

Population Dynamics of the Fish Fauna  
Found in  
Three Earthen Ponds on North Padre Island, Texas

THESIS

Presented to the Graduate Council of  
Southwest Texas State University

in Partial Fulfillment of  
the Requirements

For the Degree of  
MASTER OF SCIENCE

By

Christopher S. Caudle

San Marcos, Texas

May, 1992

## TABLE OF CONTENTS

LIST OF FIGURES.....	iii
ACKNOWLEDGEMENTS.....	v
CHAPTER	
I. <u>INTRODUCTION</u> .....	1
II. <u>MATERIALS AND METHODS</u> .....	4
A. Study Site Description .....	4
1. Pond A.....	4
2. Pond B.....	5
3. Pond C.....	5
B. Study Animals.....	10
1. <u>Cyprinodon variegatus</u> .....	10
2. <u>Fundulus grandis</u> .....	10
3. <u>Gambusia affinis</u> .....	11
C. Sampling Procedures .....	11
D. Analysis.....	13
III. <u>RESULTS AND DISCUSSION</u> .....	14
A. Pond Chemistry.....	14
1. Temperature .....	14
2. Dissolved Oxygen.....	16
3. pH.....	17
4. Alkalinity.....	19
5. Salinity.....	21
6. Turbidity .....	23
B. Fish Fauna.....	25
1. <u>Cyprinodon variegatus</u> .....	25
a. Abundance.....	25
b. Population Dynamics.....	27
b-1. Pond A.....	27

b-2. Pond B .....	30
b-3. Pond C .....	32
2. <u>Fundulus grandis</u> .....	38
a. Abundance .....	38
b. Population Dynamics .....	38
b-1. Pond A .....	38
b-2. Pond C .....	40
3. <u>Gambusia affinis</u> .....	43
a. Abundance .....	43
b. Population Dynamics .....	44
b-1. Pond B .....	44
IV. <u>SUMMARY</u> .....	50
LITERATURE CITED .....	53

## LIST OF FIGURES

Figure 1. Map of Padre Island and surrounding areas. ....	6
Figure 2. Contour relief map in meters above sea level of pond A. ....	7
Figure 3. Contour relief map in meters above sea level of pond B.....	8
Figure 4. Contour relief map in meters above sea level of pond C.....	9
Figure 5. Seasonal mid-day temperature variations in ponds A (triangle), B (box), and C (circle).....	15
Figure 6. Monthly mid-day dissolved oxygen concentrations for ponds A (triangle), B (box), and C (circle).....	15
Figure 7. Monthly pH values for ponds A (triangle), B (box), and C (circle).....	18
Figure 8. Monthly total alkalinity concentrations for ponds A (triangle), B (box), and C (circle).....	18
Figure 9. Monthly salinity concentrations for ponds A (triangle), B (box), and C (circle).....	22
Figure 10. Monthly turbidity values for ponds A (triangle), B (box), and C (circle).....	22
Figure 11. Average catch per seine of <u>Cyprinodon variegatus</u> (triangle), <u>Fundulus grandis</u> (closed circle), and <u>Gambusia affinis</u> (box) collected from ponds A, B, and C from November 1989 to October 1990.....	26
Figure. 12. Monthly length-frequency distributions of <u>Cyprinodon variegatus</u> . collected from pond A.....	28

Figure 13. Monthly length-frequency distributions of Cyprinodon variegatus collected from pond B.....31

Figure 14. Monthly length-frequency distributions of Cyprinodon variegatus collected from pond C.....33

Figure 15. Mean total length (open triangle) and modal total length (closed circle) of Cyprinodon variegatus collected from ponds A, B, and C. ....34

Figure 16. Monthly length-frequency distributions of Fundulus grandis collected from pond A. ....39

Figure 17. Monthly length-frequency distributions of Fundulus grandis collected from pond C.....41

Figure 18. Mean total length (open triangle) of Fundulus grandis collected from ponds A and C. ....42

Figure 19. Monthly length-frequency distributions of Gambusia affinis collected from pond B.....45

Figure 20. Mean total length (open triangle) of Gambusia affinis greater than 30 mm (presumably females) and modal total length of G. affinis collected from pond B.....46

## ACKNOWLEDGEMENTS

I would like to thank the following:

Dr. Sissom - for all your guidance, patience, assistance, and review of the manuscript.

Dr. Koehn - for your advice and review of the manuscript.

Dr. Tuff - for your advice and review of the manuscript.

My family - for the love, understanding, and support that got me this far and that will carry me well into the future. "ya'll are the best".

Members of the Graduate Commune - for being there. NIC NIC NIC.

National Park Service/ Padre Island National Seashore - for providing funding and assistance with this project.

Lucy - for being man's best friend.

I would also like to dedicate this work to the fond memory of Patrick M. Caudle and Dr. Rodney L. Hassage- for it is the strength, perseverance, and goodwill of men like these that make the world a better place to live.

## CHAPTER I

### INTRODUCTION

Barrier islands are composed of unique habitats that are subject to a wide range of environmental extremes. Padre Island, in Texas is a classic barrier island. It constitutes an extremely dynamic system that may experience extreme freezes in winter months, deluge from rain in the spring, and drought during the summer, as well as episodic impacts from tropical storms and hurricanes (Weise and White 1980).

In October 1990 I was involved in a base-line study to characterize three earthen ponds on North Padre Island. During this study I became interested in the ecology of the fish communities in these ponds. My interest in these fish species stemmed from the general paucity of knowledge of these ponds and particularly from the fact that a depauperate, yet functioning and unique fish community was present in each pond.

Other aspects of these ponds have been briefly examined. Serota (1971) and Perez (1971) performed studies on the primary productivity and chlorophyll standing crops of two of the three ponds examined here. Hannan (1978), while examining the drainfield for a sewer system in the park, conducted some chemical tests on the pond nearest the ranger station. A study is also currently being

conducted describing the fungal organisms of the three ponds examined in this study (Oxley 1992).

The 1990 base-line study revealed that only three fish species, Cyprinodon variegatus Lacepede, Fundulus grandis (Baird and Girard), and Gambusia affinis (Baird and Girard), were found to occur in varied assemblages within each pond. These species are highly ubiquitous and many aspects of their ecology have been widely described for the various environments where they are found. However, there is a lack of information concerning the ecology of these species in barrier island ponds. Gunter (1950) gave a brief account of the distribution and abundance with life history notes for all three of these species on the Aransas National Wildlife Refuge, Mustang Island, Texas. However, the ponds mentioned in Gunter's study were often inundated by surrounding tidal waters. This does not occur in the ponds described in this study except under extreme hurricane conditions.

Gambusia affinis is the best known of the three species because of its world wide use as a biological control agent for mosquitos. Several researchers have presented biological reviews for this species (Carlander 1976 and Plieger 1975), but none of the summarized literature deals with any aspect of the ecology of G. affinis in barrier island ponds. Cyprinodon variegatus has also been studied extensively because of its wide distribution and ability to tolerate extreme changes in environmental conditions (Foster 1967). Foster (1967) and Kail (1968) have summarized the abundance of literature concerning the biology, ecology, and behavior of C. variegatus. Fundulus grandis is the least studied of the three

species. Various aspects of F. grandis life history have been described by Kilby (1955), Simpson and Gunter (1956), Joseph and Yerger (1956), and Springer and Woodburn (1960). Meier et al. (1973) and Spence et al. (1977) described the daily plasma chloride rhythms of F. grandis and Griffith (1974) and Perschbacher et al. (1990) have examined the salinity tolerances of this species.

This study was performed to examine the population dynamics of the above three species in three earthen ponds on North Padre Island. This included a physiochemical characterization of each pond and a survey of abundance, recruitment and size class progression of the fish species. Because of the unique character of barrier islands, the ponds themselves become unique, and thus the fish that inhabit them may possess unique and interesting patterns of population development. These ponds are located in the National Seashore Park and any addition to the knowledge of the habitats and animals occurring in this area may prove valuable in maintaining the biological integrity of this unique ecosystem.

## CHAPTER II

### MATERIALS AND METHODS

#### *STUDY SITE DESCRIPTION*

Padre island is one of the southern most links in a chain of barrier islands that curve along the Texas coastline. Established in 1962 the Padre Island National Seashore Park extends south some 182 km on Padre island from Kleberg to Willacy county, Texas. The ponds examined in this study are located in the North section (27° 25' latitude, 97° 25' longitude) of the park (figure 1) and are all within 2 km of each other. This area of the coast is in a subtropical, semiarid region and has an average annual rainfall of approximately 75 cm contrasted by a annual net evaporation of 83.9 cm. Temperatures range from approximately 35° C to 0°C with a annual average of 23° C.

#### *Pond A*

Pond A (figure 2), located on the south side of Bird Island road just east of Little Dagger Hill, is the smallest of the ponds studied. This pond has a maximum total surface area of approximately 4,880 m<sup>2</sup> and its slope is characterized by two deep areas seperated by a shallow sill. The more easterly lobe is the deeper of the two with a maximum depth of approximately 1.2 m. The more easterly lobe has a maximum depth of 0.9 m The floors of both lobes are

characteristically soft and rich in organic matter. Pond A supports no aquatic macrophytes except cattails, Typha domingensis, which fringe the northwest side of the easterly lobe through out the year. This pond is a watering hole for many of the animals which inhabit North Padre Island and is also a sanctuary for many coastal and migratory bird species.

### *Pond B*

Pond B (figure 3), located on the main park road 22, 0.5 km south of the ranger station, has a maximum total surface area of approximately 10,000 m<sup>2</sup> with a maximum depth of 2.4 m. It is roughly rectangular in shape and has relatively steep banks on all sides. The floor of pond B is a firm sandy-mud mixture and is devoid of aquatic vegetation. This pond is also visited by many of the animals found within the National Seashore park, but not to the extent of pond A.

### *Pond C*

Pond C (figure 4), is located directly south of the sewage tanks near the end of park road 22. It is the largest of the three ponds, and has a maximum total surface area of approximately 30,000 m<sup>2</sup> with a maximum depth of 1.5 meters. Unlike ponds A and B pond C is brackish. Its waters are characteristically clear and are contained by sand dunes on its east coastal side and by gently sloping banks on its westward side. The floor of pond C is sandy and stable and is covered the year through with dense mats of skunk weed, Chara. Pond C, like the other ponds, is frequented by many coastal and

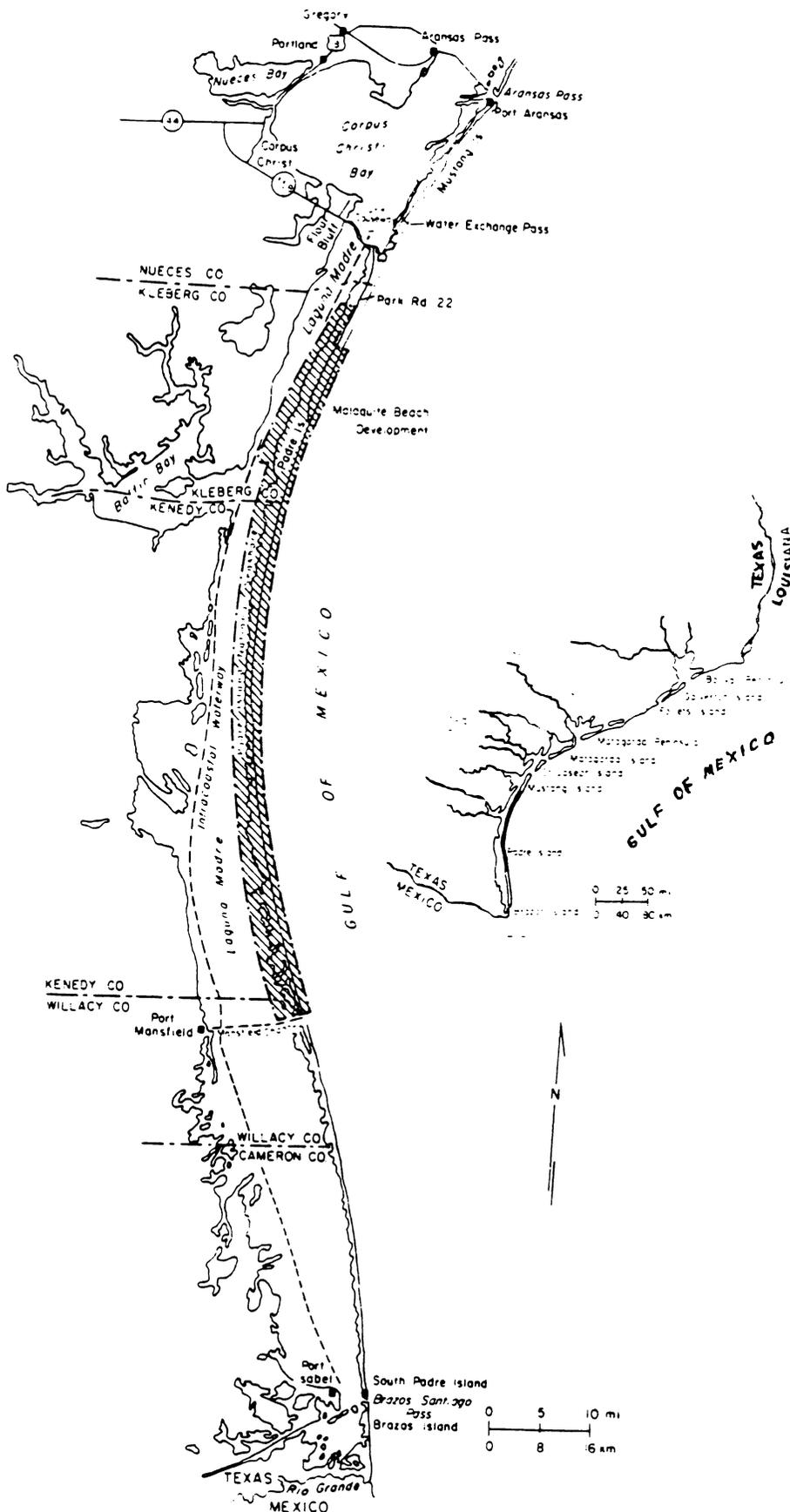


Figure 1. Map of Padre Island and surrounding areas. Hatched area represents the Padre Island National Seashore.

