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FINAL REPORT

RESEARCH AND SURVEYS

FEDERAL AID PROJECT NO. F-36-R

EVALUATION OF FACTORS INFLUENCING YIELDS OF *MICROPTERUS* BASSES IN RESERVOIRS

JOB NO. 1

EVALUATION OF ARTIFICIAL BARRIERS FOR ENHANCING PRODUCTION OF FINGERLING LARGEMOUTH BASS IN LARGE RESERVOIRS

JULY, 1975 THROUGH SEPTEMBER, 1980

FINAL REPORT

State: Oklahoma Project Number: F-36-R

Project Title: Evaluation of factors influencing yields of *Micropterus* basses in large reservoirs

Study Title: Evaluation of artificial barriers for enhancing production of fingerling largemouth bass in large reservoirs

Period Covered: 1 July 1975 through 30 September 1980

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ABSTRACT

Based on costs of \$9.91 - \$57.69/m to build various types of breakwaters and results from preliminary experiments in 1976, single and double-row floating tire breakwaters were placed across coves of Lake Carl Blackwell. Other coves served as controls. During four subsequent years, we studied the general effects of the breakwaters on physical-chemical conditions and on the abundance and distribution of fish and other organisms in the entire portions of the coves behind the breakwaters. No pronounced effects of the breakwaters, other than a 60% or more reduction in wave height, were evident. At most, the breakwaters appeared to slightly enhance differences in transparency, turbidity, and sedimentation rate that existed naturally between lakeward and shoreward areas of coves. Attenuation of waves and slight improvements in water quality were apparently not sufficient to increase populations of young largemouth bass or diversity of fish and benthic communities in the coves as a whole. However, additional studies in 1979 and 1980 showed that the distribution of fish and other organisms was often altered in the immediate area of the breakwater. Significantly more fish of most species were caught with electrofishing and hoop nets at the breakwater than on transects 30 or 60 m away. The relatively lower catches at the

breakwater in gill nets were attributed to decreased mobility of fishes near the structure. River carpsuckers apparently spawned on or near the breakwater, and larval gizzard shad were significantly longer at the breakwater than they were 60 m to either side of it. Seventy-one percent of the recaptures of tagged fish were made at the breakwater while only 40% of the tagged fish were released there. We estimated that production of green algae on the breakwater was 39.25 to 57.50 g of ash-free weight per square meter of tire surface (95% C.I.). Mean net production of periphyton was estimated to be 2.65 times that of mean net production of phytoplankton. Possible benefits of the breakwater were attraction of fish, an increase in primary production, and the formation of a protected wave shadow used by greater numbers of larval fish and zooplankton.

I. Objective:

To determine the cost and benefits in fingerling largemouth bass production from installing various types of artificial structures (barrier reefs) to provide quiet-water spawning areas in a large open water reservoir.

II. Background:

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

Another original aspect of the present study is that an attempt was made to go beyond the documentation of fish distributional patterns. The only author who examined the dynamics of entire ecological systems operating in and around artificial structures was Prince (1976). Although his work had a broader scope and was more detailed, we made a similar effort in this study to identify specific reasons for concentrations of fish near the floating breakwater.

The potential for floating tire breakwaters in reservoir fishery management programs should not be overlooked. Water is becoming an increasingly valuable resource for power companies, farmers, municipalities, and others, as well as for recreational anglers. Any new techniques capable of reducing conflicts over water use, and increasing fish production and angler success in reservoirs 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. The use of floating tire breakwaters to concentrate fishes, and potentially to increase their production in reservoirs, may become an important management tool of this nature.

Habitat Improvement in Lakes

Fisheries in man-made reservoirs often suffer from a lack of naturally submerged 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.

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, especially sport fishes. The structures used in habitat improvement may also be used for spawning and as visual reference points for some fishes.

The addition of structure to a water body can be advantageous for several reasons, the primary one being the tendency of these structures to concentrate fish quickly 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 artificial structures in Michigan lakes concentrated large numbers of fish.

Another advantage of the use of structure for lake habitat improvement is the low cost of building materials and construction. Prince and Brouha (1974) found that special interest groups (e.g., anglers, SCUBA divers) and service organizations (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 obtainable as damaged goods or refuse items. Blasting rock, while sometimes difficult to handle, can usually be obtained at little or no cost. He also recommended damaged chimney tile and ceramic piping as excellent materials for lake habitat improvement. 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 and Wilbur 1974), and log cribs, Christmas trees, and felled shoreline trees (Prince et al. 1977).

A prominent issue today centers around the ability of these types of structure to actually increase fish production. Some believe that the increase in numbers of fish near structures is only a function of fish 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, was grazed on directly by gizzard shad (Dorosoma cepedianum) and sunfish (Lepomis spp.). Kitchell and Windell (1970) found bluegill (L. macrochirus) that were fed algae in addition to a maintenance level of animal food showed a slightly greater percentage increase in weight than similar fish on a maintenance diet of animal food alone. Also, changes in the invertebrate community may indirectly affect fish populations because of their importance 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), studying bluegill production, reported linear increases in bluegill production with the addition of attachment surfaces used by fish-food organisms.

In addition, Prince (1976) observed that while bluegill and largemouth bass (Micropterus salmoides) spawned in the immediate vicinity of the reefs,

white catfish (Ictalurus catus) actually spawned between the sidewalls of some reef tires. The catfish eggs were, in turn intensively used as food by some sunfish. All of these findings, in addition to the abundance of young-of-the-year fishes in Prince's study, support Prince's opinion that production is actually increased through the use of structures. However, the number of submerged structures required to significantly increase overall 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 observe fishes within sight of these lines. Later, structures consisting of tires, chimney tile, tile pipes, and cement blocks were placed along one line. SCUBA observations were made periodically for the next two years. Pre-installation figures 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 angler exploitation on fish populations near artifical 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) offered some support of 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. A similar discovery was independently made by Wege and Anderson (1979), who 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 has been shown to 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. Although primarily interested in marine species, Ogren (1974) also noted the apparent preference of prey fishes for mid-water structures (as opposed to non-structure areas).

The last structure to be discussed 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). The mat that was developed consisted of subunits, or modules, made of 18 interconnecting tires (Figure 1). It 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 a primary function of these mats was to act as a floating breakwater, 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).

