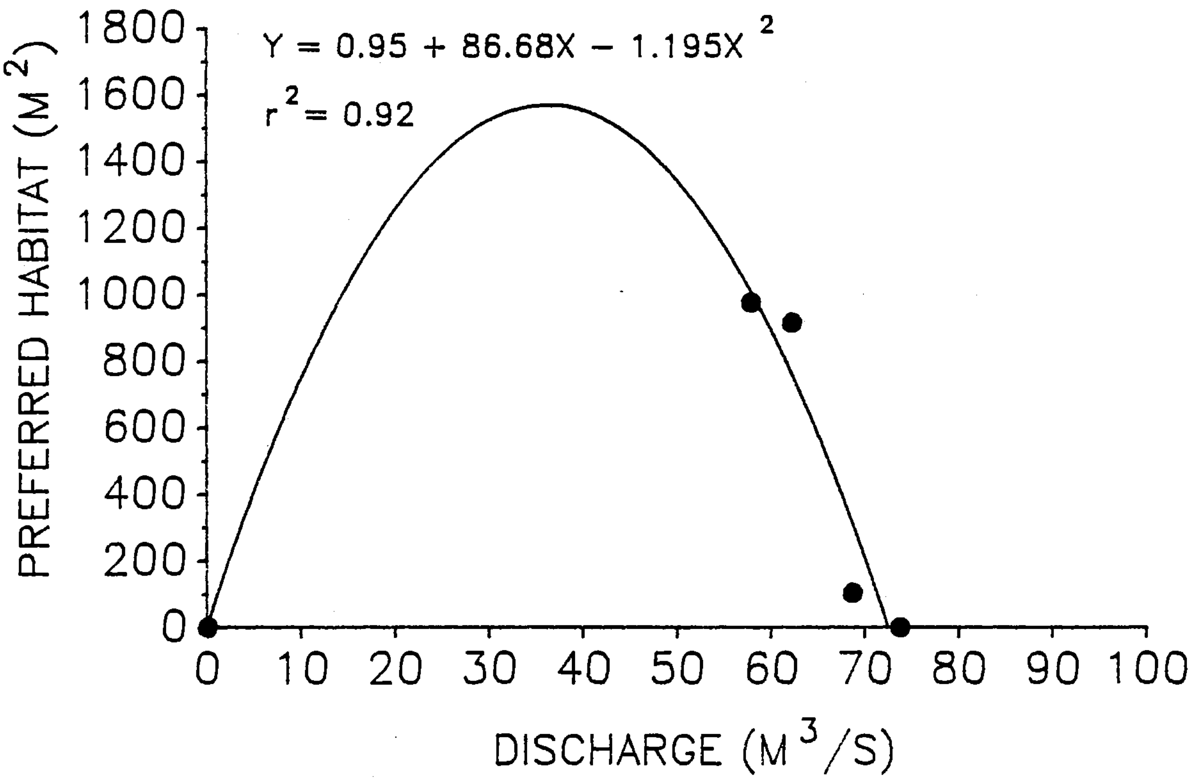

Figure 57. Relationship between mean water depth and preferred habitat area at site 2 in Glover River 1986-1988.

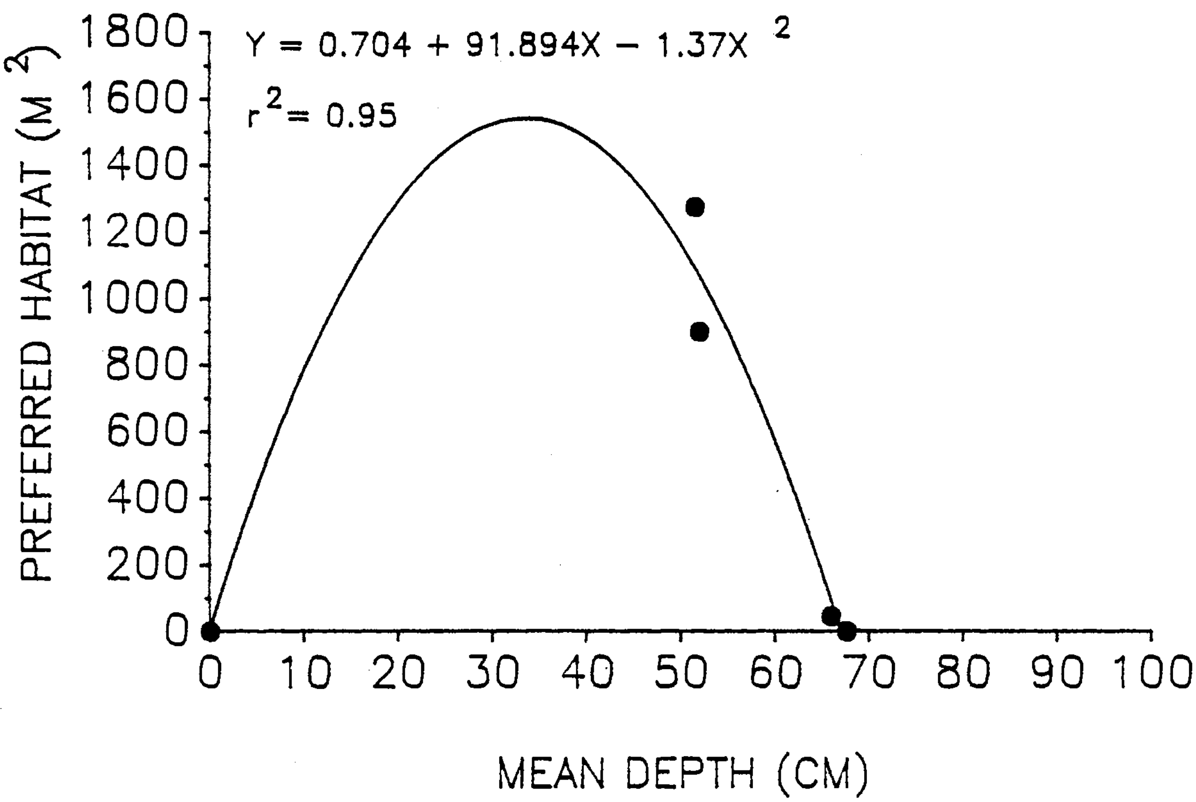

Figure 58. Relationship between mean water depth and preferred habitat area at site 3 in Glover River 1986-1988.

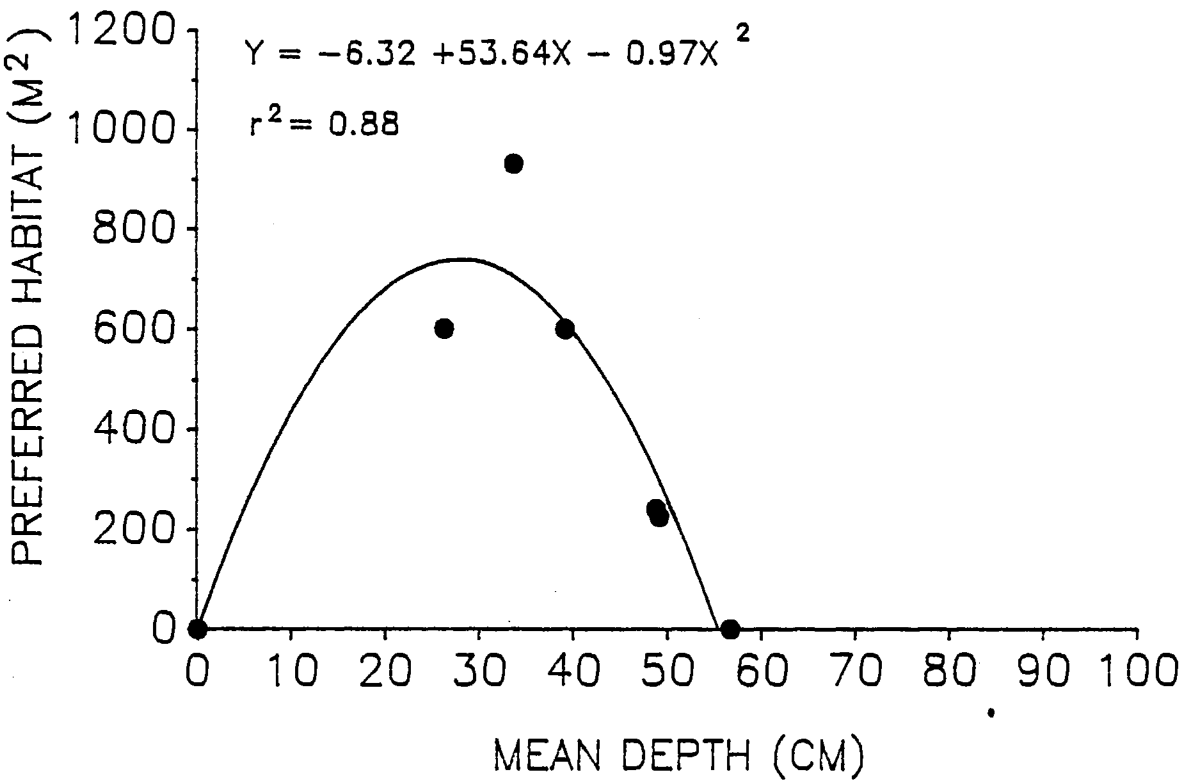

Figure 59. Relationship between mean water depth and preferred habitat area at site 4 in Glover River 1986-1988.

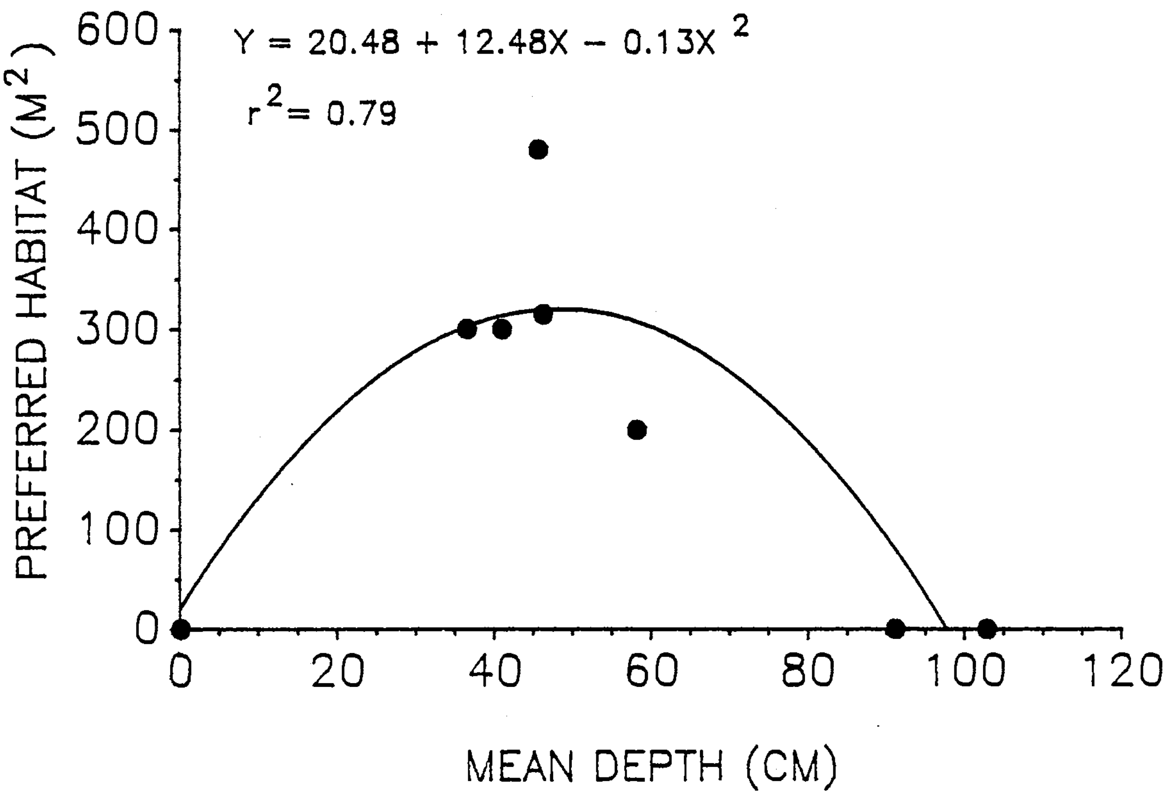

Figure 60. Relationship between mean water depth and preferred habitat area at site 5 in Glover River 1986-1988.