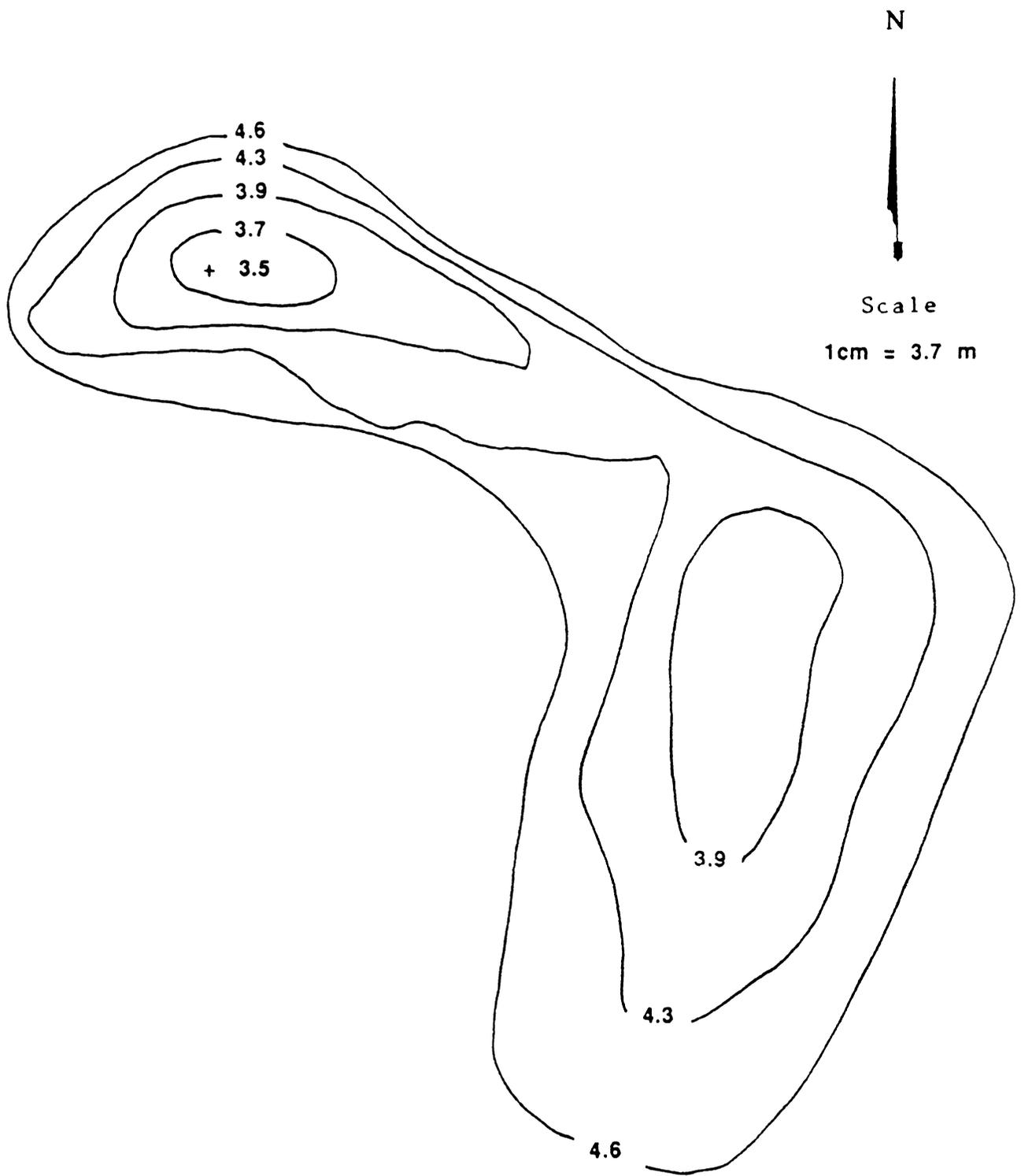


Figure 2. Contour relief map in meters above sea level of pond A.

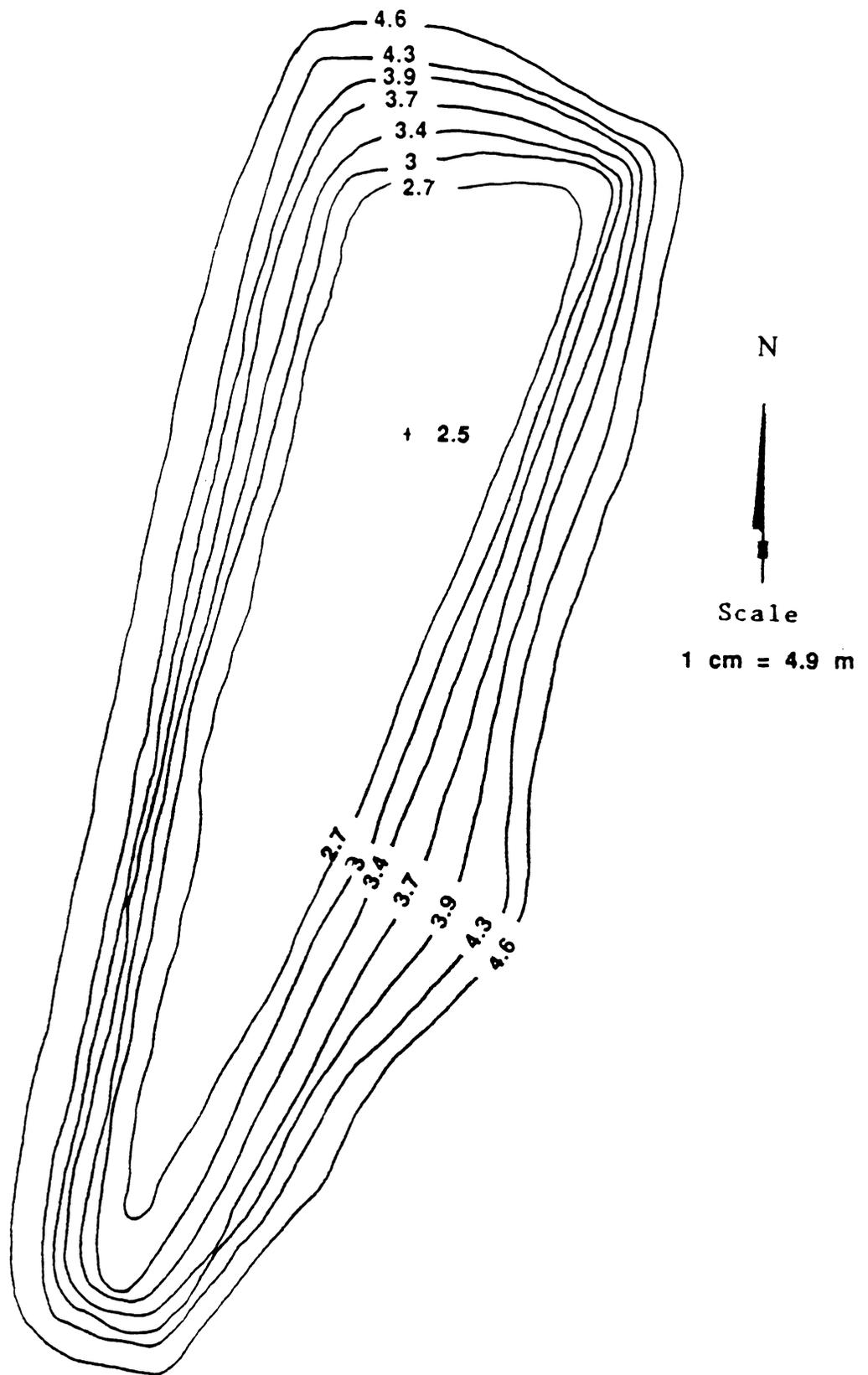


Figure 3. Contour relief map in meters above sea level of pond B.

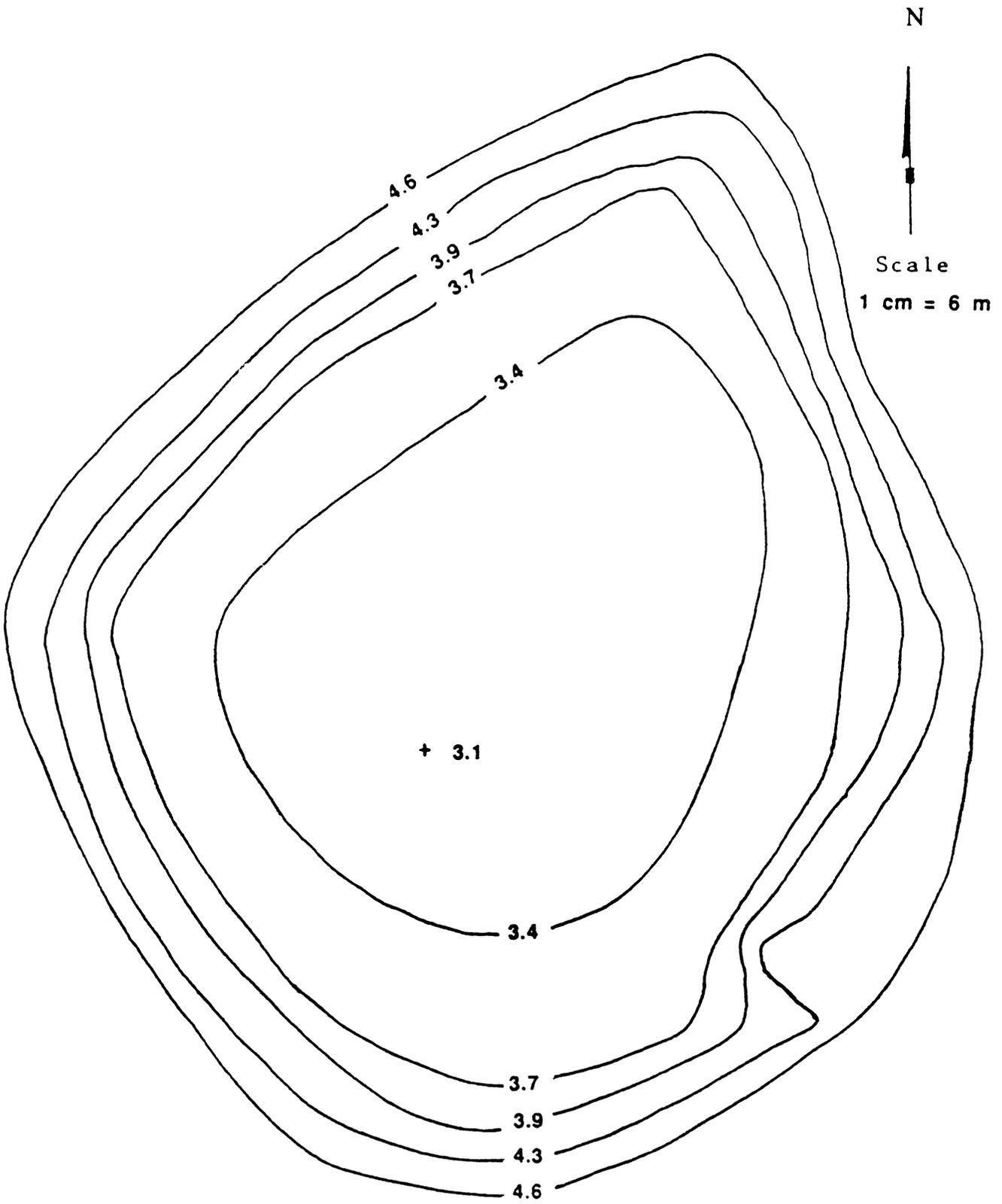


Figure 4. Contour relief map in meters above sea level of pond C.

migratory bird species, but because of its brackish nature it serves as a watering hole for very few other animals.

## STUDY ANIMALS

Cyprinodon variegatus Lacepède (Cyprinodontidae)

Sheephead minnow

According to Johnson (1978) this coastal species, found in relatively shallow brackish or fresh waters, ranges from Cape Cod, Massachusetts to the Gulf of Mexico as far south as the Yucatan Peninsula. Within this extensive range Hubbs (1936) recognized two subspecies, Cyprinodon variegatus ovinus (Mitchill) which occurs from Massachusetts to Virginia, and Cyprinodon variegatus variegatus Lacepède which is distributed from North Carolina to near Brownsville, Texas. Based upon the given distribution it seems probable that the populations reported on in this study are the latter subspecies. This fish feeds mostly on plant material but occasionally will consume mosquito larvae and small crustaceans (Reid 1954, Harrington and Harrington 1961, and Warlen 1964).

Fundulus grandis (Baird and Girard) (Cyprinodontidae)

Gulf killifish

Burgess and Shute (1979) report that Fundulus grandis grandis ranges from the mouth of the Saint Johns River, Florida to Laguna de Tamiahua, Veracruz, Mexico. This species is common along bay shores and tidal marshes in a wide range of salinities ranging from freshwater to 76 ppt. (Simpson and Gunter 1956). Fundulus are

somewhat omnivorous feeding on aquatic insects, vegetable matter and fish (Simpson and Gunter 1956).

Gambusia affinis (Baird and Girard) (Poeciliidae)

Western mosquitofish

This viviparous minnow is native to the eastern United States and is widely distributed from southern Indiana and Illinois south to Veracruz, Mexico (Lee and Burgess 1978). This species has been widely transplanted throughout the United States and into warm areas of the world as an agent for mosquito control (Krumholz 1948). This fish can thrive under a variety of conditions and is common in calm, vegetated ponds, lakes and slow moving waters and is often found in brackish or marine settings (Walden 1964).

Gambusia feed on a variety of plankton, fishes, and algae; but prefer mosquito larvae and pupae (Harrington and Harrington 1961).

## SAMPLING PROCEDURES

The fish fauna in each pond were sampled monthly from November 1989 to October 1990. Specimens were collected with a 5.5 x 1.2 m common sense seine of 3.2 mm mesh. Seining efforts were kept consistent by performing two, non-overlapping, 9 m seine hauls at random locations in each pond. Specimens were preserved in buffered 10% formalin for one week, flushed for 24 hours in running tap water and stored in 70% ethanol.

Total lengths of the fish were measured to the nearest millimeter with a vernier caliper. These lengths were used to produce a series of length-frequency histograms from which the

recruitment and growth of broods and parent stocks were followed. Since there may have been difficulties in sampling very small fish, 10 mm was used as the smallest total length for establishing entry into the population. Fish that were present in the ponds before the first detected episode of recruitment will be referred to as "parent" stocks and any fish born after that date are called  $F_1$  broods. Following  $F_1$  broods are labelled  $F_1^a, F_1^b, \dots, F_1^z$  in the order in which they were recruited.

The growth of broods were calculated using the mode of the first two months following an episode of recruitment. This method was chosen because broods of young are thought to reflect their growth by modes in their length-frequency distribution ( Krumholz 1948). In the case of Gambusia, only those modes less than or equal to 30 mm were used to follow offspring growth. This was done to compensate for the intrasexual difference in growth rate of Gambusia in which females have indeterminate growth and may attain a total length of 60 mm, whereas males have determinate growth which is halted upon reaching maturity at a size of approximately 25-30 mm ( Turner 1941). Thus by choosing the mode within this range all immature individuals will be represented.

The growth of parent stocks were followed by correlating monthly mean total length with time. To compensate for the effects of brood recruitment and growth on parent stock mean total length the mean was calculated only for those individuals whose total length was greater than the mode representative of recruits. By doing this only the parent stock should be represented in the mean total length value. Since growth is sexually dimorphic in Gambusia,

growth was calculated for females only. This was performed by taking the mean total length for all individuals above 30 mm (presumably females) and correlating them with time as above.

Prior to each collection, physiochemical data were recorded within each pond. Total salinity, dissolved oxygen, pH and, alkalinity were all measured using a LaMotte Oceanographic Test Kit. Turbidity was measured with a Hach turbidometer and water temperature was measured with a centigrade mercury thermometer. Periodically, some of these parameters were validated with a HydroLab Surveyor II. All chemistry values were augmented with October 1989 data.

## ANALYSIS

Analysis of variance (ANOVA) and Fishers PLSD multiple comparisons test were performed using STATVIEW 512+, BRAIN POWER INC. Calabasas, Ca., on all chemistry data. In all cases,  $p < 0.05$  was needed for significance.

