REPRODUCTIVE BIOLOGY AND POPULATION STRUCTURE OF THE PLAINS MINNOW, *HYBOGNATHUS PLACITUS* (PISCES: CYPRINIDAE), IN CENTRAL OKLAHOMA

By

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PREFACE

The main objective of this study was to describe several aspects of the life history of the plains minnow, *Hybognathus placitus*. This fish is small, not particularly attractive, and possesses no economic value, other than its occasional use as a bait fish. Like many other of our native, nongame fishes, it is not well known to the general public (if at all). However, plains minnows are an integral part of many prairie river ecosystems. In many rivers they are (or used to be) an extremely abundant species, providing a large forage base for "game species" and other piscine predators, as well as avian predators. Recently (the last 40 years or so), plains minnows have declined in range and abundance due to man's impact on their environment. Much riverine habitat has been replaced by a relatively new type of ecosystem to Oklahoma, ie., the many reservoirs found throughout the state. Water quality has suffered due to sewage effluent, hazardous chemicals, and feedlot wastes. Introduction of non-native fishes, intentional or not, has also taken its toll. These are some of the problems our native fishes are facing today.

This study focuses on only one animal. In order to preserve our native fish fauna, baseline life history studies like this, as well as studies at the community level, are needed before long-term management decisions are made. The more we understand each component of an ecosystem and how the various components interact, the better that ecosystem can be managed to benefit man as well as its original inhabitants.

I wish to express my thanks and appreciation to Dr. R.J. Miller for serving as major adviser, suggesting this study, and for his encouragement and advice. I especially thank him for first sparking my interest in fishes several years ago.

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CHAPTER I

INTRODUCTION

The plains minnow, *Hybognathus placitus* Girard, is found throughout the plains states from Montana and North Dakota south to Texas (Miller and Robison, 1973), but is essentially limited to large rivers having exposed, shallow, sand-filled channels (Cross et al., 1985). This species does not commonly occur in small, intermittent creeks or in rivers with a rocky or muddy substrate (Cross, 1967), although high turbidity is tolerated. *H. placitus* has a statewide distribution in Oklahoma, although it is most common in the large, sandy rivers of the western half of the state (Miller and Robison, 1973).

During the 1940's, Moore (1944) found that plains minnows were the most abundant species of fish in the Arkansas River system. This species was previously common in northwestern Oklahoma (Hubbs and Ortenburger, 1927) where in many areas it is seemingly rare now (Pigg, 1987). Cross et al. (1985) found that the abundance and distribution of *H. placitus* has decreased substantially in western portions of the Arkansas River and the Cimarron River in Kansas.

The breeding season of *H. placitus* is long in Kansas, extending from April into August (Cross, 1967). In central

Oklahoma (Cimarron River) spawning has been reported to peak in May and June with a secondary peak in August (Miller and Robison, 1973). Presumably, the eggs are scattered over the substrate communally with no nest guarding or territorial behavior (Cross, 1967). Summer growth of *H. placitus* is rapid; in Missouri (Grand River) they reportedly reach a length of 28 to 43 mm by early September of their first year (Pflieger, 1975).

The life history of *H. placitus* is poorly known and all treatments in the literature have been brief, descriptive comments. Accordingly, the objectives of this paper are to describe the reproductive biology and age and growth characteristics of this cyprinid and to relate between-year differences in reproductive patterns to certain features of the environment. This basic life history information may be helpful in understanding why plains minnows are declining in range and abundance, and may be useful in the overall understanding of prairie river ecosystems.

CHAPTER II

DESCRIPTION OF THE STUDY AREA

The Cimarron river in central Oklahoma is typical of most big prairie streams. Seasonal water flow varies tremendously throughout the year. Flow at the study sites was maintained throughout the study and ranged from 3.7 cms (cubic meters per second) on 4 August 1986 to 4616.2 cms (Perkins gauging station) on 4 October 1986. However, upstream in Kansas and the Oklahoma Panhandle, sections of the river often undergo long periods of no flow.

At the study sites, braided channels of shallow, slow moving water separated by large emergent sandbars characterize the river during dry periods. During times of high rainfall and heavy runoff, the river may have no visible sand bars, a swift current, and deep water. High water levels are most common during the spring and fall, although heavy precipitation can bring flows up at any time of the year. Flooding is not uncommon and can occur very quickly. Channel substrates are composed mostly of sand, although some main channel areas have a considerable amount of sandstone gravel interspersed in the sand. Backwater substrates are usually composed of soft, silty mud and generally are covered with an organic ooze. Water quality is variable with total dissolved solids occasionally exceeding that of seawater in some upstream areas (OWRB, 1972). The high mineral content is due primarily to high levels of sodium chloride and calcium sulfate (gypsum), both of which occur naturally in the river. The water is usually turbid, with clarity increasing slightly during extended dry periods. The immediate banks of the river support thick stands of salt cedar, cottonwood, willow, and pasture with occasional rocky bluffs and hillsides supporting oak-woodland.

CHAPTER III

MATERIALS AND METHODS

Plains minnows were collected from April 1986, through August 1987, at two sites separated by approximately 8 km of river: Station 1, 2 km N of Pleasant Valley, Logan County, Oklahoma (section 27, T18N, R1W), and Station 2, 1.6 km NE of Coyle, Logan County, Oklahoma at the state highway 33 bridge (section 8, T17N, R1E). Both sites are on the Payne-Logan county line. Samples were taken once a month (when possible) during the non-reproductive season and two to three times a month when the fish were reproductively active. All fish were pooled together due to the close proximity of the study sites.

Seines of varying mesh sizes and lengths and fine mesh dipnets were used for sampling all sizes of fish. All specimens were immediately placed in 10% formalin for fixation and later transferred to 43% isopropyl alcohol for preservation and storage until processed.

Daily precipitation and daily air temperatures were obtained from the Oklahoma State University Agronomy Department for an area in close proximity to the study sites (about 16 km E of station 2). Daily flow rates were obtained from a U.S. Geological Survey gauging station at

Perkins, Oklahoma, located about 26 km downstream from station 2. Daylengths were obtained from the Nautical Almanac Office of the United States Naval Observatory for the Oklahoma City area.