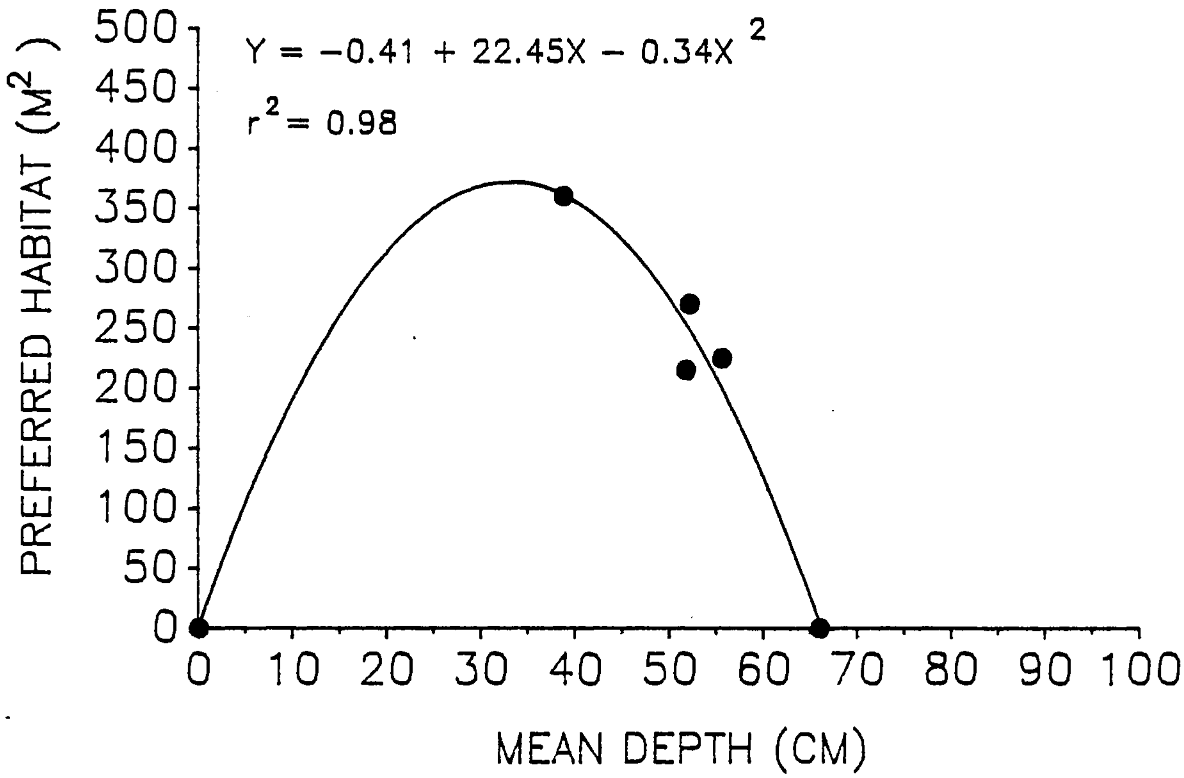

Figure 61. Relationship between mean water depth and preferred habitat area at site 6 in Glover River 1986-1988.

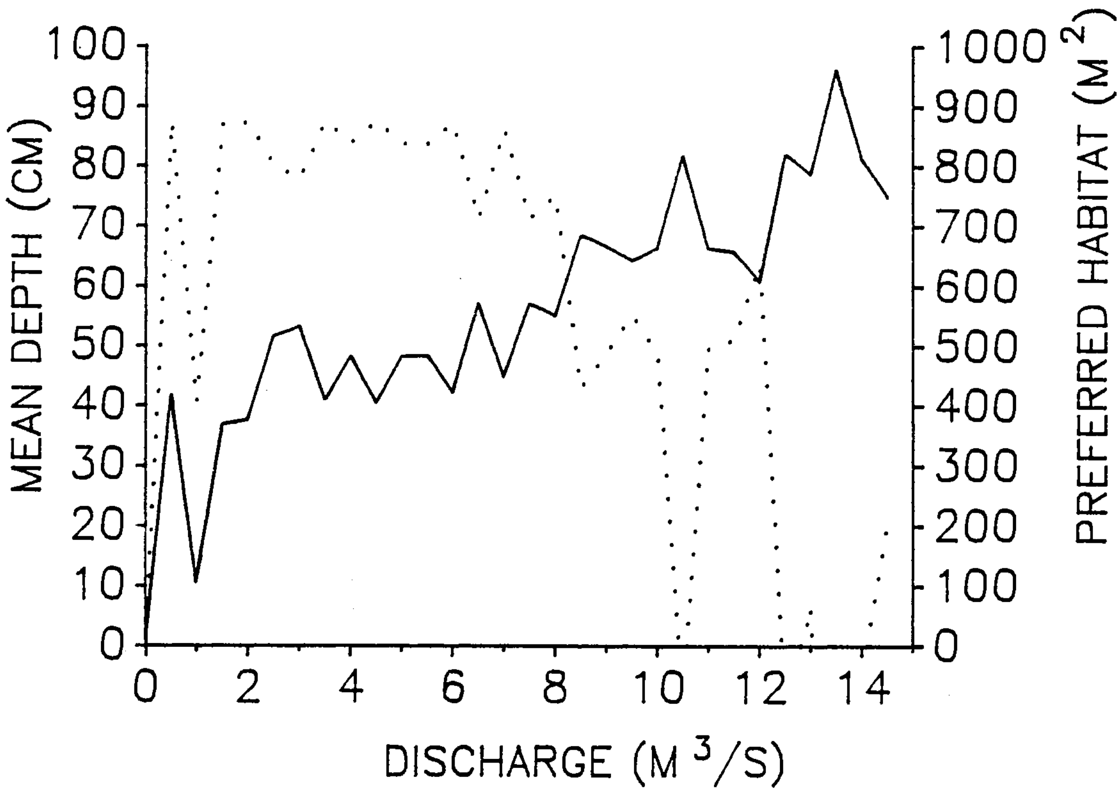

Figure 62. Effects of simulated stream discharges on mean water depth and preferred habitat area at site 1 in Glover River. (solid line = mean depth; dotted line = preferred habitat)

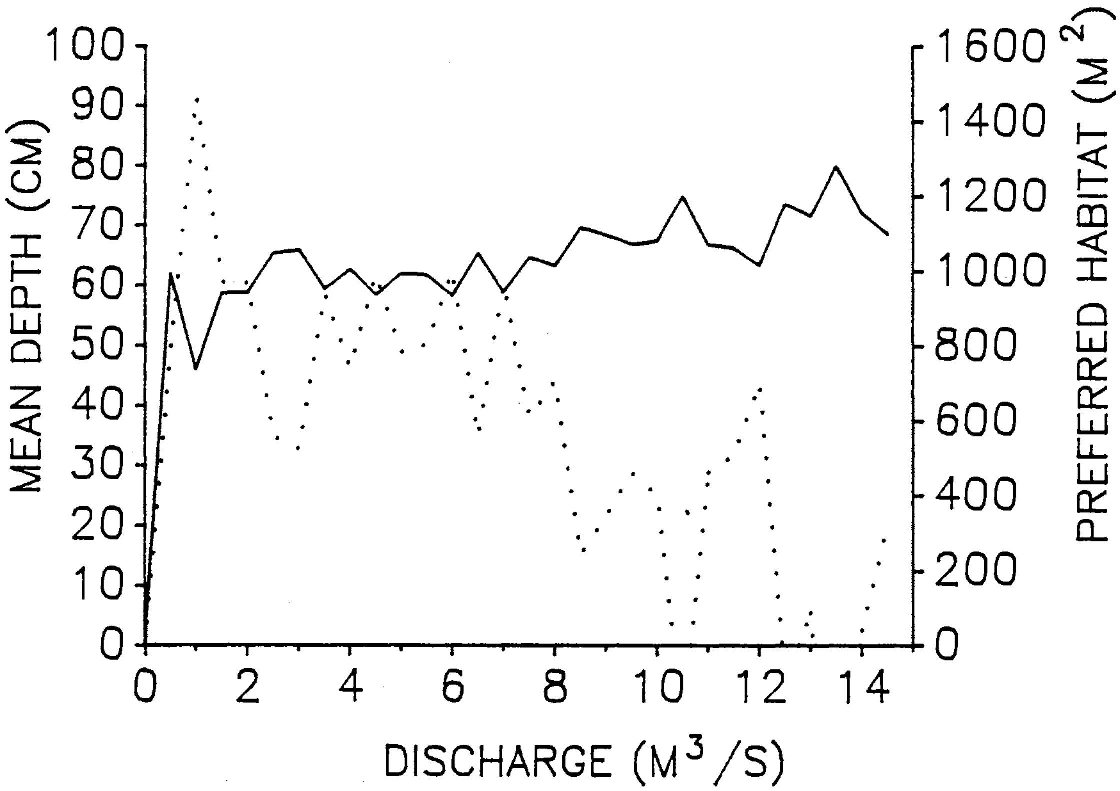

Figure 63. Effects of simulated stream discharges on mean water depth and preferred habitat area at site 2 in Glover River. (solid line = mean depth; dotted line = preferred habitat)

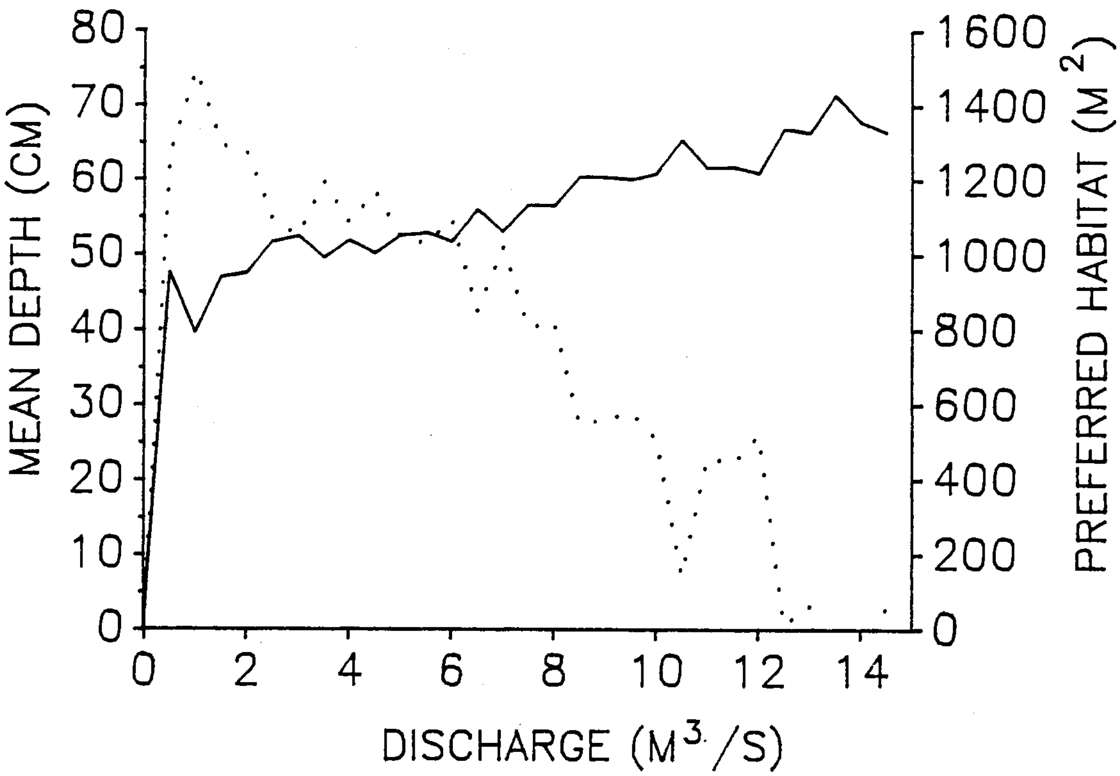

Figure 64. Effects of simulated stream discharges on mean water depth and preferred habitat area at site 3 in Glover River. (solid line = mean depth; dotted line = preferred habitat)