CHAPTER III  
RESULTS AND DISCUSSION

POND CHEMISTRY

Temperature

The seasonal temperature values for all ponds are depicted in figure 5. Temperature values were similar between all three ponds and typical seasonal cycles were evident. The Padre Island National Park personnel reported that all ponds experienced considerable ice formation during a harsh freeze on December 22 and 23.

In pond A the annual average water temperature was  $24.6 \pm 6.9$  (mean °C  $\pm$  std. dev.). The average water temperatures for the seasons were  $28.3 \pm 2.0$  for the spring,  $31.0 \pm 1.7$  for the summer,  $25.0 \pm 4.5$  for the fall, and  $14.0 \pm 1.7$  for the winter. The highest temperature measured was 33° in September and the lowest was 14° in February.

In pond B the annual mean water temperature was  $25.2 \pm 7.0$  (mean °C  $\pm$  std. dev.). The average water temperatures for the seasons were  $28.3 \pm 3.0$  for the spring,  $31.7 \pm 3.5$  for the summer,  $25.5 \pm 4.4$  for the fall, and  $15.0 \pm 3.0$  for the winter. The highest value recorded was 35° in August and the lowest was 11° in December.

In pond C the yearly mean water temperature was  $25.6 \pm 7.1$  (mean °C  $\pm$  std. dev.). The average water temperatures for the seasons were  $28.7 \pm 4.0$  for the spring,  $31.7 \pm 2.3$  for the summer

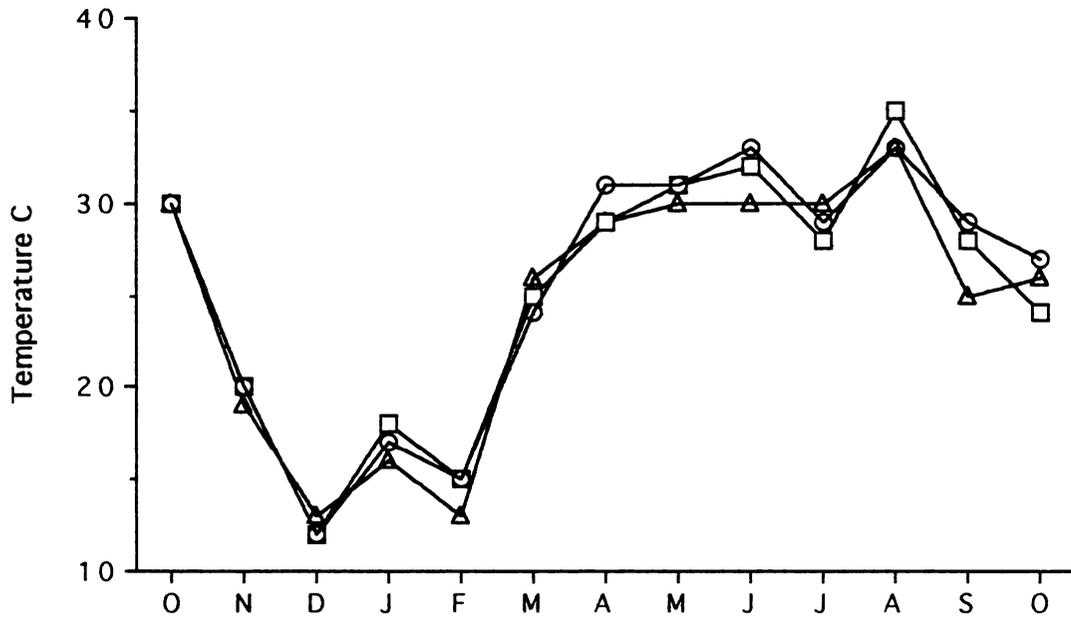


Figure 5. Seasonal mid-day temperature variations in ponds A (triangle), B (box), and C (circle).

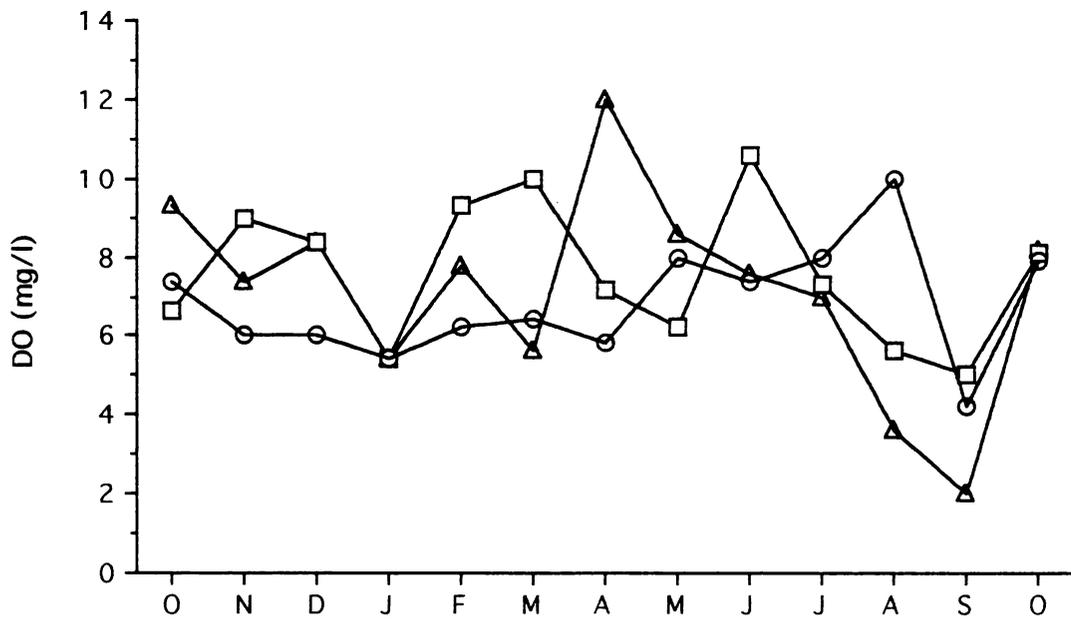


Figure 6. Monthly mid-day dissolved oxygen concentrations for ponds A (triangle), B (box), and C (circle).

26,5 ± 4.5 for the fall, and 14.7 ± 2.5 for the winter. The extremes occurred in August with a high of 33° and in December with a low of 12°.

### Dissolved Oxygen

The monthly dissolved oxygen (DO) concentrations for ponds A, B, and C are shown in figure 6. In pond A the yearly mean for DO was 7.14 ± 2.6 (mean mg/l ± std. dev.). The seasonal averages were 8.7 ± 3.2 for the spring, 6.1 ± 2.2 for the summer, 6.7 ± 3.2 for the fall, and 7.2 ± 1.6 for the winter. The highest DO concentration was 12.0 mg/l in April. Sissom (1990) reported that April is the month of greatest photosynthetic activity in pond A and consequently high DO concentrations occur during this time of the year. The lowest concentration occurred in September, during this time the pond depth had been greatly reduced from the summer dry down and the pond was loaded with organic matter from the decomposition of a heavy algal bloom that occurred in the spring and early summer. According to this situation, it is probable that pond A may have experienced nighttime DO deficits, though monthly concentrations were never found to be totally limiting to life within the pond.

In pond B the yearly mean dissolved oxygen concentration was 7.6 ± 1.8 and the seasonal averages were: 7.8 ± 1.9 for the spring, 7.8 ± 2.5 for the summer, 7.2 ± 1.8 for the fall, and 7.7 ± 2.0 for the winter. The highest DO concentration was in 10.6 mg/l in June and the lowest was 5.0 mg/l in September. As in pond A, anoxic conditions were never recorded in pond B. This pond more so than

pond A is almost constantly under the influence of the sea breeze and subsequently remains thoroughly mixed and well oxygenated.

In pond C the yearly mean DO concentration was  $6.8 \pm 1.5$ . The seasonal averages were  $6.7 \pm 1.1$  for the spring,  $8.5 \pm 1.3$  for the summer,  $6.4 \pm 1.7$  for the fall, and  $5.9 \pm 0.4$  for the winter. The highest concentration of 10.0 mg/l occurred in August. The lowest concentration of 4.2 mg/l was recorded in September. Due to the relatively low populations of planktonic algae, Sissom (1990) suggested that the DO concentrations in pond C are resultant from two factors. The first of these being sensible oxygen exchange between the air-water interface. Because of the large surface area to volume ratio of pond C and the persistent sea breezes which blow across its waters equilibration between the water and the atmosphere surely occur and contribute to the oxygenation of this pond. The second factor suggested by Sissom is the large population of Chara that lines the floor of pond C, he felt that this population of algae was a major contributor to the oxygen concentrations found in pond C.

## pH

The monthly pH values for ponds A, B, and C are depicted in figure 7. As with dissolved oxygen, there was no significant difference in pH between the three ponds.

In pond A the yearly mean of pH was  $8.3 \pm 0.2$  (mean  $\pm$  std. dev.). The seasonal means were  $8.4 \pm 0.2$  for the spring,  $8.4 \pm 0.2$  for the summer,  $8.4 \pm 0.09$  for the fall, and  $8.1 \pm 0.1$  for the winter. The largest value of 8.5 was recorded in March, April, June, and in

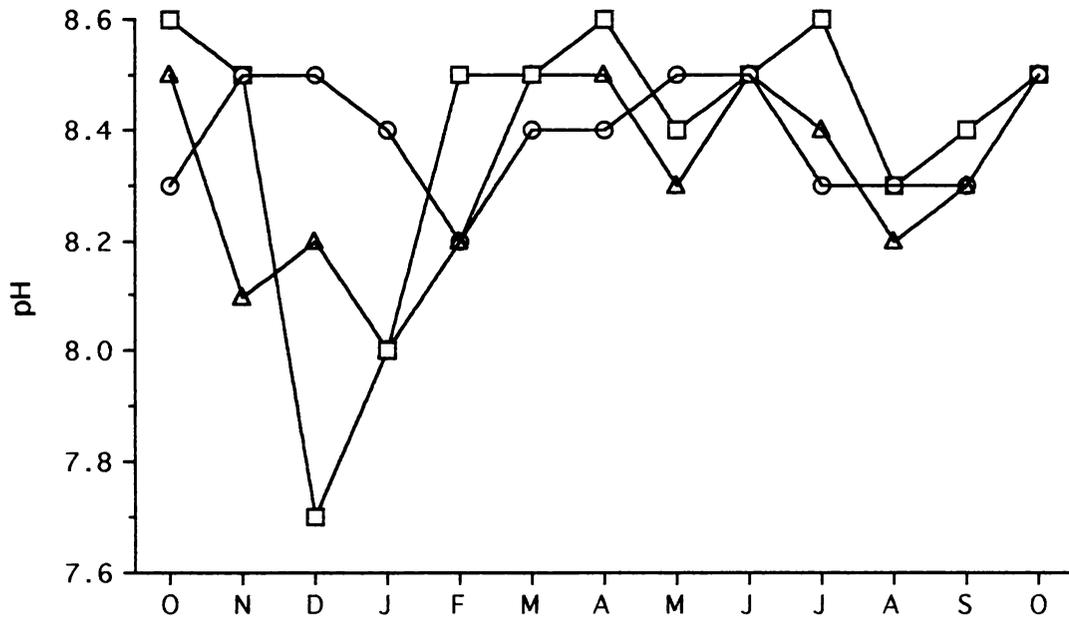


Figure 7. Monthly pH values for ponds A (triangle), B (box), and C (circle).

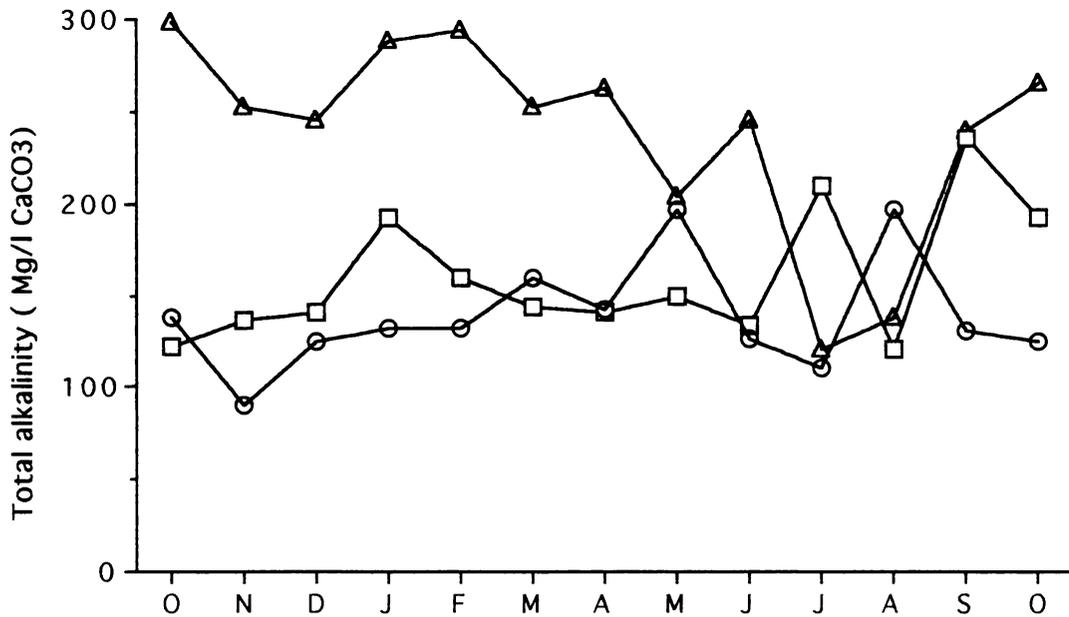


Figure 8. Monthly total alkalinity concentrations for ponds A (triangle), B (box), and C (circle).

October of 1989 and 1990. The lowest value of 8.0 was recorded in January.

In pond B the annual mean pH was  $8.4 \pm 0.3$ . The seasonal means were  $8.5 \pm 0.1$  for the spring,  $8.5 \pm 0.2$  for the summer,  $8.5 \pm 0.1$  for the fall, and  $8.0 \pm 0.4$  for the winter. The largest value of 8.6 was recorded in October 1989, April, and July. The lowest value of 7.7 was recorded in December. This value is considerably lower than all others recorded and subsequently was checked in triplicate in the field and similar values were found with each test. This apparently depressed pH in December is unexplained.

In pond C the yearly mean pH was  $8.4 \pm 0.1$  and the seasonal averages were:  $8.4 \pm 0.1$  for the spring,  $8.4 \pm 0.1$  for the summer,  $8.4 \pm 0.1$  for the fall, and  $8.4 \pm 0.2$  for the winter. The lowest value of 8.2 was recorded in February and the largest value of 8.5 occurred in several months.

### Alkalinity

The monthly total alkalinity concentrations for ponds A, B, and C are shown in figure 8. Pond A was found to be significantly more alkaline than ponds B and C ( one factor ANOVA  $p < 0.05$ , Fisher PLSD  $p < 0.05$ ).