Size at sexual maturity was based on observation of several samples taken at the onset of the reproductive season. Size differences in males and females and sex ratios were analyzed in several samples taken in 1986 and 1987. Sex was determined for six hundred and ninety-nine fish by gonadal examination. G-tests (Sokal and Rohlf, 1980) were used to test for any significant deviations from the 1:1 sex ratio. A two-way analysis of variance was used to compare mean lengths of adult male and female plains minnows.

An analysis of the reproductive cycle was conducted by calculation of ovarian weights, measurements of ova, and gross examination of ovaries and testis. Ovaries were dissected out, blotted on paper towels, and weighed to the nearest milligram. Ovarian weights and body weights were used to calculate a gonadosomatic index (GSI) for 322 specimens by the following formula:

$$GSI = \text{ovary weight/total body weight} \times 100$$

A mean GSI was calculated for each sample by averaging the GSI of 10-20 (when available) randomly picked females having a minimum size of 45 mm. During the reproductive season when adults and young-of-year were present, only adult females were used in this analysis; no young-of-year fish attaining 45 mm were sexually mature. After weighing each ovary, diameters from 10 of the largest ova were measured with an ocular micrometer in a dissecting microscope. Because ova were not always spherical, diameters were measured at the longest axis to minimize variation. Maturity in males was determined primarily by size and color of testis; tuberculation in H. placitus is poorly developed and was used to a lesser extent in gauging the maturation of males.

The ovaries of all females used in the above analysis were classified according to the criteria of Heins and Clemmer (1976) with some minor modifications. Ovaries were classified into the following four groups depending on their state of maturation: (1) Immature - ovaries small and thin; ova transparent to translucent in color, usually with a visible nucleus; mean size of largest ova less than 0.40 mm; GSI less than 1.0%. (2) Maturing - ovaries varying greatly in size depending on the extent of development; larger ova translucent to white or cream in color, without a visible nucleus. (3) Mature - ovaries quite large, filling most of the body cavity; mature ova cream to yellow-orange in color with a mean size ranging from 1.10 to 1.40 mm; GSI greater than 10.0%. (4) Spent - ovaries smaller than mature ovaries, with a relatively small number mature ova still remaining among the numerous maturing ova. All individuals fitting the maturing, mature, and spent categories were considered sexually mature adults. Individuals classified as being mature or partially spent were considered reproductive. Ova size-frequency histograms were prepared from ovary cross-sections taken from several fish in reproductive condition. All ova greater than 0.40 mm were measured to determine if more than one complement of ova was present.

Fecundity was estimated by direct counts of mature ova prior to spawning for 31 fish from 4 samples, collected throughout May and early June 1987. Mature ova were separated from maturing ova on the basis of size and color. Only fish having large, mature ovaries (GSI greater than 10.0%; mature ova present) were used for fecundity estimation. Regression analyses (SAS Institute, 1982) were conducted and various equations were used to determine the relationship between number of mature ova and standard length, and number of mature ova and body weight.

Age and growth of plains minnows were determined by an analysis of length frequency histograms. Scales were not used because annuli could not be reliably found. Standard length (SL) was measured to the nearest 0.10 mm for 4,080 individuals from 12 samples. Length-frequency histograms were prepared by plotting the percentage frequency of each 1 mm size group.

CHAPTER IV

RESULTS

Habitat and Associated Species

Plains minnows are usually collected in low-velocity, shallow water, next to emergent sand bars and in backwaters, where they feed on detritus, diatoms, and other microorganisms (Cross, 1967). I rarely collected *H. placitus* in moving water greater than 0.6 m deep or in areas having a sand/gravel substrate. Cross (1967) noted that plains minnows often inhabit the lee side of sand waves that remain in the main channels during low flow periods. Larval fish were found abundantly in small, shallow backwaters (sometimes less than 4 cm deep) on the fringes of emergent sandbars.

Twenty-nine species of fish were found in association with *H. placitus* at the study sites. Five species were collected frequently and were commonly found in seine hauls with plains minnows: *Notropis bairdi*, *N. atherinoides*, *N. lutrensis*, *Ictalurus punctatus*, and *Carpiodes carpio*. Species that were common, although collected less frequently, include *Pimephales vigilax*, *Gambusia affinis*, *Dorosoma cepedianum*, *Cyprinus carpio* and *Fundulus zebrinus*. Species taken that were rare or uncommon in the Cimarron

River include *Notropis blennius* (one individual was collected in May 1986), *Menidia beryllina*, and *Hybopsis storeriana*. Many species commonly found in the smaller tributaries of this region were occasionally collected in the river itself and include *Lepomis megalotus*, *L. microlophus*, *L. macrochirus*, *L. humilis*, *Pomoxis annularis*, *Micropterus salmoides*, *Italurus melas*, *Ictalurus natalis*, *Pimephales promelas*, *Notemigonus crysoleucas*, and *Phenacobius mirabilis*). The remainder were taken infrequently in seine hauls due to gear selectivity (*Morone chrysops*, *Aplodinotus grunniens*, *Lepisosteus osseus*, and *Pylodictus olivaris*).

Environmental Variability

Flow was maintained at both study sites throughout the sampling period, though mean monthly precipitation and mean monthly discharges were higher for most of the 1987 spawning season as compared to the corresponding time in 1986 (Fig. 1). During the 1986 reproductive season, daily flow rates ranged from 4.4 cms on 31 July to 337.0 cms on 18 May and 18 June. In 1987 (through July) discharges ranged from 45.0 cms on 29 June to 1580.1 cms on 29 May. Average monthly temperatures differed little between years during April, May, and August, although June and July temperatures were cooler in 1987 (Fig. 1).

Sexual maturation

The size at which plains minnows began to mature sexually varied greatly. Females as small as 43 mm were found with early maturing ovaries in late April of 1986 and 1987. However, two immature females 56 mm were collected on 22 May 1987. Male plains minnows showed the same variation in size at sexual maturation. Males as small as 44 mm were found with enlarging testis in late April 1987. However, several larger males (up to 61mm) in the same sample were immature and had translucent, thread-like testis. At the onset of the reproductive season, most males and females were sexually mature at 45-50 mm. However, no young-of-year individuals reaching this size during their first summer were observed to be sexually mature.