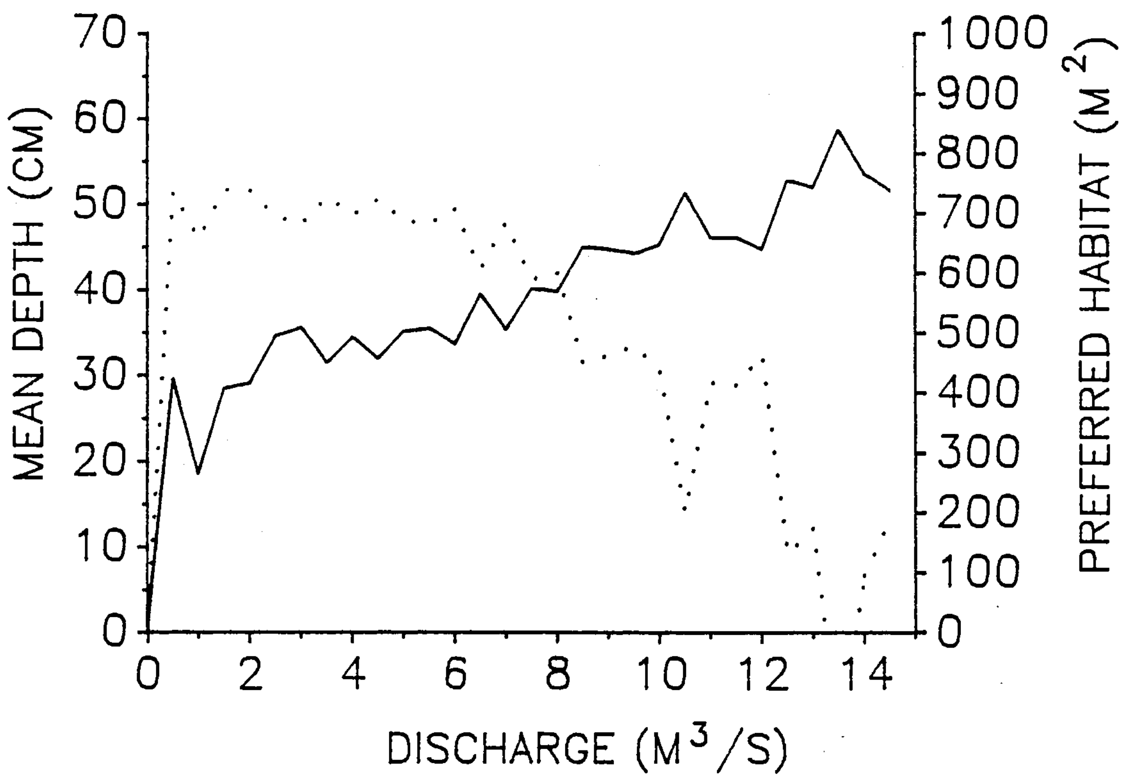

Figure 65. Effects of simulated stream discharges on mean water depth and preferred habitat area at site 4 in Glover River. (solid line = mean depth; dotted line = preferred habitat)

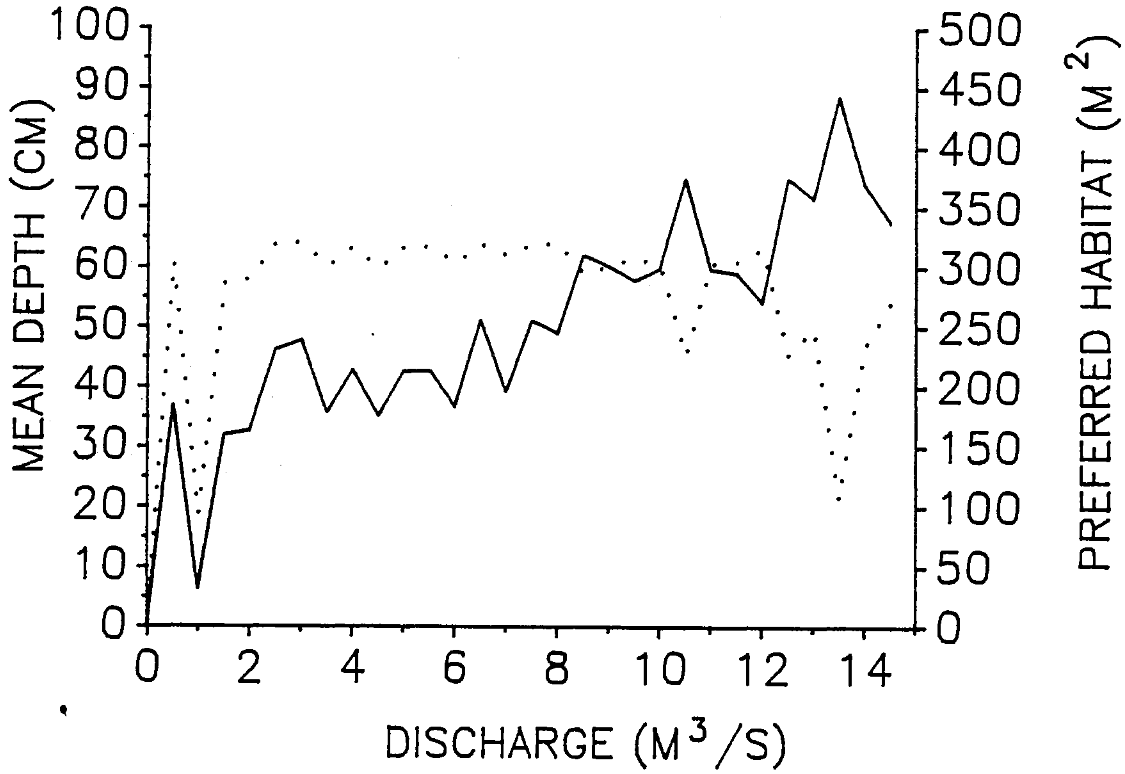

Figure 66. Effects of simulated stream discharges on mean water depth and preferred habitat area at site 5 in Glover River. (solid line = mean depth; dotted line = preferred habitat)

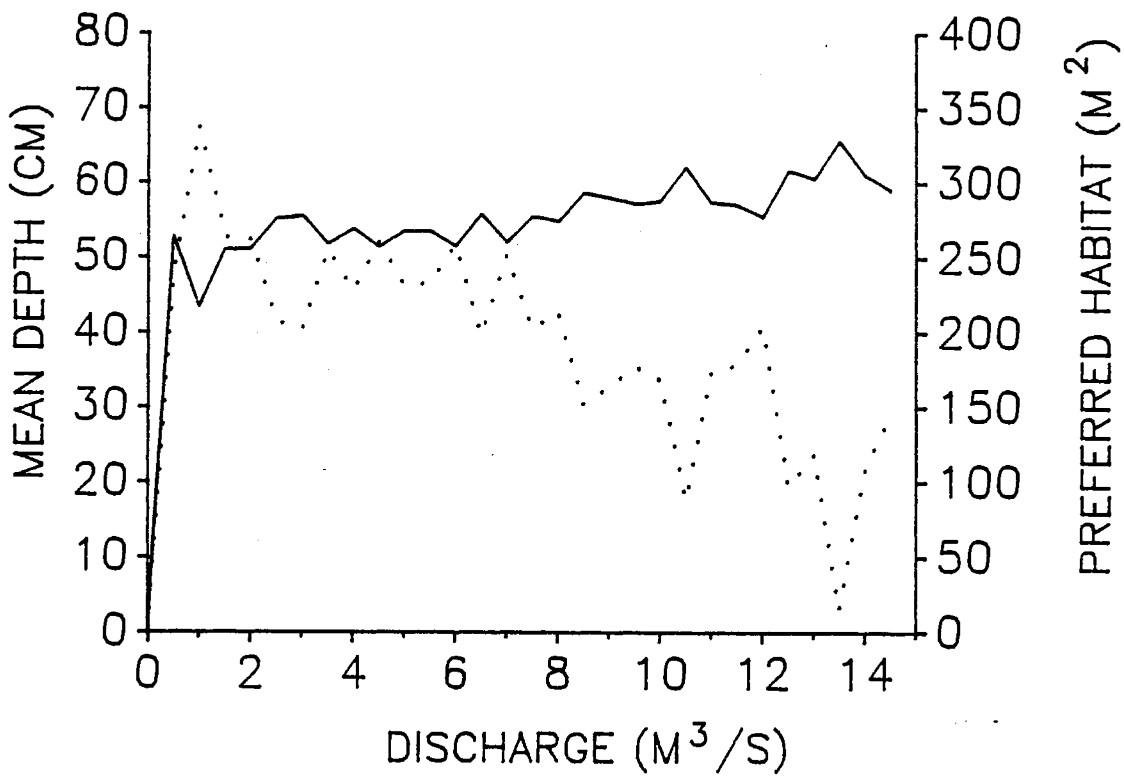

Figure 67. Effects of simulated stream discharges on mean water depth and preferred habitat area at site 6 in Glover River. (solid line = mean depth; dotted line = preferred habitat)

65).

The actual shape of the curve for the relationships between mean depth and preferred habitat area could not be determined. Lack of high variation in the mean depths of sites during most of the year that resulted in a low variation in the mean depth data precluded developing the shape of the curve for the relationships. The mean depths at all sites never reached extremely low values and thus there was an absence of data on preferred habitat at shallow mean depths (Figs. 56-61).

The simulation language, SLAM II, was relatively easy to program, required very little computer processing time, and did not require a great deal of input data. The entire simulation program length for each simulation was only 16 lines (Fig. 49). The output was easily converted into graphs representing the effects of stream discharge on _P. pantherina_ habitat (Figs. 62-67). The output from the simulations showed that preferred habitat was usually maximized at each site when stream discharges at the recording station were between 1 and 7 m^3/s. According to the simulations, a loss in the preferred habitat of _P. pantherina_ would occur if the stream discharge decreased to <1.0 m^3/s or if the discharge increased to >7.0 m^3/s. Therefore any water development project that would decrease the stream discharge or decrease water levels beow those levels (i.e., water removal for irrigation, livestock, or public use) or that would increase the discharge or increase water levels above those levels (i.e., channelization, impoundment, or hydropower generation) would result in a loss of preferred habitat and thus a decrease in *P. pantherina* population abundance (see chapter 5). Stream discharges in Glover River naturally fall below 1.0 m^3/s and rise above 7.0 m^3/s at certain times during the year (U. S. Geological Survey 1986) and thus affect preferred habitat. However, durations of these periods are usually short. The typical discharge from Glover River during a summer month (July 1986) was relatively stable with discharge decreasing gradually throughout the month (Fig. 68). However, the July 1986 discharge from Mountain Fork River below the hydropower dam showed drastic fluctuations during the month (Fig. 68). The physical habitat below the dam during periods when power generation is not occurring contains an adequate amount of preferred habitat (see chapter V) and should therefore be suitable for *P. pantherina*. The population historically known from the lower Mountain Fork River that was extirpated following construction of Broken Bow reservoir may have disappeared because of the drastic fluctuations in discharge that resulted from hydropower generation. It appears that long-term or permanent loss of preferred habitat or extreme variability of stream flows over short time periods would almost certainly have a detrimental effect on populations

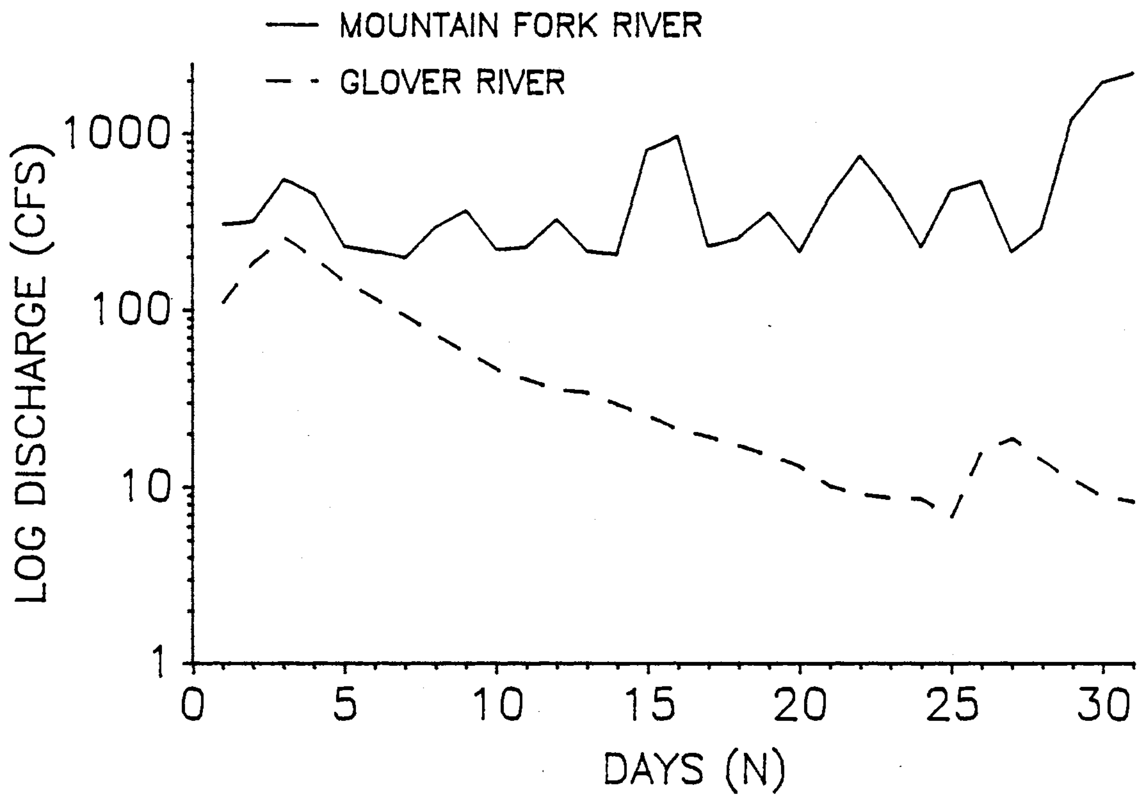

Figure 68. Mean daily discharges from Mountain Fork River and Glover River during July 1986.

of *P. pantherina*

The use of habitat simulations similar to the ones presented here may prove to be a valuable tool in determining the effects of proposed water projects on aquatic habitats. The simulations also provide a quantitative basis for addressing questions as to why some species disappear or decrease in abundance following changes in aquatic habitats. Grant (1986) listed conceptual formulation, quantitative specification, validation, and actual use as the four major phases of simulation modeling. The model presented here must first be validated before it can be useful in management decisions. Validation of the model in Glover River may not be possible because of the river's free-flowing nature. However, the precision in determining the relationships between mean water depth and preferred habitat area could be improved by measuring preferred habitat area over a wider range of discharges.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Underwater observations and measurements revealed that *P. pantherina* individuals inhabited pools exclusively during summer, fall, and winter. They were usually found in areas with water depths of 25-75 cm, substrates of rubble and boulder, and no detectable current velocity. In these areas individuals were usually seen swimming above the substrate and were rarely seen resting on the bottom. Individuals fed predominantly on nymphs of mayflies and larvae of blackflies and midges.