In pond A the annual mean alkalinity concentration was  $238.9 \pm 54.9$  (mean mg/l  $\text{CaCO}_3 \pm$  std. dev.). The seasonal concentrations were  $239.7 \pm 31.4$  for the spring,  $168.0 \pm 68.0$  for the summer,  $263.8 \pm 25.0$  for the fall, and  $276.0 \pm 26.1$  for the winter. As mentioned above pond A is more alkaline than ponds B and C, this elevated alkalinity may be attributed to the large amounts of decomposition

which occur in this pond. Wetzel (1983) has shown that the combination of heterotrophic and microbial degradation processes of organic matter lead to an increase in total carbon in the hypolimnion of eutrophic lakes. Ohle (1952) states that the origin of increasing concentrations of bicarbonate in the hypolimnion stem in part from the bacterial production of ammonium bicarbonate in the sediments, where ferrous and manganous ions are released as bicarbonates from the sediments under reducing, anoxic conditions. Throughout most of the study the floor of pond A was covered with a thick, dark layer of organic matter and anaerobic conditions were sure to persist within the sediments. This extended period of anoxia within the sediments may contribute to the elevated concentrations of total alkalinity found in this pond.

In pond B the annual mean alkalinity was  $159.6 \pm 36.2$ . The seasonal averages were  $144.7 \pm 5.0$  for the spring,  $154.7 \pm 48.2$  for the summer,  $171.5 \pm 52.6$  for the fall, and  $164.0 \pm 26.2$  for the winter. The extremes were recorded in October 1989 (122 mg/l) and September (236 mg/l).

In pond C the annual mean alkalinity was  $138.6 \pm 30.2$ . The seasonal averages were  $166.0 \pm 27.5$  for the spring,  $144.0 \pm 45.7$  for the summer,  $120.8 \pm 21.2$  for the fall, and  $129.7 \pm 4.0$  for the winter. The highest concentration of 196 mg/l was recorded in June and August. The lowest concentration of 90 mg/l was recorded in November.

## Salinity

The monthly salinity concentrations for ponds A, B, and C are shown in figure 9. Pond C was found to be significantly more saline than both ponds A and B (ANOVA  $p < 0.05$ , Fisher PLSD  $p < 0.05$ ). The salinity of ponds A and B were similar. Salinity increased in all ponds from July to October 1990. This increase is attributed to the evaporative dry down which occurs in the ponds during this time of the year.

In pond A the annual mean salinity was  $0.58 \pm 0.7$  (mean ppt  $\pm$  std. dev.). The seasonal means were  $0.23 \pm 0.02$  for the spring,  $0.20 \pm 0.09$  for the summer,  $1.32 \pm 0.8$  for the fall, and  $0.33 \pm 0.02$  for the winter. The highest value of 2.20 ppt occurred in October 1990 and the lowest concentration of 0.12 ppt was recorded in July.

In pond B the annual mean salinity was  $0.64 \pm 0.84$ . The seasonal means were  $0.187 \pm 0.01$  for the spring,  $0.95 \pm 1.3$  for the summer,  $1.08 \pm 0.9$  for the fall, and  $0.18 \pm 0.05$  for the winter. The extremes of 0.12 ppt and 2.5 ppt were recorded in February and August respectively.

In pond C the annual mean salinity was  $15.9 \pm 4.1$ . The seasonal means were  $11.4 \pm 0.8$  for the spring,  $16.1 \pm 2.6$  for the summer,  $17.7 \pm 5.5$  for the fall, and  $18.1 \pm 1.7$  for the winter. The largest concentration of 22.8 ppt occurred in October 1990 in response to the evaporative concentration of late summer dry-down. The lowest of 10.5 ppt occurred in March as a result of spring rain dilution. The brackish nature of pond C is unexplained. Sissom (1990) suggests three theories. The first of these is that salt may have been added to create a redfish pond. The second theory is that salt may be entering

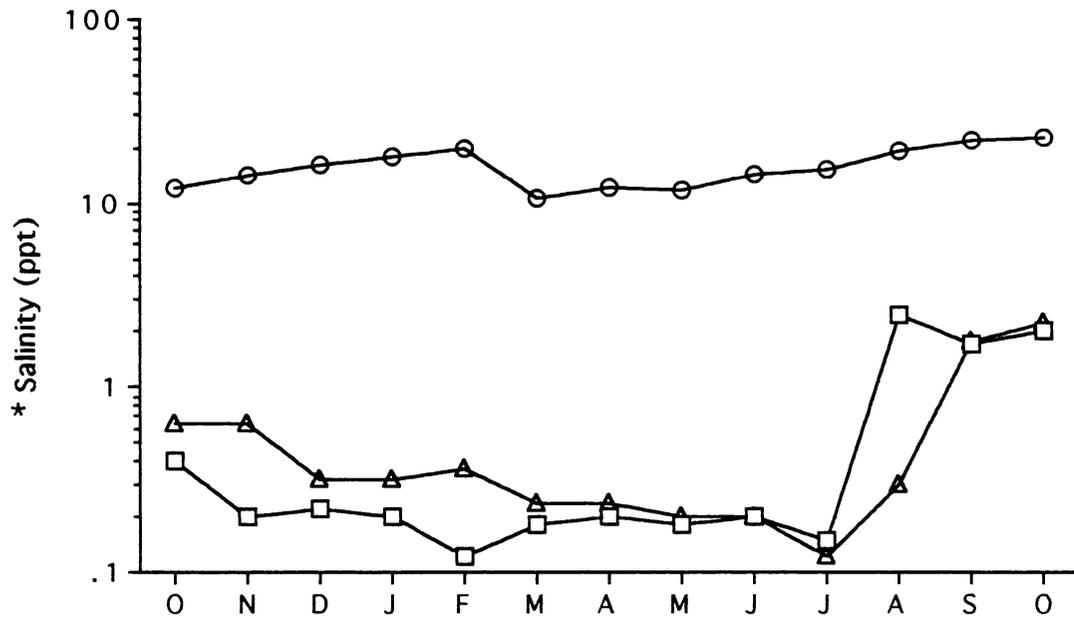


Figure 9. Monthly salinity concentrations for ponds A (circle), B (box), and C (circle). \* Log scale.

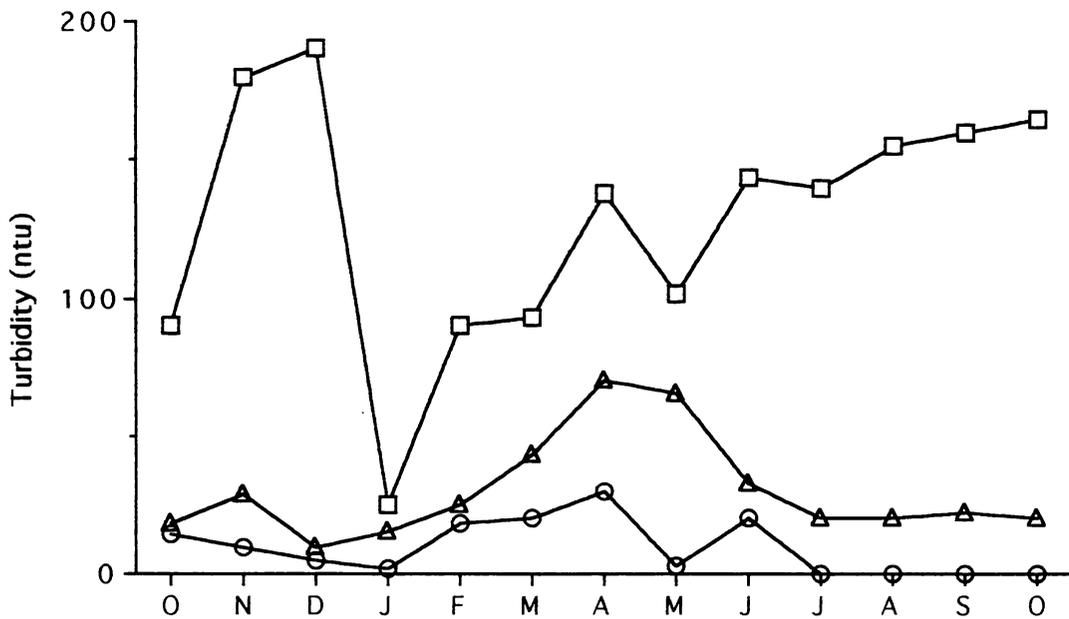


Figure 10. Monthly turbidity values for ponds A (triangle), B (box), and C (circle).

the pond from ground water originating in the bay. The third theory given is that salt may be leaching from salt deposits within the subsurface structure of the pond. A combination of the latter two theories most likely contribute to the brackish nature of this pond.

### Turbidity

The monthly turbidity values for ponds A, B, and C are given in figure 10. Pond B was found to be significantly more turbid than ponds A and C (one factor ANOVA  $p < 0.05$ , Fisher PLSD  $p < 0.05$ ). Pond A was consistently more turbid than pond C, though this difference was found not to be significant.

In pond A the annual mean turbidity was  $30 \pm 18.6$  (mean ntu  $\pm$  std. dev.). The seasonal means were  $59.3 \pm 14.4$  for the spring,  $24.3 \pm 7.5$  for the summer,  $22.3 \pm 4.8$  for the fall, and  $16.7 \pm 7.6$  for the winter. The increase in turbidity from December to April is attributed to an algal bloom which occurred over this period. The following decrease in turbidity from April to July is indicative of the death of this algal bloom.

In pond B the annual mean turbidity was  $128.5 \pm 46.2$ . The seasonal means were  $110.6 \pm 24.0$  for the spring,  $146.3 \pm 7.8$  for the summer,  $148.8 \pm 40.0$  for the fall, and  $101.7 \pm 83.1$  for the winter.

As mentioned above, pond B was more turbid than ponds A and C. This is attributed to the large populations of phytoplankton which are present in pond B. Sissom (1990) reported that large populations of blue green and green algae dominated the plankton community in pond B and the numbers of crustaceans were very low and limited to a few ostracods, copepods, and naupilus larvae. These populations most

likely dominate the plankton community because of the site selective predation on herbivorous zooplankton by the planktivorous fish species present in this pond. Hulbert et al. (1972) and Hulbert and Mulla (1981) have shown that the mosquitofish, G. affinis, can greatly alter the species present at lower trophic levels. They noted that predation by mosquitofish on planktonic herbivores can lead to an increase in phytoplankton. Lynch and Shapiro (1981) demonstrated that large herbivores were capable of suppressing large algal species, and that total phytoplankton biomass generally increased in the presence of planktivorous fish. Thus, the explanation for elevated turbidity in pond B is supported by several factors. First, is that only Gambusia and other planktivorous fish are present in pond B. Second, is the composition of the plankton community reported by Sissom and third is the established relationship between planktivore abundance and phytoplankton biomass. Also of interest is the dramatic decrease in turbidity from December to January. This event was coincident with the harsh freeze of December and was most likely caused by a decrease in the abundance of phytoplankton populations. This is supported by the findings of Sissom (1990); who reported a decrease in the abundance of blue-green algae from November to a low in January and suggested that the decrease was related to the onset of colder winter weather.

In pond C the annual mean turbidity was  $9.4 \pm 10.0$ . The seasonal means were  $17.7 \pm 13.7$  for the spring,  $6.7 \pm 11.5$  for the summer,  $6.0 \pm 7.1$  for the fall, and  $8.3 \pm 8.5$  in the summer.

## FISH FAUNA

### *CYPRINODON VARIEGATUS*

#### ABUNDANCE

Cyprinodon variegatus was the only species found to occur in all three ponds and accounted for 55.6 % of the 4,939 fish collected throughout the study period. This was the most abundant fish species in both ponds A and C and accounted for 83% and 92% of the total numbers of fish collected from each pond respectively.

In pond A the abundance of C. variegatus (Figure 11, pond A) decreased from November to a minimum of zero in March. In March pond A was choked by a very large bloom of filamentous green algae that made seining extremely difficult, it is believed that fish were present in the pond in very low numbers during March and that the difficulty in seining did not allow their detection. From March numbers began to increase to a maximum in October. In ponds B and C (figure 11 pond B and pond C) the abundance of C. variegatus decreased from December to February in which fish were not collected from either pond. The distinct decrease in all ponds from December to January is due perhaps to the effect of the harsh freeze that occurred in December. As in pond A, the abundance of C. variegatus began to increase in March in both ponds B and C. In pond C this increase continued through to a maximum in September, while in pond B maximum abundance was reached in June where numbers remained somewhat constant through the end of the study. The increase in abundance in all ponds during the summer months is attributed to the addition of young into the population. However, this

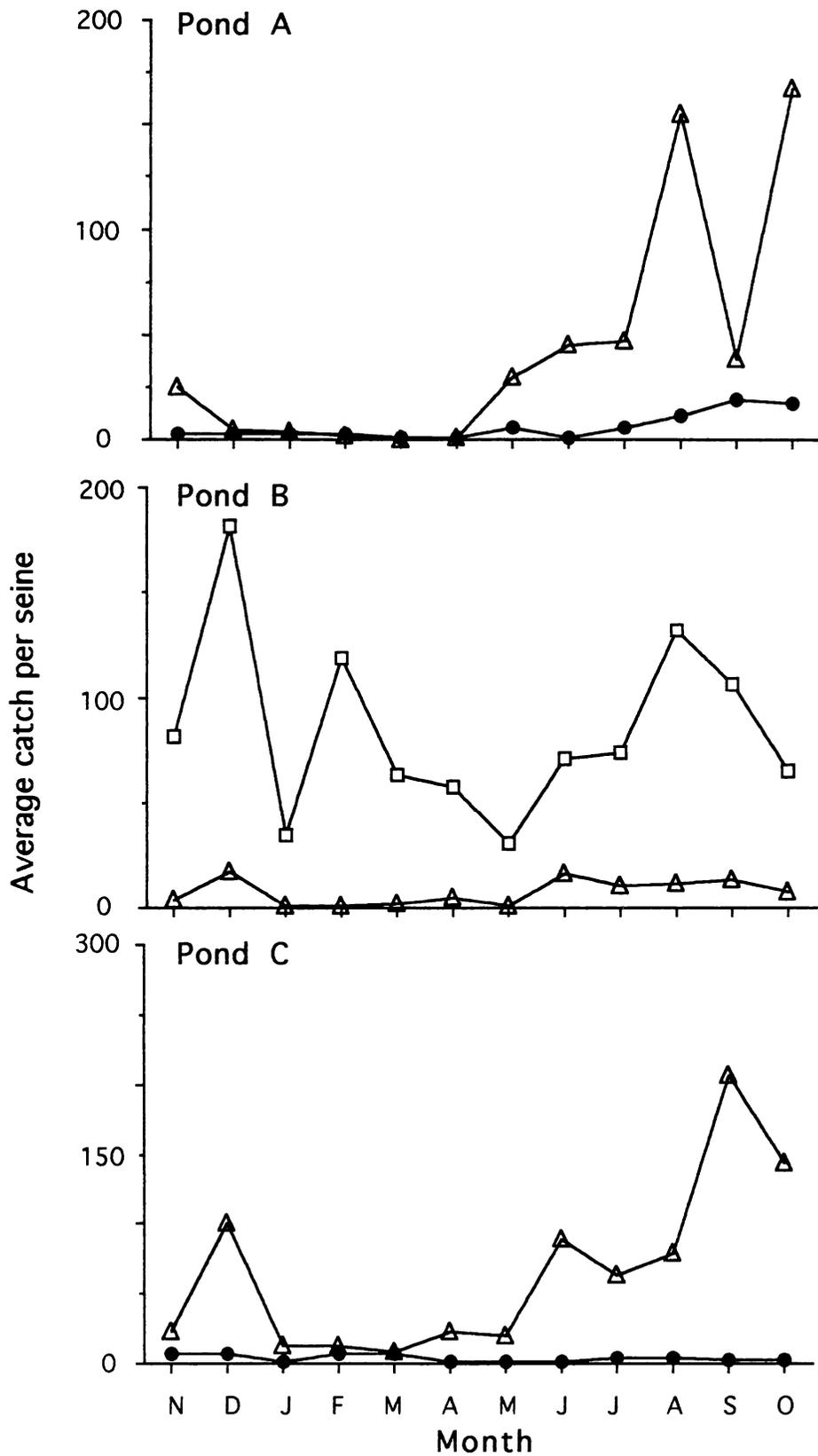


Figure 11. Average catch per seine of *Cyprinondon variegatus* (triangle), *Fundulus grandis* (closed circle), and *Gambusia affinis* (box) collected in ponds A, B, and C from November 1989 to October 1990.

increase is most likely an over estimation of the true population increase because of the reduction in pond volume in the late summer and the subsequent sampling error associated with this reduction.