The majority of work with these shore protection mats appears to have been conducted on the Rhode Island coast (Minter 1974) and in Lake Erie (DeYoung 1977a), although other projects in the northeast and Mid-west are

underway (Candle and Fischer 1977). Wave height reduction in order to protect harbor marinas, yacht clubs, and so forth, was the main objective of the aforementioned breakwaters. 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, a breakwater was constructed in 1975. The harbor became well-known for its protected nature, as was evidenced by an increase in the amount of boat fuel sold and more requests for "wintering over" slips in the harbor 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. Not surprisingly, the City of Dunkirk decided to almost double the length of the breakwater in 1976.

The two aspects of Goodyear-type breakwaters that are of most interest to those studying fisheries in reservoirs located on the plains of middle America are their abilities to concentrate fish and to attenuate 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). This quality is important in an area such as Oklahoma where particularly strong winds during the spawning season can cause serious damage to fish nests in reservoirs that are ill-protected from the wind (Tarzwell 1936; Kramer and Smith 1962; Allen and Romero 1975; and Clady 1976) and played a major role in the decision to use this type of breakwater 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) largemouth bass/ha were collected in areas of the lake designated as wind-swept, intermediate, and protected, respectively (Summerfelt and Shirley 1975). As a result, wind exposure was assumed to be a primary factor in YOY distribution. In that year, three types of floating structures were placed in coves in the reservoir by the Oklahoma Cooperative Fishery Research Unit (OCFRU) to determine their effect on production of fingerling largemouth bass (Summerfelt 1976). The structures included single and double unit pole booms, a fabric curtain, and single and double row floating tire breakwaters of the Goodyear type. All were anchored using concrete weights of approximately 40 kg connected to the breakwaters with 6.3 mm steel cable and unwelded chain. The following environmental parameters were measured: 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 by shoreline rotenone in the coves on two different dates. Some results of the study were:

1. Surface current velocity varied in direct proportion to wind velocity ($r = 0.81$).
2. Variation in water quality was largely due to individual site locations.
3. Breakwater structures attenuated surface currents; the largest reduction (57.1%) was by the single pole boom.
4. The largest percentage reduction in wave height (54.4%) occurred behind the double row breakwater.
5. Breakwater coves, as opposed to coves without structures, had water with greater transparencies and lower sedimentation rates.

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

In 1976, the OCFRU placed single row floating tire breakwaters in two coves in order to continue the evaluation (Clady 1977). The same environmental parameters were measured, with the exception of water current speeds. YOY bass density and species diversity of fishes was measured by shoreline rotenone 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 effects of 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 betweeen windward and leeward areas. Clady (1977) suggested that differences in weather conditions balanced out any effects when values were averaged.
2. Species diversity was measured before completion of the breakwaters and was lowest in experimental coves.
3. Abundance of age I+ largemouth bass was also measured before completion of construction with the same results.
4. Abundance of YOY largemouth bass was also measured before completion of construction. Highest total biomass was found in control coves, but numbers of YOY were generally the same in control and experimental coves.

Evaluation of the two breakwaters on a more intensive basis was continued by the OCFRU (Clady 1978). The same physical-chemical measurements were made with the exception of water depth. 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 characteristics of the water, other than wave height reduction, were evident. The data suggested that, 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; attached to this report).
2. Attenuation of waves and slight improvements in water quality were apparently not sufficient to increase populations of young largemouth bass or diversity of fish and benthic communities in modified coves (Clady et al. 1979, 1980).

Clady (1978) cited three reasons for the apparent lack of breakwater effect: a) the wave height reduction was not biologically significant, b) high turbidity secondarily limited year class strength, 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 the effects previously demonstrated.

The doubled breakwater was completed, and data collections were carried out through the fall of 1979. The results of this phase of research were strikingly similar to those of the year before (Lanford and Clady 1979). In

spite of the breakwater's added width and its continued attenuation of over 65% of wave heights, the improvements 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. Studies involving the submerged and mid-water structures cited earlier encouraged us to examine the floating breakwater from this point of view. In the fall of 1978, we began a pilot project designed to determine the desirable areas of emphasis.

Pilot Study

Sampling for the pilot study was carried out in October and November of 1978 and included electrofishing, gill netting, and sampling invertebrates with modified Hester-Dendy samplers. Since the invertebrate samplers were to be colonized for six weeks between collections, 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 M.S.).

Electrofishing

Electrofishing, carried out on five dates, involved the use of alternating current emitted from a 220-volt generator. 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. Data from the pilot study (Table 1) indicated a concentration of fishes near the breakwater as well as greater diversity of species. 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).

Gill Nets

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. We were unable to use the same type of net 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 were placed between the cables, each panel containing a different mesh size corresponding to the mesh sizes found in the longer nets set at F2 and B2. Because of the differences in water depth at each of the three transects, difficulty in handling the vertical panels (especially in strong winds), lack of a satisfactory method of sampling the F2 transect completely but without overlap, and extremely low catch rates using the vertical panels, the design was eventually 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 examined with caution. Numbers of fish captured at transects B2 and F2 were almost identical (156 and 162, respectively), but

the number captured at transect BO (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 in the water should have caught approximately one-half the fish captured in a horizontal net, with about 109 m^2 of net in the water. Two possible reasons for these unexpected results are:

1. Fishes could more easily avoid the narrower vertical nets fished at the breakwater.
2. Movements of fishes at the breakwater were more restricted than of fishes in areas without structure (Prince 1976). This could have lowered vulnerability to gill nets.

It was apparent that the presence of the breakwater was a primary factor influencing the interesting distribution patterns of the fishes. Not only did there appear to be more fish and more kinds of fish near the breakwater, but it was also possible that fish near the breakwater were more quiescent. Further study seemed justified, and objectives for a full-scale project to begin in the spring of 1979 were formulated. Construction details for the double-row breakwater used in the study appear in Appendix A.

Objectives

The intent of this research was to examine the potential of floating tire breakwaters as fishery management tools in turbid reservoirs by:

1. Documenting, by number and family, the distributional patterns of macroinvertebrates in the breakwater area using multiple-plate samplers.
2. Documenting, by number and species, the distributional patterns of fishes in the breakwater area using various gear types.

