DISTRIBUTION OF FISH AND OTHER ORGANISMS ASSOCIATED WITH AN ARTIFICIAL FLOATING TIRE BREAKWATER IN LAKE CARL BLACKWELL, OKLAHOMA

By

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PREFACE

The intent of this study was to examine the recently-developed floating tire breakwater and document its effects on the biota of a cove in an Oklahoma reservoir. Special emphasis was placed on the determination of densities of fishes at varying distances from the breakwater. Several sub-projects were initiated to help define reasons for the attraction of large numbers of fish to the breakwater.

This work was completed with God's welcome help and I thank Him primarily. Financial assistance was provided by the Oklahoma Department of Wildlife Conservation. Financial, as well as moral, support was also thankfully received from my family and that of my husband. Sincere appreciation is offered to the committee members, Drs. O. Eugene Maughan and Sterling S. Burks, for their support, and especially to Dr. Michael D. Clady, my major adviser, for his patience, consideration, and editorial discrimination.

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The manuscript itself was expertly typed by Mrs. Helen Murray, and the figures were completed through the talents of Ray Jones and my husband Rob. My heartfelt thanks are offered especially to Rob for motivating and encouraging me unselfishly during the study.

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CHAPTER I

RESEARCH PERSPECTIVE

Introduction

The tendency of fishes to frequent or inhabit areas with abundant cover, or structure, was as apparent to the prehistoric fisherman as it is to the present-day angler using sonar-type equipment. As a result, scientific investigators have attempted to quantify this tendency using a wide array of natural and artificial structures in both freshwater and marine environments (see Colunga and Stone 1974 and Johnson and Stein 1979). New designs continue to arise, however, and the floating tire breakwater is a relatively recently designed structure that has not been thoroughly examined in terms of its effects on the distribution of fishes and other organisms.

In the present study, an attempt was made also to go beyond the documentation of distributional patterns. The only previous author who appears to have examined the dynamics of entire ecological systems operating in and around freshwater artificial structures was Prince (1976). Although his work was broader in scope and more detailed, I made a similar effort to identify specific reasons for concentrations of fish near the floating breakwater.

The potential of floating tire breakwaters for the management of reservoir fisheries should not be overlooked. Water is becoming an increasingly valuable resource for power companies, farmers, municipalities, as well as for recreational anglers. Any new techniques capable of increasing fish production and angler success in reservoirs and reducing conflicts over water use at the same time, could be of significant value to fishery managers and should be examined closely by those charged with research in these areas.

Habitat Improvement in Lakes

Fish populations in man-made reservoirs often suffer from a lack of submerged natural structures. Prince and Maughan (1978) listed the following reasons for this problem:

1. Standing timber is usually cut before inundation in order to prevent navigational hazards.
2. Timber that remains uncut may quickly decay.
3. Siltation may occur in areas that once contained firm substrates, resulting in an unstable, mucky bottom often unsuitable for spawning.
4. Fluctuation in water levels often prevents the establishment and growth of aquatic vegetation.

A modification of habitat, termed habitat improvement, is often desirable in these cases. Habitat improvement for fishes can be described as any alteration of the aquatic environment, using natural or man-made materials, to provide additional food and/or shelter for fish. In some instances, the structures may also be used for spawning and as visual reference points for some fishes.

The addition of structure to a water body can be beneficial for several reasons, the primary one being the tendency of fishes to concentrate around structures soon after installation. Hubbs (1930) was one of the first to realize the potential that artificial structures had for concentrating fishes and worked closely with R. W. Eschmeyer (Hubbs et al. 1933) as he developed a lake improvement program in Michigan. Their work and ideas led to studies by Rodeheffer (1939, 1940, and 1945) who actually demonstrated that large numbers of fish concentrated around artificial structures in Michigan lakes.

Another advantage of the use of artificial structures is that building materials and construction are often available at low cost. Prince and Brouha (1974) found that special interest groups (e.g., anglers, SCUBA divers) and service organization (e.g., Kiwanis, Scouts, Rotary) may be willing to donate construction materials and equipment as well as labor. DeRoche (1973) emphasized that materials are often available as damaged goods or refuse items. Blasting rock, damaged chimney tile and ceramic piping, while sometimes difficult to handle, can usually be obtained at little or no cost and make excellent materials for habitat improvement structures.

One of the most popular sources of building material in recent years has been discarded automobile tires. They are non-toxic in water (T. Lindsey, pers. comm.) and also strong, flexible, and durable. Since tires are abundant--being manufactured in the United States at a rate of more than 175 million a year (Goodyear 1976)--scrap tires can generally be obtained from dealers free of charge. Other materials that have been used successfully to attract fishes in both fresh and salt water include gravel spawning boxes and minnow slabs (Tarzwell 1936), car bodies (Anderson 1964), stake beds (Petit 1972), brush piles (Manges 1959; Wilbur 1974), and log cribs, Christmas trees, and felled shoreline trees (Prince et al. 1977).

The ultimate importance of these types of structure may depend on whether they actually increase fish production. It is possible that numbers of fish near structures increases only because fish are being drawn from other areas of the lake, and that actual production is not increased. Prince (1976) closely studied several types of submerged scrap tire reefs in a Virginia reservoir. Within a week of placement, numerous fish appeared near the reefs. Periphyton, growing within three weeks of structure placement, dramatically increased dissolved oxygen concentrations near the structures and was grazed on directly by gizzard shad (*Dorosoma cepedianum*) and sunfish (*Lepomis* spp.). A positive nutritional effect may be had for some fishes since Kitchell and Windell (1970) found that bluegill (*L. macrochirus*) which were fed algae in addition to a maintenance level of animal food gained slightly more weight than similar fish on a maintenance diet of animal food alone. Also, changes in the invertebrate community through colonization of breakwaters may directly affect fish populations because of the importance of invertebrates as fish food. An early study by Cowell and Hudson (1968) documented increased invertebrate productivity as the result of added substrate in Missouri River reservoirs. Pardue (1973), reported that bluegill production increased linearly after the addition of attachment surfaces used by fish-food organisms.

Prince (1976) also observed that bluegill and largemouth bass (*Micropterus salmoides*) spawned in the immediate vicinity of the reefs and that white catfish (*Ictalurus catus*) actually spawned between the sidewalls of some reef tires. The catfish eggs were used intensively as food by some sunfish. These findings, in addition to the abundance of young-of-the-year fishes sighted near structure in Prince's study, indicated that production was increased locally through the use of structures. However, the number of submerged structures required to significantly increase production in a large reservoir is unknown.

Another striking study concerning the occupation of submerged reefs by fishes was carried out by DeRoche (1973) in a small lake in Maine. Two nylon lines were placed along opposite shores in three to five meters of water. SCUBA equipment was used to count fishes within sight of these lines. Later, structures consisting of tires, chimney tile, tile pipes, and cement blocks were placed along one line and SCUBA observations were made periodically for the next two years. Pre-installation counts ranged from 18 to 24 fish of three species along both lines. The number quadrupled on one line one day after installation of structure, and by the end of the study, five species of fish along the line with structure had become too numerous to count; only two fish were sighted along the line without structure.

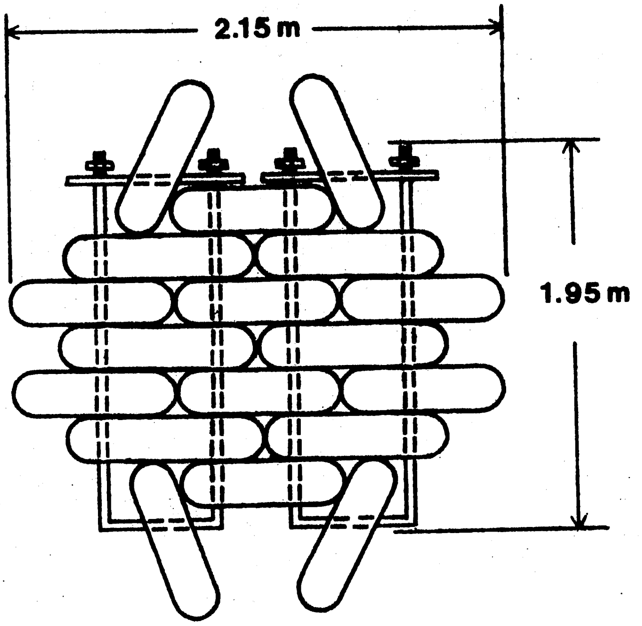
The effects of exploitation by anglers near artificial structures are not yet clear. Although no creel survey was carried out in DeRoche's study, anglers with cottages on the lake claimed that fishing had improved. Results of angling in an upground reservoir given by Paxton and Stevenson (1979) supported this claim. Their catch-per-unit-effort was consistently higher near a limestone island, or near limestone reefs with tire structures, than near bare limestone reefs or in open water. Also, Wege and Anderson (1979) found that the time required to catch 40% of their stocked largemouth bass was significantly less in ponds with structure (tires, stake beds, and brush piles) than in ponds without structure. Apparently, there is potential for the overharvest of some species near structures, although it is yet to be demonstrated in large reservoir systems.

Another form of structure that may affect the movements and behavior of fishes is mid-water floats. Helfman (1979) found that the densities of fish under wooden mid-water floats was linearly related to size of the float. He also concluded that the shade produced by the floats was used by prey fishes to avoid detection by predators. Ogren (1974) also noted the apparent preference of marine prey fishes for mid-water structures (as opposed to non-structure areas).

A final structure made use, once again, of discarded automobile tires and was originally developed entirely outside of the fisheries field. The Goodyear Tire and Rubber Company, in its search for ways to dispose of the growing number of scrap tires, developed the idea of using these tires for shoreline protection mats (Candle and Fischer 1977) that consisted of subunits, or modules, made of 18 interconnecting tires (Figure 1). The mat was relatively portable, could be built to sink or float, could absorb shock without being destroyed, and was unlimited in its dimensions of length and width. While these mats were designed primarily to act as floating breakwaters, Goodyear began to recognize other uses for them such as on-shore beach erosion mats, sand dune stabilizers, marshland protection mats, river and stream bank erosion mats, and floating biological reefs (Candle and Fischer 1977).

These shore protection mats appear to have been studied mainly on the Rhode Island coast (Minter 1974) and in Lake Erie (DeYoung 1977a),

Figure 1. Arrangement of the 18-tire module used in the construction of floating breakwaters.


2.15 m
1.95 m

although similar projects in the Northeast and Midwest are underway (Candle and Fischer 1977) to protect harbor marinas and yacht clubs through reduction of wave heights.

Outstanding results have come from the use of these structures in many areas. Dunkirk Harbor on Lake Erie is an excellent example (DeYoung 1977a). While waiting for the Corps of Engineers to construct a permanent breakwater to protect its harbor from northeasterly storm waves, the City of Dunkirk accepted a temporary solution in the form of Goodyear's floating breakwater mat. With the cooperation of Goodyear and New York Sea Grant, and the donation of money, materials, and labor from local interested citizens, the city constructed a 183-m breakwater in 1975 and lengthened it in 1976 to 305 m. Greater protection in the habor was evidenced by an increase in the amount of boat fuel sold and more requests for "wintering over" slips as opposed to the normal procedure of removing boats to dry storage. In addition, the potential for accidents was reduced by placing the breakwater directly above a navigational hazard.

The two aspects of Goodyear-type breakwaters with the greatest potential value to fisheries in reservoirs on the Great Plains are concentration of fish and attenuation of large waves. The breakwater in Dunkirk Harbor was three modules wide (ca. 8.5 m) and capable of reducing a one-meter wave by about 75% (DeYoung 1977b). Wave attenuation is important in an area such as Oklahoma where particularly strong winds during the spawning season may cause serious damage to fish nests in poorly-protected areas of reservoirs (Tarzwell 1936; Kramer and Smith 1962; Allen and Romero 1975; and Clady 1976) and was the major reason this type of breakwater was used in the present study.

Artificial Breakwaters in Lake Carl Blackwell

Research involving floating tire breakwaters began in Lake Carl Blackwell in 1975 when 32, 59, and 228 young-of-the-year (YOY) large mouth bass/ha were collected in areas of the lake designated as windswept, intermediate, and protected, respectively (Summerfelt and Shirley 1975). As a result, wind exposure was assumed to be a primary factor in distribution of YOY. In that year, three types of floating structures (single and double unit pole booms, a fabric curtain, and single and double row floating tire breakwaters of the Goodyear type) were evaluated by the Oklahoma Cooperative Fishery Research Unit (OCFRU) to determine their effect on production of fingerling largemouth bass (Summerfelt 1976). The environmental parameters measured were wave height, wind direction and velocity, water and air temperatures, suspended solids, water depth, turbidity, water current, sedimentation rate, and Secchi disc transparency. Fish samples were collected twice by shoreline rotenoning. Some results of the study were:

1. Surface current velocity was positively correlated with wind velocity (r = 0.81).
2. Variation in water quality was largely due to the location of sites.
3. Breakwaters attenuated surface currents; the largest reduction (57.1%) was by the single pole boom.
4. The largest reduction in wave height (54.4%) occurred behind the double row breakwater.
5. Breakwater coves, as opposed to coves without structures, were

more transparent and had lower sedimentation rates.

6. The double row floating tire breakwater was apparently the most effective structure for increasing populations of YOY bass (density was 4.75 times greater than behind any other structure), but was also the most expensive to build; prices for various structures ranged from $9.91 - $57.69/m.

In 1976, the OCFRU continued the evaluation by placing single row floating tire breakwaters in two coves (Clady 1977). The same environmental parameters were measured, with the exception of water current speeds. Density of YOY bass and species diversity of fishes was measured by shoreline rotenoning or seining, and age I+ bass were collected using an electrofishing unit ten times in each cove. All coves, experimental and control, were located on the north shore, as opposed to the half-north, half-south configuration used previously, to maximize the impacts of the breakwater under prevailing southwesterly winds. Some results of that year's study were:

1. Wave height was the only parameter that showed a dramatic difference between leeward and windward areas; waves up to 20 cm were reduced 70-80%. Other parameters showed more variation between days and between coves than between windward and leeward areas. Clady (1977) suggested that differences in weather conditions balanced out any effects when values were averaged.
2. Species diversity and abundance of age I+ largemouth bass were measured before completion of the breakwaters and were lowest in experimental coves.
3. Abundance of YOY largemouth bass was also measured before

completion of construction. Highest total biomass of YOY was found in control coves, but numbers of YOY were generally the same in control and experimental coves.

Evaluation of the two breakwaters was continued by the OCFRU on a more intensive basis (Clady 1978). The same physical-chemical measurements were made with the exception of water depth, and the same methods were used for collecting fish, with the addition of gill nets and electrofishing when estimating species diversity. Samples of benthic invertebrates were taken every six weeks using a variation of the Hester and Dendy (1962) multiple-plate sampler. Conclusions were:

1. No pronounced effects of the breakwaters on the water were evident, other than reduced wave height. At most, the breakwaters had slightly enhanced differences in transparency, turbidity, and sedimentation rate that exist naturally between lakeward and shoreward areas of coves (Clady et al. 1980).
2. Attenuation of waves and slight improvements in water quality in breakwater coves were apparently not sufficient to increase populations of young largemouth bass or diversity of fish and benthic communities (Clady et al. 1979, 1980).

Clady (1978) cited three possible reasons for the apparent lack of breakwater impact: a) the wave height reduction was not biologically significant, b) high turbidity secondarily limited year class strength of largemouth bass, or c) extreme water level fluctuations and associated sampling problems masked any beneficial effects. As a result, he recommended that a double row tire breakwater be placed in the deeper experimental cove in an effort to magnify any effects of the breakwaters.

The doubled breakwater was completed (construction details appear in Appendix A), and data were collected through the fall of 1979. The results of the double row breakwater study were strikingly similar to those of the previous single row breakwater studies (Lanford and Clady 1979). In spite of the breakwater's added width and its continued attenuation of over 65% of wave heights, the changes in water quality (turbidity, sedimentation rate, etc.) and largemouth bass densities remained slight. In response to these somewhat equivocal results, a decision was made in 1978 to undertake an additional aspect of the study. In conjunction with the continuing work concerning the breakwater's effects on the physical environment, it seemed reasonable to examine the possibility that the breakwater was having a substantial effect on the biological environment as a fish attractor. A myriad of questions quickly arose, reflecting a void of knowledge in this area of floating breakwater research. Studies involving the submerged and mid-water structures cited earlier encouraged me to examine the floating breakwater from this point of view, and in the fall of 1978, I began a pilot project designed to determine the most desirable areas of emphasis.

Pilot Study

The pilot study, carried out in October and November of 1978, included electrofishing, gill netting, and sampling invertebrates with modified Hester-Dendy samplers. Since the invertebrate samplers were to be colonized for six weeks, no effort was made to draw conclusions from the one sampling period encompassed by this study. Although only general methods are described below, detailed methods are given by Lanford (1979, unpublished manuscript).

Electrofishing with alternating current emitted from a 220-volt generator occurred on five dates. The following transects, used for electrofishing as well as gill netting and invertebrate sampling, were set up parallel to the breakwater: F1 - first transect, 30 m in front (lakeward) of the breakwater; F2 - second transect, 60 m in front of the breakwater; F0 - immediately adjacent to, and in front of, the breakwater; B0 - immediately adjacent to, and behind (shoreward of), the breakwater; B1 - first transect, 30 m behind the breakwater; and B2 - second transect, 60 m behind the breakwater. The results of the pilot study (Table 1) indicated a concentration of fishes, as well as greater diversity of species, near the breakwater. Catches at all transects consisted primarily of gizzard shad. Sunfish, largemouth bass, and carp (Cyprinus carpio) were caught only on breakwater transects (B0 and F0).

Sinking experimental gill nets with six mesh sizes ranging from 1.9 cm to 6.4 cm (bar lengths) were set on transects F2 and B2. The same type of net could not be used at the breakwater (arbitrarily set at transect B0 rather than F0) because it would not fit between the breakwater anchor cables. Instead, six vertical panels, each containing a different mesh size corresponding to the mesh sizes found in the longer nets set at F2 and B2, were placed between the cables. Because of the differences in water depth at each of the three transects, difficulty in handling (especially in strong winds), lack of a satisfactory method of sampling the F2 transect completely but without overlap, and extremely low catch rates, the vertical panels were eventually

Table 1. Number of fish and species caught by electrofishing and gill netting on various transects during fall, 1978. (Gill nets were set only on transects F2, B0, and B2.)

Gear	Transect					
	F2	F1	F0	B0	B1	B2
<u>Electrofishing</u>						
Number of fish	38	37	44	155	85	66
Number of species	1	1	4	5	3	2
<u>Gill Net</u>						
Number of fish	156	-	-	32	-	162
Number of species	9	-	-	5	-	10

discarded.

Since the two net types did not always sample similar areas of the water column, the data on horizontal distribution of fishes in gill nets (Table 1) should be viewed with caution. Numbers of fish captured at transects B2 and F2 were almost identical (156 and 162, respectively), but the number captured at transect B0 (32) was much smaller by comparison. Under the assumption that selectivity and catchability for the horizontal and vertical nets were the same, the vertical nets, with about 54 m^2 of net area should have caught approximately one-half the fish captured in a horizontal net, with about 109 m^2 of net area. Two possible reasons for these unexpected results are:

1. Fishes could more easily avoid the narrower vertical nets set at the breakwater.
2. Movements of fishes at the breakwater were more restricted than in areas without structure (as in Prince 1976), resulting in lower vulnerability to gill nets.

It was apparent that the presence of the breakwater was influencing the distribution patterns of the fishes. Not only did there appear to be more fish and more kinds of fish near the breakwater, but it also appeared that fish near the breakwater were more quiescent. Further study seemed justified, and objectives for a full-scale research were formulated.

Research Objectives

The intent of this research was to examine the biological effects of a floating tire breakwater in a turbid reservoir by:

1. Documenting, by number and family, the distribution patterns

of macroinvertebrates near the breakwater using multiple-plate samplers.