Sex Ratio

The sex ratio was determined from 699 adult fish in eight samples that were taken from September 1986 to August 1987. The G-test (Sokal and Rohlf, 1981) revealed statistically significant heterogeneity ($G=14.23$, $p<0.05$), meaning there was a difference in the proportion of males and females among the samples. A G-test performed on the pooled samples was not significant ($G=2.18$, $p>0.05$), indicating no departure from the 1:1 sex ratio overall. G-tests were then made in replication and significant deviations from the hypothesized 1:1 sex ratio occurred in September 1986 ($p<0.05$) and May 1987 ($p<0.05$) samples (females outnumbered males). June, July, and August samples also contained more females than males, although these differences were not significant. The higher frequency of females found in samples throughout the reproductive season could be due to sampling error. Some of the samples, especially those taken late in the reproductive season were quite small. Another possibility is that a behavioral response occurred during the spawning season and caused biased samples to be taken. Although departures from a 1:1 sex ratio were found, they were not great and do not appear to reflect a valid biological phenomenon.

Mean Size of Adult Males and Females

Analysis of mean size of adult male and female plains minnows indicated no interaction between the effects of sex and month (Table 1), therefore the two effects could be evaluated independently. The F-value for sex was non-significant, indicating that the mean sizes of adult males and females are not different.

Gonadosomatic Index

In 1986, a peak in the mean GSI occurred in May with a subsequent decline and leveling off through early July (Fig. 2). A smaller peak occurred in the latter half of July with a marked decline thereafter, until reaching a minimum value by late September 1986. Although a decrease in the mean GSI occurred after the May peak, mature and/or maturing individuals were found in all samples through August. The smaller peak occurring in late July could be a result of sampling error. However, length frequency data for July and August show a second, clearly-defined peak in numbers for young-of-year fish. Thus, a second burst of spawning activity occurred in mid-summer.

In 1987, mean GSI values indicated a slight increase in ovarian weight by March and a marked increase in weight by late April and early May (Fig. 2). Values were high throughout May and spawning was probably intense during most of this month. A gradual decrease in mean GSI occurred through July, although mature and/or maturing individuals occurred in all samples throughout this time period as they did the previous year. In early August a second peak in the mean GSI was seen. This peak occurred later in the season and was much stronger than the secondary peak seen in 1986. Seasonal variation in GSI for both years is shown in Table 2.

Ovum Development

Mature females possessed a complement of mature ova distinctly different in size from a large, variable group of immature and developing ova (Fig. 3a). Spent ovaries contained a relatively smaller number of mature ova among numerous immature and maturing ova (Fig. 3b). This type of developmental pattern suggests a reproductive strategy of intermittent or serial spawning (Macer, 1974), whereby batches of mature ova are released periodically throughout the reproductive season. Although the data indicate more than one spawning per individual, it could not be determined how many batches are produced.

In 1986, mean ovum diameters were high through July, and decreased thereafter until reaching a low in October (Fig. 2). Values increased markedly in March 1987, and followed closely the pattern of the mean GSI values (Fig. 2) thereafter.

Ovaries containing mature ova were found from late April to early September in 1986 and from late April to early August in 1987 (only one adult female was collected in late August 1987, the last sampling date, and no mature ova were found).

Fecundity

The problem associated with estimating fecundity in intermittent spawners is how to identify the oocytes that are capable of being released during the current reproductive season (Macer, 1974). In this study, fecundity (F) was estimated from the clutch sizes of 31 individuals collected throughout May and early June 1987.

Counts of mature ova ranged from 417 - 4,134 (mean = 817) in fish 51 - 87 mm (Fig. 4). GSI values for these fish ranged from 10.21% to 23.22%. Number of mature ova and standard length were highly correlated ($r = 0.89$; Fig. 4).

The linear regression equation expressing this relationship is:

$$F = -4479.32 + 89.94(SL)$$

Normally the relationship between egg number and length is curvilinear (Bagenal, 1978). In fact, the following second degree polynomial gave the highest correlation (r=0.96):

$$F = 7284.83 - 271.62(SL) + 2.71(SL^2)$$

The logarithmic transformation of both variables yielded a lower r coefficient (r = 0.85), but is presented here because it linearizes the data and equalizes variance along the regression line (Bagenal, 1978). The corresponding equation is:

$$\log F = \log 1.26 + \log 0.03(SL)$$

In other studies (e.g. Schemske, 1974; Mathur and Ramsey, 1974), fecundity has been related to body weight. Bagenal (1978) suggested that weight is a poor index of fecundity, since it changes significantly (due to increased ovary weight) as the spawning season approaches. Nevertheless, a strong correlation was found between number of ova and body weight (Fig. 5; r = 0.96). The linear regression equation expressing this relationship is:

$$F = -610.21 + 311.97(SL).$$

The 87 mm fish used in the fecundity analyses was much larger and much more fecund than the other individuals. This individual possessed 2.71 times the number of mature ova in the next largest fish (66 mm) and 9.91 times the number of mature ova in the smallest fish (51 mm). Removal of that individual gave lower correlation coefficients, ranging from 0.71 (number of ova vs. standard length) to 0.82 (number of ova vs. body weight).

Age Structure, Growth, and Mortality

Length-frequency histograms were used to analyze age and growth in H. placitus because annulus formation could not be reliably detected on scales. The histograms (Fig. 6) indicate that H. placitus is a relatively short-lived species. The population was predominantly composed of young-of-year and one-year old fish (depending on the season) with few fish reaching the age of two.

Young-of-year specimens were first collected on 26 June in 1986 and 1987 (Fig. 6). By late August in 1986 there were two clearly defined young-of-year modes; one at 26 mm and the other at 44 mm. This, along with the GSI data indicates two major spawning periods in 1986. By late August 1987, one young-of-year mode (43 mm) was observed. The second spawning peak seen in August 1987 appeared later in the season than the second peak the previous year (Fig. 2). Individuals spawned at this time apparently were not large enough to appear in my last sample in late August.

Modal shifts in both years (Fig. 6) indicate rapid summer growth of young-of-year. By late September 1986 many young-of-year had grown large enough that they could not accurately be discerned from the remaining adults, although young-of-year as small as 16 mm were collected in the same sample. Growth was undetectable during the fall and winter, probably due to the colder temperatures. At the onset of the 1987 reproductive season, there was great variation in size of adult fishes (28 - 68 mm; 17 April 1987), which may explain the great size variation seen in fish first attaining sexual maturity.