## POPULATION DYNAMICS

### POND A

The size of C. variegatus in pond A (figure 12) ranged from 5-52 mm with the largest individuals being collected in August. From November to May the size range of C. variegatus remained relatively constant, though very few individuals were collected between January and April. In June the range of total lengths widened from 7-49mm, indicating recruitment of offspring. Recruitment was followed by a period of individual and population growth from May to October. Population growth, as indicated by the increase in the average catch per seine (figure 11, pond A), is attributed to the detected episode of recruitment. Individual growth is reflected by the upward shift of total lengths in the frequency distribution, an increase in the number of larger individuals (figure 12), and by an increase in the mean total length of parent stock (figure 15, pond A). The growth of broods and parent stock during this period were followed in figure 18, pond A. Parent stock grew from  $26.5 \pm 5.6$  in May (mean total length mm  $\pm$  std. dev.) to  $32.8 \pm 3.0$  in October and the  $F_1^a$  brood grew from a modal length of 10 to 30 mm respectively.

Following this period of growth the number of larger individuals decreased in the population from August to October. This loss of larger individuals may be attributed to two factors. First, the individuals which are lost are parent stock born early in the season

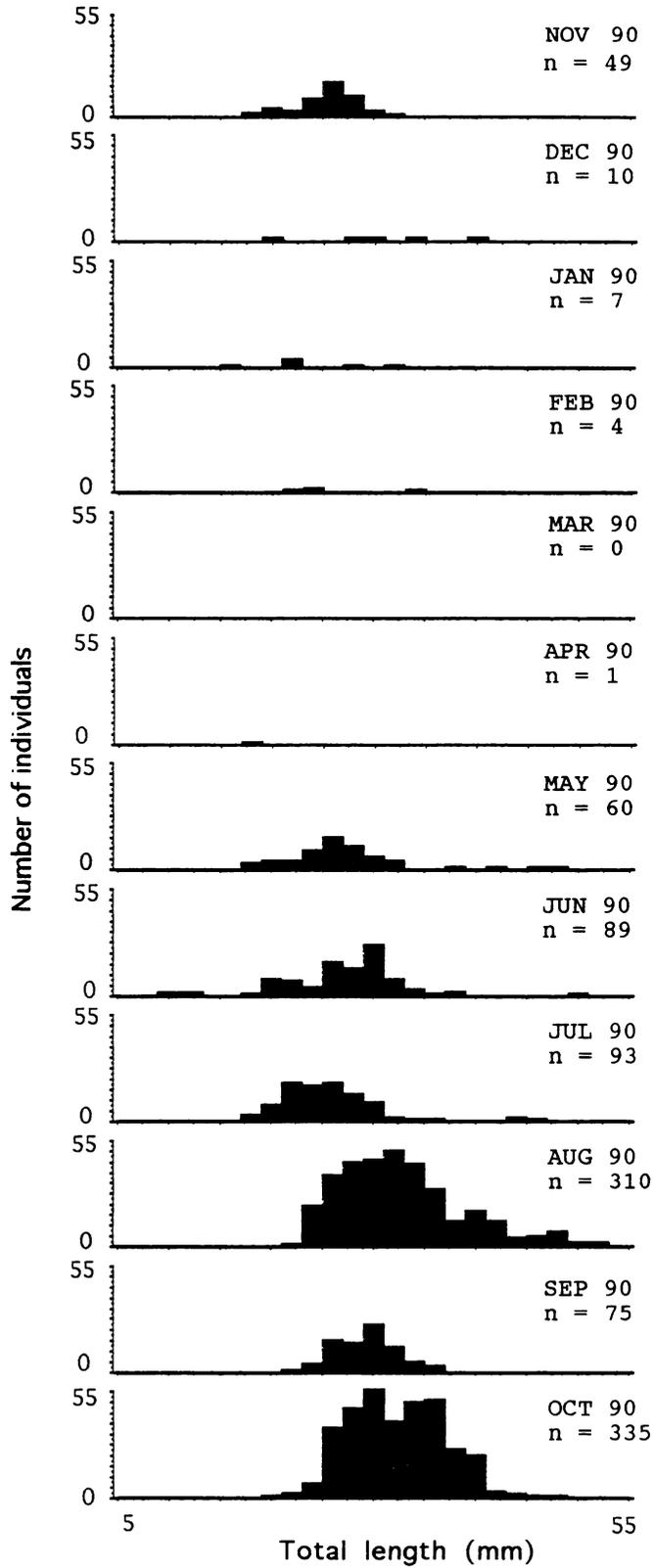


Figure. 12. Monthly length-frequency distributions of Cyprinodon variegatus collected from pond A.

or late in the previous year and are reaching the end of their life span. Gunter (1945) observed a similar loss of large individuals from a population of C. variegatus along the inner bays of the Texas coast and suggested that C. variegatus may have a rather short life cycle in this area. In his study Gunter concluded that spawning covers a long period and the young feed into the population from June to September. Growth then takes place within a closed population and the largest individuals disappear in the latter summer months, most likely after spawning. The second factor that may contribute to the loss of larger individuals is site selective predation from avian predators. Britton and Moser (1982) consider the fact that Carmarque (Rhône Delta, U.K.) herons selectively fed on larger Gambusia to result in skewed sex ratios in adult Gambusia stocks. Botsford et al. (1987) considered site selective predation by snowy egrets, Leuophoxyx thula, and green-backed herons, Butorides striatus, to be a source of mortality in larger Gambusia in a California rice field. From August to October the depth of pond A was very low ( $\approx 0.2\text{m}$ ) and the pond took on a very marsh like appearance and was an ideal habitat for wading birds. Great blue herons, Ardea herodias, and American egrets, Casmerodius albus, were observed feeding in the pond many times throughout the study and especially during the latter summer months. According to the findings above it is likely that predation by water fowl is a source of mortality of large C. variegatus in pond A during late summer and early fall.

## POND B

In pond B the size of C. variegatus ranged from 5-55 mm with the largest individuals being collected in August (figure 13). From June to August the size range of C. variegatus gradually shifted upward from 22-53 mm to 27-55 mm respectively. This period of growth is also reflected by an increase in the mean total length of parent stock (figure 15, pond B) from  $34.2 \pm 8.3$  (mean total length mm  $\pm$  std. dev.) in June to  $39.2 \pm 6.5$  in September.

Like pond A, there was a decrease in the number of larger individuals in the frequency distribution from August to October. As in pond A, it is thought that this loss is caused by death of the parent stock which were born early in the season or late in the previous year and by size selective predation from water fowl. However, because of the depth of pond B and its lack of shallow sloping edges, and due to the low numbers of wading birds sited at this pond the effect of avian predation is probably negligible.

Recruitment was not detected in pond B; but, because of the low numbers of C. variegatus collected from this pond the length-frequency data (figure 13) should be treated with some caution. With this in mind, it appears that recruitment may have taken place in May; this is thought so because the smallest individuals collected in pond B were taken in June and thus could have come from a May brood and grew to the size at which they were collected in June. This would also be consistent with episodes of recruitment detected in ponds A and C.

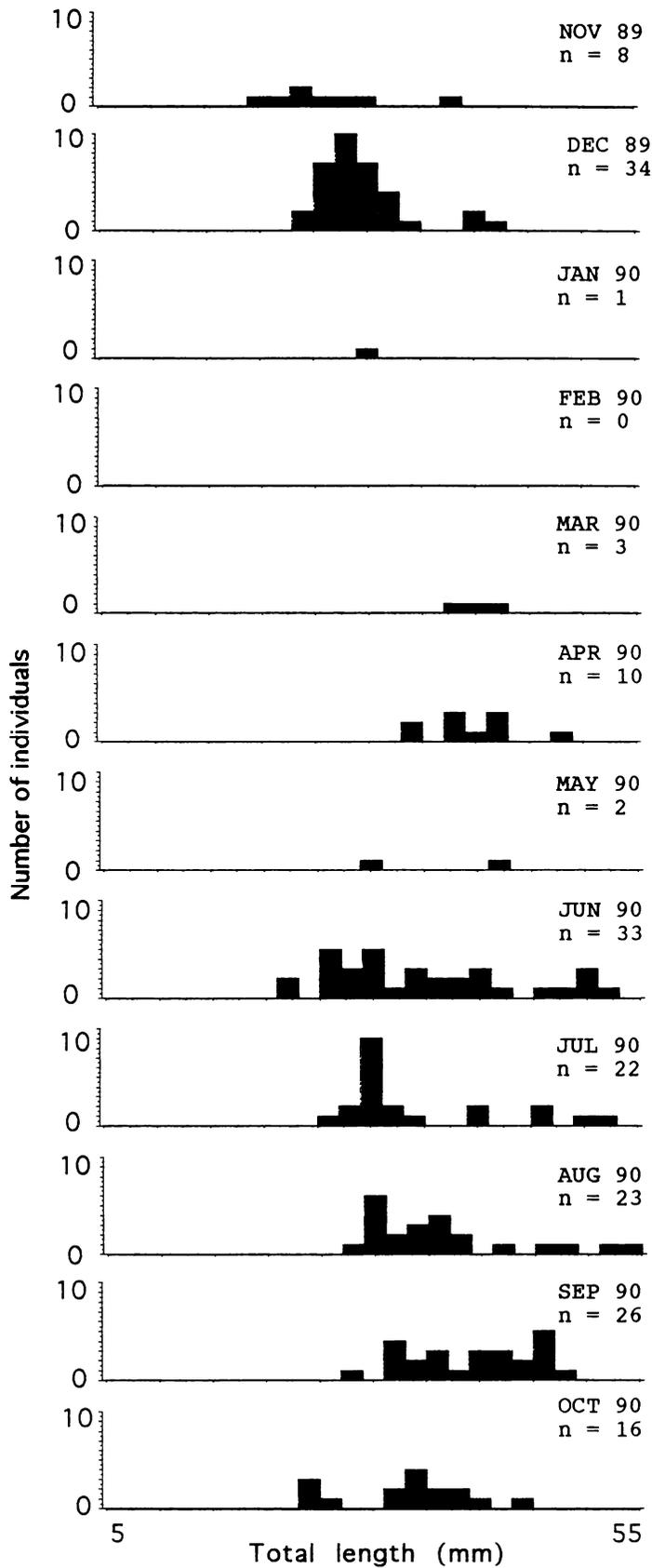


Figure 13. Monthly length-frequency distributions of *Cyprinodon variegatus* collected from pond B.

## POND C

The size of C. variegatus ranged from 5-47 mm in pond C with the largest individuals being collected in June and October (figure 14). Three episodes of recruitment with coincident periods of population and individual growth were detected in pond C.

The first period of growth and recruitment began in November 1989. During this month the size of C. variegatus ranged from 7-34 mm, this range shifted upward in December and then narrowed to 15-35 mm in January. Individual growth, reflected in figure 15, pond C, was relatively slow during this period. The  $F_1^a$  brood grew from 10 to 20 mm in 61 days and parent stock increased only slightly in mean total length from December to January. The comparatively slow growth during this period may be attributed to low winter temperatures. Population growth during this time, attributed to the pulse of recruitment, is indicated by the increase in the average catch per seine of C. variegatus (figure 11, pond C) from November to December.

The second period of growth and recruitment began in April, in which the size of fish collected ranged from 10-42 mm. The size of parent stock remained relatively constant during this second period of growth as indicated by the similar ranges of total length from March to May (figure 14) and by the similar values in mean total length from March to June (figure 15, pond C). On the other hand, the  $F_1^b$  brood recruited during this period grew rapidly from a modal length of 10 mm in April to 32 mm in June (figure 15, pond C). The increase in population numbers, attributed to the April pulse of recruitment, is reflected in the increase in the average catch per

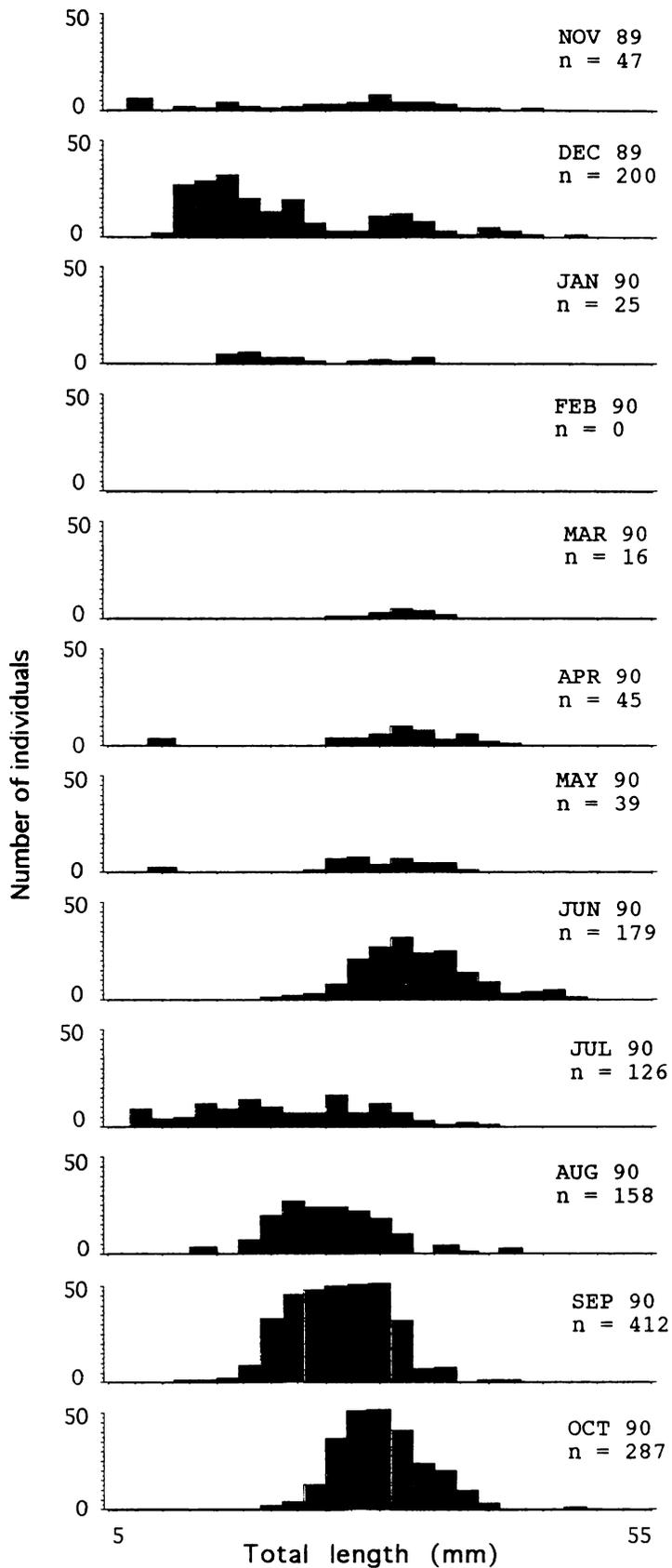


Figure 14. Monthly length-frequency distributions of *Cyprinodon variegatus* collected from pond C.