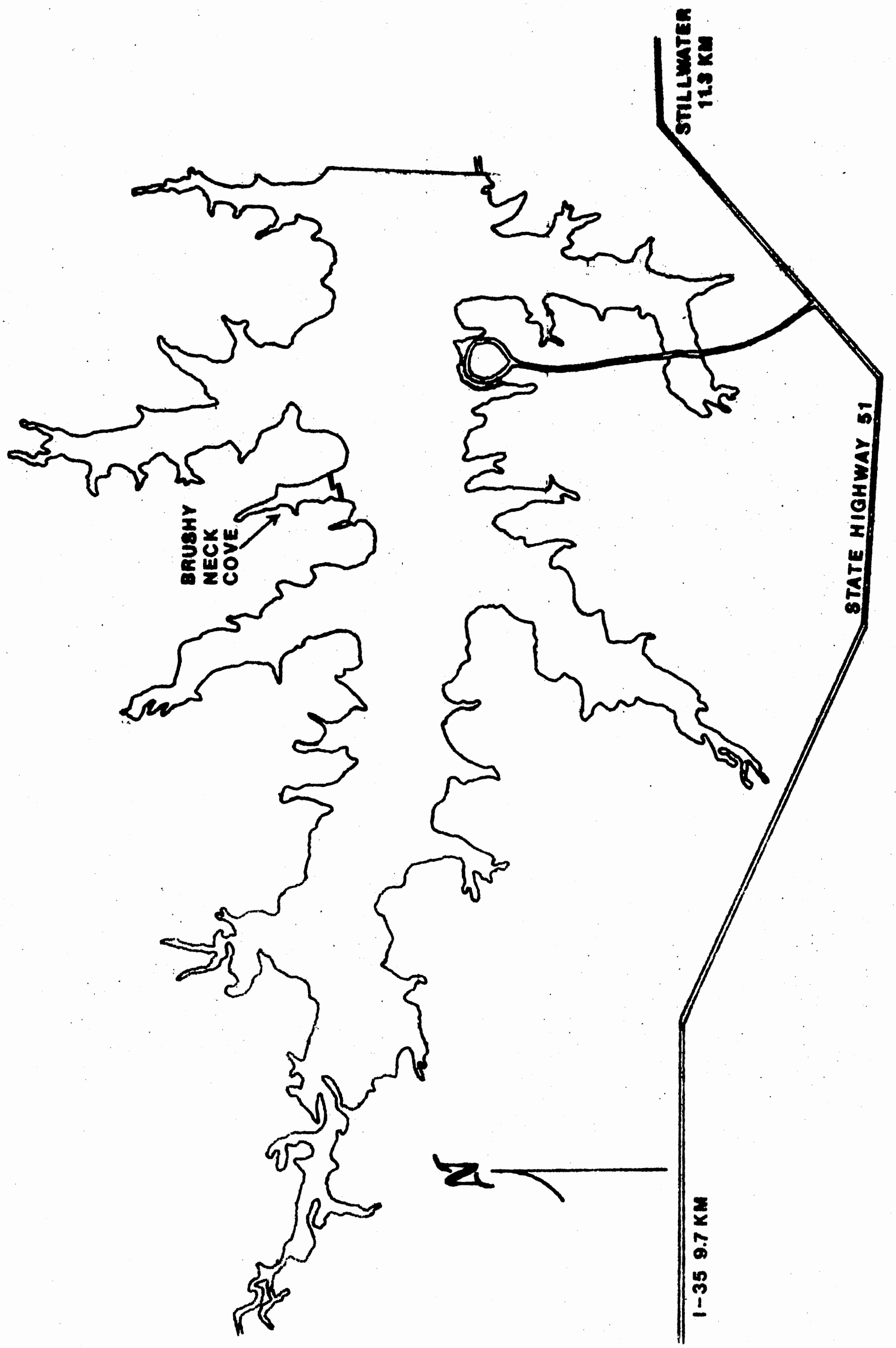
2. Documenting, by number and species, the distribution patterns of fishes near the breakwater area using several types of gear.
3. Examining possible causes for variation in distributional patterns should these variations become apparent.

Description of the Study Area

The study area was located in Brushy Neck Cove on the north side of Lake Carl Blackwell (Figure 2), a turbid reservoir 12.8 km west of Stillwater, Oklahoma. The reservoir was completed in 1938 by the Works Progress Administration and its long axis is oriented in an east-west direction with the dam at the east end. Maximum surface area is 1355 ha with a capacity of 6.8 x $10^7 m^3$ at spillway level. Spillway elevation (287.78 m above mean sea level) was exceeded during the spring of 1980 for the first time since 1975. High turbidity of up to 180 Jackson units (Norton 1968) is the result of high winds on a relatively low, unprotected shoreline, shallow depth (ca. 10 m, maximum), and a substrate on Permian redbeds (Johnson 1974). The substrates, as described by Norton (1968) are highly mobile and consist of fine silt and clays with coarser silts and sands in the shallower areas. Southerly shores are generally steeper than those of the north bank.

The study cove was oriented primarily in a north-south direction, exposing it particularly to the strong southwesterly winds common to the Great Plains. There was little structural development along the

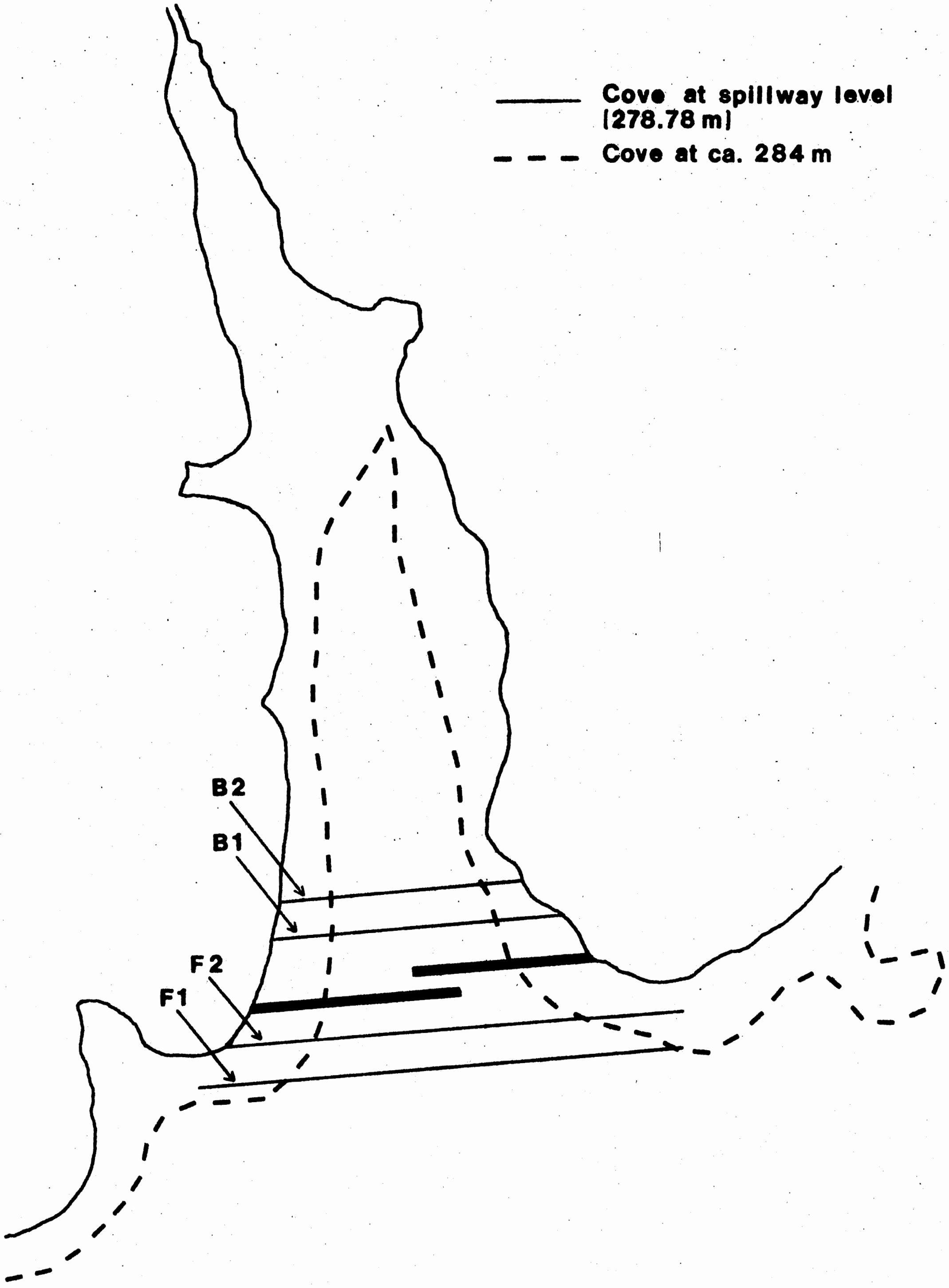
Figure 2. Brushy Neck Cove, the study area, in Lake Carl Blackwell near Stillwater, Oklahoma


STILLWATER
11.3 KM
STATE HIGHWAY 51
BRUSHY
NECK
COVE
N
I-35 9.7 KM

shoreline since the land belongs to Oklahoma State University and is used only for grazing cattle. Some standing timber remained at the upper end of the cove. Aquatic vegetation was minimal to nonexistant; however, the following macrophytes grew on the most leeward breakwater tires: yerba-de-tago (Eclipta alba) (most common), cottonwood (Populus deltoides), frogfruit (Phyla incisa), flatsedge (Cyperus sp.), knot grass (Paspalum distichum), and black willow (Salix nigra).

Water level fluctuations (see Appendix B) caused the volume and area of the cove to vary considerably during the study. Since the double breakwater was completed in August 1978, water levels varied between a low of 3.7 m below spillway level in January 1979 and a high of 0.34 m above spillway level in June 1980. Figure 3 depicts the cove shoreline at approximately these two extremes.

Figure 3. Brushy Neck Cove at two different water levels experienced during the study. B2, B1, F1, and F2 indicate locations of experimental transects.


Cove at spillway level (278.78 m)
Cove at ca. 284 m
B2
B1
F2
F1

CHAPTER II

MATERIALS AND METHODS

Benthic Macroinvertebrates and Fish

Four types of equipment--multiple-plate invertebrate samplers, an electrofishing unit, gill nets, and hoop (or barrel) nets--were used to document the distribution of macroinvertebrates and fish in the cove. The specifications for and use of these pieces of equipment are described below. All sampling involved the use of transects established parallel to and at various distances from the breakwater. These transects were described earlier ("Pilot Study" section of Chapter I) and are depicted in Figure 3. Unless otherwise noted, the level of significance for all statistical tests was 0.05.

Invertebrate Samplers

A variation of the multiple-plate sampler described by Hester and Dendy (1962) was used. These samplers were especially well-suited for Lake Carl Blackwell where brush, stumps, and hard clay limit the efficiency of Ekman dredges or other commonly used samplers, and where sediments are highly unstable.

The samplers were made with 14 plates of tempered hardboard (Masonite) 3.18 mm thick and 76.20 mm square, and 17 hardboard plates 3.18 mm thick and 25.40 mm square. A 12.7 mm hole was drilled into each of these squares. A washer and a large plate were placed on a

9.52 x 203.20 mm eyebolt first, and plate sizes were alternated afterwards with four exceptions: two small plates (versus one small plate) were placed between the fourth and fifth, sixth and seventh, eighth and ninth, and tenth and eleventh large plates. This provided for 6.35 mm spaces between some of the large plates in addition to the 3.18 mm spaces. The last large plate was secured with a washer and nut, but not too tightly since the hardboard expanded slightly when wet. Total surface area for a completed sampler was 0.165 m^2.

Five samplers were suspended from an automobile tire anchored in two meters of water. The samplers were snapped onto nylon lines so that they hung approximately one meter from the surface and one meter from the cove bottom. The sampling sites were located on the east shore of the cove in order to focus on the effects of the predominantly southwest winds. One tire (each with five samplers) was placed on transects F2, F1, B1, and B2. The fifth tire was placed on the appropriate depth (2 m) in one of the interstices between the two rows of modules (transect 0). Samplers were removed seven times from the spring of 1979 to the spring of 1980. The procedures used to collect the samplers and evaluate results were similar to those used by Wilhm et al. (1978). The samplers were removed after six weeks and transported to the laboratory in plastic bags or half-gallon milk cartons so that dislodged organisms would not be lost. In the laboratory, the contents of the bag or carton were placed in a No. 30 U.S. Standard Soil Series Seive and samplers were disassembled. Organisms were separated from detritus and placed in 70% alcohol for later identification to the lowest taxonomic group possible. Numbers, species diversity, and similarity indices were determined for each of five sites. Species diversity indices ($\bar{d}$) were calculated according to Shannon and Weaver (1963) as follows:

$$\bar{d} = -\sum^{s}(n_i/n)\ \log_2\ (n_i/n)$$

where n_i = number of individuals in the ith taxon,

n = total number of individuals collected, and

s = total number of species.

Percent community similarity (Psc) was calculated according to Brock (1977) as follows:

$$Psc = 100 - 0.5 \sum^{k} a\text{-}b$$

where a and b = percentages of the total samples A and B which a given species represents, and

k = total number of species.

Electrofishing

The electrofishing unit consisted of a 220-volt generator operated with alternating current from a fiberglass boat. On each boom, two lead-filled electrodes were suspended from the distal end, and one lead-filled electrode was suspended in a median position approximately 1.5 m from the other electrodes. In the spring of 1980 a boom design that allowed the addition or removal of up to 18 electrodes was added. Stunned fish were retrieved by one netter using a net 2.5 m long with 6.35 mm mesh.

The transects used for electrofishing were F2, F1, F0, B0, B1, and B2. To compensate for the possibility that electrofishing along one transect might affect the catch on adjacent transects, the order in which transects F2, F1, B1, and B2 were sampled on each date was randomly chosen. Since B0 and F0 were especially close to each other, they were the first and last transects to be sampled, their order being determined by the flip of a coin. The time required to make a complete trip along the transect and back was recorded as were species and total length of each fish captured. Weights of each fish were usually recorded when winds were calm or moderate. When large numbers of a species were captured, every fourth or fifth fish was weighed. Three samples were taken at night early in the study but the predicted increases in catch per unit of effort were not found and night-shocking was therefore discontinued.

Gill Nets

Nine experimental gill nets were used to determine the vertical and horizontal distribution of fishes by placing three nets at the surface or on the bottom at transects F2, B0, and B2 for 24 hours. Each net was approximately 15.2 m long (in order to fit between anchor cables) and 1.2 m deep, and each was divided into two panels of different mesh sizes. Each net contained one of the following pairs of mesh sizes (bar lengths): a) 1.9 cm and 2.5 cm, b) 3.8 cm and 4.4 cm, or c) 5.1 cm and 6.4 cm. There were a total of nine nets so that all six mesh sizes were fished at each transect. The order of placement for the three nets on each transect was randomly chosen. The nets were the floating type, so to sample the lower part of the water column, lead line was attached to the base cord of each net with bull-dog clips. A coin was tossed to determine whether the nets went on bottom or at the surface first in each pair of sampling days.

Because depth of water in some of the cove exceeded the combined depth of nets set at the surface and bottom, all mid-water areas were not sampled. No additional efforts were made to sample these areas for the following reasons:

1. Surface-to-bottom vertical panels were used at transect B0 in the pilot study caught very few fish for the amount of effort involved; the time spent determining the vertical location of fish in the panels was not justified in results.
2. If the experimental nets were deepened to sample more of the water column in some areas, overlap of the nets in more shallow areas would be inevitable; determinations of vertical distribution would become more difficult and unreliable as the water level fluctuated.
3. Most species preferring mid-water areas are probably pelagic and were not expected to be abundant.

Species, length, and weight were recorded as for fish taken by electrofishing.

Hoop Nets

The hoop nets were 1.5 m long and 1.0 m in diameter with a mesh size of 17.5 mm. The five hoops in each net were held open with wooden or metal spreader bars. Inverted funnels were woven into each end and there were no leads or bait. On each date, one hoop net was set on the bottom at transects F2, F1, 0, B1, and B2. The nets were set in 2 m of water until June 1980, when unusually high water levels increased depth at the most shoreward end of the breakwater to over 3.5 m. For the remainder of the study, the nets on all transects were set in the same depth of water as the most shoreward end of the breakwater. Nets were set for approximately 24 hours, and on species, weight, and length of fish were determined as described previously.

Sub-Projects

Results from the first year's work indicated a distinct attraction of fish to the breakwater area. These data, and the findings of other researchers, led me to conclude that the distributional patterns I had found were the result of one or more of the following:

1. The limited amount of underwater structure in the lake increased the appeal (to some fishes) of areas that could be used for cover (Helfman 1979).
2. The breakwater was used by some fish species as a spawning site (Prince and Maughan 1979).
3. Fish were drawn to the breakwater by concentrations of food organisms (Pardue and Nielsen 1979).

While I continued the fish distribution work on an abbreviated schedule, the second year (1980) also included several limited projects designed to achieve the third objective: to examine possible causes for variation in distributional patterns, and also to help me better understand the general ecological dynamics of the breakwater area in terms of fish attraction. These projects included a fish tagging experiment, distributional analyses of larval fishes and zooplankton, and an examination of periphyton[1] production on the breakwater. Unless otherwise noted, the level of significance for all

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[1] According to APHA (1975), periphyton is the community of microscopic plants and animals attached to or moving about the surfaces of submerged objects.

statistical tests was 0.05.

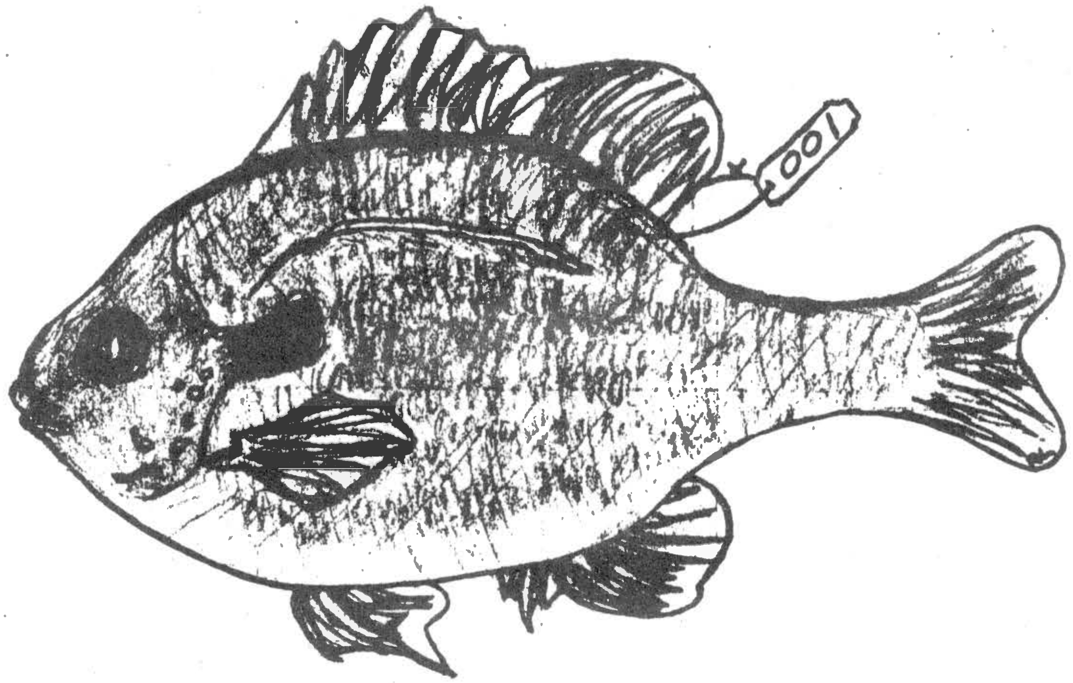
Fish Tagging

Consecutively numbered fingerling tags (Floy Manufacturing Company, Seattle, WA) were used to mark white crappie and sunfish primarily. The small average size of these species (chosen for their abundance in hoop net and electrofishing catches) dictated the use of this small tag (4.76 x 3.18 mm). Each tag was pre-threaded through a sewing needle with elastic vinyl thread.

A total of 268 tags were used in the experiment from 4 April to 5 August 1980. Each tag was attached by passing the needle and thread between any two of the last five dorsal pterygiophores and tying a knot, being careful to allow some space for fish growth. Tag placement is illustrated in Figure 4. Three mortality and tag loss experiments were carried out using a 1-m^3 plastic cage as a holding area:

1. On 6 June, 36 white crappie, 5 bluegill, and 3 longear sunfish were captured in hoop nets, measured, weighed, tagged, and placed in the cage (which was suspended from the breakwater).
2. On 27 June, 10 white crappie were captured in hoop nets and 5 of them were tagged and placed in the cage. The other five fish were transferred to the cage with minimal handling and served as controls. The cage was raised almost to the surface to minimize potential oxygen problems that might have existed at lower depths.
3. On 3 July, five white crappies were measured, weighed, and tagged under the best possible conditions by equipping the

Figure 4. Longear sunfish with fingerling tag in place.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styrofoam chest with a syphon hose and a bilge pump to circulate fresh water to the fish during the tagging process.