Mortality of adult plains minnows was assessed from their decline in relative numbers through the reproductive season as seen in the length-frequency histograms (Fig. 6). By late June of both years, the relative abundance of adult fish had declined substantially. This trend suggests that mortality occurs after spawning is completed. However, samples taken throughout the fall of 1986 and the winter and spring of 1987 consistently included specimens 5-12 mm (mean = 8.8 mm) larger than individuals in the top end of the remaining distribution. It is possible that these are adult fish that survived the summer, some of which may reproduce the next year as two-year old fish.

CHAPTER V

DISCUSSION

Ovulation in teleosts is regulated by endogenous and exogenous factors, the latter determining when endogenous factors become functional (Stacey, 1984). The environmental cues coordinating the reproductive cycles probably are those most reliable as indicators that hatchlings will appear at a time most conducive to their survival (Bye, 1984). In temperate cyprinids the most important exogenous factors in the timing of gonadal development and regression seem to be temperature and photoperiod (Schwassman, 1971; DeVlaming, 1972; Lam, 1983; Bye, 1984). Other factors, such as changing water levels, may also play a role in fine-tuning the reproductive cycle and may cause differences in reproductive patterns from year to year. Farringer et al. (1979) determined, for the red shiner (*Notropis lutrensis*) in central Texas, that high water levels and high turbidity in the spring of 1977 were associated with slower ovarian recrudescence (as compared with 1976). Lehtinen and Echelle (1979) found that between-year differences in the reproductive cycle of the big eye shiner, *Notropis boops*, may have been due to contrasting climatic conditions in south-central Oklahoma. Earlier spawning in 1977 may have been triggered by heavier amounts of spring rainfall and/or warmer temperatures. In Arizona, John (1963) found that the speckled dace, Rhinichthys osculus, may show a bimodal spawning season. The major peak occurs in the spring and is associated with flooding from melting snow. A lesser peak occurs in late summer and may be initiated by a single flash flood. If the floods arrive too early or not at all, the second spawning will not occur. Koster (1957) and Rinne (1975) have also implicated rainfall as an important stimulus for reproduction in some desert fishes. Moore (1944) found that heavy summer rains stimulate spawning in the Arkansas River shiner, Notropis girardi. The fish seem to withhold their eggs until environmental conditions are right (high flow) for survival of the larvae. Spawning apparently takes place in the main channels with the buoyant eggs developing as they drift in the current downstream.

The eggs of H. placitus are slightly demersal and nonadhesive, and develop as they bounce along the bottom (Miller and Robison, 1973). I have found aggregations of spawning plains minnows in shallow, quiet water along sandbars and in backwaters, but the turbid water prevented direct observation of spawning. This mode of reproduction is quite different than that of N. girardi, and Cross et al. (1985) stated that rising water levels may not play as important a role in the reproduction of H. placitus.

However, some evidence indicates that substantial and/or receding flows are favorable for reproduction in this species. A consequence of receding flows was the appearance of numerous, small, very shallow backwaters along the edges of emerging sandbars. This type of habitat is where all larval H. placitus were collected. As the water began to clear up somewhat, vast numbers of young plains minnows could be seen in these areas and were easily collected with a dipnet.

Young-of-year fish collected on 26 June 1986 ranged from 12 to 26 mm (mean = 18.0 mm) and on the same date in 1987 from 14 to 35 mm (mean = 27.5 mm). Bottrell, et al., (1964) found that larval Hybopsis aestivalis could attain a length of 19 mm in 3 weeks. Moore (1944) found that larval N. girardi averaged 16 mm (total length) after 22 days and 24.5 mm after 40 days. Early growth rates for H. placitus are probably similar to these figures. This would place the onset of spawning in 1986 around mid-May and near the beginning of May in 1987. In 1986, flows were low throughout the latter half of April and the first week of May. About a 15-fold increase in discharge occurred from 8 May to 11 May and flows remained high the rest of the month. A very wet winter and early spring in 1987 resulted in much higher flow rates throughout April and May, and possibly created suitable spawning conditions earlier in that year as compared to 1986.

Rainfall and discharge for June and July 1987 were considerably higher than during the corresponding time in 1986. Average monthly temperatures during the spawning season differed only slightly between years for April, May, and August; however, cooler temperatures prevailed during June and July 1987. These differences may account for the more extended spawning season in 1987, with a later and more pronounced second spawning peak.

During both spawning seasons, the first peak in mean GSI occurred in May. Sampling in April and May 1987 was more extensive than during April and May 1986. Consequently, GSI data give a better indication of reproductive condition during the onset of spawning in 1987 as compared to the corresponding time in 1986. The data indicate a period of intense spawning activity throughout the month of May 1987, with a wide size-range of fish maturing sexually and spawning at this time. Fish with mature ovaries during May 1987 ranged in size from 50.8 mm to 86.7 mm. About 25% of the fish collected on 13 May were under 45 mm SL and the majority of these individuals possessed immature ovaries. Apparently these smaller fish spawn for the first time later in the season, resulting in a second peak in mean GSI during mid-summer as was seen both years. The earliest-spawned group of young-of-year have a longer growing season and go into the winter at a greater size than individuals spawned later in the season. These bigger fish are probably the first ones to spawn the next season. This prolonged spawning season results in the great size range of fish seen at the onset of the reproductive season.

Evidently some adult fish survive the reproductive season. If environmental conditions during mid or late summer are not suitable for successful spawning then perhaps some of the smaller adults do not spawn at all at age one and instead spawn at age two. Another possibility is that some fish survive the physiological stress of spawning and reproduce again at age two. One of these 2-year old fish (86.7 mm) collected in May 1987 had mature ovaries (4,134 ova) containing almost three times the number of eggs counted in the next largest fish (66 mm) with mature ovaries (1525 ova), and almost 10 times the number of eggs found in the smallest fish (50 mm) with mature ovaries (417 ova). Although only a small percentage of the population would live to spawn at age 2, the greater fecundity of these individuals would help make up for their lack of numbers.