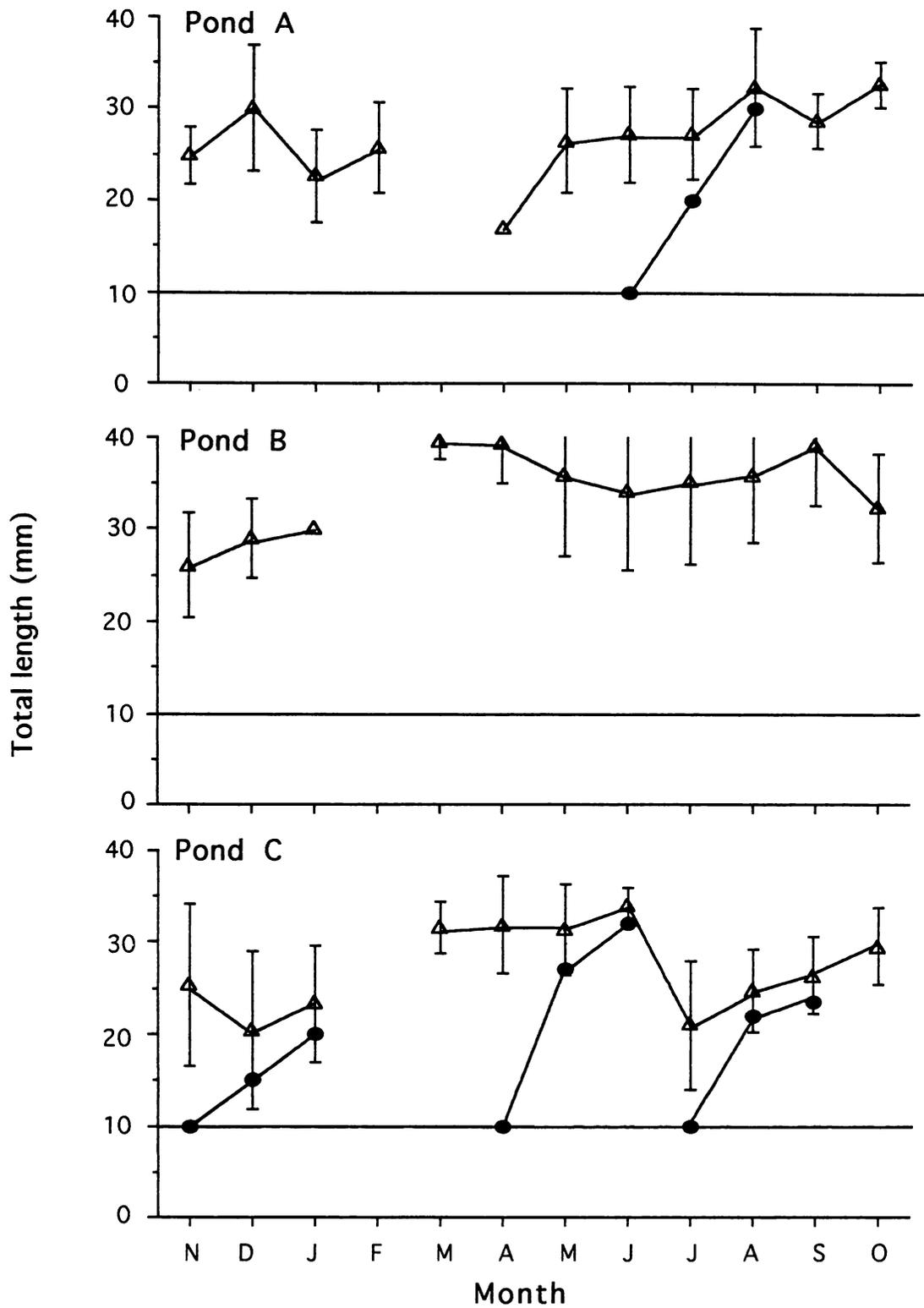


Figure 15. Mean total length (open triangle) and modal total length(closed circle) of *Cyprinodon variegatus* collected from ponds A, B, and C. Vertical lines indicate standard deviation of mean total length. Solid horizontal line indicates the total length used as a base-line for establishing entry into the population, estimating brood growth and interbrood interval. Unconnected data points correspond to those months in which fish were not captured.

seine from March to April (figure 11, pond C).

The third episode of growth and recruitment began in July and extended through October. Parent stock growth rates were greatest during this time in which mean total length increased from  $20.9 \pm 7.7$  (mean total length mm  $\pm$  std. dev.) in July to  $29.5 \pm 4.1$  in October. The growth rate of the  $F_1^c$  brood, recruited in July, was intermediate between the  $F_1^a$  and  $F_1^b$  broods (figure 15, pond C).

Following the November and April periods of growth and recruitment were two periods in which larger individuals were lost from the population. The first episode, from December to January, may be attributed to three factors. First, the larger individuals that are lost may have been born early in the summer of the previous year and are reaching the end of their life span. Second, is the possible impact of size selective predation by water fowl during this time of the year. During the winter months large numbers of migratory water fowl were observed at pond C, many of which are known to consume fish. Third, is a possible size dependent mortality in response to cold. This third factor is mentioned because this first period of larger individuals being lost from the population was coincident with a harsh freeze in late December. Gunter (1938) made the observation, previously noted by Hildebrand (1917), that there was a possible size differential mortality in marine poikilothermic animals; in which small individuals survived sudden cold spells better than larger ones. Gunter (1941) observed a similar size differential mortality in several species of fish in Copano Bay and Aransas Bay, Texas impacted by a harsh freeze in January 1941. Though no large, dead C. variegatus were collected

following the observed freeze in December it is believed that if there is a size differential mortality, that the larger dead individuals would have been quickly consumed by the birds sited around the pond.

The second period of larger individuals being lost from the population occurred from June to August and is somewhat obscured by the development of the  $F_1^b$  and  $F_1^c$  broods. The larger individuals that are lost during this period are believed to be individuals that were recruited in November of 1989. These individuals grew to maturity and were responsible for the  $F_1^b$  brood of April and then were lost from the population. Hildebrand (1917) found that broods recruited late in the breeding season, over-wintered, produced offspring early in the breeding season of the following year and then were lost from the population. As in the other ponds site selective predation by waterfowl may be partially responsible for the loss of large fish from the population. However, because of the low numbers of wading birds sited around pond C during these months and due to the absence of migratory birds in the area during this time of the year these impacts are thought to be minor.

Cyprinodon variegatus has been shown to have a long breeding season by several researchers. In Beaufort, North Carolina, Hildebrand (1917) found fish in spawning condition as early as March and late as October. In Florida, Raney et al. (1953) observed spawning behavior from March to December and concluded that the spawning season of C. variegatus may extend for more than half a year. In a coastal Florida marsh, Kilby (1955) collected young fish ( $\leq 15$  mm) in all months except January and concluded that fish might

spawn on a year a round basis in the warmer parts of the Gulf of Mexico. The breeding season of C. variegatus in pond C, as reflected by the detected episodes of recruitment, does not vary greatly from those reported above. Conversely, the observed recruitment in pond A reflects a much shorter breeding season. It is believed that the breeding season of C. variegatus in pond A is reduced because of conditions which prevail in the pond at certain times of the year. Due to the small size of pond A, it represents a much less stable system than pond C and subsequently it will experience much more diel variation in temperature, which is believed to be partially responsible for cueing spawning behavior. Favorable temperature regimes for spawning may have existed in pond A as early as March or April, as suggested by the April episode of recruitment in pond C; but, breeding may have been mechanically interfered with by the large algal bloom present in pond A during these months. Spawning nests were observed in pond A beginning in March; but they appeared unguarded and unkept perhaps because of the interference from the algal bloom. Thus, by keeping male C. variegatus from maintaining spawning nest and by retarding male/female spawning interaction the algal bloom may have delayed breeding in pond A until the bloom was reduced in late May and June. Since recruitment was not detected in pond B, little can be described about the population dynamics of C. variegatus in this system. The low population numbers and lack of detected recruitment may be influenced by the morphology of the pond. Breder (1934) and Raney et al. (1953) described the preferred breeding site of C. variegatus as being shallow (0.03 m-0.6 m), marginal areas. Because of the rather steep

edges or lack of shallow marginal areas in pond B suitable spawning habitat may be limiting for C. variegatus. This could possibly lead to fewer successful spawning episodes, due to the lack of suitable spawning habitat, resulting in low population numbers relative to the other ponds.

## *FUNDULUS GRANDIS*

### ABUNDANCE

This species was found to occur only in ponds A and C. No F. grandis were found in pond B. Why this species is excluded from this pond is unexplained. It is possible that the abundant blue-green algal population of pond B fouls the water for F. grandis. It is also possible that this species merely escaped capture throughout the study, though this is thought not to be the case.

The greatest numbers of Fundulus grandis were taken from pond A and accounted for 18% of the 1,165 fish collected from this pond. F. grandis accounted for 9% of the of the 1,564 fish collected from pond C. In both ponds A and C, few fish were collected until May 1990 (figure 11, pond A and pond C). From May numbers began to increase in both ponds. The greatest numbers of individuals were collected in September in pond A and in July in pond C.

### POPULATION DYNAMICS

#### POND A

The size of F. grandis collected in pond A ranged from 18-72 mm (figure 16). One 18 mm specimen was collected in June and the largest individuals were collected in September.

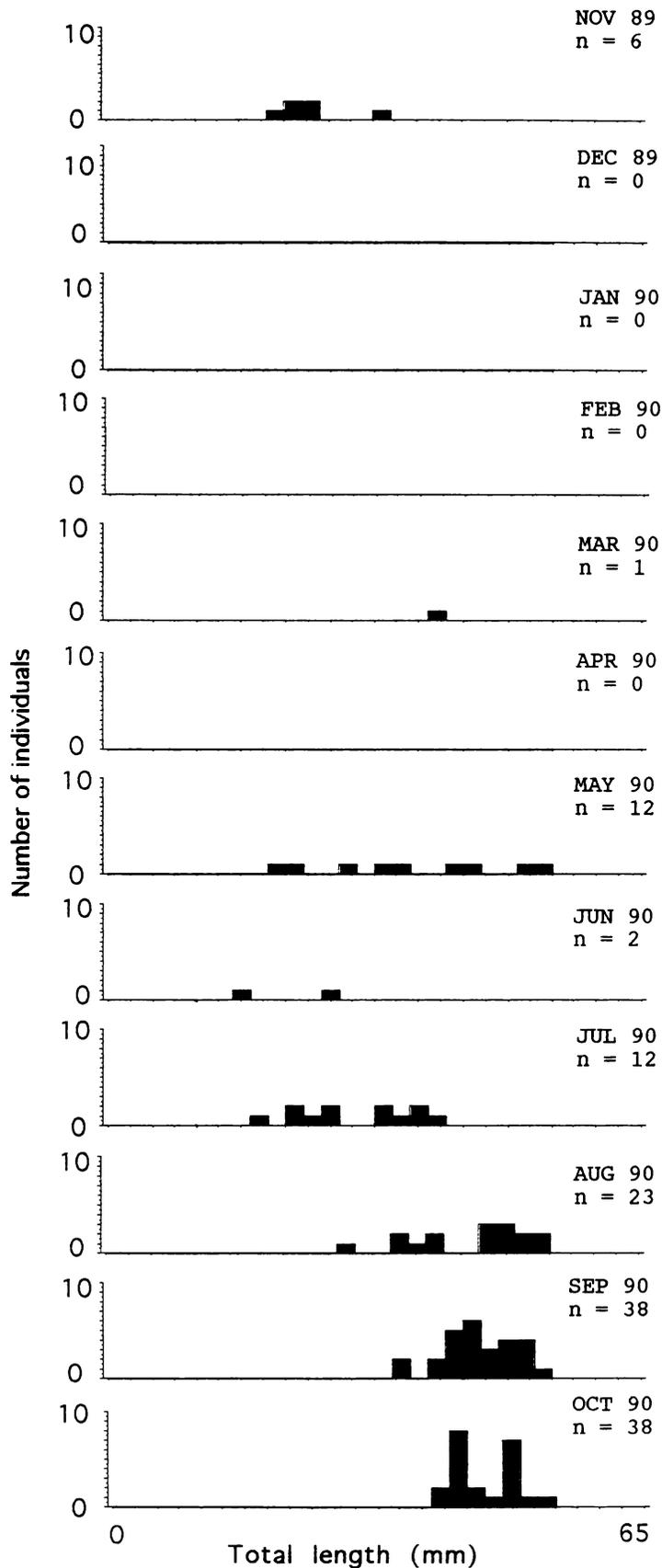


Figure 16. Monthly length-frequency distributions of Fundulus grandis collected from pond A.

Recruitment of F. grandis was not detected in pond A, but it is possible that recruitment may have occurred in early summer as indicated by the collection of the smallest individual in June. Gunter (1945) collected small individuals of F. grandis from June to August along the Texas coast. For Texas bays, Simpson and Gunter (1956) found that small individuals (23-28 mm) were present in June and July and in December and January.

From June to October there is a period of population and individual growth. Individual growth is reflected by the upward shift in the range of total lengths and by the increase in mean total length during this period (figure 18, pond A). Figure 18, pond A, shows that the parent stock grew rapidly from  $25.0 \pm 7.1$  (mean total length mm  $\pm$  std. dev.) in June to  $50.0 \pm 10.5$  in August when growth then slowed through to October. Population growth is evident by the increase in the average catch per seine during this period (Figure 11, pond A and pond C). As with Cyprinodon, this increase in numbers during the summer months may be an over estimation of the true population increase because of the reduction in pond volume from summer dry-down.

#### POND C

The size of F. grandis ranged from 15-78 mm in pond C. The smallest specimens were collected in January and the largest in September. Because of the very low numbers of F. grandis taken from pond C little information is obtainable from the length-frequency (figure 17) and growth data (figure 18, pond C).