Larval Fish

In order to determine when sampling for larval fishes should begin, attempts to collect larval fish were made weekly during late April and May 1980. Sufficient numbers were captured in the third week of May, and intensive sampling began on 22 May. Samples were taken approximately weekly until catch per unit of effort decreased sharply in mid-July; sampling ended on 16 July.

Larvae were collected at the surface using a 2.5 m tapered net having a 0.5 m diameter opening. The larger, forward section of the net consisted of coarse (#000 mesh) nylon netting, and the smaller, rear section was #0 mesh (Downey 1978). Collections were made by traveling along each transect (F2, F0, B0, and B2) and back again, keeping the net just below the surface of the water. The order in which the transects were sampled was determined randomly, as was the direction of each tow. Icthyoplankton was placed immediately in jars containing a 15% formalin solution. In the laboratory, larvae were separated from detritus, counted, and placed in vials containing 40% alcohol for later identification according to May and Gasaway (1964) and Hogue et al. (1976). The volume of water filtered for each sample was determined by the following equation, with a General Oceanics, Inc. (Miami, FL) digital model 2030 flowmeter attached to the net in the field:

$$V = \frac{3.14(N)^2}{4} \text{ X } \frac{D \text{ x } R}{999,999}$$

where V = volume filtered, m^3

N = net diameter (0.5 m)

D = difference in flowmeter counts (final minus initial), and

R = rotor constant (26,873).

Air and water temperatures, wind direction and velocity, cloud cover, and time of day were also recorded. The experiment was designed with nonparametric trend analysis in mind and did not, therefore, include replicated tows.

Zooplankton

Zooplankton collections began on 7 March 1980 and continued, approximately every other week until 25 August 1980. To facilitate the collection of zooplankters between the breakwater tires, all samples were taken with a 3.25 ℓ brass Kemmerer water bottle. Transects F2, 0 (between breakwater tires), and B2 were sampled, each transect being divided into western, middle, and eastern sections. The Kemmerer bottle was filled 15 times (48.75 ℓ) at the surface of each collection site, and the water was passed through a Wildlife Supply Company (Saginaw, MI) Model 40 Wisconsin-type plankton net with 80 μ mesh. Zooplankters were washed into a 10% formalin solution and transported to the laboratory. Water and air temperatures, wind velocity and direction, cloud cover, and time of day were recorded.

After complete mixing, one milliliter aliquots were removed from the sample jar with a Hensen-Stempel pipette and placed in a Sedgwick-Rafter counting cell for microscopic identification; magnification was 100X. One milliliter subsamples were examined until the cumulative average number of organisms in a subsample did not differ from the previous cumulative average by more than 5%; at least four subsamples were examined in each sample.

Identification categories consisted of Cladocera, Copepoda, and Rotifera. Cladocerans and copepods were identified to genus; copepod nauplii were not placed in a separate category. Density for a sample was calculated from the following equation:

$$D = \frac{VT}{SW}$$

where D = density (number of organisms per liter),

V = volume of the sample, ml,

T = total number of organisms examined,

S = number of subsamples examined, and

W = volume of water filtered (48.75 ℓ*)

*On 7 March 1980, 16.25 ℓ of water were filtered at each site.

Periphyton Productivity

Primary productivity on breakwater tires was estimated from ash-free weights of periphyton and changes in dissolved oxygen using a modification of the light and dark bottle experiment. Sixty tire pieces, each measuring approximately 441 cm^2 each, were obtained by cutting standard 15-inch automobile tires into sixteenths. These tire pieces were then attached to the breakwater, about 10 cm below the water's surface, during the last week of March, 1980, and allowed to colonize. Tire pieces for experiments were subsequently removed according to a random number table. Methods for determining primary production were largely taken from APHA (1975).

Ash-free weight. Selected tire pieces were carefully detached from the breakwater using wire cutters and lifted from the water with a No. 30 Standard Soil Series Sieve underneath to retain any periphyton which might have broken loose. The tire piece and loose algae taken from the sieve were then placed in a plastic bag and put into a styrofoam chest with ice. In the laboratory, all plant and animal matter was scraped from the tire pieces. Macroinvertebrates were separated from this material (4-6 persons examined each sample) and preserved in 70% alcohol for subsequent identification. Invertebrates were weighed with a Mettler analytical balance after being blotted dry.

The remaining material (plant matter, sediments, and distilled water used in cleaning the tire pieces) was poured into an Imhoff cone, preserved by adding formalin to create a 15% solution, and allowed to settle. The supernatant was later syphoned off and filtered through 37 mm diameter AP40 Microfiber Glass Millipore filters which had been previously washed with 100 ml of distilled water and dried to constant weight at 105 C. The settleable matter was poured into a 250 ml crucible which had been previously washed in distilled water and dried to constant weight at 105 C. Filters and crucibles, with their accompanying materials, were then dried to constant weight (crucibles often took several days), filters were placed in the crucible containing their respective sample, and each crucible was ashed for 1 h at 500 ± 50 C. Crucibles and contents were then wetted to reintroduce the water of hydration of the clay (and other minerals), which is not driven off at 105 C but is lost during ashing, and dried to constant weight at 105 C. With or without the periphytonous material, constant weights for filters and crucibles were determined to have been reached when the weight was within plus or minus 0.5 and 1.0 g, respectively, of the weight measured previously. Between weighings, the crucibles and filters were returned to the drying oven for 1 h and placed in a dessicator for an additional hour to cool. The fiberglass filters retained their integrity during ashing. Ash-free weight for each sample was determined by the following equation:

$$A = D_f + D_c - A_{f+c}$$

where A = ash-free weight, g,

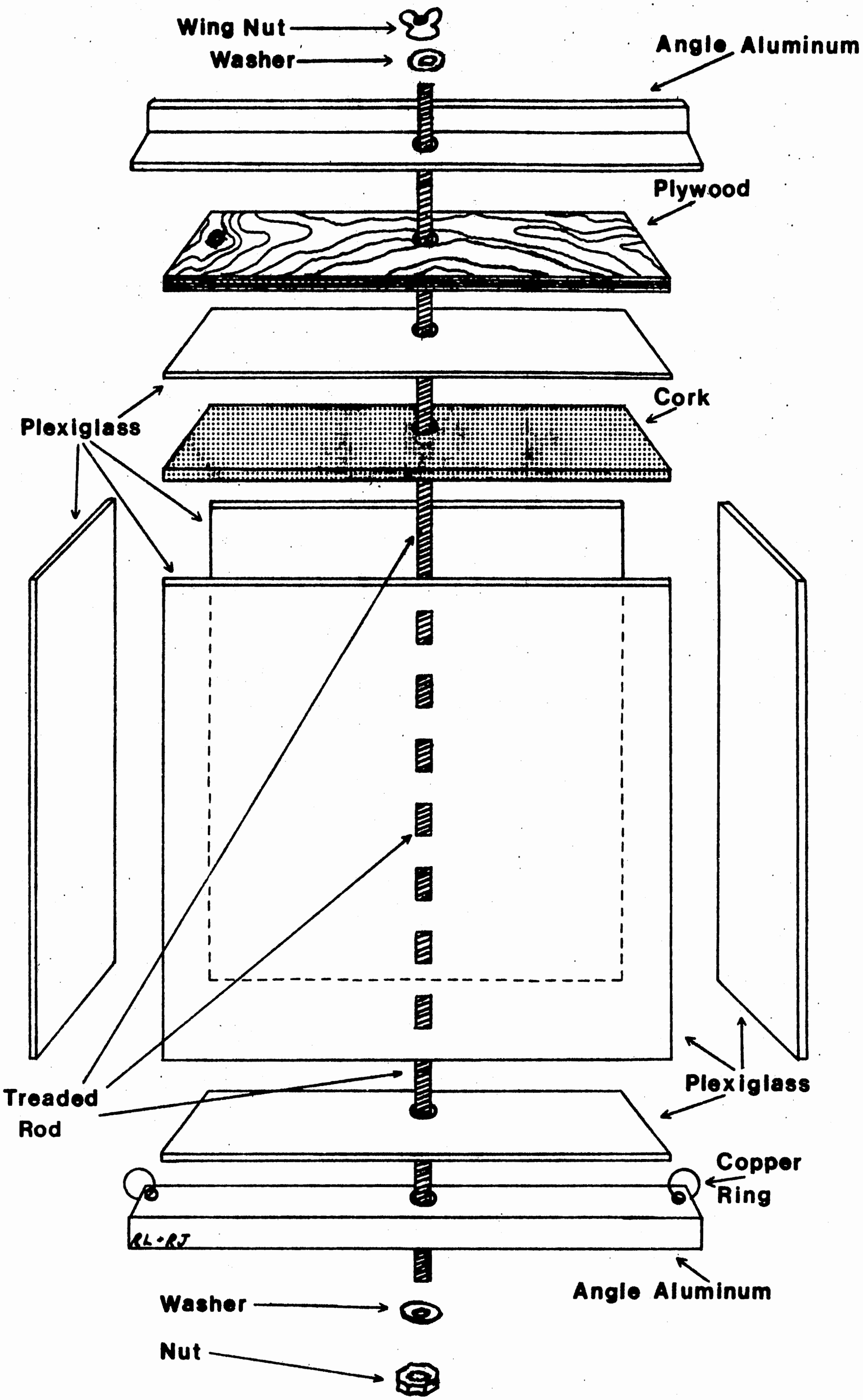
D_f = dry weight of the filter and its contents, g,

D_c = dry weight of the crucible and its contents, g, and

A_{f+c} = weight of the crucible, filters, and remaining contents after ashing, g.

Dissolved oxygen. Six boxes measuring 30.50 x 30.50 x 15.25 cm were constructed using 3.175 mm Plexiglas, each having removeable lids measuring 33.0 x 17.8 cm (Figure 9). The lids were reinforced with a 12.7 mm thick piece of plywood of the same dimensions and lined with cork gasket material. A hole was drilled into each lid for a 19 mm diameter piece of PVC pipe. After sanding, the PVC pipe provided an air-tight seal when plugged with either a No. 3 rubber stopper or with the Yellow Springs Instrument Company (Yellow Springs, OH) electrical stirring probe used while measuring dissolved oxygen. (The probe was

Figure 5. Components of a Plexiglas box used to estimate periphyton production.


Wing Nut
Washer
Angle Aluminum
Plywood
Cork
Plexiglass
Treaded Rod
Plexiglass
Copper Ring
RL+RJ
Angle Aluminum
Washer
Nut

powered by a portable generator.) The lid was held in place with a 3.175 mm all-thread rod passing through a 45 cm long section of angle aluminum under the box, the box itself, the lid gasket, the lid, the plywood reinforcement, and another section of angle aluminum on the top of the box. All permanent seals were made with Plexiglas glue and/or silicone rubber, and a bead of the latter was placed along the four edges of the box that adjoined the lid. Petroleum jelly was used in the field to insure water tightness on all non-permanent seals (around all-thread, washers, silicone bead, etc.). Copper wire loops were placed in both ends of the lower section of angle aluminum so that the boxes could be suspended between breakwater tires.

Tire pieces were carefully removed from the breakwater and placed in the boxes, containing surface water, for one-half of the day's photoperiod, as determined by the official times of sunrise and sunset. Dissolved oxygen (DO) was initially measured at the water's surface and compared with DO values in the boxes at the end of the half-photoperiod. In addition, two biochemical oxygen demand (BOD) bottles were filled with surface water (300 ml) and also suspended between two breakwater tires. One bottle was completely covered with black electrical tape, and differences in DO between the dark and light bottles were used to assess the magnitude of phytoplankton production.

CHAPTER III

RESULTS

Benthic Macroinvertebrates and Fish

Invertebrate Samplers

Mean density of organisms at a given site was calculated by dividing the total number of invertebrates collected on a particular date by the number of Hester-Dendy samplers recovered (Table 2). When plotted (Figure 6), the populations for each site fluctuated in a similar manner through time with highest densities at all sites in July 1979, and lowest densities in January 1980. Two exceptions to the trend were at site B1 on 5 June 1979 and at site F2 on 6 November 1979. The highest density for any site was on 20 July 1979 at site F2 and was due to an extremely large number of psychomyiid larvae ($\bar{x}$ = 223/sampler).

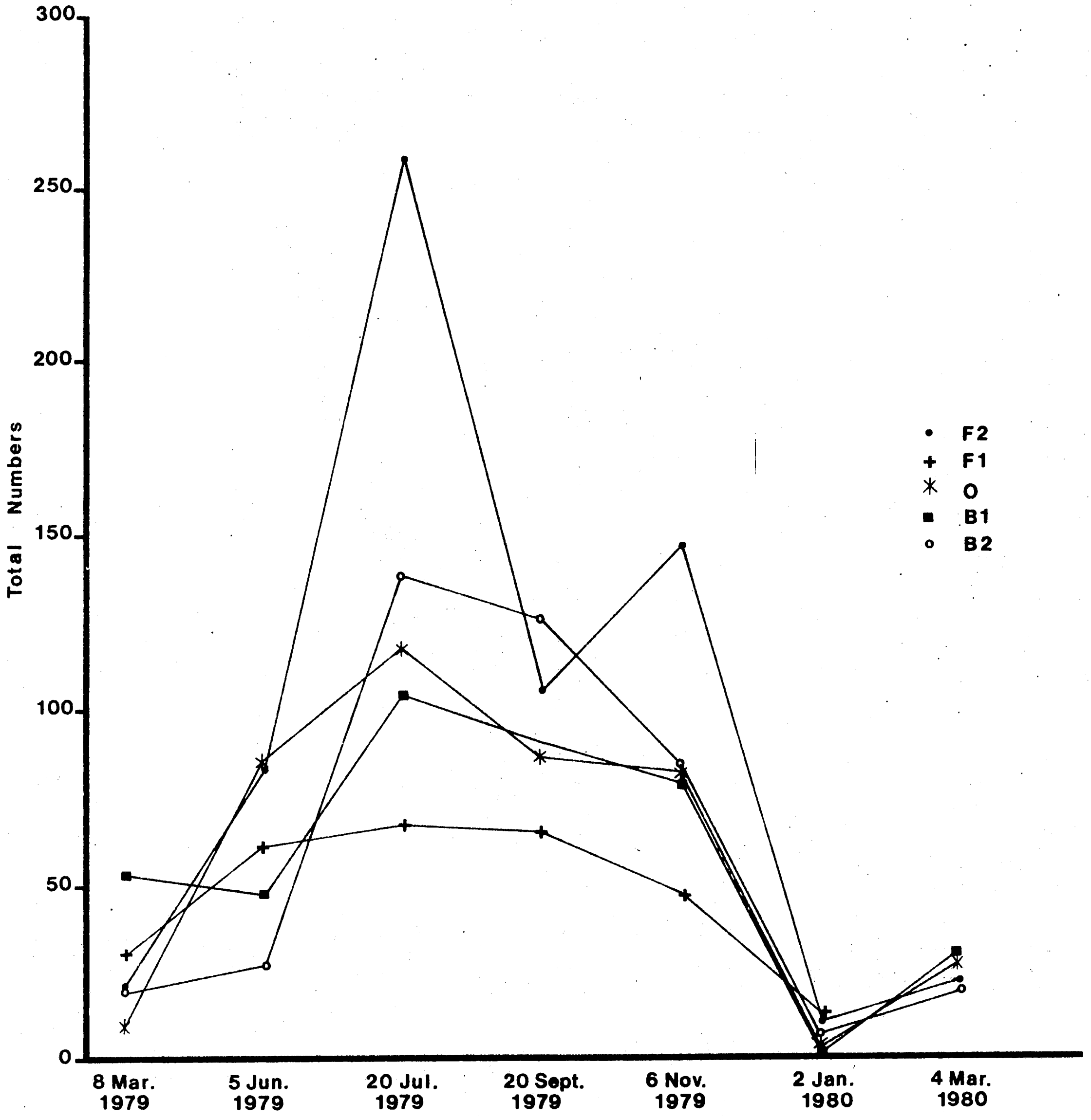
Analysis of variance indicated that mean densities of invertebrates differed significantly between transects (F = 80.90 with 4 and 29 d.f.). Individual tests comparing the breakwater site to the other sites showed that site F2 had significantly higher (t = 3.76 with 29 d.f.) mean densities of invertebrates than site 0. Comparisons of site 0 to B2, B1, and F1 revealed no significant differences (t = 0.15, 0.14, and 1.35, respectively) in mean density of invertebrates per sampler.

Table 2. Mean number of invertebrates per Hester-Dendy sampler for each date and transect. (Number of samplers recovered in parentheses.)

Date	Transect and number/sampler				
	F2	F1	0	B1	B2
1979					
8 Mar.	21(5)	30(3)	10(4)	54(5)	20(5)
5 Jun.	84(2)	62(4)	86(5)	49(5)	26(5)
20 Jul	259(4)	66(2)	118(5)	105(5)	139(3)
20 Sep.	105(4)	65(2)	88(5)	91(5)	127(5)
6 Nov.	148(5)	49(6)	84(4)	80(5)	86(4)
1980					
2 Jan.	12(6)	13(3)	5(4)	3(5)	9(5)
4 Mar.	23(5)	-[a]	27(5)	27(5)	21(5)
Total	652	285	418	409	428
Mean	93.1	40.7	59.7	58.4	61.1

[a] Unable to recover samplers

Figure 6. Number of invertebrates collected per Hester-Dendy sampler during 1979-80.


300
250
200
150
100
50
0
Total Numbers
8 Mar. 1979
5 Jun. 1979
20 Jul. 1979
20 Sept. 1979
6 Nov. 1979
2 Jan. 1980
4 Mar. 1980
• F2
+ F1
✳ O
■ B1
○ B2

Chironomids and psychomyiids were the most abundant organisms at all sites (Table 3) and together made up 98.1-99.5% of the total number of organisms at any one site. The percentage of community similarity (Psc) between each two sites was estimated from the percentage, for each family, of the total number of organisms at each site (Table 4). Communities at sites F1 and F2 appeared to be the least structurally similar (Psc = 67.56) whereas communities at sites B1 and F1 were most similar (Psc = 93.69) (0 = no similarity, 100 = identical structure).

Diversity indices ($\bar{d}$) calculated for each site (Table 5) were invariably highest in November 1979, and lowest in March of either 1979 or 1980. Analysis of variance revealed a significant difference (F = 44.0 with 4 and 29 d.f.) in mean $\bar{d}$ at site 0 was significantly higher than at either F1 or F2 (t = 2.01 and 3.53, respectively, with 29 d.f.), but not significantly different from the mean $\bar{d}$ of sites B1 and B2 (t = 0.18 and 1.47, respectively).

Electrofishing

For each of the 31 sampling dates, the total number of fish captured per hour of electrofishing was calculated on each transect (Table 6). Beginning in March 1979, catch per unit effort was very low; the only fish captured were on the breakwater transects (B0 and F0) until early April 1979. A similar pattern developed in August 1980 when few or no fish were caught on transects other than B0 and F0. Catch per unit of effort was highest on 15 May 1979 at transect B0 (420 fish/h). Statistical analysis indicated a significant difference (F = 233.5 with 5 and 169 d.f.), between transects, in the

Table 3. Mean number of invertebrates per Hester-Dendy sampler at each transect and the percent of the total make-up of each family, 1979-80. Data for all dates are combined.