It appears that H. placitus is a short-lived species possessing a relatively high seasonal reproductive effort. Since plains minnows are intermittent spawners, the total number of eggs spawned per individual throughout the season is probably much greater than my estimates based on clutch size. Intermittent spawning would seem to be advantageous since successful spawning and recruitment would not be dependent upon only one batch of eggs. However, spawning intensity at any one time may be reduced (Starrett, 1951). Williams (1975) suggested that mortality of larvae and juveniles is not necessarily a random event in high fecundity species, and that surviving individuals are more suited to their environment during existing conditions. Furthermore, if mortality in these early stages is influenced by genotype, then major changes in gene frequencies could occur in one generation.

High reproductive effort, intermittent spawning, differential spawning, and extended survival of part of the population all seem to be adaptive responses to the highly unstable plains rivers. Alteration of rivers and streams is known to cause changes in faunal structure although reasons for these changes are not well understood. The elimination of highly variable water levels, unstable streambeds, and fluctuating water temperatures are some of the reasons that many true prairie fishes are on the decline (Cross et al., 1985). The decreasing abundance and range of H. placitus in northwestern Oklahoma and in other parts of the Arkansas River System are attributed by Cross et al. (1985) primarily to altered volume and periodicity of flows. Although plains minnows are still quite abundant and were the numerically dominant species at my study sites in the Cimarron River their decline elsewhere attests to their vulnerability to habitat alteration. Baseline life history studies are critical for understanding the requirements of our native fishes and will prove essential to the management of prairie stream ecosystems.

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APPENDIX A

TABLES

Table 1. Mean length (mm), number of observations (in parenthesis), and results from analysis of variance to test for significant differences in the mean length of adult male and female Hybognathus placitus from the Cimarron River.

	Date of Collection								
Sex	9 Sep 1986	21 Nov 1986	8 Feb 1987	17 Apr 1987	13 May 1987	26 Jun 1987	27 Jul 1987	24 Aug 1987	Mean
Male	67.700	54.663	52.556	52.971	52.578	55.443	60.227	60.620	54.444
	(6)	(72)	(43)	(103)	(32)	(49)	(15)	(10)	(330)
Female	68.813	54.967	52.514	52.808	52.233	56.045	57.283	60.412	54.902
	(16)	(58)	(42)	(100)	(51)	(62)	(23)	(17)	(369)

Analysis of Variance

Source of Variation	df	SS	MS	F-value
Sex	1	36.44385	36.44385	1.68ns
Month	7	7242.74481	1034.67780	47.75*
Interaction	7	100.03298	14.29043	0.66ns
Error	683	14801.09530	21.67071	
Total	698			

* significant at 1% level

Table 2. Seasonal variation in gonadosomatic index (GSI) of *Hybognathus placitus* from the Cimarron River.

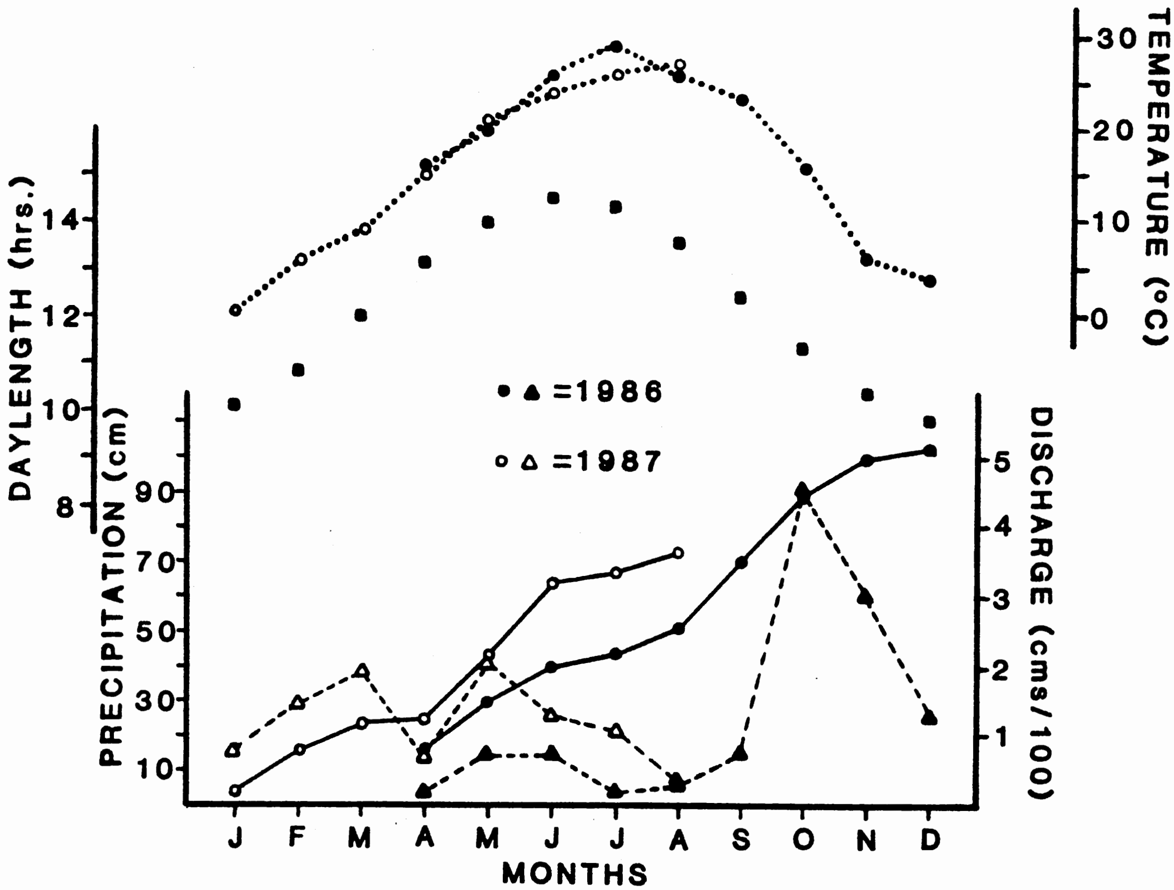
1986				1987			
Date	Mean	Range	N	Date	Mean	Range	N
20 April	4.54 ± 0.68*	0.9 - 11.5	20	8 February	0.78 ± 0.04	0.6 - 1.0	10
22 May	8.70 ± 1.21	4.4 - 18.2	16	15 March	0.89 ± 0.07	0.6 - 1.2	10
26 June	5.46 ± 0.64	1.3 - 14.0	20	1 April	1.61 ± 0.28	0.8 - 3.3	10
10 July	5.45 ± 1.39	0.7 - 10.5	7	17 April	2.18 ± 0.37	1.0 - 4.5	10
22 July	6.26 ± 0.97	0.4 - 15.5	20	24 April	3.30 ± 0.76	1.1 - 7.7	10
7 August	4.15 ± 1.73	0.5 - 14.8	8	2 May	9.51 ± 1.65	1.0 - 23.2	15
22 August	1.67 ± 0.48	0.2 - 2.8	5	13 May	8.92 ± 0.72	2.8 - 12.4	15
9 September	1.47 ± 0.36	0.5 - 6.3	15	22 May	9.34 ± 1.34	0.8 - 19.3	20
26 September	0.61 ± 0.04	0.3 - 0.9	20	6 June	7.86 ± 1.11	0.7 - 17.9	18
21 October	0.69 ± 0.05	0.4 - 1.2	15	26 June	5.11 ± 0.79	0.5 - 10.7	20
				12 July	4.12 ± 0.91	0.9 - 7.5	7
				27 July	3.84 ± 0.87	0.8 - 10.9	15
				9 August	12.57 ± 1.31	2.3 - 22.1	15
				24 August	1.31		1