P. pantherina exhibited a shift in habitat preference from pools to riffles in late February and early March. Spawning occurred on riffles from mid-March to mid-April at water temperatures of 12-17 ^{o}C. Initiation of spawning appeared to be influenced more by daylength than by water temperature. Eggs were buried in patches of fine gravel at water depths of 30-90 cm with current velocities of 0-50 cm/s. Larvae hatched in about seven days and presumably drifted downstream into pools. Growth was extremely rapid with the young-of-year attaining an adult size by mid-August. Juveniles inhabited the same habitats within pools as the adults. All individuals involved in spawning were

Age-I and maximum longevity was about 18 months. The survival of future populations therefore appears dependent upon successful annual reproduction. Population abundances were relatively low at all sites and decreased continually throughout summer months.

The life history of P. pantherina was characterized by rapid growth to maturity, short longevity, and high mortality of post-spawning and young-of-the-year individuals. These characteristics, as well as stochastic environmental effects, caused P. pantherina population abundances to fluctuate drastically from year to year.

Spawning occurred only on riffles that had specific water depth and substrate characteristics. Most riffles in Glover River lacked suitable spawning substrate (deposits of fine gravel). Although the amount of spawning habitat on suitable riffles did not appear to be a limiting factor, the number of suitable spawning riffles within Glover River appeared to be limiting. The suitability of riffles for spawning by P. pantherina might be improved if suitable spawning substrate could be placed in areas of preferred water depth and current velocity.

P. pantherina's specific habitat preference was identified as areas with water depths of 25-75 cm, rubble and boulder substrate, and no detectable current velocity. It was determined that a minimum of 240 m^2 of this preferred habitat within a 45 m-long stream section was necessary for an area to be suitable for *P. pantherina*. The occurrence of *P. pantherina* was successfully predicted at sites throughout the Little River drainage based on the presence or absence of preferred habitat. *P. pantherina* population abundance at the study sites was proportional to the amount of preferred habitat available. The relationship between *P. pantherina* population abundance and preferred habitat area suggested that this habitat may be limiting. Therefore, it appears that the population abundance of *P. pantherina* at a site would change in proportion to any gain or loss of preferred habitat at the site.

Computer simulations of changes in stream flow and the response of *P. pantherina*'s preferred habitat area revealed the upper and lower limits of stream discharges necessary to maintain preferred habitat at each study site. Based on the simulations any major increase or decrease in either discharge or water depth would result in a decrease in the amount of preferred habitat at the study sites, and thus a decrease in *P. pantherina*'s abundance.

In conclusion, the future survival of *P. pantherina* in the Little River drainage appears directly dependent upon the identification, protection, maintenance, and adequate accessibility by *P. pantherina* to areas of preferred habitat and preferred spawning habitat.

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APPENDIXES

APPENDIX A

HABITAT PREFERENCE DATA FROM PERCINA PANTHERINA CAPTURE LOCATIONS IN GLOVER RIVER, OKLAHOMA 1986-1988

Date	Site	N	Mean SL (mm)	Mean water depth (cm)	Mean substrate value	Mean current velocity (cm/sec)
1/19/86	4	4	54.75	59.47	6.25	5.50
2/22/86	1	4	45.25	100.46	7.00	14.00
2/23/86	5	1	74.00	62.78	5.00	4.00
6/24/86	5	3	39.00	39.04	7.00	0.00
6/25/86	4	7	31.57	44.38	6.00	2.00
9/19/86	1	9	57.56	36.37	5.89	2.22
9/20/86	2	4	52.00	39.78	6.00	0.00
9/21/86	6	4	57.25	39.31	5.50	0.00
11/1/86	1	2	62.50	43.17	6.00	16.00
11/3/86	4	3	58.00	46.15	6.00	1.33
11/29/86	6	3	49.67	54.30	6.00	0.00
1/24/87	6	1	64.00	42.78	6.00	46.00
1/25/87	6	1	56.00	66.22	6.00	36.00
2/6/87	5	4	61.00	71.31	5.00	0.00
3/7/87	5	7	61.14	67.51	5.43	17.14
3/9/87	6	6	56.83	63.83	6.00	14.67
3/10/87	4	10	58.70	51.28	5.70	15.60
3/11/87	2	3	61.00	45.22	5.67	7.33
3/28/87	6	12	63.42	55.23	5.75	19.00
4/12/87	5	3	58.67	57.82	6.00	0.00
4/25/87	2	7	57.14	51.86	5.86	0.00
4/26/87	5	1	53.00	49.33	7.00	0.00
4/26/87	6	1	49.00	38.00	6.00	0.00
5/20/87	2	7	23.43	45.14	6.00	0.00
5/21/87	1	10	34.10	58.64	6.70	0.00
6/12/87	1	12	53.25	51.13	6.50	8.17
6/14/87	3	8	38.00	53.71	6.25	6.00
7/16/87	1	14	56.86	48.71	6.50	0.00
7/17/87	6	4	55.25	40.42	6.25	0.00
7/21/87	2	13	42.38	42.30	6.46	0.00
7/22/87	3	16	47.38	44.43	6.56	0.00
7/22/87	4	16	50.50	35.60	6.06	0.00
7/23/87	5	6	59.33	54.09	6.00	0.00
8/11/87	5	1	53.00	50.37	5.00	0.00

APPENDIX A (Continued)

Date	Site	N	Mean SL (mm)	Mean water depth (cm)	Mean substrate value	Mean current velocity (cm/sec)
8/12/87	3	10	50.40	57.60	6.60	0.00
8/12/87	4	5	52.80	110.76	6.60	0.00
8/13/87	1	10	55.90	52.20	6.40	0.00
9/12/87	2	10	51.70	52.11	6.00	0.00
9/12/87	3	11	57.18	39.44	6.27	0.00
9/13/87	1	10	59.20	56.60	6.30	0.00
10/10/87	4	2	63.50	28.06	7.00	0.00
1/30/88	4	1	54.00	63.78	7.00	18.00
1/30/88	5	4	70.00	57.11	7.25	0.00
3/5/88	5	2	61.50	77.44	6.50	9.00
3/7/88	6	3	60.00	67.74	5.67	10.00
4/10/88	6	2	66.50	30.83	5.50	7.00
5/27/88	1	5	27.20	68.49	6.20	0.00
5/27/88	2	5	23.60	55.84	6.00	0.00
5/27/88	4	1	29.00	45.78	6.00	0.00

APPENDIX B

STANDARD LENGTH (SL) DATA FROM ALL PERCINA PANTHERINA SPECIMENS CAPTURED IN GLOVER RIVER, OKLAHOMA 1985-1988

Date	Site	N	Mean SL	Range
10/26/85	4	3	42.67	41-45
1/5/86	4	1	60.00	60
1/19/86	4	13	54.38	42-66
2/22/86	1	4	45.25	42-48
2/23/86	5	11	55.64	40-74
3/1/86	4	20	49.60	42-65
3/10/86	5	5	62.00	50-77
3/29/86	5	4	59.00	52-78
3/30/86	4	4	48.00	46-50
5/30/86	4	9	41.11	21-52
6/24/86	5	3	39.00	27-46
6/25/86	4	9	31.56	26-54
7/11/86	6	14	36.71	20-73
7/12/86	2	14	28.43	19-43
7/13/86	1	27	29.74	18-44
7/14/86	3	15	32.00	19-44
7/31/86	4	28	25.54	18-41
8/3/86	5	13	43.85	31-62
8/12/86	1	2	46.00	45-47
8/12/86	6	6	56.50	40-66
8/13/86	2	10	44.90	42-47
8/13/86	3	18	48.83	44-52
8/30/86	4	14	52.36	48-57
8/31/86	5	7	52.57	46-66
8/31/86	6	4	50.00	42-61
9/19/86	1	9	57.56	55-62
9/20/86	2	4	52.00	50-55
9/21/86	6	4	57.25	51-64
11/1/86	1	2	62.50	61-64
11/3/86	4	3	58.00	57-60
11/29/86	6	3	49.67	45-56
1/24/87	6	1	64.00	64
1/25/87	6	1	56.00	56
2/6/87	5	4	61.00	52-70
3/7/87	5	7	61.14	52-71
3/9/87	6	6	56.83	51-61
3/10/87	4	10	58.70	52-65
3/11/87	2	3	61.00	54-66
3/28/87	6	12	63.42	56-68
4/12/87	5	3	58.67	54-65
4/25/87	2	7	57.14	52-62

APPENDIX B (Continued)

Date	Site	N	Mean SL	Range
4/26/87	5	1	53.00	53
4/26/87	6	1	49.00	49
5/20/87	2	7	23.43	18-25
5/21/87	1	21	34.09	22-69
6/12/87	1	60	40.90	27-81
6/14/87	3	22	35.77	29-69
7/16/87	1	35	54.06	45-81
7/17/87	6	4	55.25	47-70
7/21/87	2	26	42.85	35-47
7/22/87	3	32	46.75	39-67
7/22/87	4	16	50.50	44-55
7/23/87	5	6	59.33	48-71
8/11/87	5	1	53.00	53
8/12/87	3	12	49.92	41-55
8/12/87	4	5	52.80	48-59
8/13/87	1	18	56.61	52-71
9/12/87	2	11	51.91	46-55
9/12/87	3	16	56.88	54-68
9/13/87	1	33	58.36	54-72
10/10/87	4	2	63.50	62-65
1/30/88	4	1	54.00	54
1/30/88	5	4	70.00	68-73
3/5/88	5	2	61.50	61-62
3/7/88	6	3	60.00	58-63
4/10/88	6	13	65.69	58-76
5/26/88	3	4	45.50	21-70
5/27/88	1	11	37.72	21-68
5/27/88	2	11	34.91	22-66
5/27/88	4	1	29.00	29
7/9/88	2	24	37.83	29-69
7/9/88	3	25	45.96	33-70
7/10/88	1	13	51.85	41-76
7/10/88	4	13	43.15	38-47
7/10/88	5	2	41.50	39-44
7/10/88	6	8	48.63	37-66
9/10/88	1	4	55.25	53-57
9/10/88	2	6	48.50	45-52
9/11/88	3	14	53.21	46-70
9/11/88	4	8	58.13	54-60
9/11/88	5	1	54.00	54
9/11/88	6	1	51.00	51

APPENDIX C

FREQUENCY DISTRIBUTIONS OF PERCINA PANTHERINA HABITAT PREFERENCE AND HABITAT AVAILABILITY FOR WATER DEPTH, SUBSTRATE, AND CURRENT VELOCITY