3. Examining possible causes for variation in distributional patterns should these variations become apparent.

4. Evaluating the potential for use of these structures in reservoir fishery management programs.

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 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 turibidity of up to 180 Jackson units (Norton 1968) is the result of many factors including 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 test cove was oriented primarily in a north-south direction, exposing it particularly to the strong southwesterly winds common to the Great Plains area. There was little structural development along the shoreline since the area 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 were observed growing on the most coveward 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 have 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.

DISTRIBUTION OF FISH AND MACROINVERTEBRATES

III. Procedures

In order to meet the first two objectives of this study (i.e., to document the distribution of macroinvertebrates and fish in the cove), four types of equipment were used--multiple-plate invertebrate samplers, an electrofishing unit, gill nets, and hoop (or barrel) nets. The specifications for and use of these pieces of equipment are described below. Procedures for all sampling involved the use of transects established parallel to and at various distances from the breakwater. These transects are described in the "Pilot Study" section of Chapter 1, and are depicted in Figure 3. Unless otherwise noted, the level of significance for all statistical tests was 0.05.

Methods and Materials

Invertebrate Samplers

The samplers were a variation of the multiple-plate sampler described by Hester and Dendy (1962). These samplers are especially well-suited for

areas such as 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 constructed using 14 plates of tempered hardboard (Masonite) 3.175 mm thick and 76.200 mm square, and 17 hardboard plates 3.175 mm thick and 25.400 mm square. A 12.7 mm hole was drilled into each of these squares. A washer and a large plate were placed on a 9.525 x 203.200 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 6.350 mm spaces between some of the large plates in addition to the 3.175 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 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, similarity indices, and species diversity 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 (P_{sc}) was calculated according to Brock (1977) as follows:

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

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

k = total number of species.

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 at the appropriate depth (2 m) in one of the interstices between the two rows of modules, on the transect labeled 0 due to its centrality. Samplers were removed seven times from the spring of 1979 to the spring of 1980.

Electrofishing

The electrofishing unit consisted of a 220-volt generator operating 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, we randomly chose the order in which transects F2, F1, B1, and B2 ould be sampled on each date. 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 along with the species and total length of each fish captured. Weights of each fish were usually recorded when wind speeds were lower. When large numbers of a certain species were captured, a random sample was usually taken by weighing every fourth or fifth fish. Three electrofishing samples were taken at night early in the study in order to catch those fish presumed to move into shallower areas after dark. We did not find the predicted increases in catch per unit of effort and therefore discontinued night-shocking.

Gill Nets

Experimental gill nets were used to determine the vertical and horizontal distribution of fishes in the cove. Nets were placed at transects F2, B0, and B2. Three nets were placed on each transect for approximately 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 of 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 bulldog clips. A coin was tossed to deter-

mine 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 top-set and bottom-set nets, all mid-water areas were not sampled. The sacrifice of sampling these areas was made for the following reasons:

1. Surface-to-bottom vertical panels were used at transect B0 in the pilot study with extremely low catches 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 more pelagic and will not be found in large numbers in nearshore areas.

Species, length, and weight was recorded as in electrofishing samples.

Hoop Nets

The hoop nets were 1.5 m long and 1.0 m in diameter. Five hoops were incorporated into the 17.5 mm mesh, and the nets were held open with wooden or metal spreader bars. Inverted funnels were woven into each end and there were no leads. 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 information

on species, weight, and length were taken as when electrofishing or gill netting.

IV. Findings

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 4), the populations for each site were similar through time with highest densities at all sites in July 1979, and lowest densities in January 1980. Two exceptions 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 a significant difference (F = 80.90 with 4 and 29 d.f.) in mean densities of invertebrates between transects. 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.

The most abundant organisms at all sites were chironomids and psychomyiids (Table 3) which, together, made up 98.1-99.5% of the total number of organisms at any one site. The percentage, for a given family, of the total number of organisms at each site (Table 3) was used to determine the percentage of community similarity (P_{sc}) between each two sites (Table 4). Communities at sites F1 and F2 appeared to be the least structurally similar (P_{sc} = 67.56) whereas communities at sites B1 and F1 were most similar (P_{sc} = 93.69).

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 statistically significant difference ($F = 44.0$ with 4 and 29 d.f.) in mean $\bar{d}$ between transects. When compared with the other sites individually, the mean $\bar{d}$ at site 0 was significantly higher than either F1 or F2 ($t = 2.01$ and 3.53, respectively, with 29 d.f.). There were no statistically significant differences getween the mean $\bar{d}$ of site 0 and 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 on each transect was calculated (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 the fourth electrofishing effort was made in early April 1979. A similar pattern developed in August 1980 when few or no fish were caught on transects other than B0 and F0. The highest catch per unit of effort for any date occurred 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 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 all of the non-breakwater transects.

Loeb (1957), Witt and Campbell (1959), Latta and Myers (1961), and Bennett (1970) attributed increased efficiencies when night-shocking to onshore

fish movement after dark. However, it appeared that our practice of electro-shocking across the cove rather than around its shoreline was a critical factor since we did not find the predicted increases in catch per unit of effort.

The numbers of fish of a certain species that were captured per hour of electrofishing were established for each transect and then converted into percentages so that relative abundance reflected the species' distribution (Table 8). The unidentified fish were the result of a common occurrence: stunned fish would recover and disappear 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.) The percentages of various species in Table 8 are graphically presented in Figure 5. Gizzard shad, making 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 collected 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 at one breakwater transect was always significantly higher than at

the other breakwater transect. 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 the means on transects B2 and F1 (F1 not significantly higher), and the mean number of river carpsuckers on transect B0 were lower than the means calculated on transects B2, F1 and F2 (although not significantly lower). The highest mean catch for all nine species was made on a breakwater transect and most commonly was 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 that the condition of fish could be compared between transects. A regression equation was calculated for each transect using the common logarithms of total length and estimated weight. The y-intercept and slope of transect B0 were not significantly different than the y-intercepts and slopes of equations computed 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 lenghts of shad were significantly different between transects ($F = 9.74$ with 249 d.f.). The DMR test revealed that 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: <u>F0 B0</u> <u>F1 B2</u> <u>F2 B1</u> (M.S. = 853.367 with 249 d.f.). Transects that are connected by one line had mean values that 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. The mean number of fish taken on transect F2 was significantly higher than means 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 lowest mean catches were made 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 was lowest at B2 transect.