* 1 standard error

APPENDIX B

FIGURES

Figure 1. Mean monthly temperature (dotted lines), mean monthly daylength (squares, Oklahoma City), cumulative monthly precipitation (solid line), and mean monthly discharge (dashed line) for the vicinity of the study sites.



TEMPERATURE (°C)
30
20
10
0
DAYLENGTH (hrs.)
14
12
10
8
PRECIPITATION (cm)
90
70
50
30
10
DISCHARGE (cms/100)
5
4
3
2
1
● ▲ =1986
○ △ =1987
J F M A M J J A S O N D
MONTHS

Figure 2. Mean gonadosomatic index (GSI, solid line) and mean ovum diameters (dashed line) for *Hybognathus placitus* from the Cimarron River.

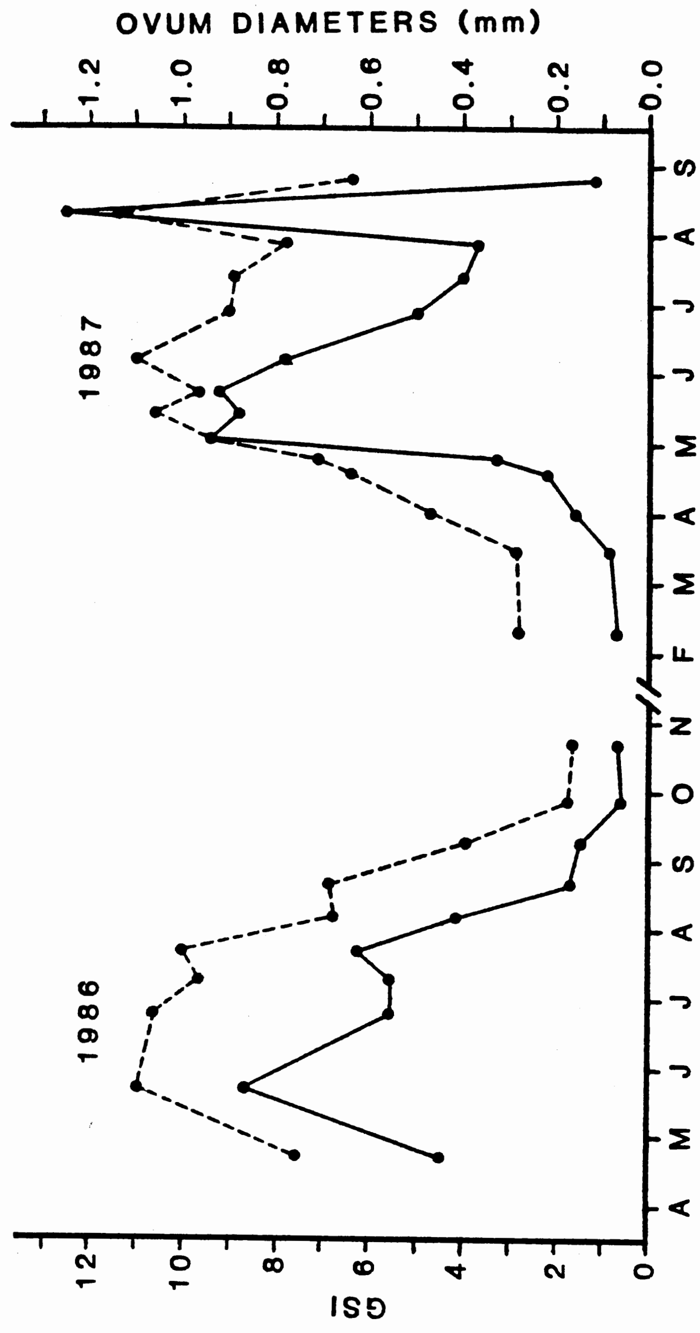

OVUM DIAMETERS (mm)
0.0 0.2 0.4 0.6 0.8 1.0 1.2
GSI
0 2 4 6 8 10 12
MONTHS
A M J J A S O N F M A M J J A S
1986
1987

Figure 3. Size-frequency distribution for ova greater than 0.40 mm in mature ovaries (A) and spent ovaries (B) of *Hybognathus placitus* from the Cimarron River.