	Transect, number/sampler, and percent of transect total				
	F2	F1	0	B1	B2
Organism	(31 samplers)	(20 samplers)	(32 samplers)	(35 samplers)	(32 samplers)
Chironomidae	32.10	28.20	32.69	36.37	25.69
%	37.55	68.37	52.49	62.13	46.36
Psychomyiidae	52.94	12.85	28.75	21.06	28.69
%	61.92	31.15	46.16	35.97	51.77
Heptageniidae	0.06	0.05	0.06	0.09	0.03
%	0.07	0.12	0.10	0.15	0.06
Talitridae	0.19	0.05	0.22	0.57	0.28
%	0.23	0.12	0.35	0.97	0.50
Hydroptilidae	0.03	0.05	0.03	0.03	0.03
%	0.04	0.12	0.05	0.05	0.06
Coenagrionidae	0.10	0.05	0.09	0.31	0.50
%	0.11	0.12	0.15	0.53	0.90
Tipulidae	0.0	0.0	0.0	0.03[a]	0.0
%	0.0	0.0	0.0	0.05	0.0
Caenidae	0.0	0.0	0.09	0.0	0.09
%	0.0	0.0	0.15	0.0	0.17
Tubificidae	0.0	0.0	0.0	0.03[a]	0.0
%	0.0	0.0	0.0	0.05	0.0
Poduridae	0.0	0.0	0.0	0.03	0.03
%	0.0	0.0	0.0	0.05	0.06
Sialidae	0.0	0.0	0.0	0.0	0.03
%	0.0	0.0	0.0	0.0	0.06
Baetidae	0.03[a]	0.0	0.0	0.0	0.0
%	0.04	0.0	0.0	0.0	0.0
Chaoboridae	0.03[a]	0.0	0.0	0.0	0.0
%	0.04	0.0	0.0	0.0	0.0

Table 3. Continued.

	Transect, number/sampler, and percent of transect total				
	F2	F1	0	B1	B2
Organism	(31 samplers)	(20 samplers)	(32 samplers)	(35 samplers)	(32 samplers)
Staphylinidae	0.0	0.0	0.0	0.03[a]	0.0
%	0.0	0.0	0.0	0.05	0.0
Hydridae	0.0	0.0	0.31[a]	0.0	0.0
%	0.0	0.0	0.50	0.0	0.0
Unid. Platyhelminthes	0.0	0.0	0.03[a]	0.0	0.0
%	0.0	0.0	0.05	0.0	0.0
Unid. Isopoda	0.0	0.0	0.0	0.0	0.03[a]
%	0.0	0.0	0.0	0.0	0.06
Total	85.48	41.25	62.27	58.55	55.40

[a] Taxonomic group collected only once during the study.

Table 4. Similarity indices for invertebrates collected on Hester-Dendy samplers, 1979-80.

	Transect and index				
Transect	F2	F1	0	B1	B2
F2	-	67.56[a]	82.68	72.49	88.27
F1	67.56[a]	-	84.03	93.69[b]	77.87
0	82.68	84.03	-	89.11	93.28
B1	72.49	93.69[b]	89.11	-	83.52
B2	88.27	77.87	93.28	83.52	-

[a] least similar

[b] most similar

Table 5. Diversity indices, by family, of invertebrates on Hester-Dendy samplers, 1979-80.

Date	Transect and index				
	F2	F1	0	B1	B2
<u>1979</u>					
30 Mar.	0.08	0.09	0.00	0.52	0.86
5 Jun.	0.58	0.59	0.67	0.82	1.00
20 Jul.	0.58	0.94	0.99	1.05	1.00
20 Sep.	0.87	0.78	0.89	1.03	0.88
6 Nov.	1.07	1.06	1.20	1.15	1.13
<u>1980</u>					
2 Jan.	0.11	0.17	0.90	0.67	0.73
4 Mar.	0.18	-[a]	0.70	0.21	0.53
Total	3.47	3.63	5.35	5.45	6.13
Mean	0.50	0.60	0.76	0.79	0.88

[a] samplers not recovered

Table 6. Number of fish captured per hour of electrofishing (c/f) on various transects during 1979-80.

Date	Transect and c/f					
	F2	F1	F0	B0	B1	B2
1979						
21 Mar.	0	0	0	18	0	0
26 Mar.	0	0	18	36	0	0
30 Mar.	0	0	32	33	0	0
4 Apr.	12	15	14	30	0	0
9 Apr.	0	22	14	45	34	43
13 Apr.	112	148	51	150	60	170
17 Apr.	10	0	0	8	0	0
23 Apr.	28	30	24	45	27	86
11 May	148	265	148	28	135	250
15 May[a]	61	34	173	420	32	46
16 May[a]	11	6	144	119	24	46
22 May	14	97	40	78	42	30
29 May[a]	11	6	19	43	8	27
30 May	13	4	32	72	20	15
4 Jun.	12	7	75	54	0	0
8 Jun.	20	70	236	55	70	78
11 Jun.[a]	11	17	53	81	16	18
25 Jun.	0	6	0	51	0	0
26 Jun.[ab]	5	9	40	124	20	22
29 Jun.	5	7	0	20	38	84
3 Jul.	–[c]	–[c]	–[c]	23	–[c]	–[c]
9 Jul.[b]	40	19	70	94	30	9
13 Jul.	0	0[a]	15	101	22	17
19 Jul.[b]	42	185	–[c]	111	–[c]	210
1980						
4 May	58	–[c]	63	282	–[c]	45
22 Jul.	0	0	38	72	0	0
6 Aug.	0	16	66	106	24	8
8 Aug.	0	9	–[c]	51	–[c]	12
13 Aug.	0	0	65	81	15	0
15 Aug.	0	0	66	86	0	0
20 Aug.	0	0	32	63	0	0
Total	613	972	1528	2580	617	1216
Mean	20.4	33.5	54.6	83.2	22.8	40.5

[a] Time not recorded, average number of minutes for each transect used to calculate c/f

[b] Night samples

[c] Transect not sampled

number of fish captured per hour of electrofishing. Individual t-tests compared each breakwater transect (F0 and B0) with each non-breakwater transect (F2, F1, B1, B2) (Table 7). While the mean number of fish captured per hour on transect B0 was significantly higher than on transect F0, mean catch at both breakwater transects was significantly higher than at any of the non-breakwater transects.

The relative abundance (percentages) of various species collected on each transect (Table 8) are graphically presented in Figure 7. The unidentified fish in Table 8 recovered and disappeared before they could be identified or netted. All of the sunfish were combined in one category for a similar reason; i.e., some fish that were initially recognized as sunfish would recover and submerge before further identification was possible. The 160 sunfish captured were categorized as follows: bluegill - 87, unidentified - 38, longear - 32, redear - 1, longear/spotted hybrid - 1, and bluegill/longear sunfish - 1. (Species are defined by scientific name in Appendix C.) Gizzard shad, which made up approximately 70% of the total catch, seemed to be most evenly distributed over the transects. Sunfish were collected only on breakwater transects, and with the exception of one fish in each case, Mississippi silversides and carp were also taken only on breakwater transects. All species constituting more than 0.5% of the total catch were most abundant on one of the breakwater transects.

The mean numbers of the nine most abundant species captured per hour of electrofishing at various transects were statistically compared (Table 9). With the exceptions of largemouth bass and carp, mean catches of a given species was always significantly higher at one

Table 7. Results of t-tests comparing the mean number of fish captured per hour of electrofishing at various transects (degrees of freedom = 169) during 1979-80.[a]

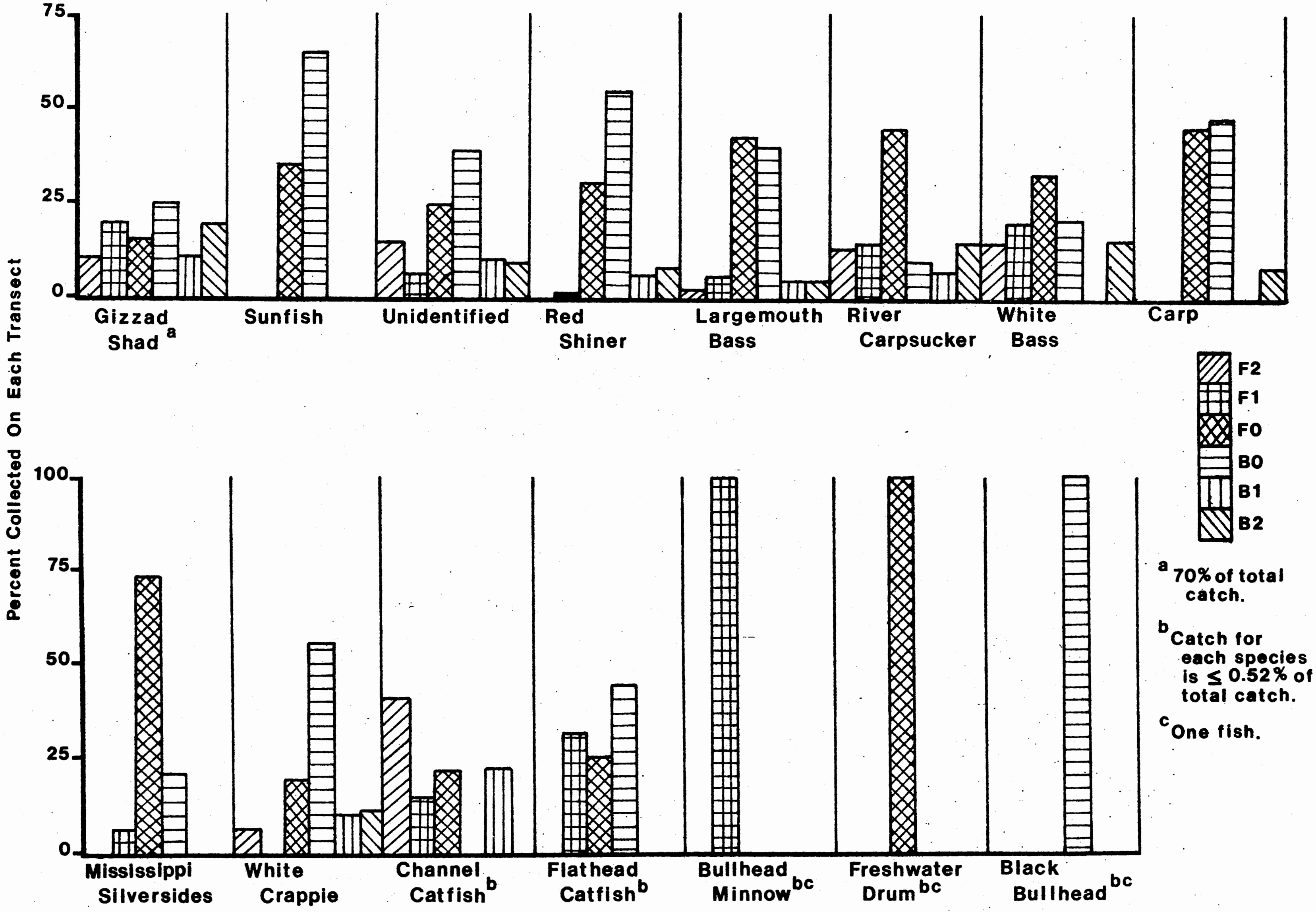
Transect	Relationship	Transect	t-statistic
B0	>	F0	4.97
B0	>	B2	7.75
B0	>	F1	8.68
B0	>	B1	10.36
B0	>	F2	11.03
F0	>	B2	2.41
F0	>	F1	3.58
F0	>	B1	5.30
F0	>	F2	5.86

[a] Breakwater transects (F0 and B0) were individually compared to non-breakwater transects (F2, F1, B1, B2) in decreasing order of the magnitude of their mean value. The relationship between the two transect means is described as significantly greater than (>), significantly less than (<), or not significantly different (=).

Table 8. Number of fish captured per hour of electrofishing (c/f) and the percentage of the total number of each species taken at various transects during 1979-80. (Refer to Appendix C for scientific name of each species.)

	Transect												
	F2		F1		F0		B0		B1		B2		Total
Species	c/f	%	c/f	%	c/f	%	c/f	%	c/f	%	c/f	%	c/f
Gizzard shad	20.0	10.8	36.0	19.4	28.9	15.6	45.5	24.5	20.1	10.8	35.1	18.9	185.6
Sunfish	0.0	0.0	0.0	0.0	8.1	35.7	14.6	64.3	0.0	0.0	0.0	0.0	22.7
Unidentified	2.3	14.6	1.0	6.4	3.6	23.1	5.9	37.9	1.5	9.9	1.3	8.1	15.6
Red shiner	0.0	0.0	0.2	1.5	4.2	32.1	7.2	54.5	0.6	4.7	0.9	7.2	13.1
Largemouth bass	0.2	2.6	0.4	5.5	3.2	43.4	2.9	39.8	0.3	4.3	0.3	4.4	7.3
River carpsucker	0.6	12.8	0.6	13.4	2.0	43.6	0.4	9.2	0.3	6.9	0.6	14.1	4.5
White bass	0.6	13.6	0.8	19.2	1.4	32.3	0.8	19.8	0.0	0.0	0.6	15.1	4.2
Carp	0.0	0.0	0.0	0.0	1.8	44.6	1.9	47.6	0.0	0.0	0.3	7.8	4.0
Miss. silversides	0.0	0.0	0.2	6.1	2.4	73.0	0.7	20.9	0.0	0.0	0.0	0.0	3.3
White crappie	0.2	5.9	0.0	0.0	0.6	18.8	1.8	55.9	0.3	9.6	0.3	9.8	3.2
Channel catfish	0.6	41.4	0.2	14.5	0.3	21.8	0.0	0.0	0.3	22.3	0.0	0.0	1.4
Flathead catfish	0.0	0.0	0.0	32.1	0.2	23.9	0.3	44.0	0.0	0.0	0.0	0.0	0.7
Bullhead minnow	0.0	0.0	0.2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Freshwater drum	0.0	0.0	0.0	0.0	0.2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Black bullhead	0.0	0.0	0.0	0.0	0.0	0.0	0.1	100.0	0.0	0.0	0.0	0.0	0.1
Electrofishing time (hours):	5.24		4.98		6.64		7.24		3.23		3.16		

Figure 7. Percentage of fish collected on each transect while electrofishing during 1979-80.



[a] 70% of total catch.

[b] Catch for each species is ≤ 0.52% of total catch.

[c] One fish.

Table 9. Results of t-tests comparing the mean numbers of the nine most abundant species captured per hour of electrofishing at various transects during 1979-80.[a]

Species	Transect	Relationship	Transect	d.f.	t-statistic
Gizzard shad	B0	>	B2	157	4.15
	B0	>	F1		6.19
	B0	>	B1		9.62
	B0	>	F2		11.06
	F0	<	B2		-2.08
	F0	=	F1		-0.02
	F0	>	B1		3.43
	F0	>	F2		4.65
	B0	>	F0		6.16
Sunfish	B0	>	(B2,B1,F1,F2)[b]	133	8.63
	F0	>	(B2,B1,F1,F2)[b]		4.53
	B0	>	F0		4.04
Red shiner	B0	>	B2	71	5.78
	B0	>	B1		5.95
	B0	>	F1		6.45
	B0	>	F2[b]		6.57
	F0	>	B2		2.96
	F0	>	B1		3.18
	F0	>	F1		3.61
	F0	>	F2[b]		3.72
	B0	>	F0		2.65
Largemouth bass	B0	>	B2	86	5.77
	B0	>	F1		5.86
	B0	>	B1		5.72
	B0	>	F2		5.98
	F0	>	B2		5.49
	F0	>	F1		5.57
	F0	>	B1		5.53
	F0	>	F2		5.69
	B0	=	F0		0.04
River carpsucker	F0	>	B2	48	4.78
	F0	>	F1		5.25
	F0	>	F2		5.27
	F0	>	B1		5.89
	B0	=	B2		-0.58
	B0	=	F1		-0.11
	B0	=	F2		-0.09
	B0	=	B1		0.53
	F0	>	B0		5.36

Table 9. Continued.

Species	Transect	Relationship	Transect	d.f.	t-statistic
White bass	F0	>	F1	46	2.28
	F0	>	B2		3.43
	F0	>	F2		4.01
	F0	>	B1		5.49
	B0	=	F1		0.10
	B0	=	B2		1.18
	B0	>	F2		1.76
	B0	>	B1		3.31
	F0	>	B0		2.26
Carp	B0	>	B2	72	5.24
	B0	>	(F2,F1,B1)[b]		5.98
	F0	>	B2		3.80
	F0	>	(F2,F1,B1)[b]		4.54
	B0	=	F0		1.44
Mississippi silversides	F0	>	F1	22	3.00
	F0	>	(B1,B2,F2)[b]		3.76
	B0	=	F1		0.69
	B0	=	(B1,B2,F2)[b]		1.35
	F0	>	B0		2.45
White crappie	B0	>	B1	44	4.47
	B0	>	B2		5.13
	B0	>	F2		5.27
	B0	>	F1		5.55
	F0	=	B1		0.76
	F0	=	B2		1.15
	F0	=	F2		1.29
	F0	>	F1		1.79
	B0	>	F0		3.85

[a] Breakwater transects (F0 and B0) were individually compared to non-breakwater transects (F2, F1, B1, B2) in decreasing order of the magnitude of their mean value. The relationship between the two transect means is described as significantly greater than (>), significantly less than (<), or not significantly different (=).

[b] No fish were collected on these transects.

breakwater transect than at the other breakwater transect. However, the two highest mean catches within a species were made at the two breakwater transects, with two exceptions: the mean number of gizzard shad on transect F0 fell below transects B2 and F1 (F1 not significantly higher), and the mean number of river carpsuckers on transect B0 were lower than on transects B2, F1 and F2 (although not significantly lower). The highest mean catch for all nine species was made on one of the breakwater transects and most commonly occurred behind the breakwater (B0). The exceptions to that trend were carpsuckers, white bass, and silversides, each of which were found most frequently on transect F0.

Only one species, gizzard shad, was abundant enough on all transects to allow a comparison of their condition. A regression equation ($X = 100{,}000\ W/L^3$) was calculated for each transect using the common logarithms of total length regressed on logs of weight. The y-intercept and slope for transect B0 were not significantly different than for transects B2, F2, B1 and F1 (243 d.f.). However, the y-intercept of transect F0 was significantly higher, and the slope was significantly lower, than the corresponding values calculated for transect B0 ($F = 7.61$ and 7.41, respectively).

Fish lengths were analyzed with the Duncan's Multiple Range (DMR) test after analysis of variance indicated that the lengths of shad were significantly different between transects ($F = 9.74$ with 249 d.f.). According to the DMR test, the mean lengths of fish taken from transects B0 and F0 were similar, as were those from transects F1, B2, F2 and B1. However, the mean length of B0 and F0 fish was significantly greater than the mean length of F1, B2, F2 and B1 fish:

F0 B0 F1 B2 F2 B1 (M.S. = 853.367 with 249 d.f.). (Mean values at transects that are connected by one line were not significantly different.)

Gill Nets

Numbers of fish taken per net (each net contained two mesh sizes) were computed for catches from 57 gill nets set on the bottom (discontinued in 1980) and 91 gill nets set at the surface (Tables 10 and 11, respectively) and tested with analysis of variance for differences between transects. In both cases the mean number of fish taken on transect F2 was significantly higher than on either of the other two transects (B0 and B2) (surface: t = 5.35 and 3.74, respectively, with 30 d.f., and bottom: t = 3.22 and 4.02, respectively, with 18 d.f.). Comparing transects B0 and B2, neither surface nor bottom catches were significantly different (t = -1.61 with 30 d.f. and t = 0.80 with 18 d.f.). At the surface, the catches were lowest at the breakwater, but near the bottom mean catches decreased from the front to the back of the cove; i.e., the abundance of fish near the bottom was lowest at B2 transect.

The four most abundant species at both the surface and the bottom were white crappie, channel catfish, river carpsucker, and gizzard shad (Table 12). Largemouth bass, bluegill, and blue catfish were particularly rare (n = 3, n = 2, n = 1, respectively). The relative percentages of each species caught at the surface and on the bottom (Figure 8) were similar at each of the transects for the six most numerous species (white crappie, channel catfish, river carpsucker, gizzard shad, white bass, and carp). On transects F2 and B2, four of

Table 10. Number of fish captured per gill net (c/f) set on the bottom at various transects during 1979.

Date	Transect and c/f		
	F2[a]	B0[b]	B2[c]
17-18 May	7.0	7.7	6.7
22-23 May	5.0	4.7	8.3
7-8 Jun.	0.5	3.0	3.7
13-14 Jun.	7.5	15.5	3.5
11-12 Jul.	39.0	9.3	10.5
9-10 Aug.	16.3	7.3	8.0
22-23 Aug.	4.7	3.7	3.3
Total	80.0	51.2	44.0
Mean	11.43	7.31	6.28

[a] 18 nets set

[b] 20 nets set

[c] 19 nets set

Table 11. Number of fish captured per gill net (c/f) set at the surface on various transects during 1979-80.