As with electrofishing data, the distributional patterns of the various species were determined from the numbers of fish collected per net and the percentage of that species collected on each transect for surface and bottom catches (Table 12). The four most abundant species in both cases were white crappie, channel catfish, river carpsucker, and gizzard shad. Largemouth bass, bluegill, and blue catfish were particularly rare ($n = 3$, $n = 2$, $n = 1$, respectively). A graph of the relative percentage of each species caught on each transect at the surface and on the bottom (Figure 6) suggested a pattern 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, a higher percentage of four of the six species was taken 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 we 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. For all species except river carpsucker, mean catches at transect B0 were significantly lower than the catches at transect F2 or B2. Also, as expected from Table 10, 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, 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 fairly consistent pattern among catches near the bottom was that the mean number 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 than on transect B2 or F2.

Condition factors of white crappie, channel catfish, river carpsucker, and gizzard shad taken by surface nets, which were analyzed as described previously, varied significantly only for channel catfish (Table 14). For the catfish, the y-intercept of transect B2 was significantly higher, and the slope was significantly lower, than the corresponding values for transect B0. Intercept values were the lowest at B0 for all species except river carpsucker, and slope values were highest on B0 with the same exception.

When mean lengths of the same four species were tested with analysis of variance, there were no significant differences 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 (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

The highest catches of fish in 110 hoop net sets on 22 dates from August 1979 through August 1980 (Table 15) occurred during May, June, and July 1980, and lowest catches were made in the fall of 1979 and spring of 1980. Analysis of variance demonstrated that fish were unevenly distributed over the five transects (F = 314.18 with 4 and 105 d.f.). Individual t-tests showed that 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, bluegill, and gizzard shad--made up almost 97% of all 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 7). 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 7, the mean number of crappie and longear sunfish at the breakwater was significantly higher than on any other transect. For bluegill, however, the breakwater catch was not significantly different from either of the catches at the two back transects (B1 and B2), although it was 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.

Regression analysis for the above four species (Table 18) revealed significant differences in the y-intercepts and slopes of white crappie and gizzard shad taken at transect 0 compared to the corresponding values for fish taken on other transects. White crappie captured at transect B1 had a significantly lower y-intercept and a significantly higher slope than white crappie captured at transect 0. Gizzard shad taken at transect B2 had a significantly higher y-intercept and significantly lower slope than shad captured at transect 0. The lowest 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). The results for bluegill and gizzard shad were essentially the same; analysis of variance showed that mean lengths did not differ between transects ($t = 1.66$ with 201 d.f., and $t = 1.83$ with 71 d.f., respectively), but 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.

V. Analysis

Invertebrates

In a comparison of multiple-plate samplers and basket-type samplers filled with limestone or porcelain spheres, Mason et al. (1973) found that basket samplers collected a greater abundance and diversity of organisms than the multiple-plate samplers. The difference, however, was attributed to the larger surface area of the basket samplers and could be corrected by increasing the surface area of the multiple-plate samplers.

Densities of macroinvertebrates on Hester-Dendy samplers were not significantly affected by the breakwater, with the possible exception of organisms on transect F2. High densities on transect F2 on 20 July and 6 November 1979 were due to large numbers of psychomyiid larvae (223 and 85 larvae/sampler, respectively). Data from these two dates, 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.

Because P_{sc} indices are especially responsive to dominant and semi-dominant taxonomic groups (Brock 1977), the high numbers of chironomids and psychomyiids strongly influenced these values also. Transects F1 and B1 (indicated by P_{sc} values to be most similar) had percentages of chironomids and psychomyiids that were almost identical (Table 3). The two transects found to be least similar according to P_{sc} values (F1 and F2) differed the most in percentages of chironomids and psychomyiids. It is likely 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 significantly higher than mean values in front of the breakwater (F1 and F2). While this ordering of the means probably represents real differences in diversity between the transects, it also suggests that mean diversity decreased (slowly at first and more rapidly in front of the breakwater) from inside the cove toward its mouth. A decrease in diversity during the progression from the littoral to the profundal zone is commonly observed (Jónasson 1969; Wetzel 1975) and appears to have occurred in the study area regardless of the presence of the breakwater.

Electrofishing

Electrofishing catches suggested that fish were attracted to the breakwater. In March 1979, fish were first caught only at the breakwater transects. Again during mid-August of 1980, the only fish captured were at breakwater transects. Stress related to factors such as high temperatures and insufficient food and oxygen supplies may have been reduced in some way during these months by the 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. The predominantly southwesterly winds and the attenuation of waves and currents by the breakwater itself were undoubtedly instrumental in attracting fish to transect B0.

While cover-seeking fishes such as minnows and centrarchids might be expected to inhabit areas of structure, the significantly higher catches of

river carpsuckers, carp, and white bass at the breakwater are less easily accounted for. Carp probably were grazing on the tires, since they were occasionally seen grazing along the rip-rap of the dam and there was very little other structure in the vicinity on which to feed. River carpsucker were caught predominantly from mid-May to mid-June, which, coupled with the reproductively "ripe" condition in which we generally observed these fish, indicated that the species was concentrated at the breakwater for spawning. There were no apparent 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 BO were not significantly different from non-breakwater transects, the regression for shad at transect FO had a significantly higher y-intercept, and a significantly lower slope than the corresponding values for transect BO. Since higher slopes may accompany better growth rates (Le Cren 1951), fish on transect BO may have been in better condition than fish on transect FO. 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 include length measurements only. Lengths were typically easier to measure in the field and more accurate than weights which are affected more by movements of the boat, wind, and changing personnel.

Gill Nets

Because fishes dwelling in open waters are often highly mobile, and because gill nets are particularly selective for mobile fishes (Lagler 1971; Hamley 1975), 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 and B2. Gill net catches on the bottom at transect B0 were intermediate in value 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 the lowest catches per unit of effort occurred 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 during their time spent at the breakwater, and thus were less vulnerable to gill nets set there.