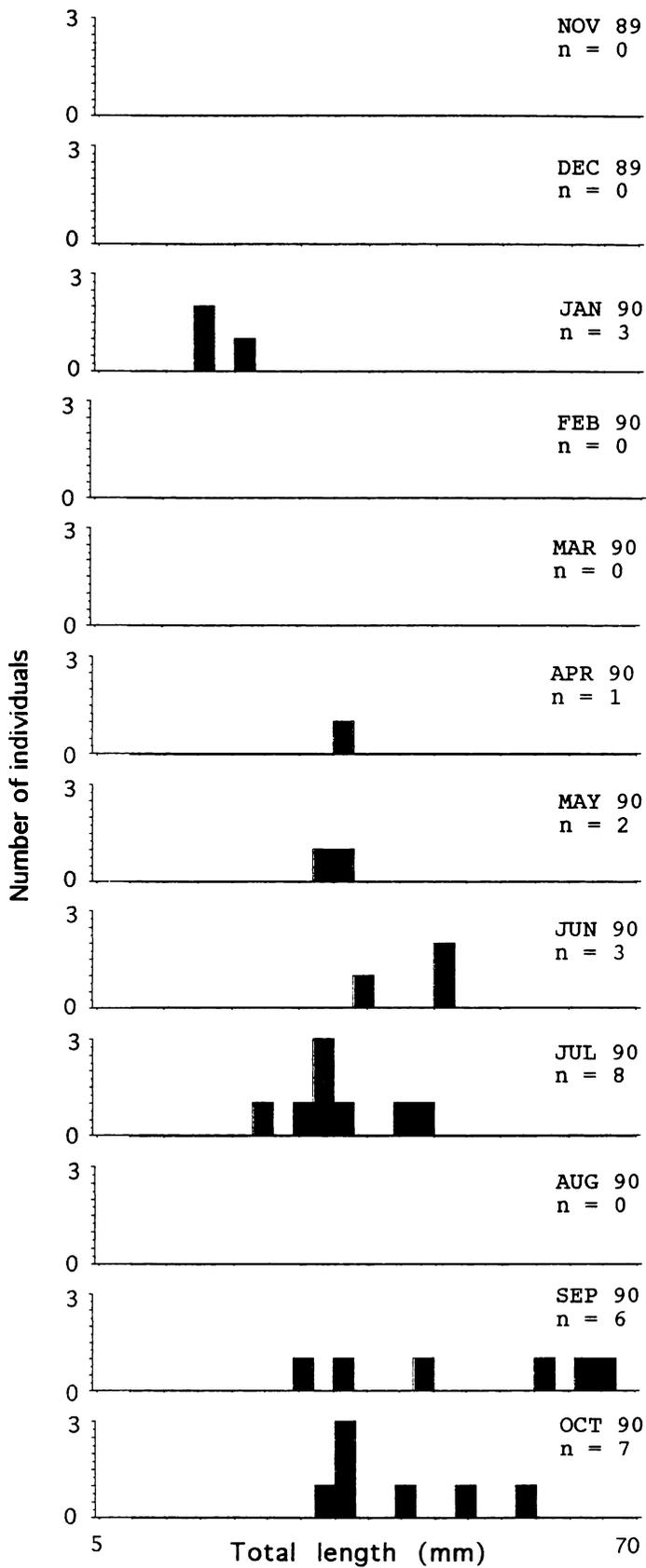


Figure 17. Monthly length-frequency distributions of *Fundulus grandis* collected from pond C.

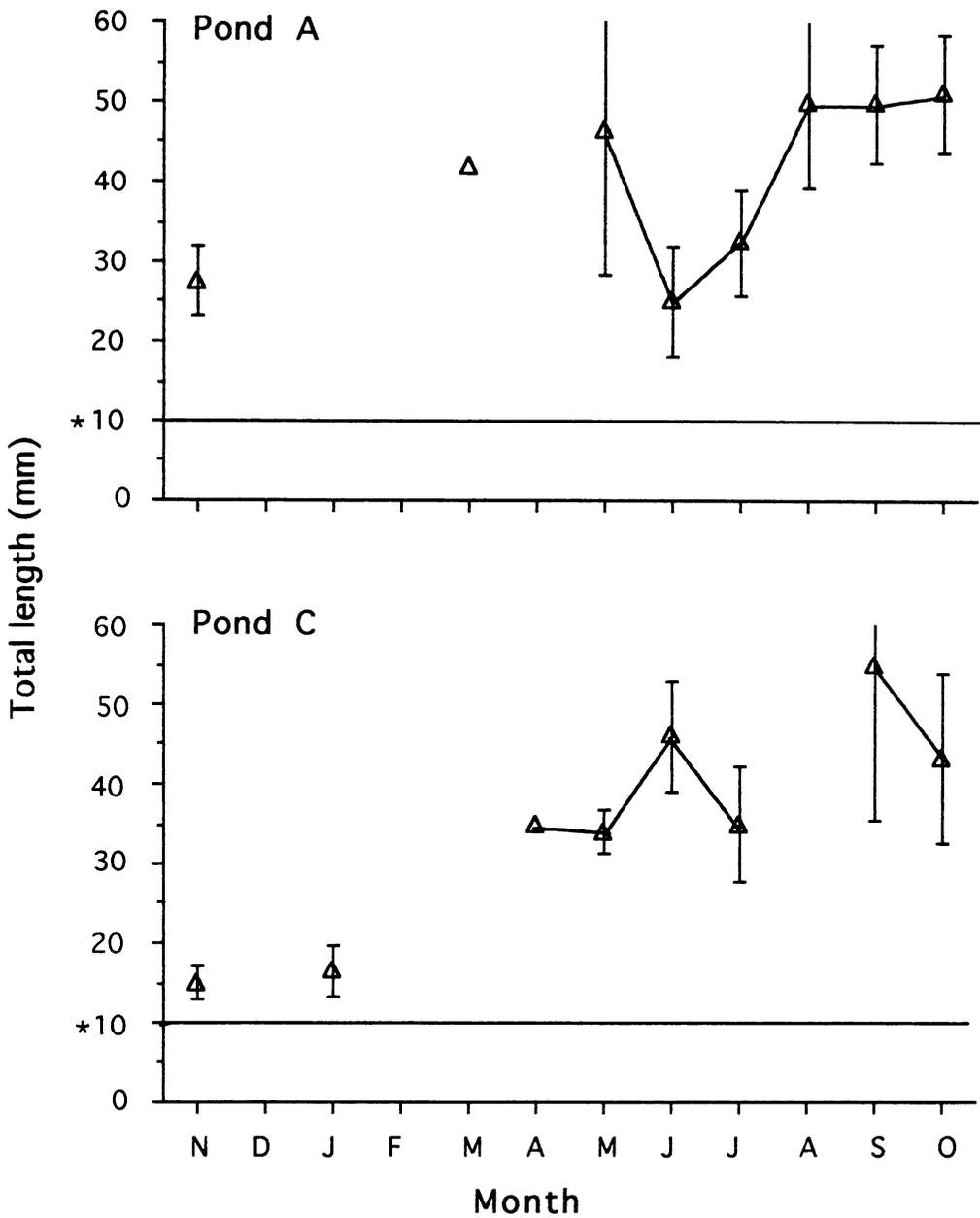


Figure 18. Mean total length of *Fundulus grandis* collected from ponds A and C. Vertical lines indicate the standard deviation of mean total length. Solid horizontal line indicates the total length used as a base-line for recruit entry into the population, estimating brood growth, and interbrood interval. Unconnected data points correspond to those months in which fish were not captured. \*Note broods of *F. grandis* were not detected in either pond resulting in the absence of modal total lengths within this figure.

As in pond A, recruitment of F. grandis was not detected in pond C. Given that the smallest individuals were collected in January, it is possible that F. grandis has a long breeding season in pond C as did C. variegatus and recruitment was simply not detected. In a Florida coastal marsh, Kilby (1955) found fish of all size ranges at all seasons of the year and concluded that F. grandis exhibited a continuous breeding season in this area. Recruitment may not have been detected due to sampling bias. Because of the depth and large size of pond C, seining efforts were restricted to the shoreline areas and thus the middle portions of the pond were not sampled. It is possible that F. grandis may remain in the middle or deeper portions of the pond and subsequently do not make themselves readily available for capture.

Because of the low numbers of F. grandis collected from either pond A or C little information concerning this species population dynamics was generated. According to the literature, the spawning season of F. grandis varies according to locale and may extend year-round in warm areas of the Gulf of Mexico (Kilby 1955, Joseph and Yerger 1956, and Springer and Woodburn 1960). It is believed that F. grandis should have a breeding season similar to those reported for C. variegatus in ponds A and C.

## *GAMBUSIA AFFINIS*

### ABUNDANCE

Gambusia affinis was found to occur primarily in pond B where it accounted for 90% of the 2,210 fish collected from this pond. In April and June a few small individuals were collected in pond C and

no fish were found in pond A. The absence of this fish from pond A is unexplained and raises some interesting questions. Though pond A would appear to be a suitable habitat for Gambusia something restricts this fish from occurring here and further study is needed in this area to explain its absence.

The average catch per seine of G. affinis (figure 11, pond B) initially increased from November to December 1989; population numbers then decreased in January. This decrease is due perhaps to the freeze of late December. From January numbers began until increase to February, following was a steady decrease in the average catch per seine to a low in May. Then as with the other fish species numbers increased from May to August.

## POPULATION DYNAMICS

### POND B

The size of G. affinis ranged from 7-55 mm in pond B. The largest individuals were collected in November and small individuals (7-10 mm) were taken seven out of the 12 months sampled (figure 19). In November, the frequency distribution was strongly bimodal and reflects two groups in the population, immature individuals and males (7-30 mm), and females (31-55 mm). From November to February there was a loss of large females from the population. This loss of larger females is also reflected by the decrease in mean total length of females from November to January (figure 20). The females that are lost during this period are believed to be individuals that were born late in the breeding season of the previous year. These individuals were responsible for the  $F_1^a$  brood

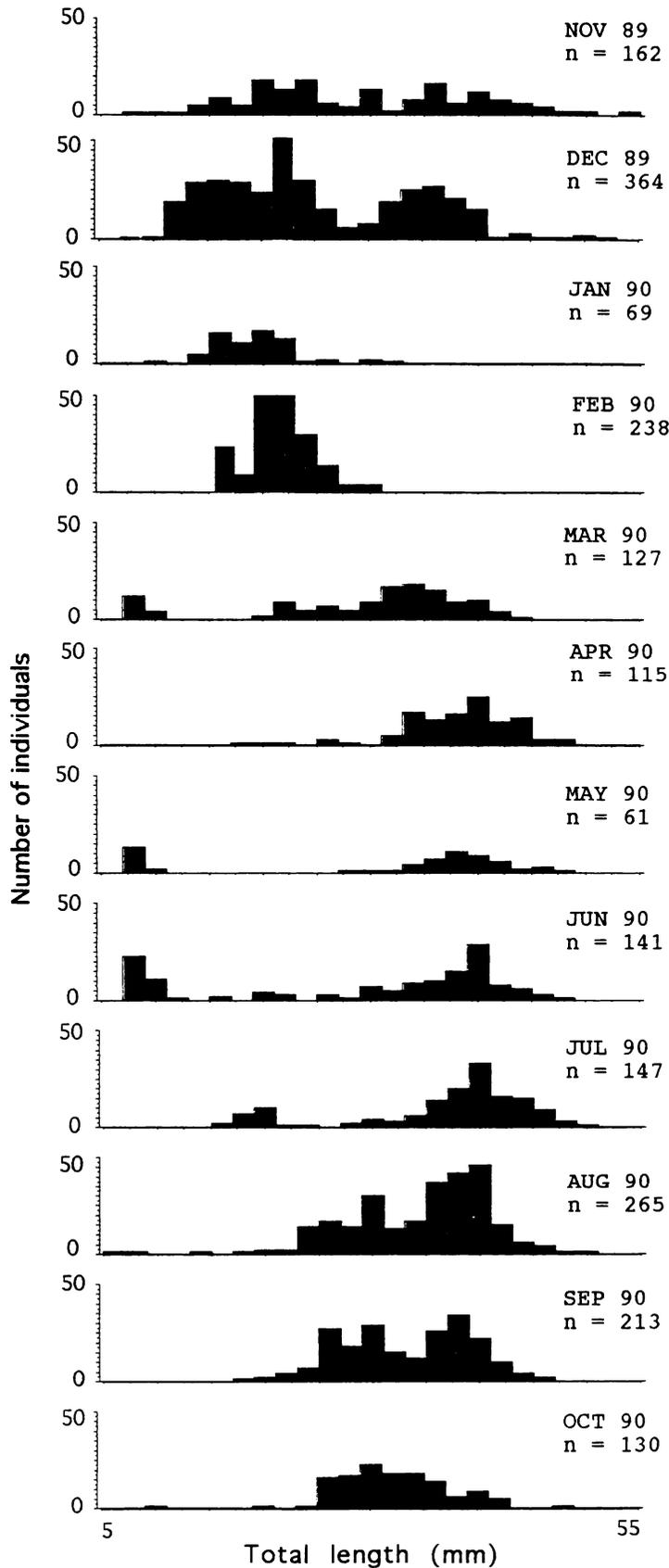


Figure 19. Monthly length-frequency distributions of *Gambusia affinis* collected from pond B.

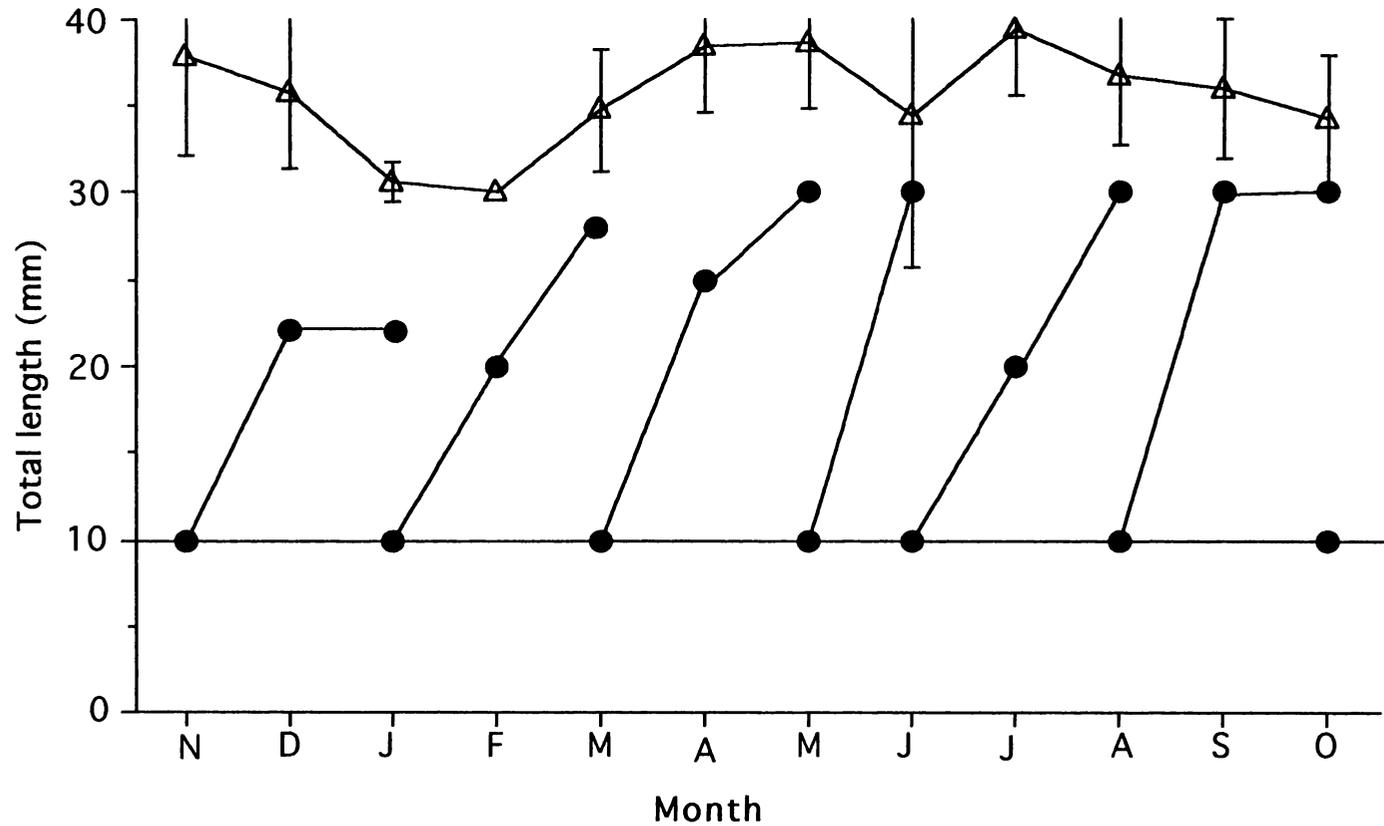


Figure 20. Mean total length (open triangle) of *Gambusia affinis* greater than 30 mm (presumably females) and modal total length of *G. affinis* collected from pond B. Vertical lines indicate the standard deviation of mean total length. The horizontal line indicates the total length used as a base-line for establishing entry of fish into the population, estimating brood growth, and interbrood interval.

in November and then died. Krumholz (1948) found that fish born after mid-July, in an Illinois pond, do not reproduce that year, but rather overwinter and are present at the beginning of the following season as parent stock. For a population of mosquitofish in a small southcentral Texas pond, Davis (1978) found that sexually mature females, recruited in mid-summer, gave birth in December and then were lost from the population. Thus the episode of female mortality from November to February is not in variance with the findings of Krumholz (1948) and Davis (1978). As mentioned for the other fish species, size selective predation by avian predators may be partially responsible for the removal of larger individuals from the population. However, because of the morphology of pond B and due to the low numbers of birds observed at this site the impact of avian predation would appear to be minimal if not negligible.