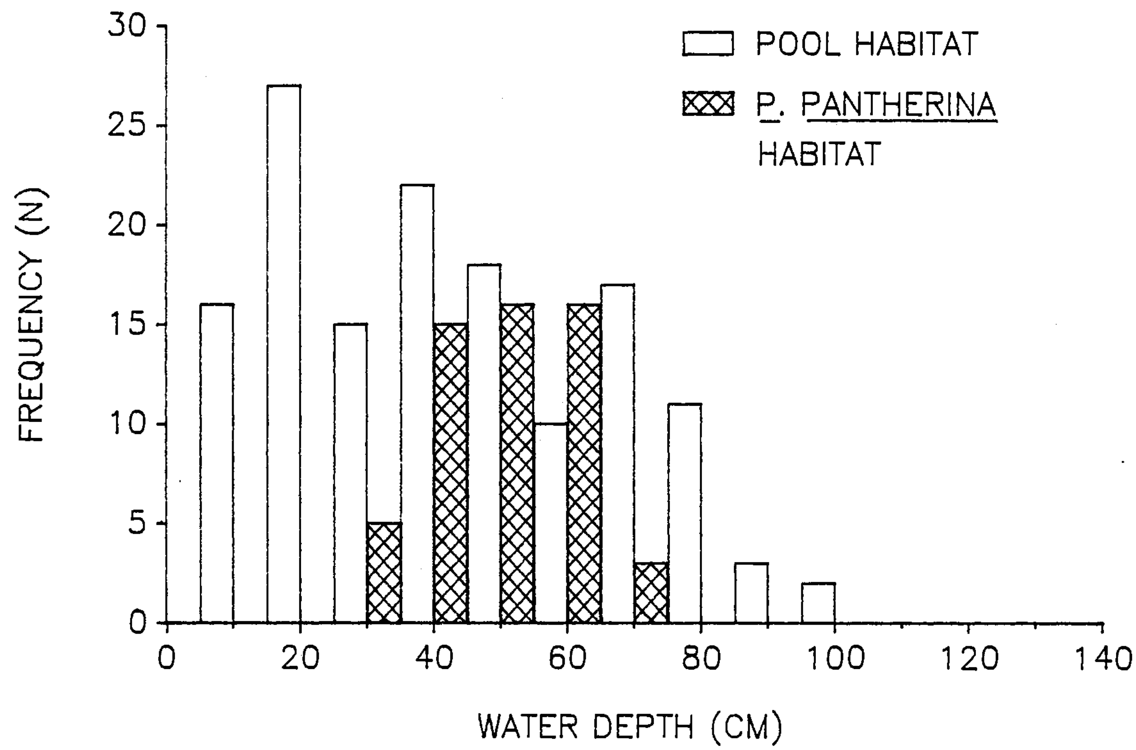

Figure 69. Frequency distributions of water depths at P. pantherina capture locations and at points along habitat transects at site 1 in Glover River.

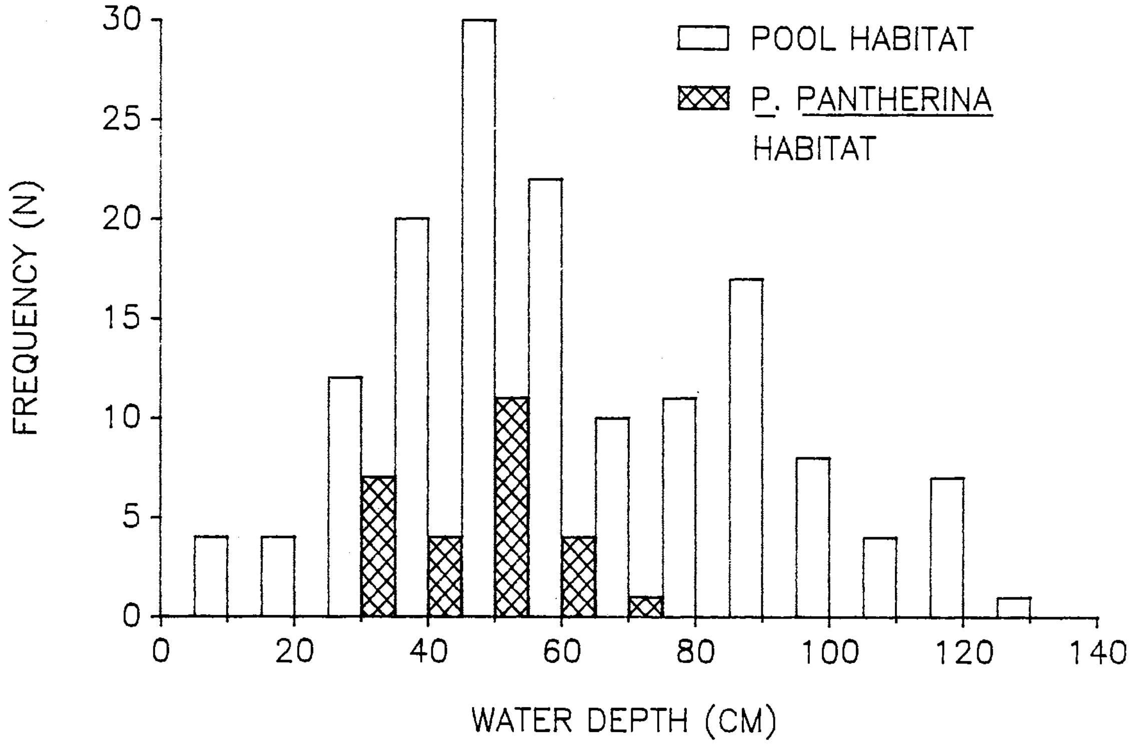

Figure 70. Frequency distributions of water depths at P. pantherina capture locations and at points along habitat transects at site 2 in Glover River.

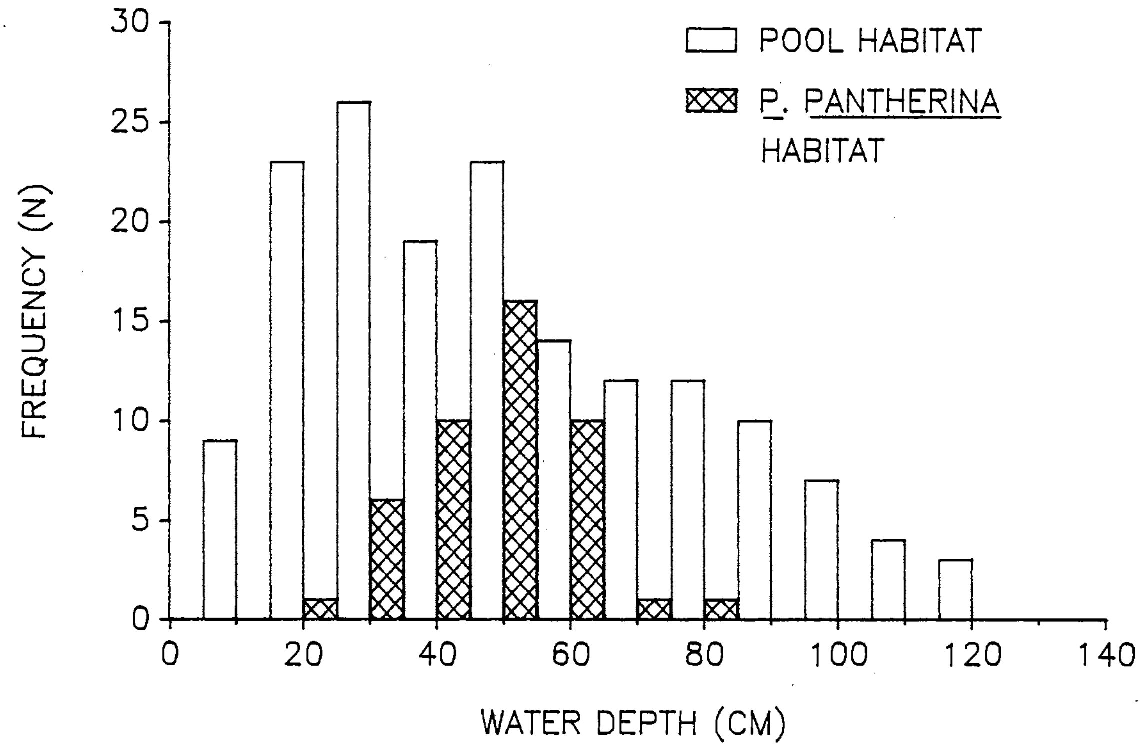

Figure 71. Frequency distributions of water depths at _P. pantherina_ capture locations and at points along habitat transects at site 3 in Glover River.

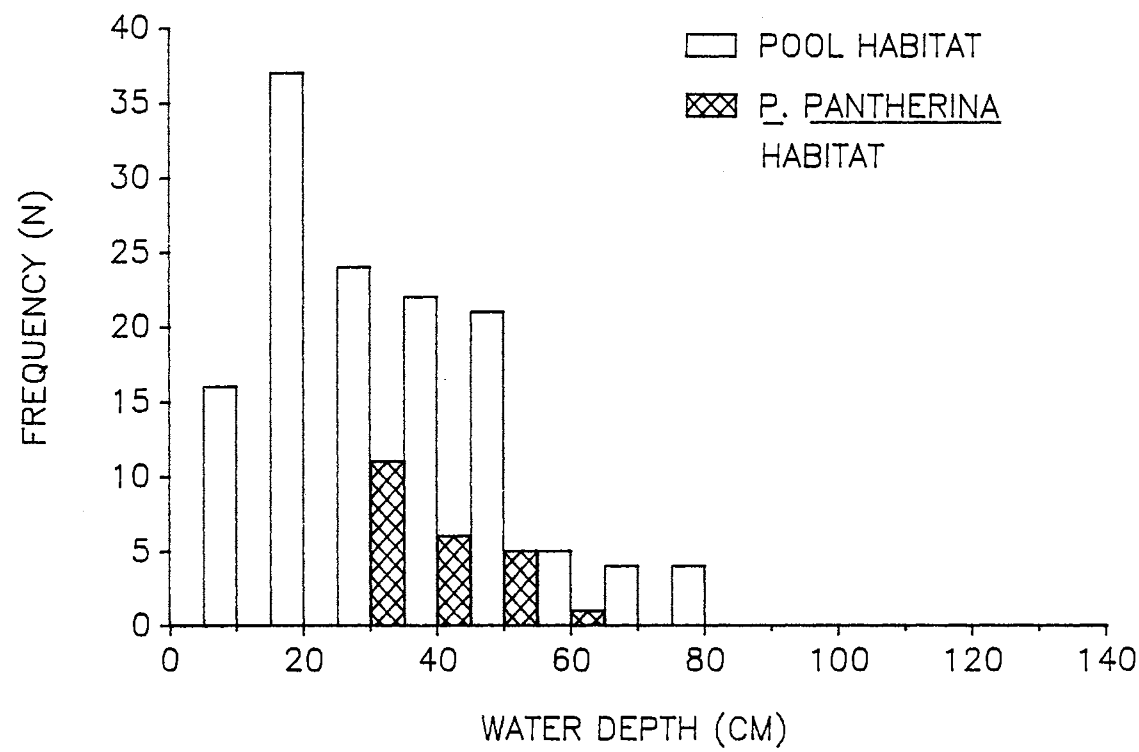

Figure 72. Frequency distributions of water depths at *P. pantherina* capture locations and at points along habitat transects at site 4 in Glover River.

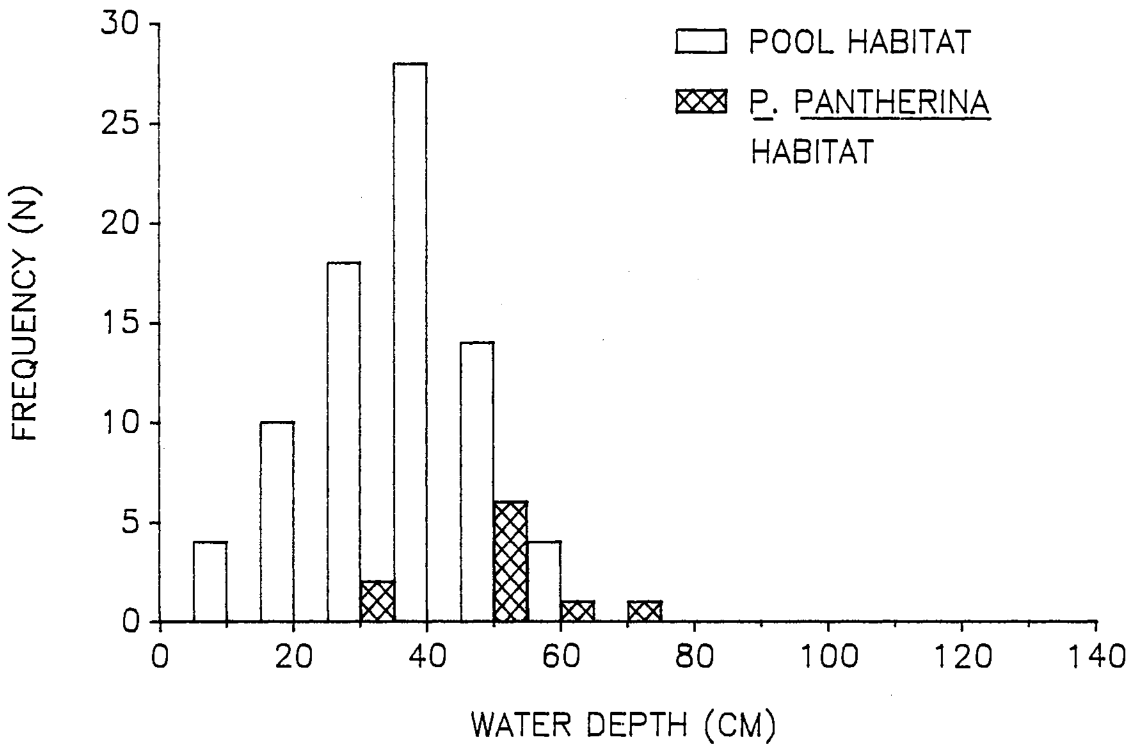

Figure 73. Frequency distributions of water depths at P. pantherina capture locations and at points along habitat transects at site 5 in Glover River.