Examination of the species involved 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 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 transect 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 and B2.

There were no significant differences in length-weight regressions between transects for white crappie, river carpsucker, or gizzard shad. However, the regression for channel catfish collected on transect B2 had a significantly higher y-intercept and a significantly lower slope than for catfish from transect B0, which may indicate faster growth and/or better condition for channel catfish nearer the breakwater.

Of total lengths of the four species mentioned above, only those of white crappie differed significantly between transects. Mean length of white crappie from transect B2 was significantly greater than on transects F2 and B0. However, this was because the five largest crappies taken in gill nets (244, 249, 281, 365, and 416 mm) were captured on transect B2.

Hoop Nets

Significantly more fish were caught in hoop nets at the breakwater (transect 0) than at any other transect. This pattern was most evident for white crappie and longear sunfish. Bluegill were not more abundant at the breakwater than behind it. This could have been the result of some additional cover near transects B1 and B2 in the form of a cattle fence that extended across the transects in a southeast-northwest direction and/or an increase in cover 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. This was not true for either gizzard shad or white crappie, however. The

significantly higher y-intercept and lower slope for gizzard shad on transect B2 compared to transect 0 suggests that shad grew 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 higher y-intercept and a lower slope than corresponding values for white crappie captured on transect 0. This suggests that conditions for growth were better for white crappie at transect B1.

Of the nine analyses of regression equations (electrofishing--one species, gill nets--four species, and hoop nets--four species) six showed lowest y-intercepts and highest slopes on transects B0 (or 0). Since LeCren (1951) discovered that, for a given group of fishes, slopes did not appear to change throughout the seasons, slopes are particularly useful in a study such as this in which data were not analyzed seasonally. The higher slopes for fish living at the breakwater, although all were not statistically greater, suggests that fish grew faster and were in better condition near the breakwater.

POSSIBLE CAUSES FOR DISTRIBUTION OF FISHES

III. Procedures

Results from the first year's work indicated an attraction of fish to the breakwater area. Our data, and the findings of other researchers, led us to believe that the distributional patterns we had documented 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 acceptable to some fish species as a spawning site (Prince and Maughan 1979).
3. Fish were drawn to the breakwater by concentrations of fishfood organisms (Pardue and Nielsen 1979).

While we continued our fish distribution work on an abbreviated schedule, our second year (1980) also included several smaller projects designed to achieve the third objective: to examine possible causes for variation in distributional patterns should these variations become apparent. These projects included a fish tagging experiment, distributional analyses of larval fishes and zooplankton, and an examination of periphyton productivity ocurring on the breakwater. These preliminary projects were carried out to help us better understand the general ecological dynamics of the breakwater area in terms of fish attraction. Unless otherwise noted, the level of significance for all statistical tests was 0.05.

Materials and Methods

Fish Tagging Experiment

Consecutively numbered fingerling tags (Floy Manufacturing Company, Seattle, WA) were mainly applied to white crappie and two species of sunfish. 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 vinyl thread which offered a good margin of elasticity.

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 8. Three tag experiments to test for mortality and tag loss 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 (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. 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 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 indicate when our 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 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 25 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 1973). 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 starting direction on each transect. 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 future identification according to May and Gasaway (164) 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 being used in the field:

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

where V = volume filtered, m^3

N = net diameter, m (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, date, and time of day were also noted. The experiment was designed with non-parametric trend analysis in mind and did not, therefore, include sample replication.

Zooplankton

Zooplankton collections began on 7 March 1980 and continued, approximately bi-weekly, 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 utilized, each transect being divided into western, middle, and eastern sections, resulting in a total of nine collection sites. The

Kemmerer bottle was filled 15 times (48.71 ℓ) at the surface of each collection site, and the water from each bottle 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, date 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 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, ℓ (48.75 ℓ*).

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

Periphyton Productivity

Measures of primary productivity occurring on breakwater tires were made in two ways: ash-free weights of periphyton samples, and dissolved oxygen measurements using a modification of the light and dark bottle experiment.

Sixty tire pieces, 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. The subsequent removal of these tire pieces for experiments proceeded according to a random number table. Methods for determining primary production were largely taken from APHA (1975).

Ash-free weights. 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 wich might have broken loose. The tire piece and loose algae taken from the sieve were then placed in a plastic bag with a label, and into a styrofoam chest with ice. In the laboratory, the tire pieces were scraped to remove all plant and animal matter. Macroinvertebrates were separated from this material as completely as possible (4-6 persons examined each sample) and preserved in 70% alcohol for subsequent identification. Invertebrate weights were obtained with a Mettler analytical balance after the organisms were 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 rewet 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 mg, respectively, of the weight measured previously. Between weighings, the crucibles and filters were returned to the drying oven for one hour and placed in a dessicator for an additional hour to cool. The fiberglass filters used in this project retain their integrity during ashing, unlike membrane-type filters. 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 plexiglass boxes measuring 30.50 x 30.50 x 15.25 cm were constructed using 3.175 mm plexiglass with removeable lids measuring 33.0 x 17.8 cm. 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, suitable for the insertion of 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 we used to measure dissolved oxygen. (The probe was 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 (Figure 9). All permanent seals were made with plexiglass glue and/or silicone rubber, and a bead of the latter was placed along the four edges of the box that met 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 angle aluminum section 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, determined by the official times of sunrise and sunset. An initial reading of dissolved oxygen (DO) was taken at the water's surface to be compared with final DO values in the boxes at the end of the half-photoperiod. In addition, two biological oxygen demand (BOD) bottles were filled with surface water (300 ml) and 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 productivity.

IV. Findings

Fish Tagging

The three experiments designed to study mortality and/or tag loss led to one basic conclusion: white crappie were adversely affected by some aspect(s) of the tagging and holding procedure employed. The results of those three

experiments described in the procedures section 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.

The distribution of tags by species, equipment used for capture, and the transect on which the fish were originally captured are given in Table 19. Since most fish were caught at the breakwater or behind it, the majority of fish were tagged at transects 0, B1 and B2. Theoretically, there were 268 fish available for recapture since 44 of the fish originally tagged died during the mortality/tag loss experiments.