Date	Transect and c/f		
	F2[a]	B0[a]	B2[b]
1979			
16-17 May	20.0	9.0	8.7
23-24 May	8.7	0.3	7.0
6-7 Jun.	9.3	3.3	2.0
14-15 Jun.	10.0	7.5	1.5
10-11 Jul.	15.7	0.7	3.5
8-9 Aug.	6.0	0.3	2.7
21-22 Aug.	6.0	3.5	1.0
1980			
5-6 Jun.	18.3	3.0	13.0
24-25 Jun.	9.0	15.0	11.0
6-7 Aug.	7.3	1.0	8.0
18-19 Aug.	14.7	0.7	10.3
Total	125.0	44.3	68.7
Mean	11.36	4.03	6.24

[a] 31 nets set

[b] 29 nets set

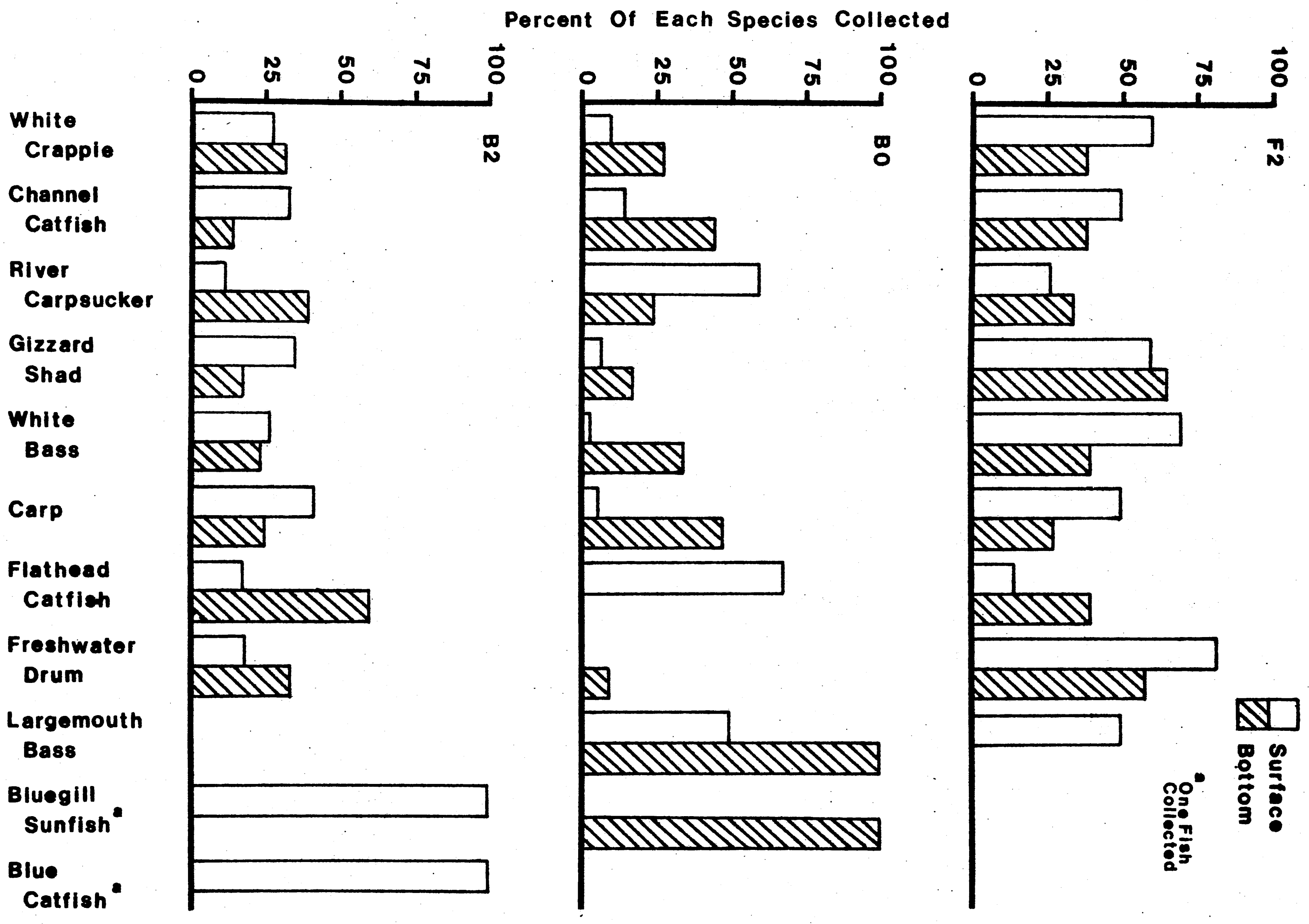
Table 12. Number of fish of each species captured per gill net (c/f) and the percentage of the total number of each species taken at various transects during 1979-80.

Net depth and species	Transect						Total
	F2		B0		B2		
	c/f	%	c/f	%	c/f	%	c/f
Surface:[a]							
White crappie	4.06	60.2	0.68	10.1	2.00	29.7	6.74
Channel catfish	3.36	52.2	0.94	14.6	2.14	33.2	6.44
River carpsucker	0.81	25.6	1.90	60.1	0.45	14.2	3.16
Gizzard shad	1.81	59.0	0.19	6.2	1.07	34.8	3.07
White bass	1.03	70.0	0.03	2.2	0.41	27.8	1.47
Carp	0.29	51.6	0.03	5.7	0.24	42.7	0.56
Flathead catfish	0.03	16.3	0.13	66.3	0.03	17.3	0.19
Freshwater drum	0.16	82.5	0.00	0.0	0.03	17.5	0.19
Largemouth bass	0.03	50.0	0.03	50.0	0.00	0.0	0.06
Bluegill	0.00	0.0	0.00	0.0	0.03	100.0	0.03
Blue catfish	0.00	0.0	0.00	0.0	0.03	100.0	0.03
Bottom:[b]							
White crappie	2.50	39.1	1.90	29.7	2.00	31.2	6.40
Gizzard shad	4.11	65.6	1.05	16.8	1.10	17.6	6.26
Channel catfish	1.33	38.5	1.60	46.2	0.53	15.3	3.46
River carpsucker	1.00	34.4	0.75	25.8	1.16	39.8	2.91
Carp	0.56	28.3	0.95	48.0	0.47	23.7	1.98
Freshwater drum	0.89	53.3	0.20	12.0	0.58	34.7	1.67
White bass	0.39	39.0	0.35	35.0	0.26	26.0	1.00
Flathead catfish	0.11	40.7	0.00	0.0	0.16	59.3	0.27
Largemouth bass	0.00	0.0	0.05	100.0	0.00	0.0	0.05
Bluegill	0.00	0.0	0.05	100.0	0.00	0.0	0.05

[a] Number of nets set on transects F2, B0, and B2 were 31, 31, and 29, respectively.

[b] Number of nets set on transects F2, B0, and B2 were 18, 20, and 19, respectively.

Figure 8. Percentage of fish collected on each transect in gill nets set at the surface and on the bottom during 1979-80.


Percent Of Each Species Collected
0
25
50
75
100
F2
B0
B2
Surface
Bottom
a One Fish Collected
White Crappie
Channel Catfish
River Carpsucker
Gizzard Shad
White Bass
Carp
Flathead Catfish
Freshwater Drum
Largemouth Bass
Bluegill Sunfish a
Blue Catfish a

the six species were more abundant at the surface. At the breakwater, however, more fish were taken near the bottom for five of the six species. The river carpsucker was the exception to these patterns at all three transects.

Each species for which I caught more than 15 fish was analyzed statistically for differences, between transects, in the mean catch per gill net (Table 13). The results were very consistent for fishes caught at the surface. Mean catches for all species except river carpsucker were significantly lower at transect B0 than at transect F2 or B2. Also, as expected (Table 11), the mean catch on transect F2 was usually significantly higher than that on transect B2. This was not the case for river carpsuckers or carp; mean numbers of both species were statistically similar at transects B2 and F2.

Although catches of fish in bottom-set nets were more variable than at the surface, the relationship between mean catches on transects F2 and B2 was similar to that of fishes taken in surface nets; i.e., the F2 mean was significantly greater than the B2 mean for all species except river carpsuckers and carp. Another consistent pattern among catches near the bottom was that the mean number of fish captured at the breakwater was either significantly less than, or not significantly different from, the mean number captured on non-breakwater transects (F2 and B2). This was true for all species except channel catfish and carp, both of which were significantly more abundant at the breakwater (transect B0) than on transect B2 or F2.

Condition factors of white crappie, channel catfish, river carpsucker, and gizzard shad taken at the surface were compared as described previously, but varied significantly for channel catfish

Table 13. Results of t-tests comparing mean numbers of fishes caught per gill net set at the surface or on the bottom at various transects during 1979-80. Species included are those for which at least 15 fish were caught.[a]

Species	Depth location	Transect and mean value F2	BO	B2	Statistical relationship	d.f.	t-statistic
White crappie	Surface	3.74	0.63	1.94	BO < F2	30	-5.46
					BO < B2		-2.30
					F2 > B2		3.16
	Bottom	2.80	2.10	2.17	BO < F2	15	-3.50
					BO = B2		-0.35
					F2 > B2		3.15
Channel catfish	Surface	3.29	0.93	2.02	BO < F2	30	-5.49
					BO < B2		-2.53
					F2 > B2		2.95
	Bottom	1.14	1.70	0.46	BO > F2	18	1.93
					BO > B2		4.28
					F2 > B2		2.34
River carpsucker	Surface	1.33	3.04	0.71	BO > F2	18	3.00
					BO > B2		4.09
					F2 = B2		1.09
	Bottom	1.17	1.13	1.33	BO = F2	15	-0.67
					BO < B2		-3.33
					F2 < B2		-2.67

Table 13. Continued.

Species	Depth location	Transect and mean value			Statistical relationship	d.f.	t-statistic
		F2	B0	B2			
Gizzard shad	Surface	1.80	0.28	1.16	B0 < F2	27	-5.24
					B0 < B2		-3.03
					F2 > B2		2.21
	Bottom	33.30	6.90	8.60	B0 < F2	12	-15.44
					B0 = B2		-0.99
					F2 > B2		14.44
White bass	Surface	1.17	0.03	0.42	B0 < F2	27	-5.18
					B0 < B2		-1.77
					F2 > B2		3.41
	Bottom	0.80	0.58	0.58	B0 < F2	9	-2.53
					B0 = B2		0.00
					F2 > B2		2.53
Carp	Surface	0.40	0.06	0.29	B0 < F2	21	-4.86
					B0 < B2		-3.28
					F2 = B2		1.57
	Bottom	0.64	1.18	0.48	B0 > F2	18	3.18
					B0 > B2		4.12
					F2 = B2		0.94

Table 13. Continued.

Species	Depth location	Transect and mean value			Statistical relationship	d.f.	t-statistic
		F2	B0	B2			
Freshwater drum	Bottom	0.87	0.20	0.58	B0 < F2	18	-4.78
					B0 < B2		-2.71
					F2 > B2		2.07

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[a] The statistical relationship between the two transects being tested is described as significantly greater than ( ), significantly less than ( ), or not significantly different (=).

only (Table 14). For catfish, the y-intercept for transect B2 was significantly higher, and the slope was significantly lower, then the corresponding values for transect B0. Intercepts were lowest at B0 for all species except river carpsucker, and slopes were highest at B0 with the same exception.

Mean lengths were not significantly different between transects for channel catfish (F = 1.88 with 2 and 156 d.f.), river carpsucker (F = 0.07 with 2 and 81 d.f.), or gizzard shad (F = 0.45 with 2 and 57 d.f.). However, lengths of white crappie differed significantly between transects (F = 2.32 with 2 and 113 d.f.). Further testing with DMR demonstrated that crappies at transect B2 were significantly longer than crappies captured at either F2 or B0 (M.S. = 1542.13 with 113 d.f.).

Hoop Nets

Catches of fish in 110 hoop nets set on 22 dates from August 1979 through August 1980 (Table 15) were highest during May, June, and July 1980, and lowest in the fall of 1979 and spring of 1980. According to analysis of variance, fish were unevenly distributed over the five transects (F = 314.18 with 4 and 105 d.f.). The mean number of fish taken at the breakwater (transect 0) was significantly greater than at each of the non-breakwater transects (F2, F1, B1 and B2) as follows, according to the decreasing magnitude of their mean value: B1, t = 5.28; B2, t = 6.40; F1, t = 8.36; and F2, t = 9.21. Each calculation involved 105 degrees of freedom.

Overall, the most abundant species was white crappie (62% of the total catch), and four species--white crappie, longear sunfish, blue-

Table 14. Comparison of regressions of condition on length for the four most abundant fishes captured in gill nets at various transects during 1979-80. (Number of fish in parentheses.)[a]

Species	r^2	Parameter	Transect	Estimate	Relationship to B0-estimate	F-statistic
Channel catfish (159)	0.91	Intercept	B0	-14.81		
			B2	-12.48	S[b]	4.18
			F2	-12.92	NS[c]	2.87
		Slope	B0	3.54		
			B2	3.13	S	4.09
			F2	3.20	NS	2.88
Gizzard shad (40)	0.77	Intercept	B0	-11.74		
			B2	- 6.79	NS	0.01
			F2	- 9.55	NS	0.00
		Slope	B0	3.07		
			B2	2.01	NS	0.01
			F2	2.56	NS	0.00
River carpsucker (84)	0.52	Intercept	B0	- 7.49		
			B2	- 5.79	NS	0.13
			F2	- 7.63	NS	0.00
		Slope	B0	2.36		
			B2	2.09	NS	0.12
			F2	2.38	NS	0.00

Table 14. Continued.

Species	r^2	Parameter	Transect	Estimate	Relationship to B0-estimate	F-statistic
White crappie (116)	0.92	Intercept	B0	-15.98		
			B2	-13.32	NS	0.24
			F2	-12.19	NS	0.48
		Slope	B0	3.90		
			B2	3.35	NS	0.25
			F2	3.11	NS	0.50

[a] B0 is the transect to which all other transects are compared.

[b] S = significant

[c] NS = non-significant

Table 15. Number of fish caught in hoop nets at various transects during 1979-80.

	Transect and number of fish					
Date	F2	F1	0	B1	B2	Total
1979						
2 Aug.	2	2	24	2	3	33
17 Aug.	5	4	2	0	2	13
24 Aug.	6	2	5	2	3	18
30 Aug.	0	0	3	5	3	11
13 Sep.	0	3	8	4	1	16
19 Sep.	2	0	8	1	1	12
27 Sep.	1	0	4	2	6	13
1980						
11 Mar.	2	3	3	4	2	14
21 Mar.	0	2	4	0	6	12
27 Mar.	3	2	8	3	2	18
4 Apr.	2	1	5	0	11	19
23 May	18	105	151	136	58	468
29 May	19	7	56	24	39	145
27 Jun.	29	47	80	81	60	297
3 Jul.	35	10	31	11	17	104
16 Jul.	30	10	71	3	28	142
24 Jul.	4	2	7	49	5	67
5 Aug.	8	7	17	19	28	79
13 Aug.	1	1	20	2	3	27
19 Aug.	1	7	34	2	8	52
22 Aug.	1	5	73	11	7	97
26 Aug.	12	4	29	17	29	91
Total	181	224	643	378	322	1748
Mean	8.2	10.2	29.2	17.2	14.6	

gill, and gizzard shad--made up almost 97% of the fish captured in hoop nets (Table 16). Nine of the sixteen species were taken only rarely ($n \leq 3$). Of the species contributing more than 0.5% of the total catch, white crappie, longear sunfish, and channel catfish were relatively more abundant at the breakwater (Figure 9). Bluegill appeared more frequently at or behind the breakwater than in front of it. Gizzard shad, river carpsuckers, and freshwater drum were relatively more abundant in front of the breakwater.

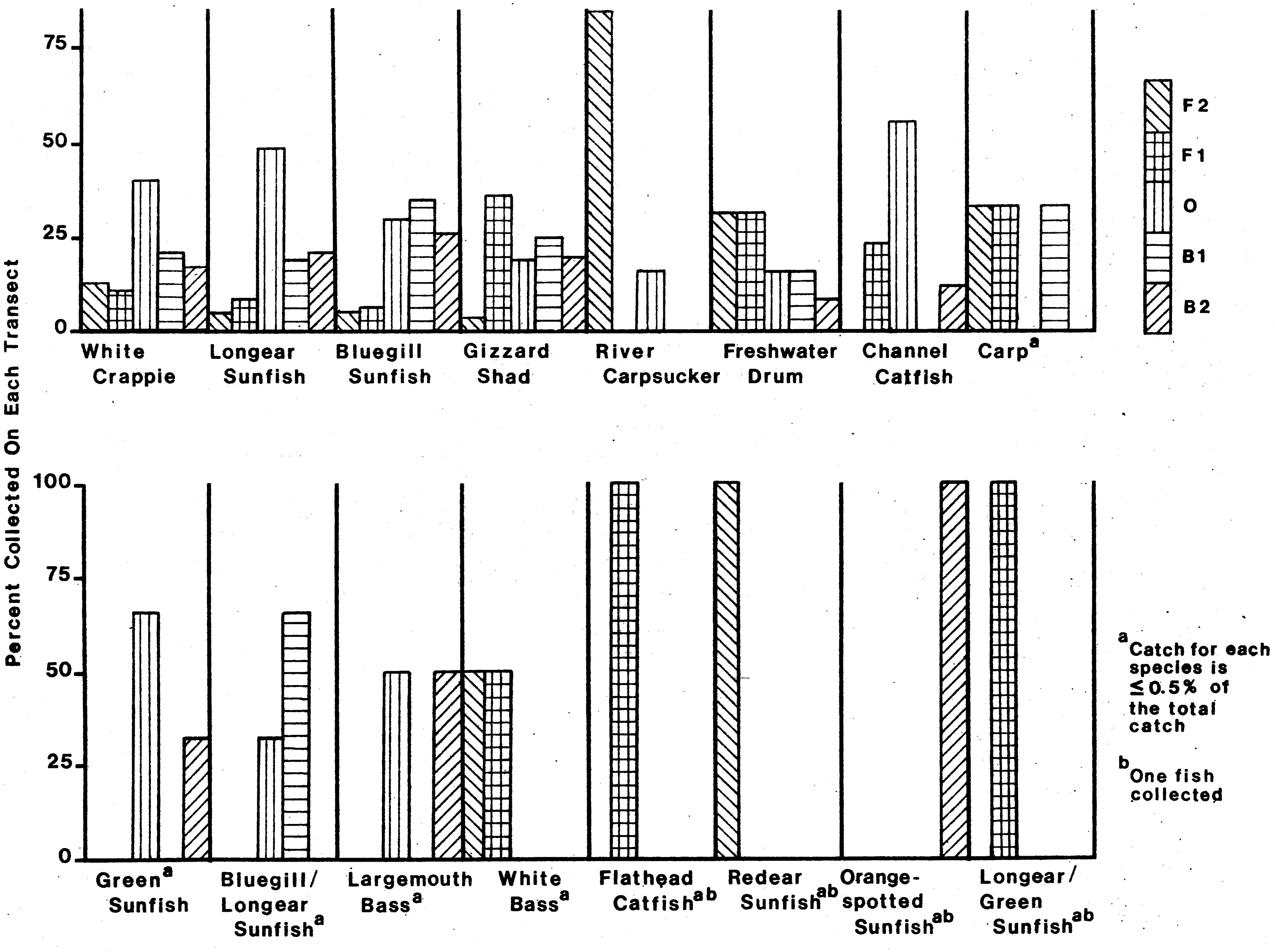
To more closely examine some of the numerical differences between transects, parametric t-tests were used to compare the mean number of the four most abundant species (crappie, longear, bluegill, and shad) taken at the breakwater with the mean at each of the non-breakwater transects (Table 17). As suggested in Figure 9, crappie and longear sunfish were more abundant at the breakwater than on any other transect. Catches of bluegill at the breakwater were similar to catches at the two back transects (B1 and B2), although they were significantly higher than the mean catch on the two front transects (F1 and F2). Abundance of gizzard shad did not differ significantly between transect 0 and any other transect, perhaps because 181 of the 187 gizzard shad were collected on one day.

Y-intercepts and slopes of length-weight regressions for white crappie and gizzard shad taken at transect 0 were significantly different than those for fish taken on other transects (Table 18). White crappie at transect B1 had a significantly lower y-intercept and a significantly higher slope than white crappie at transect 0. Gizzard shad at transect B2 had a significantly higher y-intercept and significantly lower slope than shad captured at transect 0. The lowest

Table 16. Number of fish captured in hoop nets and the percentage of the total number of each species taken at each transect during 1979-80.