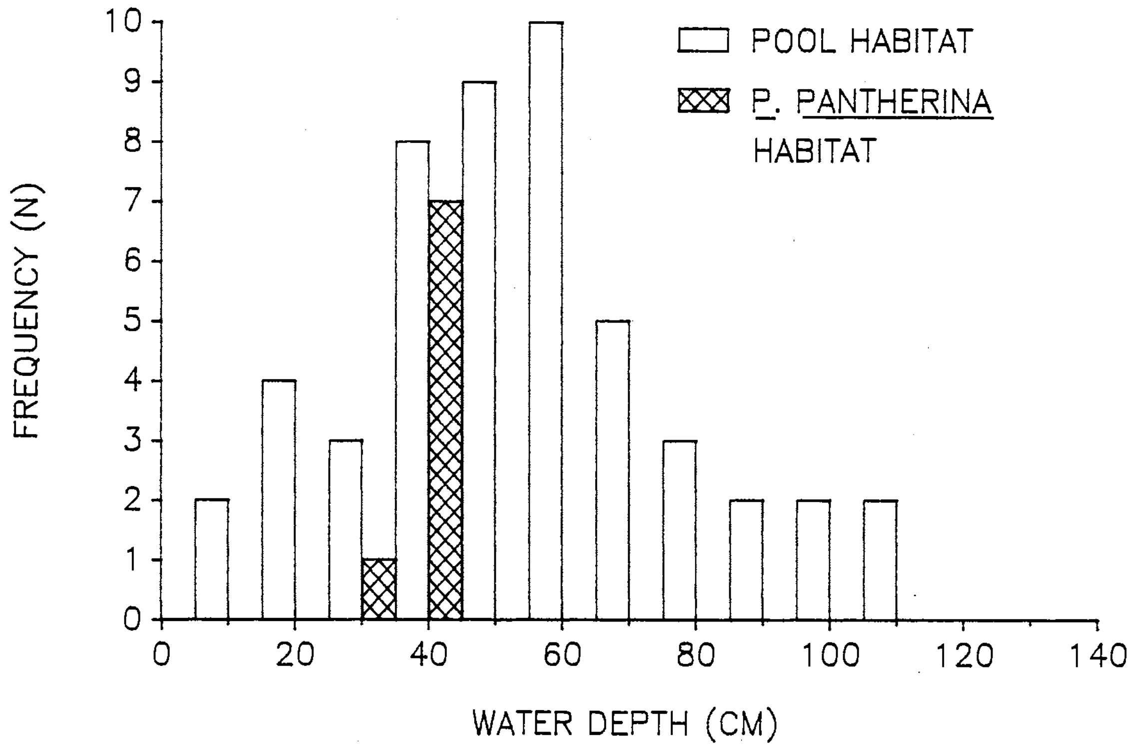

Figure 74. Frequency distributions of water depths at P. pantherina capture locations and at points along habitat transects at site 6 in Glover River.

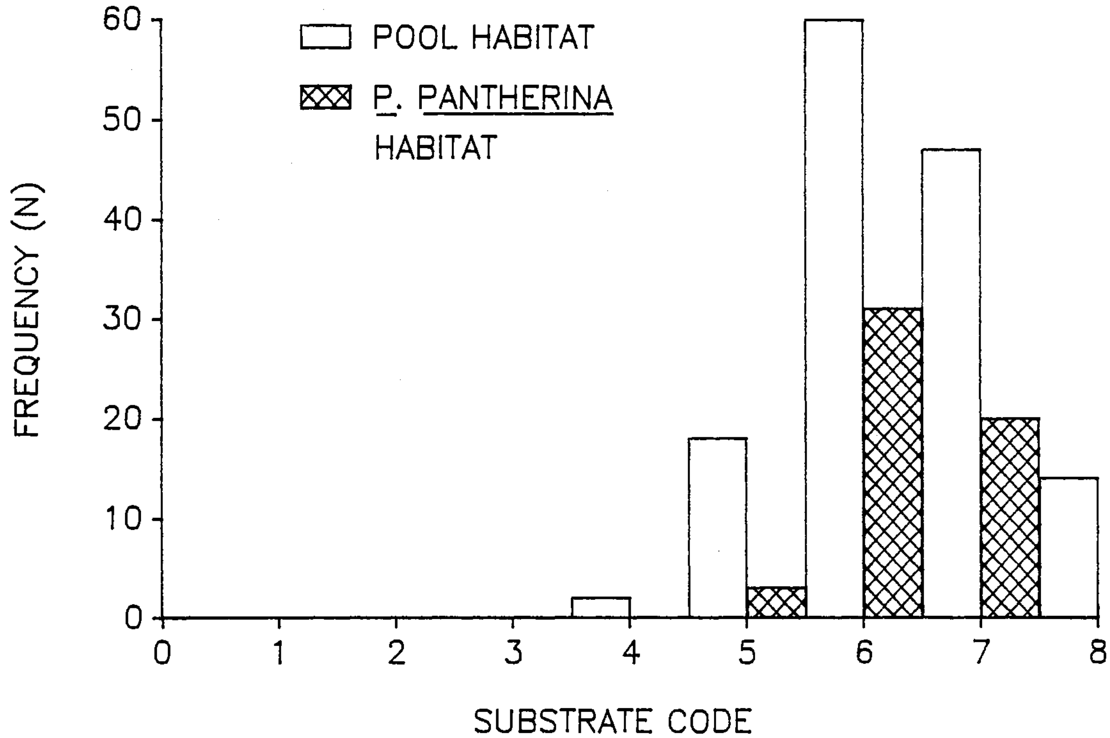

Figure 75. Frequency distributions of substrates at P. pantherina capture locations and at points along habitat transects at site 1 in Glover River.

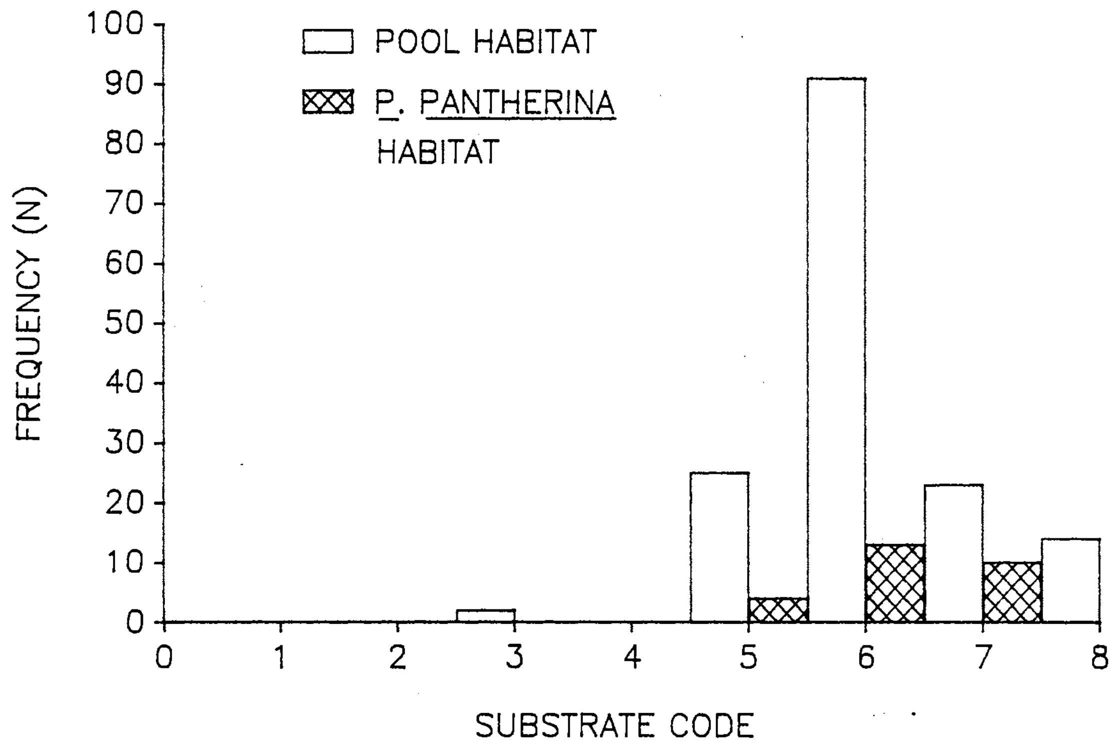

Figure 76. Frequency distributions of substrates at P. pantherina capture locations and at points along habitat transects at site 2 in Glover River.

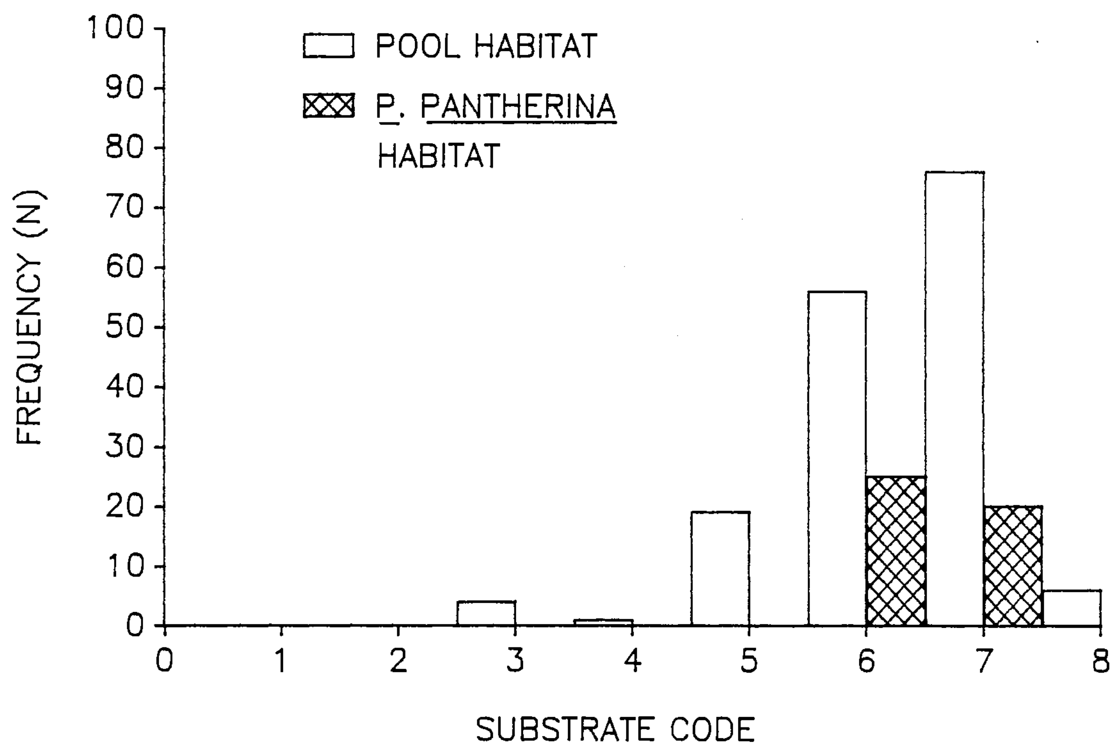

Figure 77. Frequency distributions of substrates at P. pantherina capture locations and at points along habitat transects at site 3 in Glover River.