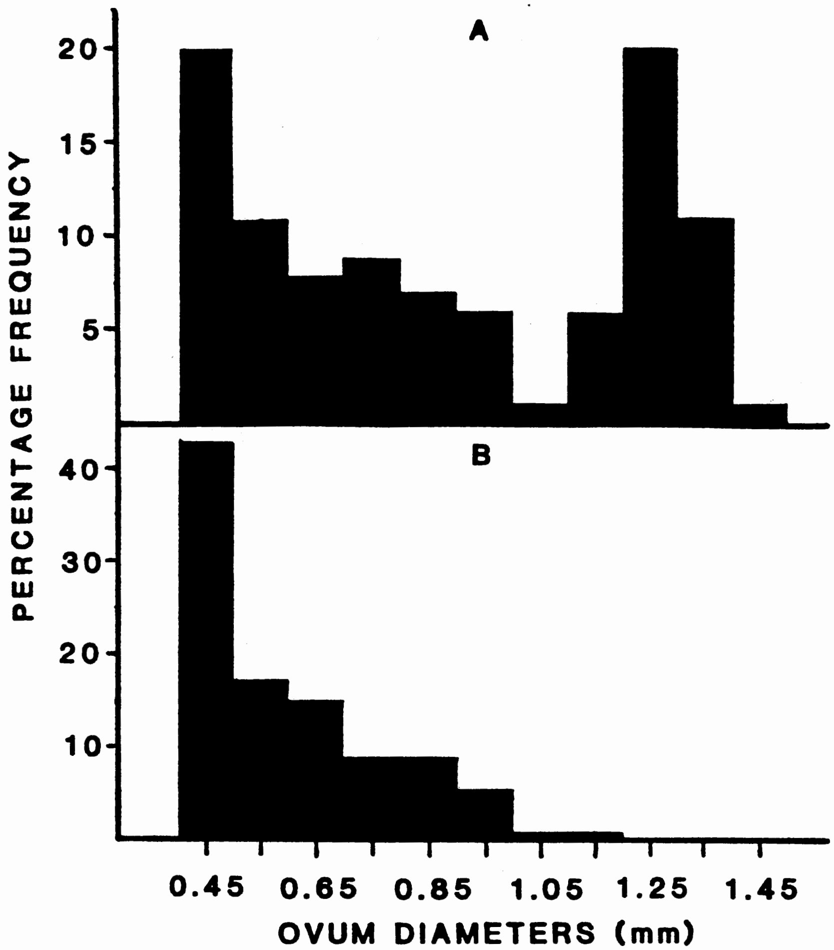

A
B
PERCENTAGE FREQUENCY
20
15
10
5
40
30
20
10
0.45
0.65
0.85
1.05
1.25
1.45
OVUM DIAMETERS (mm)

Figure 4. Relationship between number of mature ova and standard length for 31 *Hybognathus placitus* females from the Cimarron River, 1987. Three observations are hidden.

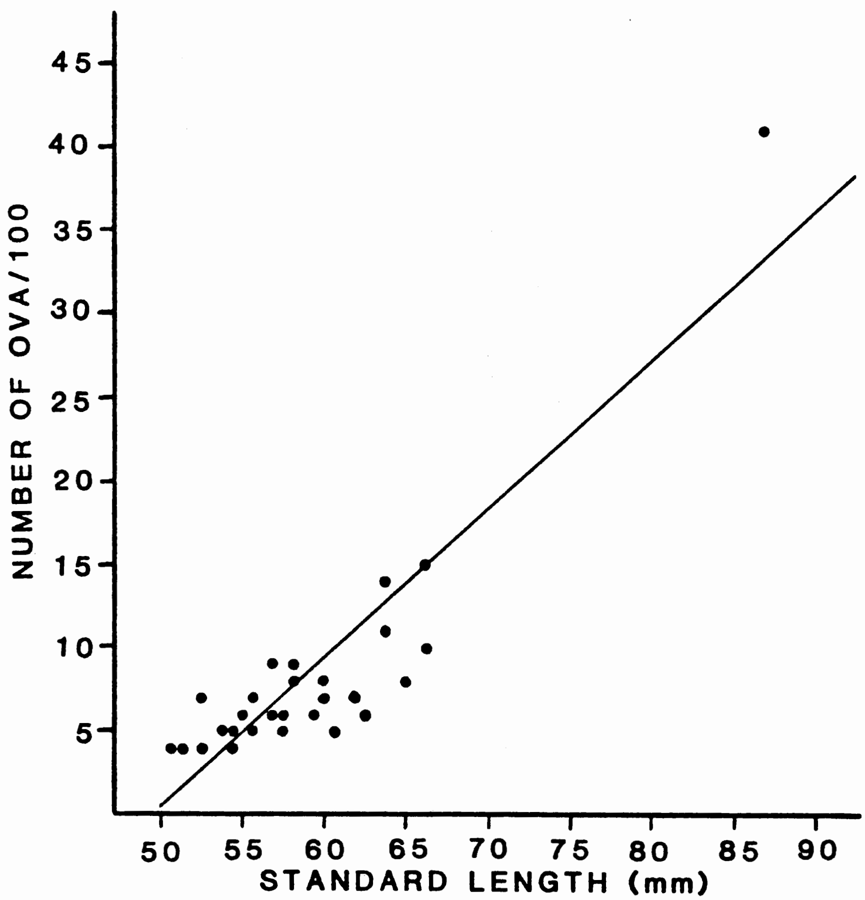

NUMBER OF OVA/100
45
40
35
30
25
20
15
10
5
50 55 60 65 70 75 80 85 90
STANDARD LENGTH (mm)

Figure 5. Relationship between number of mature ova and body weight for 31 Hybognathus placitus females from the Cimarron River, 1987. Three observations are hidden.