	Transect, number of fish, and transect percent										
	F2		F1		0		B1		B2		Total
Species	N	%	N	%	N	%	N	%	N	%	N
White crappie	138	12.8	115	10.6	429	39.6	218	20.1	183	16.9	1083
Longear sunfish	10	4.4	19	8.3	110	48.3	42	18.4	47	20.6	228
Bluegill	9	4.5	13	6.5	57	28.7	69	34.7	51	25.6	199
Gizzard shad	5	2.7	67	35.8	34	18.2	45	24.1	36	19.2	187
River carpsucker	11	84.6	0	0.0	2	15.4	0	0.0	0	0.0	13
Freshwater drum	4	30.8	4	30.8	2	15.4	2	15.4	1	7.6	13
Channel catfish	1	11.1	2	22.2	5	55.6	0	0.0	1	11.1	9
Carp	1	33.0	1	33.0	0	0.0	1	34.0	0	0.0	3
Green sunfish	0	0.0	0	0.0	2	66.0	0	0.0	1	34.0	3
Bluegill/longear sunfish	0	0.0	0	0.0	1	34.0	2	66.0	0	0.0	3
Largemouth bass	0	0.0	0	0.0	1	50.0	0	0.0	1	50.0	2
White bass	1	50.0	1	50.0	0	0.0	0	0.0	0	0.0	2
Flathead catfish	0	0.0	1	100.0	0	0.0	0	0.0	0	0.0	1
Redear sunfish	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	1
Orange-spotted sunfish	0	0.0	0	0.0	0	0.0	0	0.0	1	100.0	1
Longear/green sunfish	0	0.0	1	100.0	0	0.0	0	0.0	0	0.0	1

Figure 9. Percentage of fish collected on each transect in hoop nets during 1979-80.



[a] Catch for each species is ≤0.5% of the total catch

[b] One fish collected

Table 17. Results of t-tests comparing the mean number of fish caught in hoop nets at various transects during 1979-80.[a]

	Transect and mean value					Statistical		
Species	F2	F1	0	B1	B2	relationship	d.f.	t-statistic
White crappie	6.27	5.23	19.50	9.91	8.32	0 > B1	105	6.11
						0 > B2		7.12
						0 > F2		8.43
						0 > F1		9.09
Longear sunfish	0.62	1.19	6.88	2.62	2.94	0 > B2	75	4.92
						0 > B1		5.32
						0 > F1		7.11
						0 > F2		7.82
Bluegill	0.50	0.72	3.17	3.83	2.83	0 = B1	85	-1.43
						0 = B2		0.74
						0 > F1		5.33
						0 > F2		5.80
Gizzard shad	1.67	22.33	11.33	15.00	12.00	0 = F1	10	-1.65
						0 = B1		-0.55
						0 = B2		-0.10
						0 = F2		1.45

[a] The statistical relationship between the two transects being tested is described as significantly greater than (>), significantly less than (<), or not significantly different (=).

Table 18. Comparison of regressions of condition on length for the four most abundant fishes captured in hoop nets at various transects during 1979-80. (Number of fish in parentheses.)[a]

Species	r^2	Parameter	Transect	Estimate	Relationship to B0-estimate	F-statistic
Bluegill (206)	0.91	Intercept	B0	-10.75		
			B2	-11.29	NS	0.32
			F2	- 9.83	NS	0.22
			B1	-11.38	NS	0.53
			F1	-10.34	NS	0.10
		Slope	B0	2.98		
			B2	3.08	NS	0.27
			F2	2.77	NS	0.26
			B1	3.11	NS	0.60
			F1	2.88	NS	0.13
Longear sunfish (237)	0.83	Intercept	B0	-10.78		
			B2	-10.29	NS	0.19
			F2	- 6.57	NS	1.67
			B1	-10.77	NS	0.00
			F1	- 9.05	NS	0.34
		Slope	B0	3.02		
			B2	2.90	NS	0.25
			F2	2.10	NS	1.74
			B1	3.02	NS	0.00
			F1	2.65	NS	0.33

Table 18. Continued.

Species	r^2	Parameter	Transect	Estimate	Relationship to BO-estimate	F-statistic
Gizzard shad (75)	0.84	Intercept	BO	-16.04		
			B2	- 7.49	S	13.73
			F2	–[b]		
			B1	-11.80	NS	3.02
			F1	-12.07	NS	2.20
		Slope	BO	3.84		
			B2	2.12	S	13.88
			F2	–[b]		
			B1	2.99	NS	3.05
			F1	3.06	NS	2.14
White crappie (540)	0.88	Intercept	BO	-11.43		
			B2	-12.27	NS	1.83
			F2	-11.38	NS	0.00
			B1	-13.41	S	8.49
			F1	-11.58	NS	0.03
		Slope	BO	2.99		
			B2	3.14	NS	1.58
			F2	2.97	NS	0.01
			B1	3.36	S	7.75
			F1	3.02	NS	0.03

[a] BO is the transect to which all other transects are compared.

[b] Regression equation not calculated--only one gizzard shad collected on transect F2.

y-intercepts for all the species were found at either transect 0 or B1, as were the highest slopes.

Analysis of variance revealed that mean lengths of white crappie and longear sunfish did not differ significantly between transects (t = 0.38 with 535 d.f., and t = 0.23 with 233 d.f., respectively). Although mean lengths of bluegill and gizzard shad apparently did not differ between transects (t = 1.66 with 201 d.f., and t = 1.83 with 71 d.f., respectively), the Duncan's Multiple Range test indicated subtle differences that might best be described in this way: bluegill: B1 B2 F2 F1 B0; gizzard shad: B0 F1 B1 F2 B2.

Sub-Projects

Fish Tagging

The three experiments designed to study mortality and tag loss revealed that white crappie were adversely affected by some aspect(s) of the tagging and holding procedure employed. The results of the three experiments described in Chapter II were:

1. Within six days, all white crappie died (34 fish); one of five bluegill was found dead on the fourth day. The other four bluegill and the three longear sunfish appeared to be in good health and were released after six days.
2. Three of five tagged crappies and three of five control crappies died by the second day after tagging; the remaining four crappies died by the third day.
3. All crappies in the cage (five fish) died within three days of being tagged.

As a result, no additional white crappie were tagged.

Since most fish were caught at the bteakwater or behind it, the majority of fish were tagged at transects 0, B1 and B2 (Table 19). Theoretically, there were 268 fish available for recapture since 44 of the fish originally tagged died during the mortality/tag loss experiments. Longear sunfish were recaptured most frequently, with 14 of the 95 individuals originally tagged being recaptured at least once (14.7%) (Table 20). Only 2 of the 91 bluegills originally tagged were recaptured (2.2%). The length of time that passed between release and recapture ranged from 4 to 95 days and was always lower for a fish that had already been recaptured once. The median period of time between release and recapture was 21 days ($\bar{x}$ = 28 days with S.D. of 24). While only 8 of the 20 recaptured fish (40%) were released at the breakwater (transect 0), 15 of the 21 (71.4%) recaptures were made at this location. In addition, nine fish released on non-breakwater transects were recaptured at the breakwater while the reverse was true for only two fish.

Larval Fish

Larval fish were collected eight times from 22 May through 16 July 1980 (Table 21). Densities were highest on 30 May when cloud cover was greatest (70%); however, cloud cover and density were not strongly correlated and density appeared to be most closely related to season. On 20 June, winds were from the northwest, the only exception to prevailing southwesterly winds. This change in wind direction coincided with a relatively high density of larvae on transect B0.

The density on four of the sampling dates was highest at the

Table 19. Distribution of tags by species, method of capture, and transect where the fish were originally captured and released, 1980.

Species	Total N	Equipment	Transect	N	Known mortalities[a]
White crappie	109	Hoop net	B2	38	12
			B1	9	0
			0	46	27
			F1	3	0
			F2	8	2
			Unidentified	5	5
Longear sunfish	95	Hoop net	B2	19	0
			B1	27	0
			0	39	0
			F1	5	0
			F2	3	0
		Electrofishing	0	2	0
Bluegill	91	Hoop net	B2	26	1
			B1	27	0
			0	22	0
			F1	8	0
			F2	3	0
			Unidentified	1	0
		Electrofishing	0	4	0
Freshwater drum	5	Hoop net	B1	1	0
			F1	2	0
			F2	2	0
Bluegill/ longear hybrid	3	Hoop net	B1	2	0
		Electrofishing	0	1	0
River carpsucker	3	Hoop net	F2	3	0
Unidentified	2	Hoop net	0	2	0
Channel catfish	2	Hoop net	B2	1	0
			0	1	0
Carp	1	Hoop net	F2	1	0
Green sunfish	1	Hoop net	B2	1	0
Total	312				44

[a] These fish died during mortality/tag loss experiments and were never available for recapture.

Table 20. Summary of data for fishes recaptured during 1980. (All recaptures were made in hoop nets.)

		Release				Recapture				
Tag number	Species	Date	Transect	Total length (mm)	Weight (g)	Date	Transect	Total length (mm)	Weight (g)	Days[a]
009	Longear sunfish	4 Apr.	B2	101	18	8 Jul.	0	110	25	95
		8 Jul.	0	110	25	24 Jul.	0	110	32	16
037	Bluegill	23 May	-	-	-	24 Jul.	B1	164	90	62
		24 Jul.	B1	164	90	22 Aug.	0	169	95	19
118	Longear sunfish	12 Jun.	B2	116	20	3 Jul.	0	-	-	21
120	Bluegill	12 Jun.	B2	166	100	22 Aug.	0	169	90	71
143	Longear sunfish	27 Jun.	0	134	62	3 Jul.	0	134	58	6
146	Longear sunfish	3 Jul.	B1	99	25	17 Jul.	0	104	23	14
155	Longear sunfish	3 Jul.	0	119	46	22 Aug.	B1	119	43	50
168	Longear sunfish	3 Jul.	0	112	31	8 Jul.	0	104	32	5
187	Longear sunfish	8 Jul.	0	104	28	24 Jul.	B1	105	30	16
		24 Jul.	B1	105	30	5 Aug.	0	106	-	12
206	Longear sunfish	17 Jul.	F1	109	32	26 Aug.	F2	112	24	40
208	Longear sunfish	17 Jul.	F1	91	19	13 Aug.	0	95	22	27
211	Longear sunfish	17 Jul.	0	117	40	13 Aug.	0	120	48	27
212	Longear sunfish	17 Jul.	0	106	32	13 Aug.	0	111	36	27
		13 Aug.	0	111	36	19 Aug.	0	115	30	6
247	Longear sunfish	24 Jul.	B2	95	20	22 Aug.	B1	93	17	29
		22 Aug.	B1	93	17	26 Aug.	B1	95	17	4
265	Longear sunfish	24 Jul.	B1	107	30	5 Aug.	0	107	-	12
274	Longear sunfish	24 Jul.	B1	112	40	5 Aug.	0	111	-	12

[a] Number of days between release and recapture; median = 21 days, mean = 28 days with a standard deviation of 24 days.

Table 21. Number of larval fish (N) collected per cubic meter (m^3) of water on four transects during 1980.

Date		Transect				Wind	Clouds
		F2	FO	BO	B2		%
22 May	N	179	133	116	142	SE	60
	m^3	136.92	98.66	96.28	69.71		
	N/m^3	1.31(2)[a]	1.35(3)	1.20(1)	2.04(4)		
30 May	N	2204	1182	433	811	SW	70
	m^3	127.56	95.87	91.34	74.32		
	N/m^3	17.28(4)	12.33(3)	4.74(1)	10.91(2)		
5 Jun.	N	360	264	317	267	SW	2
	m^3	137.34	96.32	100.80	78.50		
	N/m^3	2.62(1)	2.74(2)	3.14(3)	3.40(4)		
20 Jun.	N	133	93	623	98	NW	50
	m^3	119.16	96.92	89.36	76.98		
	N/m^3	1.12(2)	0.96(1)	6.97(4)	1.27(3)		
25 Jun.	N	62	52	108	41	SW	0
	m^3	143.25	89.72	75.88	78.03		
	N/m^3	0.43(1)	0.58(3)	1.42(4)	0.52(2)		
1 Jul.	N	8	30	73	26	SW	0
	m^3	147.76	87.65	84.45	67.03		
	N/m^3	0.05(1)	0.34(2)	0.86(4)	0.39(3)		
9 Jul.	N	7	8	5	11	SW	5
	m^3	144.51	86.74	81.30	64.60		
	N/m^3	0.05(1)	0.09(3)	0.06(2)	0.17(4)		
16 Jul.	N	3	25	20	5	SW	35
	m^3	129.29	90.68	91.59	72.80		
	N/m^3	0.02(1)	0.28(4)	0.22(3)	0.07(2)		
Total N/m^3		22.88	18.67	18.61	18.77		
Mean N/m^3		2.86	2.33	2.33	2.35		
Total rank		13	21	22	24		

[a] Numbers in parentheses indicate rank within a sampling day.

breakwater (transect B0 or F0), and on the other four dates was highest at non-breakwater transects (B2 and F2). The transect with the highest overall mean density was F2 (2.86 larval fish/m^3), primarily as the result of a large catch collected at that transect on 30 May. There was no significant difference in density between transects (Friedman test, T = 5.25 with 3 d.f.).

As expected, the most abundant species of larval fish on each date was gizzard shad (Table 22); on the first five dates, gizzard shad composed over 90% of the catch. White crappie were most abundant on 30 May and 5 June, and sunfish began to make up a large portion of the catch in July. The numbers in Table 22 represent actual fish rather than densities and should not, therefore, be used to make comparisons of relative abundance between transects.

For the five dates on which more than ten larval gizzard shad were caught on each transect, their mean total lengths were ranked within dates (Table 23). Mean lengths of larval gizzard shad differed significantly between transects according to Friedman's rank test (T = 9.24 with 3 d.f.) and was highest on the two breakwater transects, F0 and B0. Mean lengths were greatest on the breakwater transects on four of the five dates, and on transect F2 on the fifth date. This large mean length at transect F2 occurred on 25 June and was caused by the capture of many post-larval shad that had completely undergone metamorphosis.

Zooplankton

Zooplankton was collected 12 times, and mean densities were plotted according to date and transect (Figure 10). The densities on

Table 22. Species composition of larval fishes collected during 1980.

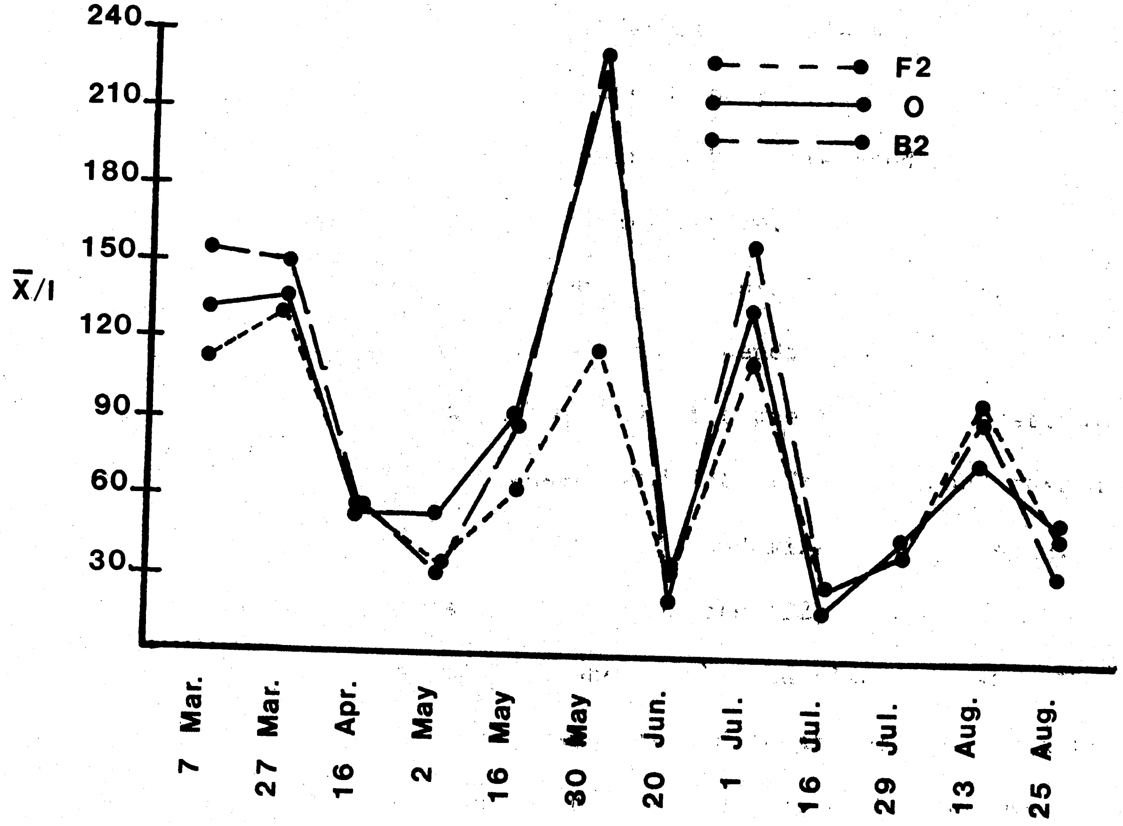
Date	Species	Transect and number of fish				
		F2	F0	B0	B2	Species %
22 May	*Dorosoma cepedianum*	175	133	115	138	98.42
	Menidia audens	1		1		0.35
	Aplodinotus grunniens	1				0.18
	Pomoxis annularis	1			3	0.69
	Cyprinus carpio	1				0.18
	Lepomis sp.				1	0.18
30 May	*Dorosoma cepedianum*	2158	1168	417	783	97.75
	Menidia audens	2	1	4	1	0.17
	Aplodinotus grunniens	1				0.02
	Pomoxis annularis	43	11	12	25	1.97
	Lepomis sp(p).		2		2	0.09
5 Jun.	*Dorosoma cepedianum*	339	237	293	255	93.05
	Menidia audens		1	1	3	0.42
	Aplodinotus grunniens	5	1	7	2	1.24
	Pomoxis annularis	15	25	15	6	5.05
	Lepomis sp.				1	0.08
	Cyprinidae	1				0.08
	Unidentified			1		0.08
20 Jun.	*Dorosoma cepedianum*	127	91	615	91	97.57
	Menidia audens	2	2	7	6	1.80
	Lepomis sp(p).	4		1		0.53
	Percina caprodes				1	0.10
25 Jun.	*Dorosoma cepedianum*	59	48	107	40	97.58
	Menidia audens	3	4	1	1	3.42
1 Jul.	*Dorosoma cepedianum*	7	11	47	18	60.58
	Menidia audens		5	1	1	5.11
	Aplodinotus grunniens		8			5.84
	Pomoxis annularis			2		1.46
	Lepomis sp(p).		2	23	7	23.36
	Unidentified	1	4			3.65
9 Jul.	*Dorosoma cepedianum*	3	5	1	1	32.26
	Menidia audens		3		3	19.35
	Aplodinotus grunniens	2		1	1	12.90
	Lepomis sp(p).			2	6	25.81
	Unidentified	2		1		9.68
16 Jul.	*Dorosoma cepedianum*		1	2		5.66
	Menidia audens		1	1	1	5.66
	Pomoxis annularis		1	4	1	11.32
	Lepomis sp(p).	3	22	13	3	77.36

Table 23. Mean total lengths (mm) of larval gizzard shad collected during 1980. (Ranks in parentheses.)

Date		Transect and mean length (mm)			
		F2	F0	B0	B2
22 May	Mean	5.47(1)	7.03(3)	7.50(4)	6.20(2)
	N	166	147	109	130
30 May	Mean	5.92(1)	11.30(4)	8.92(3)	6.32(2)
	N	100	100	100	99
5 Jun.	Mean	7.89(1)	9.30(2)	10.82(4)	10.80(3)
	N	100	365	100	100
20 Jun.	Mean	9.18(1)	11.25(3)	11.42(4)	9.71(2)
	N	151	93	100	91
25 Jun	Mean	14.25(4)[a]	11.10(3)	9.80(1)	9.92(2)
	N	59	48	100	38

[a] Sample contained many well-developed post-larval fish.

Figure 10. Mean number of zooplankters collected per liter of water ($\bar{x}/\ell$) on three transects, presented by date, 1980.