The capture and recapture data (Table 20) show that longear sunfish were recaptured most frequently, with 14 of the 95 individuals originally tagged being recaptured at least once (14.7%). 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 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). The highest densities were found 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 on transect B0.

The highest density on half of the sampling dates was found at the breakwater (transect B0 or F0), and on the other dates 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 high numbers collected 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 sampling 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 length was calculated and ranked within dates (Table 23). The greatest mean length occurred on a breakwater

transect 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 fish that had completely undergone metamorphosis. Mean length of larval gizzard shad differed significantly between transects according to Friedman's rank test (T = 9.24 with 3 d.f.).

Zooplankton

Zooplankton were collected 12 times, and mean densities were plotted according to date and transect (Figure 10). The densities on 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 seemed to fluctuate less drastically; densities 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 collected in highest numbers most often behind the breakwater (transect B2). Highest overall mean density (91 plankters/ℓ) was 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 somewhat (see Appendix A).

Densities 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, east, middle, and western sections of the study areas had similar mean zooplankton densities. 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 tests because loss of precision in detecting differences between whole plots (transects) is inherent in this design (Steele and Torrie 1960).] Parametric t-tests, for which differences in mean density (averaged over locations E, M, and W) between transects were tested, 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 significantly 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 calculated over the 12 sampling dates. Trends for eastern and middle regions of the study area 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; highest densities were at transect B2 rather than 0.

Densities of cladocerans, copepods, and rotifers were also tested with the split-plot randomized block design (Table 25), which showed that differences between the numbers of organisms on different transects were significant ($F = 3.34$ 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 during the study ($F = 17.25$ 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 we compared the changes in mean numbers of organisms between any two transects, 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 lesser degree, when moving from transect 0 to B2.

Periphyton Productivity

The results of the primary productivity experiments were divided into two segments, ash-free weights and dissolved oxygen. Twenty-two tire pieces and twenty-five tire pieces, respectively, were required for these experiments. The periphyton growing on the tires was made up of primarily the green algae *Cladophora* and *Spriogyra*; another green algae, *Closterium*, and a blue-green algae (*Microcystis*) were present in small quanities.

Ash-free weights. A synopsis of ash-free weights of periphyton for each tire piece (Table 26) showed that weights varied somewhat within, as well as between, dates. Of primary importance, however, was the overall mean weight, 2.0009 g, of non-animal organic matter per tire piece. 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 psychomiids, which contributed 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.

Dissolved oxygen. Over the four dates on which we tested dissolved oxygen (DO), we used a total of ten light boxes and ten dark boxes to estimate periphyton productivity. 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 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 over the four sampling dates (1.5375 mgO/ℓ) was then subtracted from gross periphyton-plus-phytoplankton production, also averaged over the four sampling dates (8.9125 mgO/ℓ), to determine the mean gross periphyton production during the experiment (7.3750 mgO/ℓ). It was, therefore, 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.

V. Analysis

Tagging Experiment

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 capture was probably the primary cause of mortality, possibly compounded by high water temperatures and resultant lowered dissolved oxygen levels.

Longear sunfish was the most suitable species for tagging and recapture. In addition to those tagged individuals recovered (Table 20), two (or perhaps three) other longear sunfish were recaptured but not identifiable. 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 fish when recaptured may have been real, since the tags could have caused temporary weight loss (Stott 1971).

The most important finding from the tagging results 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. In the case of longear sunfish, and probably bluegill, the breakwater seems to attract and, moreover, encourage fish to remain in the vicinity.

Larval Fish

Although densities of larval fish did not differ statistically between transects, the highest density for a given date usually fell 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 resulted in 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. Relative to other transects, abundance on transect B0 (6.97 fish/m^3) was higher 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. Relative abundance of species varied seasonally. Although gizzard shad were ubiquitous, early spawning white crappie appeared before sunfish.

Mean total lengths of gizzard shad were regularly greatest on breakwater transects (B0 or F0) (Table 23). Had a large number of post-larval fish not been 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 lowered energy demands for maintaining themselves in the water column; however, due to their semi-planktonic existence, perhaps only the larger larval fishes were able to actively maintain themselves in this area.

Zooplankton

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. Pennack (1953) found that zooplankters were more abundant near the margins of lakes and rivers, so it is likely that zooplankton density would decrease when moving from shallower to deeper areas of the lake. Although significantly lower densities on the most lakeward transect (F2) support this generalization, densities at the breakwater (transect 0) and on the most nearshore transect (B2) were not significantly different from one another. The breakwater may have altered physical and/or biological conditions so that the zone of higher zooplankton densities was artifically extended toward the

cove mouth.

The interaction that occurred 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 western 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.

Periphyton Productivity

The design of breakwater modules, the differences in tread-wear of each tire, and the 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 have 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 (0.0441 m^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 2.009 g per tire piece (Table 26), the breakwater provided substrate for plant growth equivalent to at least 7.6 kg ash-free weight.

Although primary production of periphyton was roughly 2.65 times higher than that of phytoplankton, actual production of periphyton was probably greater. Decreases in DO concentration in light boxes (as apparently occurred on 11 July and 5 August) are highly unlikely and probably were erroneous.

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 on or near the breakwater. Large numbers of fish congregated nearby; they apparently moved less than fish elsewhere, and some were in slightly better condition near the breakwater. River carpsuckers, in particular, spawned nearby, and the presence of longer gizzard shad larvae at the breakwater also suggested that stronger-swimming larvae sought to maintain their position in this area.

Potentially, however, the most significant benefit 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. 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 was found to 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.

VI. Recommendations

Although there was some evidence that fish populations and primary production were greater in the immediate area, biological impacts of floating tire breakwaters--either positive or negative--were minimal in coves of a turbid reservoir. Physical-chemical impacts of biological significance were largely limited to wave attenuation. We found little support for the use of floating tire breakwaters as a fishery management tool, but we also found no ecological basis (such as rapid silting in the wave shadow) for opposing their use for protection of shores, harbors, or marinas in turbid reservoirs with fluctuating water levels.

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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
Electrofishing						
Number of fish	38	37	44	155	85	66
Number of species	1	1	4	5	3	2
Gill Net						
Number of fish	156	-	-	32	-	162
Number of species	9	-	-	5	-	10

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

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

Table 3. Continued.