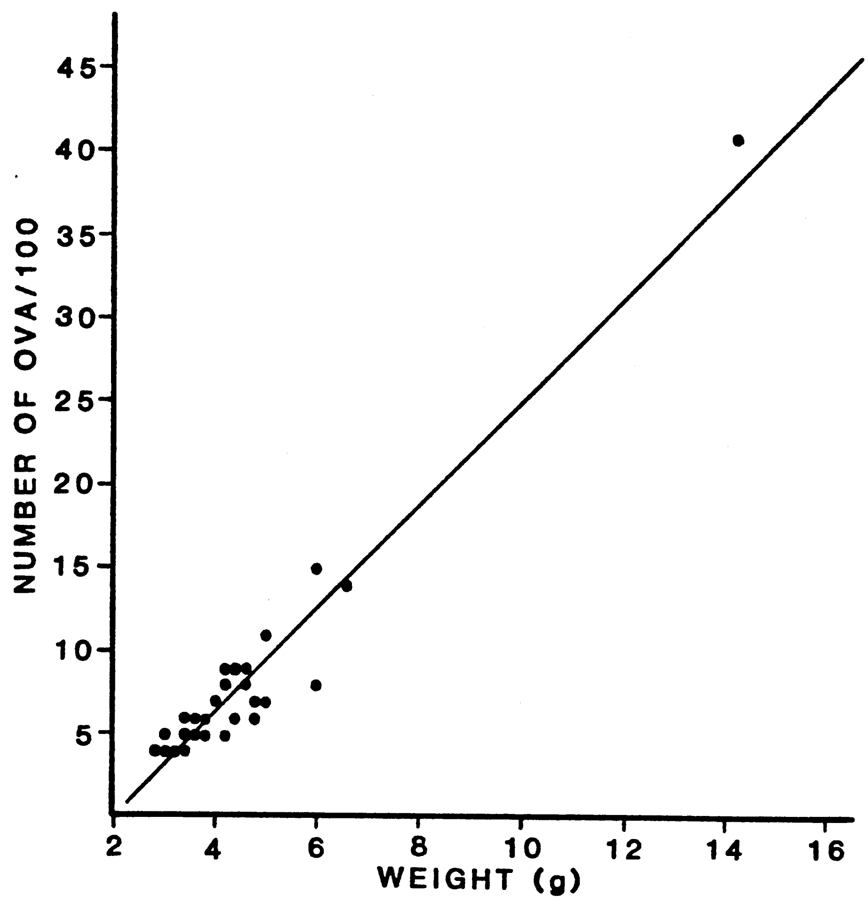
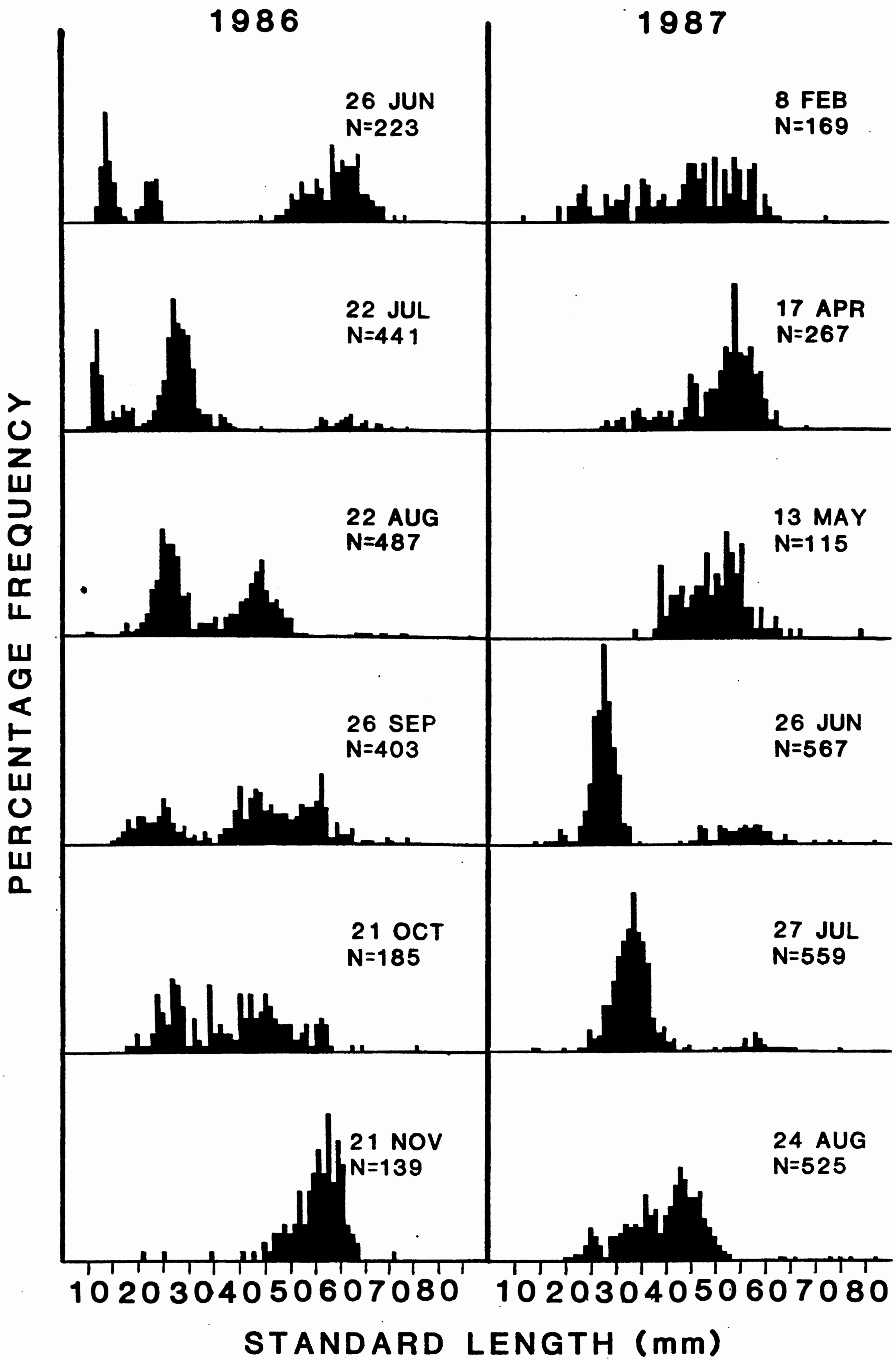

45
40
35
30
25
20
15
10
5
NUMBER OF OVA/100
2
4
6
8
10
12
14
16
WEIGHT (g)

Figure 6. Length-frequency distributions for *Hybognathus placitus* from the Cimarron River.


1986
1987
26 JUN
N=223
8 FEB
N=169
22 JUL
N=441
17 APR
N=267
22 AUG
N=487
13 MAY
N=115
26 SEP
N=403
26 JUN
N=567
21 OCT
N=185
27 JUL
N=559
21 NOV
N=139
24 AUG
N=525
PERCENTAGE FREQUENCY
10 20 30 40 50 60 70 80
10 20 30 40 50 60 70 80
STANDARD LENGTH (mm)

VITA 2

Christopher Mark Taylor

Candidate for the Degree of

Master of Science

Thesis: REPRODUCTIVE BIOLOGY AND POPULATION STRUCTURE OF THE PLAINS MINNOW, HYBOGNATHUS PLACITUS (PISCES: CYPRINIDAE), IN CENTRAL OKLAHOMA

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