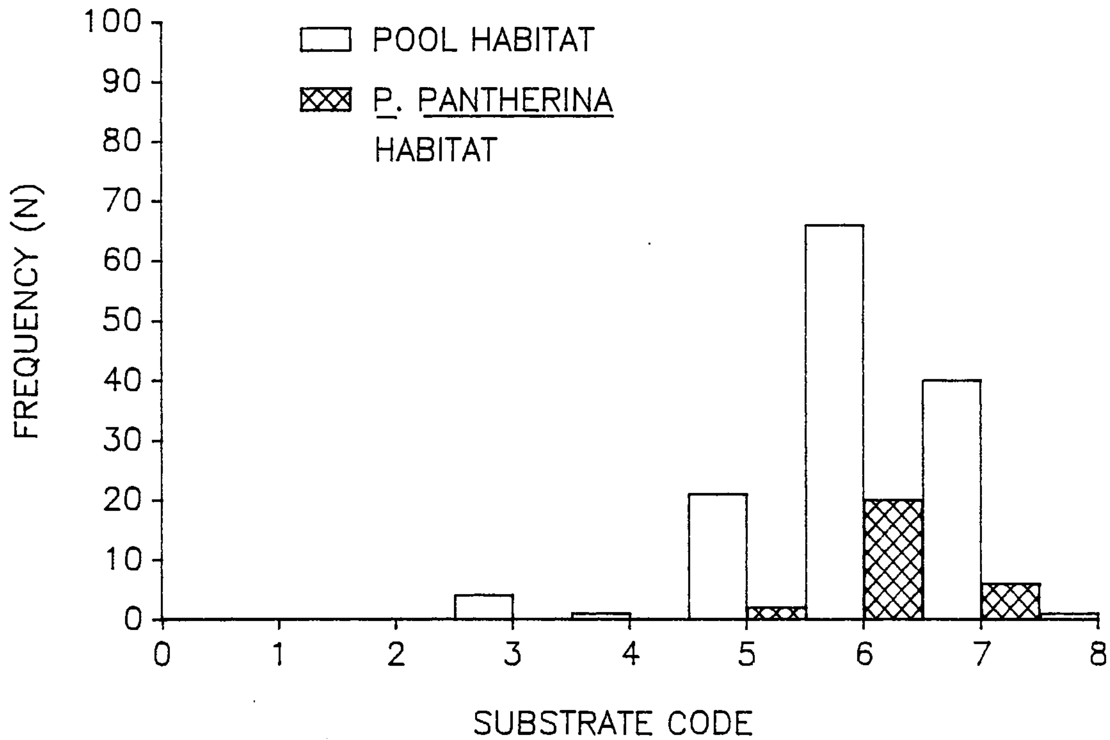

Figure 78. Frequency distributions of substrates at P. pantherina capture locations and at points along habitat transects at site 4 in Glover River.

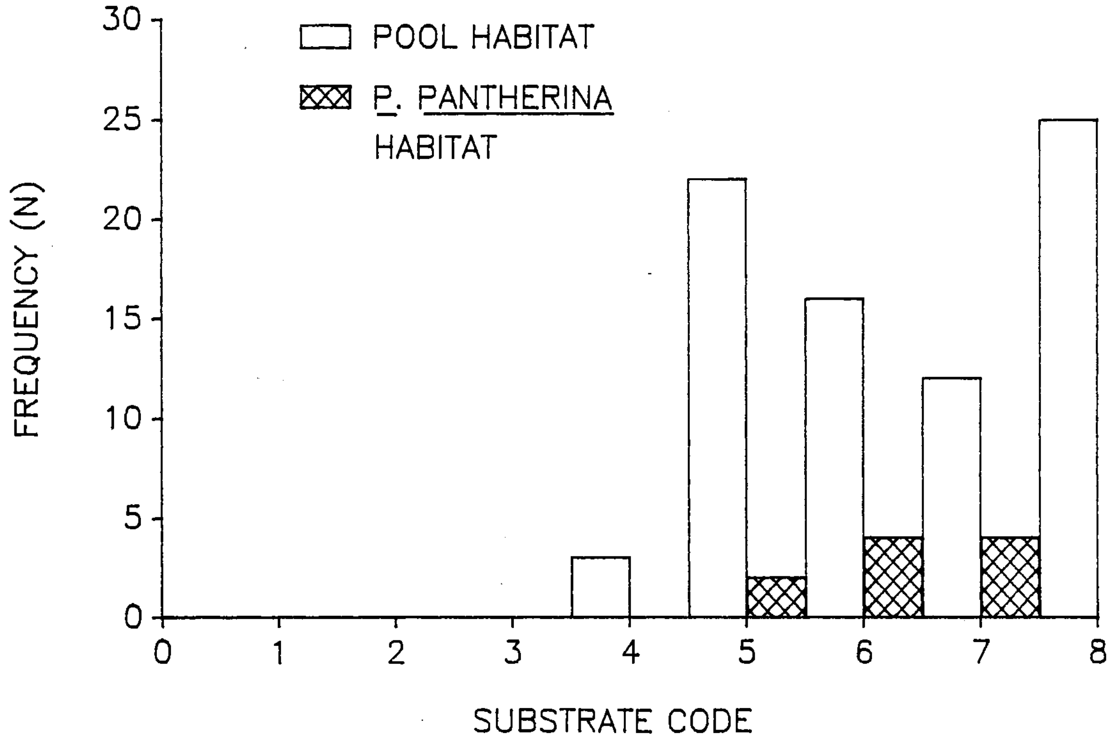

Figure 79. Frequency distributions of substrates at P. pantherina capture locations and at points along habitat transects at site 5 in Glover River.

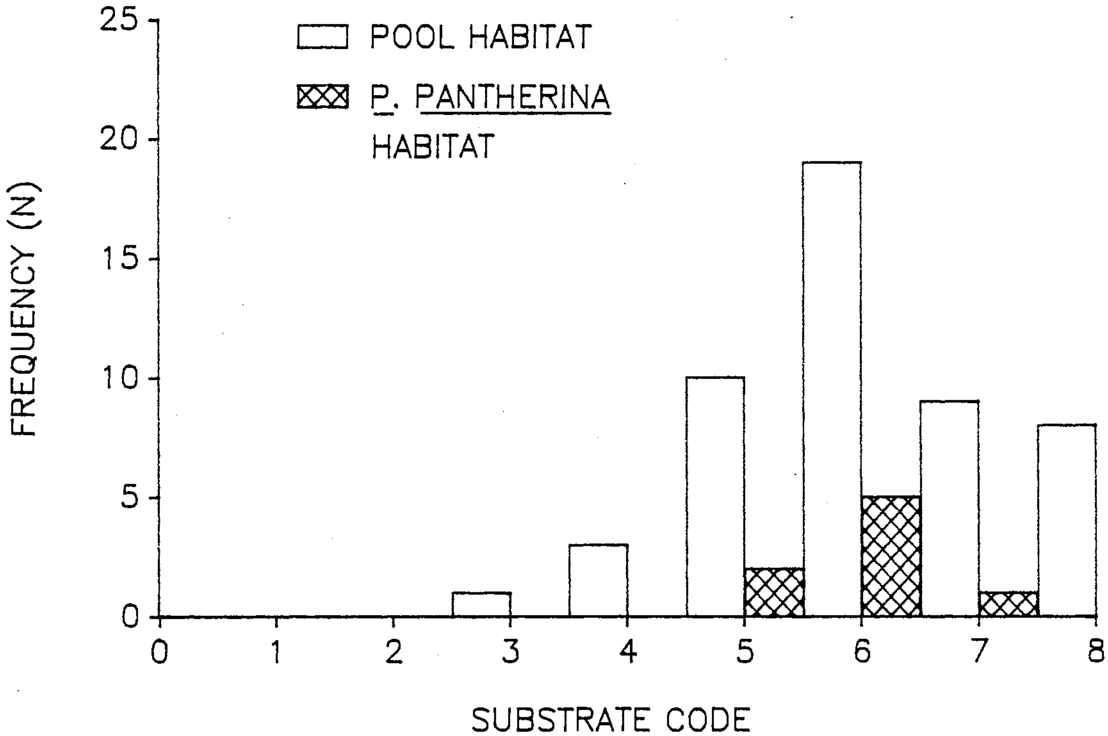

Figure 80. Frequency distributions of substrates at _P. pantherina_ capture locations and at points along habitat transects at site 6 in Glover River.

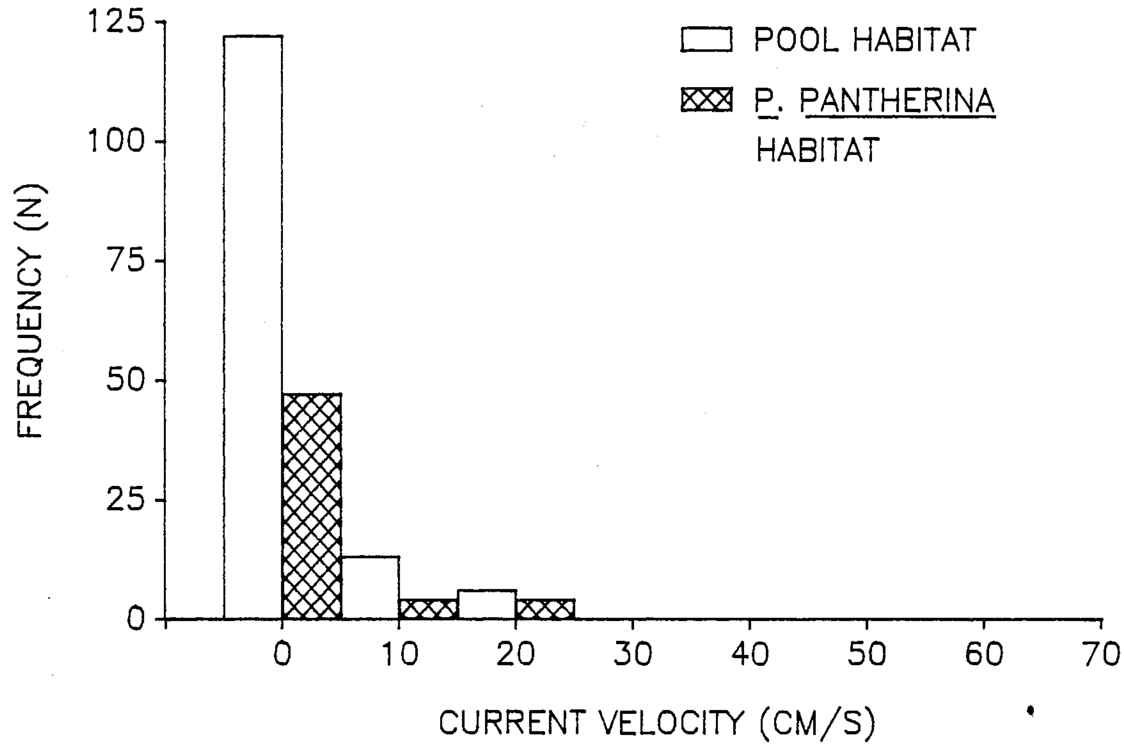

Figure 81. Frequency distributions of current velocities at P. pantherina capture locations and at points along habitat transects at site 1 in Glover River.

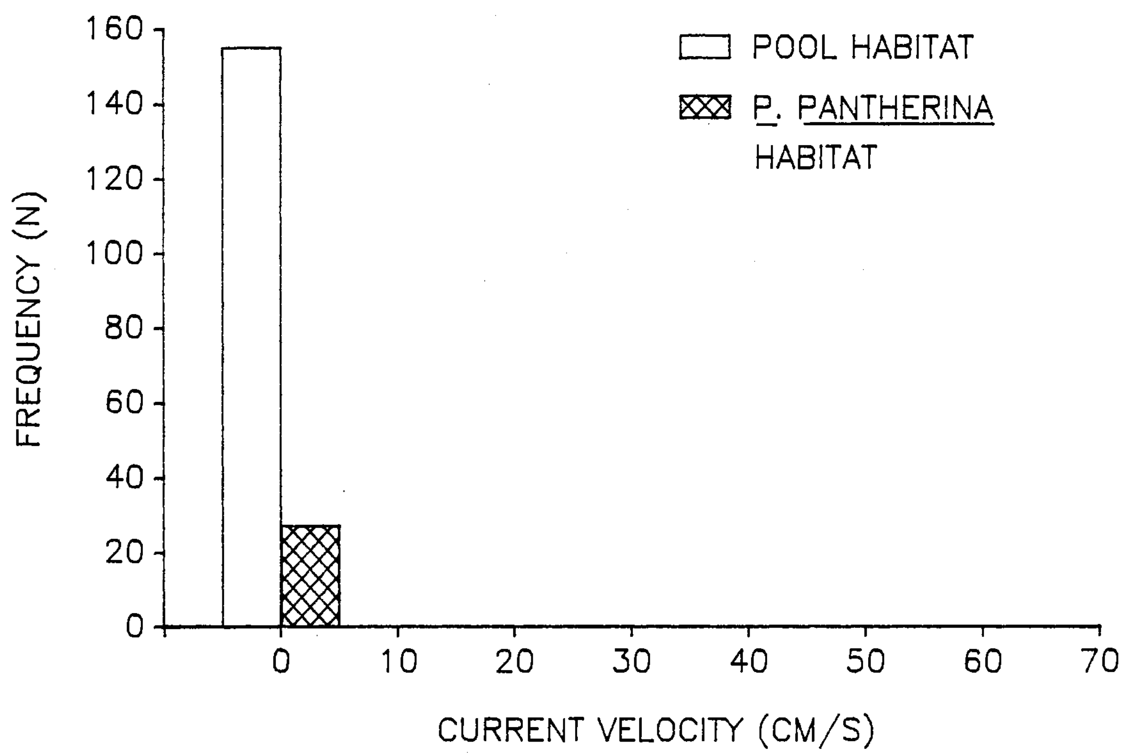

Figure 82. Frequency distributions of current velocities at P. pantherina capture locations and at points along habitat transects at site 2 in Glover River.