240
210
180
150
120
90
60
30
X̄/l
F2
O
B2
7 Mar.
27 Mar.
16 Apr.
2 May
16 May
30 May
20 Jun.
1 Jul.
16 Jul.
29 Jul.
13 Aug.
25 Aug.

transects 0 and B2 were highest on 30 May (223 and 231 plankters/ℓ) and lowest on 16 July (20 plankters/ℓ) and 20 June (21 plankters/ℓ), respectively. Densities on transect F2 fluctuated less drastically and were highest early in the season on 27 March (132 plankters/ℓ) and lowest on both 20 June and 16 July (26 plankters/ℓ). In terms of abundance, there were no consistent differences between transects, although zooplankters were more abundant most often behind the breakwater (transect B2). Overall mean density (91 plankters/ℓ) was highest at transect B2, followed by transects 0 (88 plankters/ℓ) and F2 (73 plankters/ℓ). Density did not appear to be correlated with any of the climatic variables (air and water temperature, cloud cover, and wind speed and direction). Large amounts of rainfall in April and June may have diluted zooplankton densities (see Appendix A).

Densities of zooplankton for each of three sections--east, middle, and west--were recorded by transect and date (Table 24) and tested with analysis of variance using a split-plot randomized block design. This design allowed comparisons between transects (F2, 0, and B2) and between locations (east, middle, and west), and also indicated the degree of interaction between transects and locations. No significant difference was found between locations (F = 0.85 with 2 and 66 d.f.; P<0.10); i.e., regardless of transect, mean zooplankton densities in east, middle, and western sections of the study areas were similar. A significant difference was found, however, in zooplankton densities between transects (F = 2.76 with 2 and 22 d.f.; P<0.10). [A P-level of 0.10 was chosen in these split-plot tests because loss of precision in detecting differences between whole plots (transects) is inherent in this design (Steele and Torrie 1960).] Parametric t-tests, which

Table 24. Number of zooplankters per liter of water (N/ℓ) collected during 1980, listed by transect (F2, 0, B2) and section (east, middle, west) where caught.

	Transect, location and N/ℓ								
	F2			0			B2		
Date	East	Middle	West	East	Middle	West	East	Middle	West
7 Mar.	132	99	108	182	108	107	114	112	235
27 Mar.	124	137	136	159	153	127[a]	115	141	195
16 Apr.	60[a]	66	47	60	55	50	65	41	66
2 May	34	41	34	61	63	37	39	22	34
16 May	63	66	61	128	81	71	75	98	95
30 May	81	100	173	316	239	114	275	151	266
20 Jun.	21	24	32	14	44	35	17	24	22
1 Jul.	123	140	84	155	129	117	133	167	177
16 Jul.	19	30	30	25	21	15	25	24	30
29 Jul.	39	37	49	42	45	47	29	45	52
13 Aug.	144	74	76	81	80	66	66	127	96
25 Aug.	69	48	34	73	41	43	46	22	41
Total	909	862	864	1296	1059	829	999	974	1309
Mean	75.8	71.8	72.0	108.0	88.2	69.1	83.2	81.2	109.1

[a] Sample containers accidentally broken; values estimated according to Steele and Torrie (1960) p. 241.

tested differences in mean density (averaged over locations east, middle, and west) between transects, did reveal significantly higher mean densities on transects 0 and B2 than on transect F2 (t = 4.54 and 5.33, respectively, d.f. = 33). Mean densities on transects 0 and B2 were not different from one another (t = 0.79, d.f. = 33).

Significant interaction was found between locations and transects (F = 4.24 with 4 and 66 d.f.; Figure 11). Each point on Figure 11 represents the mean density of zooplankters in a specific section of each transect on the 12 sampling dates. Trends for eastern and middle regions were quite similar when moving from the front of the cove to the region behind the breakwater. However, densities in the western section responded in the reverse manner; lowest densities, rather than highest, were found at transect 0.

Densities of cladocerans, copepods, and rotifers were also tested with the split-plot randomized block design (Table 25), and showed significant differences in the numbers of organisms on different transects (F = 3.34 with 2 and 22 d.f.; $P<0.10$), as would be expected from the results of the previous split-plot tests. The abundance of the three taxonomic groups also differed significantly (F = 17.25 with 2 and 66 d.f.). Copepods were most numerous on all transects followed by cladocerans and rotifers (Table 25).

No significant interactions were found between transects and taxonomic groups (F = 0.14 with 66 d.f.). In other words, when the changes in mean numbers of organisms between any two transects were compared, the fluctuations occurred in the same direction for cladocerans, copepods, and rotifers. The average number of all three groups increased when moving from transect F2 and 0 and again, to a

Figure 11. Mean number of zooplankters per liter of water ($\bar{x}/\ell$) on three transects, 1980. West, middle, and east were geographical sections of the transects.

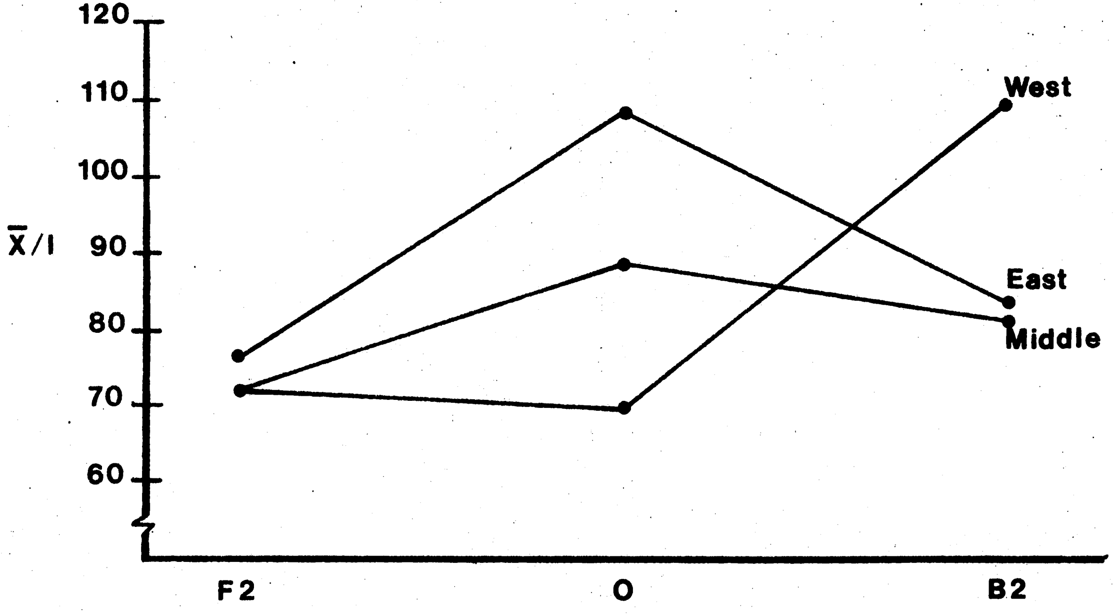

120
110
100
X̄/I
90
80
70
60
F2
O
B2
West
East
Middle

Table 25. Mean number of zooplankters per liter of water ($\bar{x}/\ell$), averaged over section (east, middle, west) and listed by transect and taxonomic group, 1980.

	Transect, taxonomic group, and mean $\bar{x}/\ell$								
	F2			0			B2		
Date	Cladocera	Copepoda	Rotifera	Cladocera	Copepoda	Rotifera	Cladocera	Copepoda	Rotifera
7 Mar.	5.8	45.6	15.8	3.7	37.9	52.8	5.5	44.8	58.4
27 Mar.	11.9	51.0	18.4	8.9	62.8	12.0	33.4	65.3	8.5
16 Apr.	10.7	21.8	1.9	10.6	19.4	2.7	12.6	21.6	1.7
2 May	8.1	12.8	2.6	11.2	19.6	3.2	9.3	8.8	4.8
16 May	21.5	20.4	0.9	27.3	31.6	2.8	26.4	29.4	4.0
30 May	19.7	47.7	2.9	45.5	83.6	10.5	38.9	92.5	6.7
20 Jun.	5.4	9.7	0.9	8.7	9.7	2.9	3.0	7.6	2.8
1 Jul.	39.1	31.0	14.3	30.4	42.5	17.7	22.1	51.1	34.6
16 Jul.	2.8	7.5	2.5	3.6	9.8	3.1	5.0	9.3	2.7
29 Jul.	10.6	14.8	1.5	9.8	16.9	1.1	8.8	16.3	0.8
13 Aug.	44.4	18.7	16.2	27.6	16.4	15.3	42.9	19.0	15.3
25 Aug.	15.8	17.2	0.3	12.0	20.0	1.1	13.3	11.1	0.9
Total	195.8	298.2	78.2	199.3	370.2	125.2	221.2	376.8	141.2
Mean	16.32	24.85	6.52	16.61	30.85	10.43	18.43	31.40	11.77

lesser degree, when moving from transect 0 to B2.

Periphyton Productivity

The primary productivity experiments were divided into two segments, ash-free weights and dissolved oxygen. The periphyton growing on the tires consisted primarily of the green algae *Cladophora* and Spirogyra; another green algae, *Closterium*, and a blue-green algae *Microcystis* were present in very small quantities.

Ash-free weight. Ash-free weights of periphyton for each tire piece (Table 26) varied somewhat within, as well as between, dates. The overall mean weight of non-animal organic matter per tire piece was 2.0009 g. The 95% confidence interval for this figure ranged from 1.7308 g to 2.2710 g per 441 cm^2 tire piece, which is equivalent to 39.25 to 51.50 g of ash-free weight per square meter of tire surface.

As with macroinvertebrate populations on the Hester-Dendy samplers, the most abundant organisms on the tire pieces were chironomids and psychomyiids; they made up 94.1-98% of the total number of organisms on a given date (Table 27). Certain organisms such as hydroptilids, tabanids, tipulids, and gyrinids, were found on only one date, and an unidentified turbellarian appeared only in August.

As with ash-free weights, the numbers of organisms varied somewhat within, as well as between, dates. The mean number of invertebrates collected per tire piece (389) was transformed into number of organisms per square meter (8817). Although a direct comparison cannot be made, the highest mean density on a Hester-Dendy sampler during this study was 259 organisms on 20 July 1980, which is equivalent to only 1573 organisms per square meter.

Table 26. Ash-free weights (g) of periphyton growing on 21 tire pieces (441 cm^2 each) attached to the breakwater the last week of March, 1980.

	Date removed and weight (g)			
	11 Jul.	30 Jul.	12 Aug.	28 Aug.
	1.1679	1.0138	1.5555	1.8968
	2.0479	1.9717	2.1931	3.5349
	2.2609	1.4397	1.8998	2.0847
	1.9881	1.5074	1.8051	2.9020
	2.7755	2.1308	1.3741	-
	-	1.9527	2.5163	-
Total	10.2403	10.0161	11.3439	10.4184
Mean	2.04806	1.66935	1.89065	2.60460

$\Sigma x = 42.0187$

$\bar{x} = 2.0009 \pm 0.27011$

95% C.I. = 1.7308 to 2.2710 g/441 cm^2

= 39.25 to 51.50 g/m^2

Table 27. Number of invertebrates of various families inhabiting 22 tire pieces formerly attached to the breakwater. Tire pieces were placed in the lake during the last week of March, 1980.

	Date and location of tire piece													
	11 July							30 July						
Family	11	25	36	43	48	49	Total	01	13	20	28	32	41	Total
Insecta														
Chironomidae	115	82	177	129	160	208	871	588	695	888	582	264	399	3416
Psychomyiidae	9	25	29	33	44	63	203	52	30	43	27	9	19	180
Hydroptilidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coenagrionidae	-	-	-	-	-	-	-	-	1	1	-	-	-	2
Tabanidae	-	-	-	-	-	1	1	-	-	-	-	-	-	-
Tipulidae	-	-	-	-	-	1	1	-	-	-	-	-	-	-
Gyrinidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydrophilidae	-	-	-	-	-	4	4	-	-	-	-	-	-	-
Unknown tricopteran pupae	-	-	-	-	-	-	-	-	-	1	2	-	-	3
Gastropoda														
Physidae	-	-	-	-	-	2	2	7	-	3	1	-	1	12
Planorbidae	-	-	1	1	-	-	2	1	-	-	-	-	-	1
Crustacea														
Talitridae	-	2	5	-	-	8	15	9	1	-	11	-	3	24
Turbellaria														
Unknown	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Date total	124	109	212	163	204	287	1099	657	727	936	623	273	422	3638

Table 27. Continued

	Date and location of tire piece												
	12 Aug.							28 Aug.					
Family	05	10	16	37	44	50	Total	08	38	39	58	Total	Total
Insecta													
Chironomidae	317	466	785	380	379	281	2605	139	198	284	126	747	7639
Psychomyiidae	48	30	70	27	38	39	252	10	13	30	28	81	716
Hydroptilidae	6	4	2	-	-	-	12	-	-	-	-	-	12
Coenagrionidae	-	-	-	-	-	-	-	-	3	-	-	3	5
Tabanidae	-	-	-	-	-	-	-	-	-	-	-	-	1
Tipulidae	-	-	-	-	-	-	-	-	-	-	-	-	1
Gyrinidae	-	-	-	-	-	-	-	-	-	-	1	1	1
Hydrophilidae	-	-	-	-	1	-	1	-	-	-	-	-	5
Unknown tricopteran pupae	-	-	-	-	-	-	-	-	-	-	-	-	3
Gastropoda													
Physidae	-	3	3	-	1	-	7	-	1	-	1	2	23
Planorbidae	-	11	1	1	-	1	14	5	1	-	-	6	23
Crustacea													
Talitridae	-	1	10	5	3	4	23	1	5	4	1	11	73
Turbellaria													
Unknown	-	8	14	-	1	-	23	19	4	2	4	29	52
Date total	368	523	885	413	423	325	2937	174	225	320	161	880	8554

Dissolved oxygen. Over the four dates on which I measured changes in dissolved oxygen (DO) to estimate periphyton productivity, ten light boxes and ten dark boxes were used. Three boxes of each type were used on the first three dates, but failure of the generator on the fourth date permitted measurements from only one light box, one dark box, and the two (light and dark) BOD bottles. Final DO measurements for each box were subtracted from their corresponding initial measurement (Table 28). As expected, DO concentration in the light boxes and BOD bottles usually increased; conversely, DO concentration in each dark box and BOD bottle decreased.

On a given date, the mean difference between initial and final DO concentrations in the light boxes represents net periphyton-plus-phytoplankton production (for example, 1.10 mgO/ℓ on 11 July). The mean difference between DO concentrations in dark boxes represents periphyton-plus-phytoplankton respiration. The difference between net production and respiration represents gross periphyton-plus-phytoplankton production for that particular day. Similarly, net production in light BOD bottles and respiration in dark BOD bottles were used to determine gross phytoplankton production for a particular day. Gross phytoplankton production averaged for the four dates (1.5375 mgO/ℓ) was then substracted from gross periphyton-plus-phytoplankton production, also averaged for the four dates (8.9125 mgO/ℓ), to determine the mean gross periphyton production during the experiment (7.3750 mgO/ℓ). It was estimated that mean gross periphyton production was 4.8 times greater than mean gross phytoplankton production and, by similar calculation, that mean net periphyton production was 2.65 times mean net phytoplankton production.

Table 28. Differences (D) in initial and final dissolved oxygen readings in light and dark Plexiglas boxes and BOD bottles that were used to estimate gross and net production (mgO/ℓ) of periphyton and phytoplankton, 1980.

		Container and D-value			
		Plexiglas boxes (periphyton and phytoplankton)		BOD bottles (phytoplankton)	
Date		Light	Dark	Light	Dark
11 Jul.		-2.50[a]	- 7.60	0.30	-1.90
		1.30	- 5.30		
		4.50	- 7.10		
	Total	3.30	-20.00		
	Mean	1.10	- 6.67		
	Gross production	7.77		2.20	
5 Aug.		2.90	- 7.40	2.00	-0.05
		-0.05[b]	- 7.50		
		-2.05	- 7.45		
	Total	0.80	-22.35		
	Mean	0.27	- 7.45		
	Gross production	7.72		2.05	
21 Aug.		5.45	- 3.95	-0.15	-1.15
		7.20[c]	- 5.20		
		6.75	- 5.50		
	Total	19.40	-14.65		
	Mean	6.47	- 4.88		
	Gross production	11.35		1.00	
26 Aug.[d]		2.40	- 6.60	0.60	-0.30
	Gross production	9.00		0.90	

Table 28. Continued.

		Container and D-value			
		Plexiglas boxes (periphyton and phytoplankton)		BOD bottles (phytoplankton)	
Date		Light	Dark	Light	Dark
	Mean gross production		8.9600		1.5375
	Mean net production	2.5600		0.6875	

Mean gross periphyton production = 8.9600 - 1.5375 = 7.4225

$$\frac{7.4225}{1.5375} = 4.83$$

Mean net periphyton production = 2.5600 - 0.6875 = 1.8725

$$\frac{1.8725}{0.6875} = 2.72$$

---

[a] Tire piece had slid close to the bottom of its host tire.

[b] Tire piece was partially exposed at the water's surface.

[c] YSI needle "pegged" on upper end of the scale; value actually > 7.20.

[d] Unable to finish DO measurements due to generator breakdown.

CHAPTER IV

DISCUSSION AND SUMMARY

Benthic Macroinvertebrates and Fish

Densities of macroinvertebrates on Hester-Dendy samplers were apparently not significantly affected by the breakwater, with the possible exception of organisms on transect F2, where high densities on 20 July and 6 November 1979 were due to large numbers of psychomyiid larvae (223 and 85 larvae/sampler, respectively). These large numbers, in turn, were largely responsible for the significantly greater overall mean density on transect F2 than on transect 0. However, there were probably no consistent differences in macroinvertebrate densities between transects. Since macroinvertebrates were very abundant on experimental tire pieces (Table 27), it is possible that organisms would have been more numerous at the breakwater transects if the samplers had been closer to the tires. An examination of Hester-Dendy samplers that had been suspended from the breakwater in a vertical series would have been useful in identifying the size of the zone that was commonly occupied by macroinvertebrates around the breakwater tires.

Because Psc indices are especially responsive to dominant and semi-dominant taxonomic groups (Brock 1977), the abundance of chironomids and psychomyiids strongly influenced these values also. Percentages of chironomids and psychomyiids were almost identical at transects F1 and B1 (indicated by Psc values to be most similar; Table 3). The two transects found to be least similar according to Psc values (F1 and F2) differed the most in percentages of chironomids and psychomyiids. It is likely, however, that the differences in community similarity indicated by the indices are temporary.

The breakwater also did not significantly impact the diversity of that part of the macroinvertebrate community which colonizes Hester-Dendy samplers. Mean values of $\bar{d}$ averaged over the entire study at the breakwater (0) were not significantly different than behind the breakwater (B1 and B2), but were significantly higher than in front of the breakwater (F1 and F2). This ordering of the means suggests that mean diversity decreased (slowly at first and more rapidly in front of the breakwater) from inside the cove toward its mouth. Diversity typically decreases during the progression from the littoral to the profundal zone (Jónasson 1969; Wetzel 1975) and appears to have occurred in the study area regardless of the presence of the breakwater.

Loeb (1957), Witt andCampbell (1959), Latta and Myers (1961), and Bennett (1970) attributed increased efficiencies when night-shocking to onshore movement of fish after dark. However, it appeared that shocking across the cove rather than around its shoreline was responsible for the absence of predicted increases in catch per unit of effort.

Electrofishing catches suggested that fish were attracted to the breakwater. In March 1979 and August 1980, fish were caught only at the breakwater transects. Prince (1976) found that structure was occupied by fish before areas without structure in the spring and was not abandoned in the fall until after fish had abandoned areas without structure. Stress related to insufficient food supplies and high temperatures may have been reduced in some way during these months by food, shade, or cover present at the breakwater. Catch per unit of effort was significantly higher at either of the two breakwater transects than on any other transect. Catch per unit of effort was also significantly higher on transect B0 than on transect F0. Waves and currents caused by predominantly southwesterly winds were undoubtedly attenuated somewhat by the breakwater. This attenuation apparently resulted in the attraction of greater numbers of fish to transect B0.

While cover-seeking fishes such as centrarchids might be expected to inhabit areas of structure, the significantly higher catches of river carpsuckers, carp, and white bass at the breakwater are more difficult to explain. Carp probably were grazing on the tires, since they were occasionally seen grazing along the rip-rap of the dam and they had little other structure in the vicinity on which to feed. River carpsucker were caught predominantly from mid-May to mid-June, which, coupled with their reproductively "ripe" condition, indicated that the species was concentrated at the breakwater for spawning. There were no obvious reasons for the high incidence of white bass, a normally pelagic species, at the breakwater except that concentrations of prey (shad, sunfish, etc.) might have attracted them.