Organism	Transect, number/sampler, and percent of transect total F2 (31 samplers)	F1 (20 samplers)	0 (32 samplers)	B1 (35 samplers)	B2 (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	84.48	41.25	62.27	58.55	55.40

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

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

Organism	Transect, number/sampler, and percent of transect total				
	F2 (31 samplers)	F1 (20 samplers)	0 (32 samplers)	B1 (35 samplers)	B2 (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	78.69
%	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 4. Similarity indices for invertebrates collected on Hester-Dendy samplers, 1979-80.

Transect	Transect and index				
	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[a]	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
1979					
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
1980					
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 and 1980.

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

Table 7. Results of t-tests comparing number of fish captured per hour of electrofishing at various transects (degrees of freedom = 169).[1]

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

[1]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 d.c. electrofishing (c/f) and the percentage of the total number of each species taken at various transects. (Refer to Appendix C for scientific names of each species.)

Species	Transect												Total
	F2		F1		F0		B0		B1		B2		
	c/f	%	c/f	%	c/f	%	c/f	%	c/f	%	c/f	%	c/f
Gizzard shad	20.0	18.8	36.0	19.4	28.9	15.6	45.5	24.5	20.1	18.8	35.1	18.9	185.6
Sunfish	0.0	0.0	0.0	0.0	8.1	35.7	14.6	0.0	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	919	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		

Table 9. Results of t-tests comparing the numbers of the nine most abundant species captured per hour of electrofishing at various transects.[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 (=).

Table 10. Number of fish captured per gill net (c/f) set at the surface of various transects during 1979 and 1980.

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 11. Number of fish captured per gill net (c/f) set on the bottom of 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 12. Number of fish of each speices captured per gill net (c/f) and the percentage of the total number of each species taken at various transects.

Net depth and species	Transect F2 c/f	F2 %	B0 c/f	B0 %	B2 c/f	B2 %	Total 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	27.7	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.

Table 13. Results of t-tests comparing the mean number of fish caught per gill net set at the surface or on the bottom at various transects. Species included are those for which at least 15 fish were caught.

Species	Depth location	Transect and mean value F2	B0	B2	Statistical relationship	d.f.	t-statistic
White crappie	Surface	3.74	0.63	1.94	B0 < F2	30	-5.46
					B0 < B2		-2.30
					F2 > B2		3.16
	Bottom	2.80	2.10	2.17	B0 < F2	15	-3.50
					B0 = B2		-0.35
					F2 > B2		3.15
Channel catfish	Surface	3.29	0.93	2.02	B0 < F2	30	-5.49
					B0 < B2		-2.53
					F2 > B2		2.95
	Bottom	1.14	1.70	0.46	B0 > F2	18	1.93
					B0 > B2		4.28
					F2 > B2		2.34
River carpsucker	Surface	1.33	3.04	0.71	B0 > F2	18	3.00
					B0 > B2		4.09
					F2 = B2		1.09
	Bottom	1.17	1.13	1.33	B0 = F2	15	-0.67
					B0 < B2		-3.33
					F2 < B2		-2.67

Table 13. Continued.

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

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

Table 14. Comparison of regressions of condition on length for the four most abundant fishes captured in gill nets at various transects during 1979 and 1980. (Number of fish in parentheses.)

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[1]	4.18
			F2	-12.92	NS[2]	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

[1]S = significant

[2]NS = non-significant

Table 15. Number of fish caught in hoop nets at various transects during 1979 and 1980.

Date	Transect and number of fish					
	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
3 Jul.	35	10	31	11	17	104
16 Jul.	30	10	71	3	28	142
24 Jul.	4	2	7	49	5	67
27 Jul.	29	47	80	81	60	297
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	

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

Species	Transect, number of fish, and transect percent										Total
	F2		F1		0		B1		B2		
	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

Table 17. Results of t-tests comparing the mean number of fish caught in hoop nets at various transects.[1]

Species	Transect and mean value					Statistical relationship	d.f.	t-statistic
	F2	F1	0	B1	B2			
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

Table 18. Comparison of regressions of condition on length for the four most abundant fishes captured in hoop nets at various transects during 1979 and 1980. (Number of fish in parentheses.)

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	- 6.59	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 B0-estimate	F-statistic
Gizzard shad (75)	0.84	Intercept	B0	-16.04		
			B2	- 7.49	S	13.73
			F2	-[a]		
			B1	-11.80	NS	3.02
			F1	-12.07	NS	2.20
		Slope	B0	3.84		
			B2	2.12	S	13.88
			F2	-[a]		
			B1	2.99	NS	3.05
			F1	3.06	NS	2.14
White crappie (540)	0.88	Intercept	B0	-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	B0	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]Regression equation not calculated--only one gizzard shad collected on transect F2.

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

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.)

Tag number	Species	Release				Recapture				Days[a]
		Date	Transect	Total length (mm)	Weight (g)	Date	Transect	Total length (mm)	Weight (g)	
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	29
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 strained on four transects during 1980.

Date		Transect F2	Transect F0	Transect B0	Transect B2	Wind	Clouds %
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.

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					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	96.58
	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 May and June, 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 June	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.

Table 24. Number of zooplankters per liter of water strained during 1980, listed by transect (F, O, B) and section (east, middle, west) where caught.

	Transect, location and N/ℓ								
	F			O			B		
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.

Table 25. Mean number of zooplankters per liter of water strained, averaged over section (east, middle, west) and listed by transect and taxonomic group, 1980.

	Transect, taxonomic group, and mean value								
	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

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
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
Insecta														
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	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 27. Continued.

Family	Date and location of tire piece												
	12 Aug.							28 Aug.					
	05	10	16	37	44	50	Total	08	38	39	58	Total	Total
Chironomidae	314	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
Insecta													
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

Table 28. Differences (D) in initial and final dissolved oxygen readings in light and dark plexiglas boxes and BOD bottles that were used to determine gross and net production (mgO/ℓ).

Date		Container and D-value			
		Plexiglas boxes (periphyton and phytoplankton)		BOD bottles (phytoplankton)	
		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.

Date		Container and D-value			
		Plexiglas boxes (periphyton and phytoplankton)		BOD bottles (phytoplankton)	
		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.