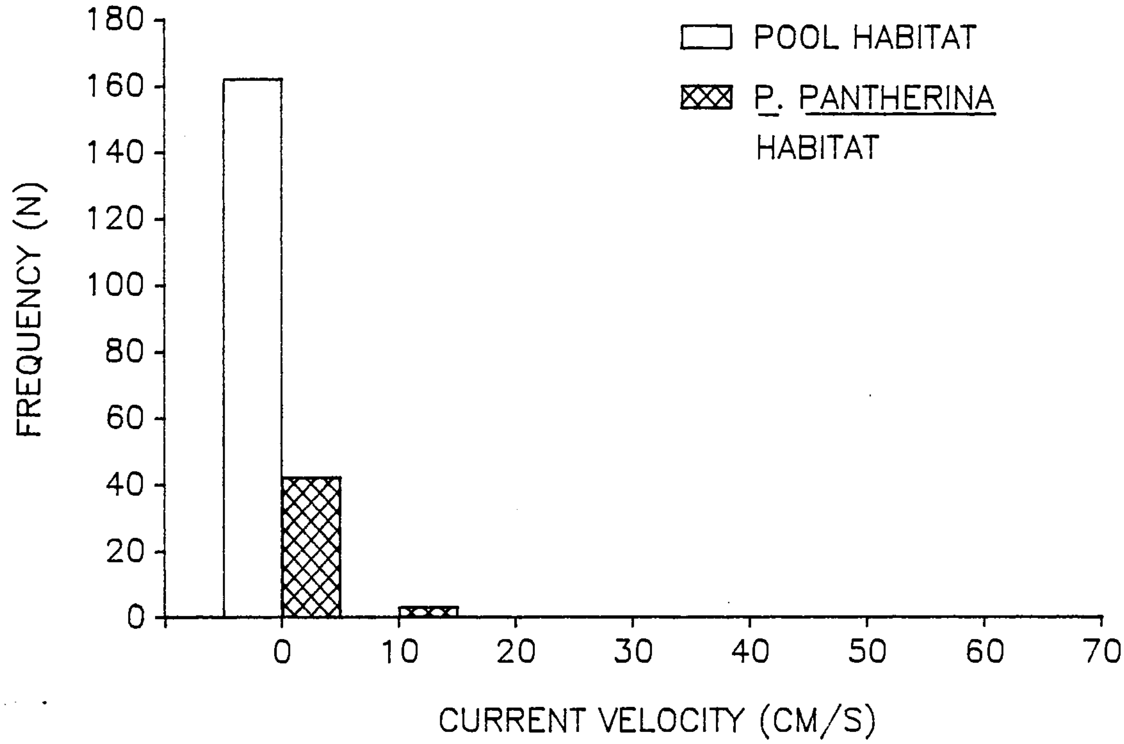

Figure 83. Frequency distributions of current velocities at *P. pantherina* capture locations and at points along habitat transects at site 3 in Glover River.

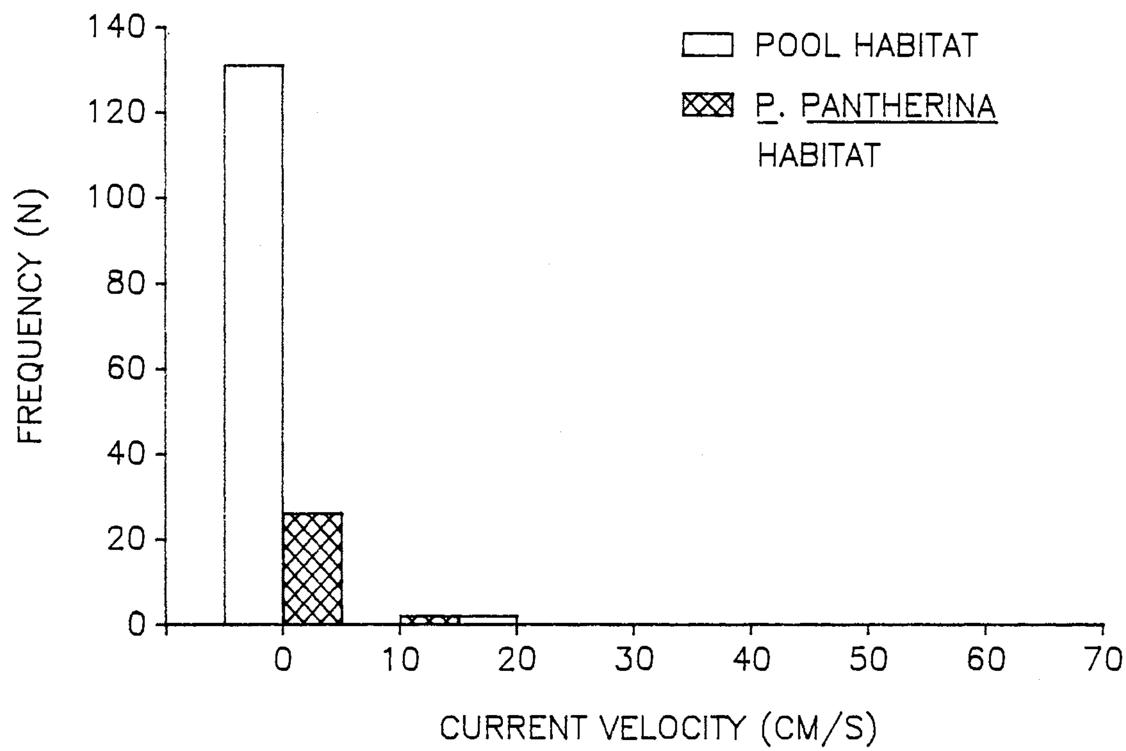

Figure 84. Frequency distributions of current velocities at P. *pantherina* capture locations and at points along habitat transects at site 4 in Glover River.

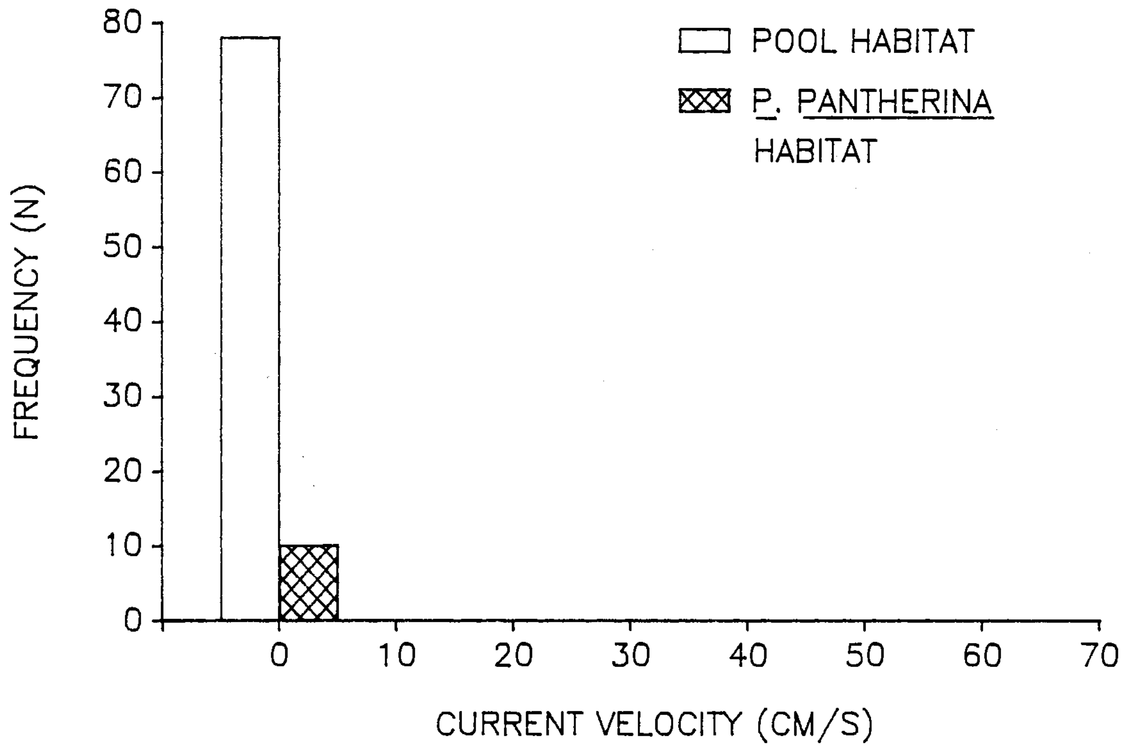

Figure 85. Frequency distributions of current velocities at *P. pantherina* capture locations and at points along habitat transects at site 5 in Glover River.

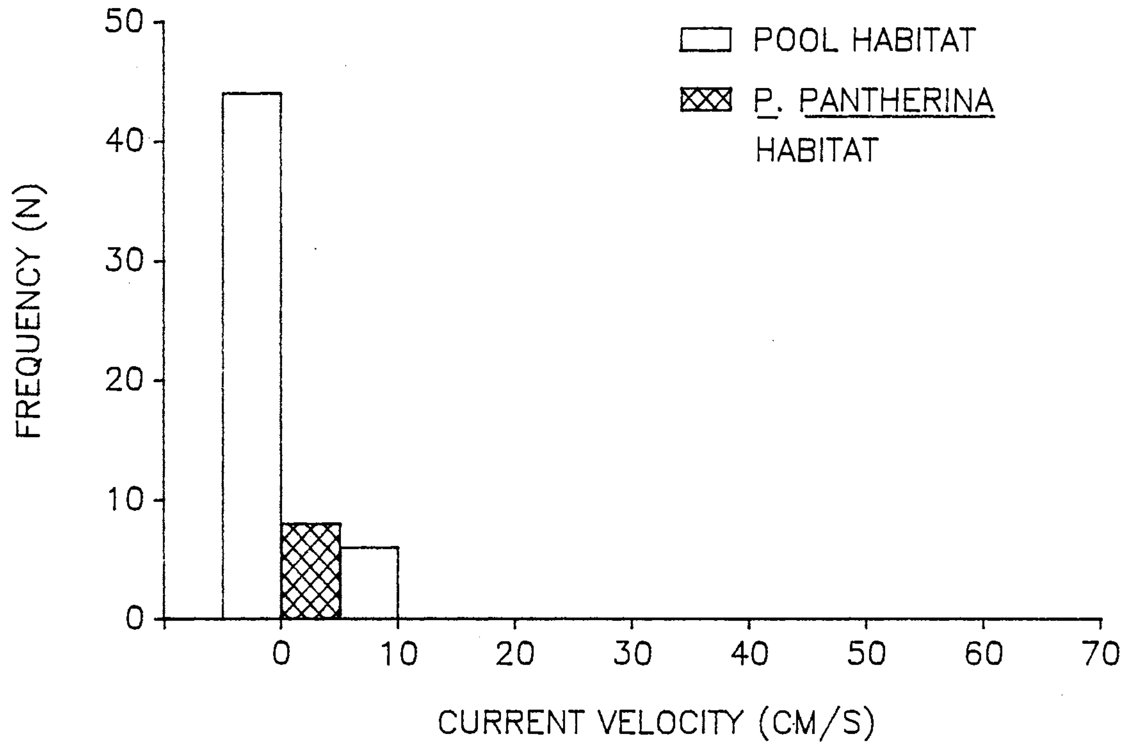

Figure 86. Frequency distributions of current velocities at P. *pantherina* capture locations and at points along habitat transects at site 6 in Glover River.

VITA

Paul William James

Candidate for the degree of

Doctor of Philosophy

Dissertation: REPRODUCTIVE ECOLOGY AND HABITAT PREFERENCE OF THE LEOPARD DARTER, PERCINA PANTHERINA

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American Fisheries Society
Oklahoma Academy of Science
Sigma Xi