While length-weight regressions of gizzard shad at transect B0 were not significantly different from non-breakwater transects, the regression for shad at transect F0 had a significantly higher y-intercept, and a significantly lower slope than the corresponding values for transect B0. Since higher slopes may accompany better growth rates (Le Cren 1951), fish on transect B0 may have been in better condition than fish on transect F0. On the other hand, the DMR test showed that fish were significantly longer at both breakwater transects than at non-breakwater transects. Since condition normally improves with length, condition at both of the breakwater transects may have been higher compared to non-breakwater transects. The results of the DMR test may also be more reliable since they were derived from length measurements only. Lengths were typically easier to measure in the field and more accurate than weights, which were affected more by movements of the boat, wind, and changing personnel.

Because fishes dwelling in open waters are often highly mobile, and because gill nets are particularly selective for mobile fishes (Carlander 1953; Lagler 1978), catch per unit of effort in gill nets would be expected to decrease when moving from the most pelagic area (transect F2) to the most littoral area (transect B2). Accordingly, gill net catches on transect F2 were significantly higher, at the surface and on the bottom, than catches at either transect B0 or B2. Gill net catches on the bottom at transect B0 were intermediate although catches at transects B0 and B2 were statistically similar to one another. Surface catches on transect B0 were also statistically similar to those on B2, but catches were lowest on transect B0 rather than transect B2. These relatively low catches on transect B0 (surface and bottom) may have indirectly resulted from the presence of the breakwater. Perhaps those fishes occupying or encountering the breakwater were either less mobile by nature or became less mobile while near the breakwater, and thus were less vulnerable to gill nets set there.

Examination of species composition also suggests that fish at the breakwater were less mobile. Those species that were relatively more abundant on transects B2 and F2 at the surface generally were most abundant on transect B0 at the bottom (Figure 6). The only substantial exception to this trend was river carpsuckers, which were caught at the surface with gill nets and electrofishing gear only during May and June. The number of river carpsuckers taken at the surface on transect B0 was significantly higher than the number taken on transects F2 and B2. This concentration of carpsuckers at the breakwater was probably a result of spawning activity. For the other six most abundant species caught at the surface, numbers were significantly lower at transect B0 than at transect F2 or B2.

There were no significant differences in length-weight regressions between transects for white crappie, river carpsucker, or gizzard shad taken in gill nets. However, the regression for channel catfish on transect B2 had a significantly higher y-intercept and a significantly lower slope than for catfish from transect B0, which may indicate better growth and/or better condition for channel catfish nearer the breakwater. Mean length of white crappie from transect B2 was significantly greater than on transects F2 and B0. This occurrence was inevitable because the five largest crappies taken in gill nets (244, 249, 281, 365, and 416 mm) were captured on transect B2.

As with electrofishing results, data from hoop net catches supported the hypothesis of significantly higher densities of fishes at the breakwater. On a species basis, this pattern was most evident for white crappie and longear sunfish. Bluegill were equally abundant at the breakwater and behind it. This could have been the result of some additional cover near transects B1 and B2: a cattle fence and/or an increase in submerged vegetation during high water levels near these two transects. Gizzard shad appeared to be equally abundant at breakwater and non-breakwater transects but, since 181 of the 187 gizzard shad caught in hoop nets during the study were taken on one date, these results are inconclusive.

Length-weight equations for longear sunfish and bluegill caught at transect 0 were similar to those for fish captured on all other transects. However, significant differences between transects were found for gizzard shad and white crappie. The significantly higher y-intercept and lower slope for gizzard shad on transect B2 compared to transect 0 suggests that gizzard shad may have grown faster at the breakwater. Length-weight regressions for shad taken at transect 0 were similar to those for shad caught on the remaining transects (B1, F1, F2). The equation for white crappie captured on transect B1 had a significantly lower y-intercept and a higher slope than corresponding values for white crappie captured on transect 0. This finding suggests that conditions for growth may have been better for white crappie at transect B1.

Of the nine analyses of length-weight regression (electrofishing--one species, gill nets--four species, and hoop nets--four species) six had lowest y-intercepts and highest slopes on transects B0 (or 0). The higher slopes for fish living at the breakwater, although all were not statistically greater, suggests that fish may have grown better and been in better condition near the breakwater.

Sub-Projects

In spite of careful handling, all white crappie used in mortality/tag loss experiments died, including control crappies which were not weighed, measured, or tagged. Stress due to tagging and crowding were not the primary causes because untagged and relatively uncrowded crappies ($5/m^3$) also died. Stress due to handling was probably the primary cause of mortality, possibly compounded by high water temperatures and lowered oxygen levels.

Longear sunfish was the most suitable species for tagging. In addition to those tagged individuals recovered (Table 20), two (or perhaps three) other longear sunfish were recaptured but could not be identified. One longear, bearing what appeared to be a tag scar, was captured on two separate occasions at transects 0 (13 August) and B2 (26 August). The fish's lengths on those dates were 91 and 92 mm, respectively, and its weights were 17 and 14 g, respectively, so it may have been one fish or two fish with similar scars. The tag number was not recorded for another longear sunfish, recaptured on 24 July at transect F2. The three fish for which shorter total lengths were recorded at recapture than at release were apparently mismeasured; however, lesser weights for 7 of the 21 recaptured fish may have been real, since the tags could have caused temporary weight loss (Dequine and Hall 1949; Stott 1971).

The most important finding from the recapture of tagged fishes was the direction of movement between the time of release and the time of recapture. Five fish were recaptured twice. Two (#009 and 212) were first recaptured at the breakwater, although one of them (#009) was originally released on transect B2. The other three (#037, 187, and 247) were first recaptured on transect B1 after being released on various other transects. All five were recaptured for the second time at the breakwater. Overall, 40% of the fish were originally released at the breakwater and 71.4% were recaptured there. Fish released at the breakwater were generally recaptured at the breakwater, as were fish released at non-breakwater sites. The breakwater seems to be attractive to fishes and, moreover, it apparently encourages some fish species to remain in the vicinity.

Although densities of larval fish were similar at all transects, density for a given date was usually highest on transect B0 (3 dates) or B2 (3 dates). Turbulence and waves caused by predominantly southwesterly winds were undoubtedly diminished somewhat by the breakwater, which could have provided more favorable physical conditions for larval fish on these leeward transects. Another phenomenon apparently related to wind occurred on 20 June, when winds were from the north. On that date, abundance of larvae on transect B0 (6.97 fish/m^3) was higher, relative to other transects, than on any other date. If densities were higher behind the breakwater during normally southwesterly winds, then a temporary "pile-up" of larval fish may have occurred at transect B0 when winds shifted to a northerly direction.

Netsch et al. (1971) and Mayhew (1976) found that densities of larval fish in tributary arms of reservoirs were higher than densities in the main channel. It was evident, however, that this distributional pattern was modified in Lake Carl Blackwell (Table 21). Although the overall mean density of larval fish was highest on transect F2, that same transect consistently ranked low in terms of density (except on 30 May). The rank totals (F2 = 13, F0 = 21, B0 = 22, B2 = 24) suggest that larval fish were usually least abundant on transect F2, the most lakeward transect. Rank totals (and mean density values) indicate that populations of larval shad behind the breakwater (B2) were very similar to populations adjacent to it (F0 and B0). Since the densities in these two areas differed very little, the presence of the breakwater may have concentrated slightly more larval fish at the breakwater than would have been expected in that part of the cove considering the distributional patterns described by Netsch et al. (1971) and Mayhew (1976).

Mean total lengths of gizzard shad were regularly greatest on breakwater transects (B0 or F0) (Table 23). Except for the large number of post-larval fish caught at transect F2 on 25 June, mean lengths would have been greatest at the breakwater on every date. The breakwater may have provided favorable habitat for the larval fish in terms of cover and protection from predators, food availability, and/or lowered energy demands for maintaining themselves in the water column; however, due to their limited swimming ability, perhaps only the larger larval fish were able to actively maintain themselves in this area.

In three out of four studies on Canton and Thunderbird reservoirs in Oklahoma, Mense (1979) found that cladocerans were more abundant than copepods. However, in the present study, and in a study in Arbuckle and Ham's lakes, Oklahoma (McClintock and Wilhm 1977), copepods were more abundant than cladocerans. Although Pennack (1953) stated that some species of zooplankton were more abundant near the margins of lakes and rivers, little quantitative research has been done on nearshore/offshore distribution of these organisms except for

Hutchinson (1967), who reported consistently higher zooplankton densities in littoral (versus pelagic) areas in a Swedish lake. Lower densities of zooplankters on transect F2 in the present study suggest that a similar pattern existed in Lake Carl Blackwell. However, as was the case with larval fishes, densities of zooplankton adjacent to and behind the breakwater (transects 0 and B2, respectively) were not significantly different from one another. Perhaps the breakwater altered physical and/or biological conditions so that the nearshore zone with higher zooplankton densities was artificially extended toward the cove mouth. More nearshore/offshore studies of a species-specific nature would be beneficial in determining the impact of structures on zooplankton distribution.

The interaction between transects and locations (Figure 11) suggests that environmental factors were operating differently in each section of the study area. Densities at the eastern and middle locations both increased between transects F2 and 0 and decreased between transects 0 and B2. Changes in density at the middle, however, were less pronounced than those to the east, and densities at the west location reacted in the opposite manner. The most likely factors involved in these interactions were the predominantly southwesterly wind and the water currents it generated.

The design of breakwater modules, the differences in tread-wear of each tire, and decreasing light penetration with water depth all contribute to non-uniform colonization of individual tire surfaces. For example, tires on the edges of the breakwater modules had more surface area available for algal colonization than tires in the interior of the module. Tire pieces used in this study were one sixteenth of a standard 15-inch automobile tire (441 cm^2 surface area), and a conservative estimate is that there was at least this much surface area available for colonization on each individual tire. Based on 3600 tires in modules plus 198 tires interconnecting the modules and a mean ash-free weight of 2.0009 g per tire piece (Table 26), the breakwater provided substrate for plant growth equivalent to at least 7.6 kg ash-free weight.

Although net primary production of periphyton was roughly 2.72 times higher than that of phytoplankton, actual production of periphyton was probably greater for several reasons. Decreases in DO concentration in light boxes (as apparently occurred on 11 July and 5 August) are highly unlikely and probably were erroneous. Some dissolved oxygen was probably lost to dissolution when bubbles were formed on the inner lid surfaces of several light boxes, and production was usually at a peak during the second half of the photoperiod (Stay et al. 1967). In addition, Prince (1976) cited several authors who found peak periphyton production in May and June. Since my measurements were made in July and August, it is likely that I underestimated maximum seasonal production rates as well. Regardless of these errors and the limited scope of the experiment, periphytonous growth definitely increased primary production near the breakwater.

Summary

The breakwater appears to have had two basic impacts. The most dramatic was the alteration of the immediate surroundings so that organisms concentrated or or near the breakwater. Large numbers of fish congregated nearby; they apparently moved less and were in slightly better condition than fish elsewhere. River carpsuckers, in particular, spawned nearby, and the presence of longer gizzard shad larvae at the breakwater suggested that stronger-swimming larvae sought to maintain their position in this area.

Potentially, however, the most significant impact of the breakwater may have been an increase in primary production, although our examination of periphytonous growth was only cursory. Primary production, as the base of most food webs, is usually a major factor determining the form and stability of biological systems. If macrophytes and periphyton are the two major primary producers in lacustrine food webs (Lindeman 1942), then the establishment of additional periphytonous growth in lakes with poor macrophytic growth (such as Lake Carl Blackwell) could substantially affect primary production. Kowalski and Ross (1975) suggested that plant production on floating breakwaters would be greater than on submerged structures in turbid waters because the breakwaters exist within or very near the photic zone. As cited earlier (Cowell and Hudson 1968), plant growth can increase invertebrate production, and invertebrate production has been positively correlated to fish growth (Pardue 1973). More intensive work in this area is needed to determine if floating tire breakwaters do indeed directly increase fish production, as opposed to the more traditional view that structures function strictly to attract fish.

The second basic impact of the breakwater was more subtle, and appeared to influence the inshore/offshore distribution of various organisms. In several instances, populations of organisms at the breakwater (transects F0, B0, or 0) were not significantly different from those on transects behind the breakwater (B1 or B2), but were significantly different from populations on transects in front of the breakwater (F1 or F2). Examples include diversity of macroinvertebrates on Hester-Dendy samplers, densities of zooplankton, and the number of fish caught per gill net. In cases such as these, the possible benefits of the breakwater appeared to be directly related to its ability to diminish waves produced by prevailing southwesterly winds and, in essence, to extend the protected nature inherent to inshore reaches of a cove out toward the breakwater itself.

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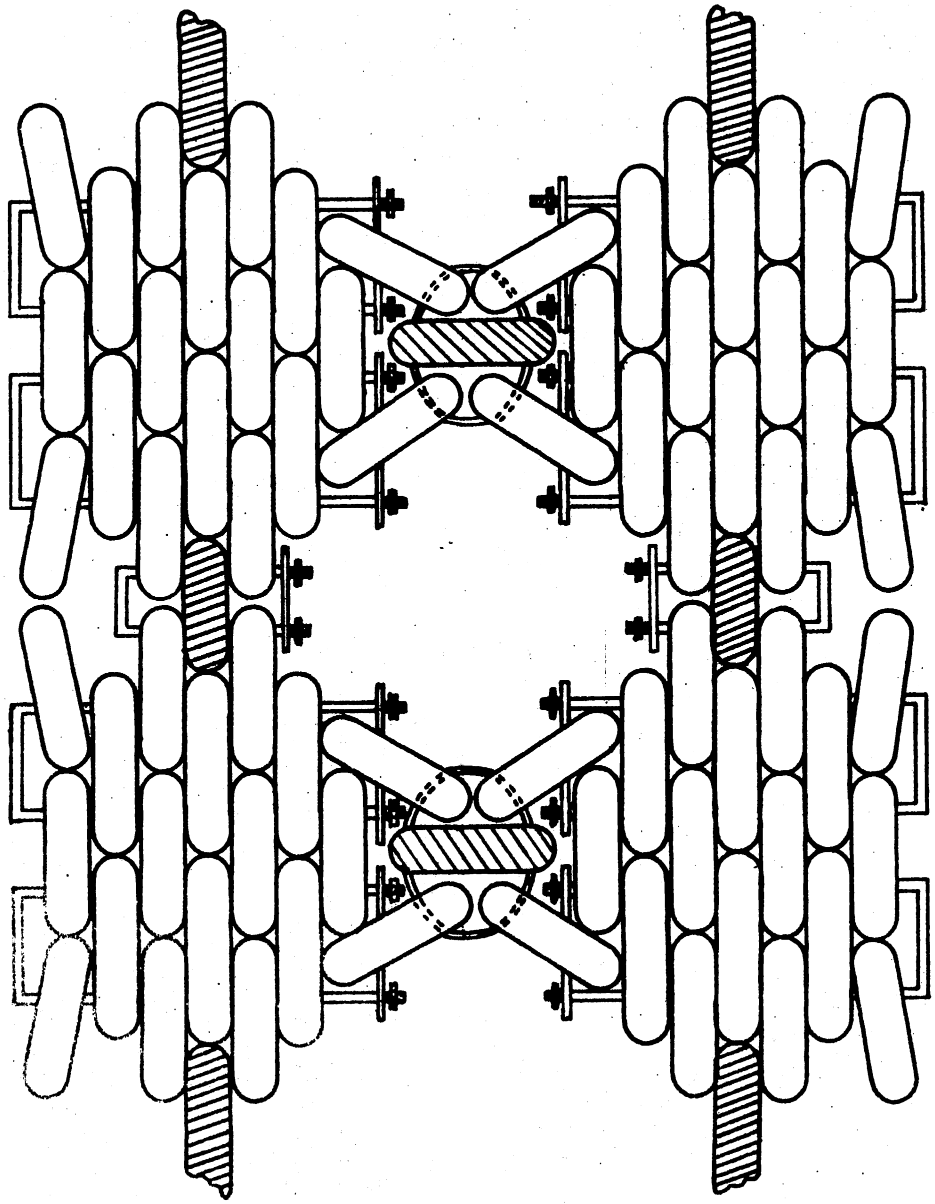
APPENDIXES

APPENDIX A

DETAILS OF CONSTRUCTION OF THE DOUBLE-ROW FLOATING TIRE BREAKWATER

Individual modules were constructed using 18 tires and 2 U-bolts, each U-bolt measuring 1.9 m (when straightened) as in Figure 12. The modules were then connected end-to-end using a small U-bolt, 57.2 cm in length, to pass through the two end-most tires and an additional connector tire. All U-bolts were secured with metal strips 38.1 cm long and 38.1 mm wide. The two breakwater rows were connected by folding out two side tires on facing modules, placing a fifth tire between them and passing a 10 cm wide strip of rubber belting between the tires (Figure 12). The breakwater was in two sections extending approximately 350 m from each shore and overlapping in the center of the cove to allow the passage of boats. Concrete anchors weighing approximately 40 kg were connected to the breakwater with unwelded chain (6.7 x 2.0 cm links, 1.3 cm in diameter) and 6.3 mm diameter steel cable. Cables were 15.2 and 22.9 m long on the north and south sides of the breakwater, respectively.

Figure 12. Arrangement of a four-module section of the floating breakwater.



APPENDIX B

LAKE CARL BLACKWELL WATER LEVELS

The following monthly water levels for Lake Carl Blackwell were selected from observation recorded at the Hydrology Laboratory of Oklahoma State University. Spillway level is 287.78 m above mean sea level.

Date	Level	Date	Level
1978		1979	
2 Aug.	285.20	4 Sep.	285.62
1 Sep.	285.10	10 Oct.	285.21
2 Oct.	284.74	8 Nov.	285.23
6 Nov.	284.55	28 Dec.	284.96
10 Dec.	284.56	1980	
1979		10 Jan.	284.93
8 Jan.	284.41[a]	29 Feb.	284.87
28 Feb.	284.47	12 Mar.	284.84
2 Mar.	284.46	3 Apr.	284.92
2 Apr.	284.66	1 May	285.61
1 May	284.62	20 Jun.	288.09[b]
7 Jun.	285.27	3 Jul.	287.85
3 Jul.	285.48	12 Aug.	287.20
10 Aug.	285.53		

[a] Lowest level recorded during the study.

[b] Highest level recorded during the study.

APPENDIX C

COMMON AND SCIENTIFIC NAMES OF FISHES ENCOUNTERED

The following common and scientific names describe the fishes that were encountered during the study.[1]

Black bullhead	*Ictalurus melas* (Rafinesque)
Blue catfish	*Ictalurus furcatus* (LeSueur)
Bluegill	*Lepomis macrochirus* (Rafinesque)
Bullhead minnow	*Pimephales vigilax* (Baird and Girard)
Carp	*Cyprinus carpio* Linnaeus
Channel catfish	*Ictalurus punctatus* (Rafinesque)
Freshwater drum	*Aplodinotus grunniens* Rafinesque
Flathead catfish	*Pylodictis olivaris* (Rafinesque)
Gizzard shad	*Dorosoma cepedianum* (LeSueur)
Green sunfish	*Lepomis cyanellus* Rafinesque
Largemouth bass	*Micropterus salmoides* (Lacépède)
Logperch	*Percina caprodes* (Rafinesque)
Longear sunfish	*Lepomis megalotis* (Rafinesque)
Mississippi silversides	*Menidia audens* (Hay)
Orange-spotted sunfish	*Lepomis humilis* (Girard)
Red Shiner	*Notropis lutrensis* (Baird and Girard)
River carpsucker	*Carpiodes carpio* (Rafinesque)
White bass	*Morone chrysops* (Rafinesque)
White crappie	*Pomoxis annularis* Rafinesque

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[1] Bailey, R. M., J. E. Fitch, E. S. Herald, E. A. Lachner, C. C. Lindsey, C. R. Robins, and W. B. Scott. 1970. A list of common and scientific names of fishes from the United States and Canada, 3rd edition. American Fisheries Society Special Publication Number 6, Washington, D. C., USA.

VITA 2

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Candidate for the Degree of

Master of Science

Thesis: DISTRIBUTION OF FISH AND OTHER ORGANISMS ASSOCIATED WITH AN ARTIFICIAL FLOATING TIRE BREAKWATER IN LAKE CARL BLACKWELL, OKLAHOMA

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