Coincident with this period of female mortality were the recruitment and growth of  $F_1^a$  and  $F_1^b$  broods (figure 20). These broods can be observed to grow through progressive size classes in the frequency distribution from November to March. The growth rate of the  $F_1^a$  brood (figure 20) was considerably slower than the  $F_1^b$  and following broods. The slow growth of the  $F_1^a$  brood is attributed to the low water temperature in the month of December.

In March a third episode of recruitment occurred and the size pulse divides into males which do not grow greater than 30 mm and females which continue to grow. The growth of these females is reflected by the increase in mean total length from February to May and by an increase in the number of larger individuals during this period (figure 19 & 20). A fourth pulse of recruitment occurred in

May and was followed by a fifth brood in June. The growth rates of the  $F_1^c$  and  $F_1^e$  broods were similar to the  $F_1^b$  brood, while the rate of the May  $F_1^d$  brood was considerably greater. However, the growth of the  $F_1^d$  and  $F_1^e$  broods may be obscured by variations in the periodicity at which broods are liberated and because individuals of the previous broods, having become mature, give birth to young at intervals not necessarily coincident with those of the parent stock. All broods prior to and after the  $F_1^d$  and  $F_1^e$  broods were cast at rather regular intervals, whereas The  $F_1^d$  and  $F_1^e$  interbrood interval was approximately half that of all other broods. This suggests that the offspring of broods prior to the  $F_1^d$  have become mature and began to produce offspring and are responsible for the asynchrony of the  $F_1^e$  brood.

From July to October there was a loss of larger individuals from the population, presumably the offspring from the  $F_1^a$  and  $F_1^b$  broods. The loss was partially offset by the parturition of a sixth and seventh brood in August and October respectively. During this time there is an influx of immature young into the population, an increasing contribution of the season's young to the reproductively active population, and death of the parent stock. This constitutes a dynamic period in the breeding season of Gambusia, in which the parent stock continues to bear offspring until they disappear from the population during the late summer, and the season's young become mature and reproductively active (Krumholz 1948, and Davis 1978).

The reproductive season of G. affinis in pond B extends throughout the year and is not in great variance with the length of seasons reported at similar latitudes. Kilby (1955) found new recruits throughout the year in a coastal marsh in Florida. Gunter (1950) also reported similar results for fish within the Aransas National Wildlife Refuge, Texas, where he collected gravid females in every month from February 1946 to January 1947. Davis (1978) reported a slightly shorter breeding season for G. affinis (February to December) in a small southcentral, Texas pond. Hubbs (1971) reported a breeding season that extended from March to September in Menard county, Texas. Therefore, it seems that the reproductive season of G. affinis in south Texas is slightly longer than in more northern latitudes, possibly because of the warmer southern weather. However, Hubbs (1971) proposes that photoperiod rather than temperature is the primary regulator of the reproductive season in G. affinis.

## CHAPTER IV

### SUMMARY

From November 1989 to October 1990 a study was performed to characterize the physiochemistry and fish faunal population dynamics of three earthen ponds on North Padre Island. All ponds had similar chemistries except for alkalinity, salinity, and turbidity. The smallest freshwater pond (pond A) was more alkaline than the other ponds. The elevated alkalinity of this pond is attributed to the relatively large amounts of decomposition and to the anoxic condition of the sediments which persist in this system. The larger freshwater pond (pond B) was significantly more turbid than ponds A and C. The high turbidity of this pond is caused by the large population of blue-green and green algae which dominate the water column in this system. The largest of the three ponds (pond C) was significantly more saline than ponds A and B, and is considered brackish. The brackish nature of pond C is unexplained, but may be attributed to leaching of subsurface salt deposits and saltwater intrusion from the surrounding bays.

Cyprinodon variegatus was the most abundant of the three fish species and was found to occur in all three ponds. Fundulus grandis was found only in ponds A and C. The absence of this fish from pond B may be attributed to the fouling properties of the large population of blue-green algae which occur in this pond. Gambusia affinis was the second most abundant species though it was found to occur

primarily in pond B. The absence of this fish from pond A is a mystery and additional research is needed to explain this absence.

Cyprinodon variegatus exhibited a long breeding season in pond C with recruitment being detected from April through November. The breeding season of C. variegatus in pond C is not in great variance with findings under similar conditions in the literature. Recruitment occurred in June in pond A and was not detected in pond B. It is possible that the breeding season of C. variegatus is shortened in pond A because of conditions which exist in this pond at certain times of the year. Due to the small size of pond A it is subject to much more environmental variation than pond C. This variation, freezing in the winter, extreme algal blooms in the spring, and almost complete evaporation in the summer creates an environment much different from that which exists in pond C, these seasonal differences in the habitats may explain the shorter breeding season of C. variegatus in pond A. Both population and individual growth of C. variegatus occurred from May through October in all ponds, while the number of larger individuals decreased during the late summer months.

Fundulus grandis was captured sporadically and in such low numbers that the data are somewhat inconclusive. Yet, growth appears to occur in the summer. The breeding season of F. grandis is believed to resemble that described for C. variegatus in ponds A and C.

Gambusia affinis exhibited a long breeding season in pond B with recruitment occurring seven out of twelve months sampled. Larger individuals of G. affinis were lost from the population during the winter and summer months and were coincident with periods of population and individual growth. The population dynamics of G. affinis in pond B are similar to those at similar locations reported in the literature.

## LITERATURE CITED

- Breder, C. M. 1934. Ecology of an oceanic fresh-water lake, Andros Island, Bahamas, with special reference to its fishes. *Zoologica* (18) 3: 57-88.
- Botsford, L.W., B. Vondracek, T.C. Wainwright, A.L. Linden, R.G. Kope, D.E. Reed, and J.J. Cech, jr. 1987. Population development of the mosquitofish, Gambusia affinis, in rice fields. *Environmental Biology of Fishes* 20 (2):143-154.
- Britton, R.H. and M.E. Moser. 1982. Size specific predation by herons and its effect on the sex ratio of natural populations of the mosquitofish, Gambusia affinis Baird and Girard. *Oecologia* 53: 146-151.
- Burgess, G. H. and J. R. Shute 1979. Fundulus grandis Baird and Girard, Gulf killifish p. 516 in D. S. Lee, et al. Atlas of North American Freshwater Fishes. N. C. State Museum of Natural History, Raleigh, 854 pp.
- Carlander, K. D. 1969. Handbook of Freshwater Fishery Biology, volume 1 : The Iowa State University Press Ames, Iowa . 752 pp.
- Davis, J. R. 1978. Reproductive seasons in Gambusia affinis and Gambusia geiseri (Osteichthyes: Poeciliidae) from southcentral Texas. *Texas Journal of Science* 30: 97-99.
- Foster, N. R. 1967. Comparative study on the biology of killifishes (pisces, Cyprinodontidae). Unpublished Ph.D. dissertation, Cornell University.
- Griffith, R. W. 1974. Environment and salinity tolerance in the genus Fundulus. *Copeia* 2: 319-331.
- Gunter, G. 1938. Seasonal variations in the abundance of certain estuarine and marine fishes in Louisiana, with particular referenece to life histories. *Ecological Monographs* 8: 313-346.

- \_\_\_\_\_. 1941. Death of fishes due to cold on the Texas Coast. Ecology 22 (2) : 203-208.
- \_\_\_\_\_. 1945. Studies on the marine fishes of Texas. Publication of the Institute of Marine Science, University of Texas, 5: 1-190.
- \_\_\_\_\_. 1950. Distributions and abundance of fishes on the Aransas National Wildlife Refuge, with life history notes. Publication of the Institute of Marine Science, University of Texas, 1 (2): 89-101.
- Hannan, H. H. 1978. A water quality and limnological study of the sewage system-pond complex at the ranger station, North Padre Island, Texas. Contract PX 7029-8-0469, National Park Service, Santa Fe, New Mexico.
- Harrington, R. W., Jr. and E. S. Harrington. 1961. Food selection among fishes invading a high subtropical salt marsh : from onset of flooding through the progress of a mosquito brood. Ecology 42 (4): 646-666.
- Hildebrand, S. F. 1917. Notes on the life history of the minnows Gambusia affinis and Cyprinodon variegatus. Appendix VI Report U. S. Commercial Fisheries. Bureau of Fisheries Document Number 857, 15 pp.
- Hubbs, C. L. 1936. Fishes of the Yucatan Peninsula. Carnegie Institute Washington, Publication, 457: 157-287.
- \_\_\_\_\_. 1971. Competition and isolating mechanisms in the Gambusia affinis x G. heterochir hybrid swarm. Bulletin Texas Mem. Museum number 19: 1-46.
- Hulbert, S. H., J. Zedler, and D. Fairbanks. 1972. Ecosystem alteration by mosquitofish (Gambusia affinis) predation. Science 175: 639-641.
- Hulbert, S. H. and M. S. Mulla. 1981. Impacts of mosquitofish (Gambusia affinis) predation on plankton communities. Hydrobiologia 83: 125-151.

- Johnson, W. E. 1978. Cyprinodon variegatus Lacepede, Sheephead minnow. p. 504 in D. S. Lee, et al. Atlas of North American Freshwater Fishes. N. C. State Museum of Natural History, Raleigh, 854 pp.
- Joseph, E. D. and R. W. Yerger. 1956. The fishes of Alligator Harbor, Florida, with notes on their natural history. Florida State University Studies. 22 : 111-156.
- Kail, W. M. 1968. Ecology and behavior of the Cyprinodontid fishes Jordanella floridae Goode & Bean, Floridichtheys carpio (Gunter), and Cyprinodon variegatus Lacepede. Unpublished Ph. D. dissertation Cornell University.
- Kilby, J. D. 1955. The fishes of two Gulf coastal marsh areas Florida. Tulane Studies in Zoology 2 (8): 175-247.
- Krumholz, L. A. 1948. Reproduction in the western mosquitofish, Gambusia affinis (Baird and Girard), and its use in mosquito control. Ecological Monographs 18: 1-43.
- Lee, D. S. and G. H. Burgess. 1978. Gambusia affinis (Baird and Girard), Mosquitofish. p. 516 in D. S. Lee, et al. Atlas of North American Freshwater Fishes. N. C. State Museum of Natural History, Raleigh, 854 pp.
- Lynch, M., and J. Shapiro. 1981. Predation enrichment, and phytoplankton community structure. Limnology and Oceanography 26 (1): 86-102.
- Meier, A. H., G. R. Lynch, and L. E. Garcia. 1973. Daily rhythms of plasma chloride in two teleosts Fundulus grandis and F. chrysotus . Copeia 1: 90-92.
- Ohle, W. 1952. Die hypolimnische Kohlendioxyd Akkumulation als produktionbiologischer Indikator. Hydrobiologia 46: 153-285.
- Oxley, F. M. 1992. A fungal survey of three ponds on North Padre Island. Unpublished M.S. thesis, Southwest Texas State University, San Marcos, Texas.

- Perez, R. G. 1971. Relationships between phytoplankton and chlorophyll standing crops in two permanent freshwater ponds in a marine supratidal environment. Unpublished M.S. thesis, Texas A & I University, Kingsville, Texas.
- Perschbacher, P. W., D. V. Aldrich, and K. Strawn. 1990. Survival and growth of the early stages of gulf killifish in various salinities. *The Progressive Fish Culturist* 52: 109-111.
- Pflieger, W. L. 1975. Fishes of Missouri. Missouri Department of Conservation. 324 pp.
- Raney, E. C., R. H. Backus, R. W. Crawford, and C. R. Robbins. 1953. Reproductive behavior in Cyprinodon variegatus Lacepede in Florida. *Zoologica* 38 (2): 97-104.
- Reid, G. K., jr. 1954. An ecological study of the Gulf of Mexico fishes, in the vicinity of Cedar Key, Florida. *Bulletin of Marine Science of Gulf and Caribbean*. 4 (1): 1-94.
- Serota, T. D. 1971. Relationships between phytoplankton and chlorophyll standing crops in two permanent freshwater ponds in a marine supratidal environment. Unpublished M.S. thesis, Texas A & I University, Kingsville, Texas.
- Simpson, D. G. and G. Gunter. 1956. Notes on habitats, systematic characters and life histories of Texas salt water Cyprinodontes. *Tulane Studies in Zoology*. 4: 115-134.
- Sissom, S. L. 1990. A base-line study of three ponds within the Padre Island National Park. Final report to the United States Department of the Interior National Park Service, Padre Island National Seashore, Corpus Christi, Texas. Contract # 7490-9-0009.
- Spence, B., A. H. Meirer, and T. H. Dietz. 1977. Circadian chloride rhythms in the gulf killifish, Fundulus grandis. *Copeia* 3: 557-566.
- Springer, V. G. and K. D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Professional Paper Series 1: 1-104.

Turner, C. L. 1941. Morphogenesis of the gonopodium in Gambusia affinis. Journal of Morphology. 69: 161-185.

Walden, H. T. 1964. Familiar Freshwater Fishes of America. Harper and Row, New York, New York. 324 pp.

Warlen, S. M. 1964. Some aspects of the life hoistory of Cyprinodon variegatus Lacepede 1803, in Southern Delaware. [abstract of thesis] Sport Fisheries Abstracts 9 (4) : 212-213.

Weise, B. R. and W. A. White. 1980. Padre Island National Seashore, A guide to the geology, natural environments and history of a Texas barrier island. Bureau of Economic Geology, Guidebook # 17, University of Texas at Austin, Austin, Texas. 94 pp.

Wetzel, R. G. 1983. Limnology. Second Edition. Saunders Publishing Company, Orlando, Florida. 767 pp.