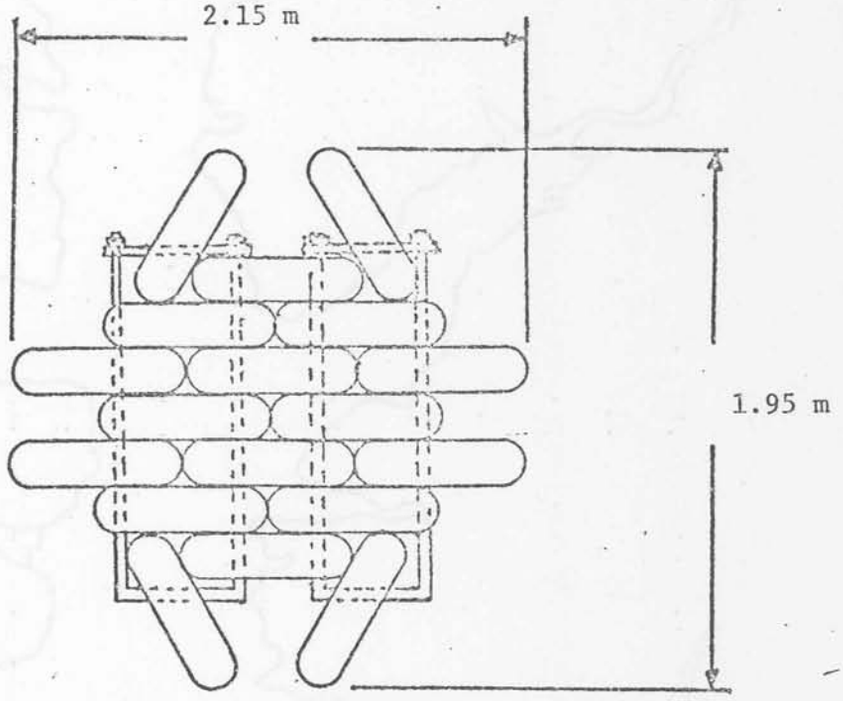


Figure 1. Arrangement of 18-tire module.

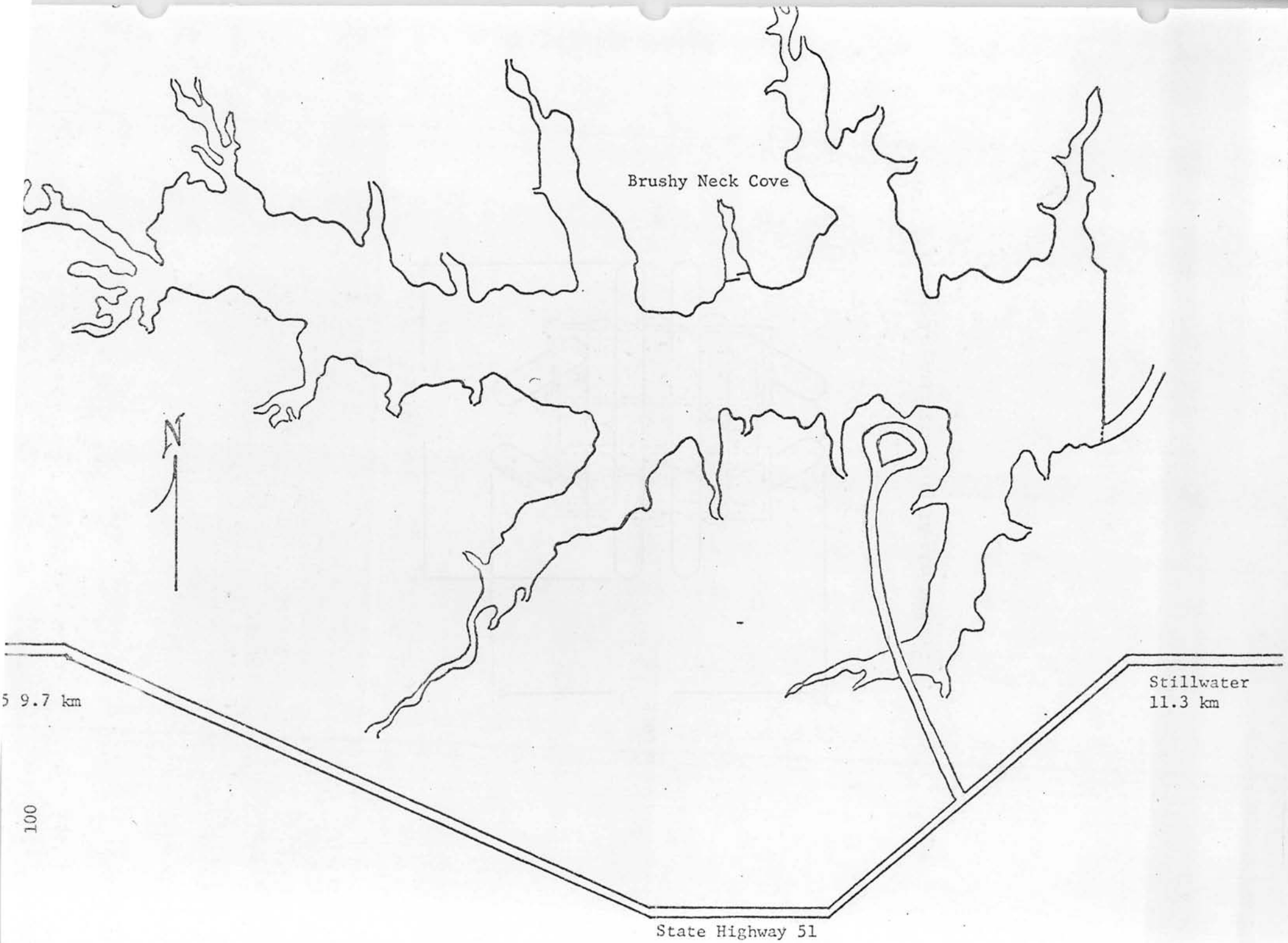

Brushy Neck Cove
N
5 9.7 km
Stillwater
11.3 km
State Highway 51

Figure 3. Brushy Neck Cove of Lake Carl Blackwell at two different water levels; B2, B1, F., and F2 indicate locations of experimental transects.

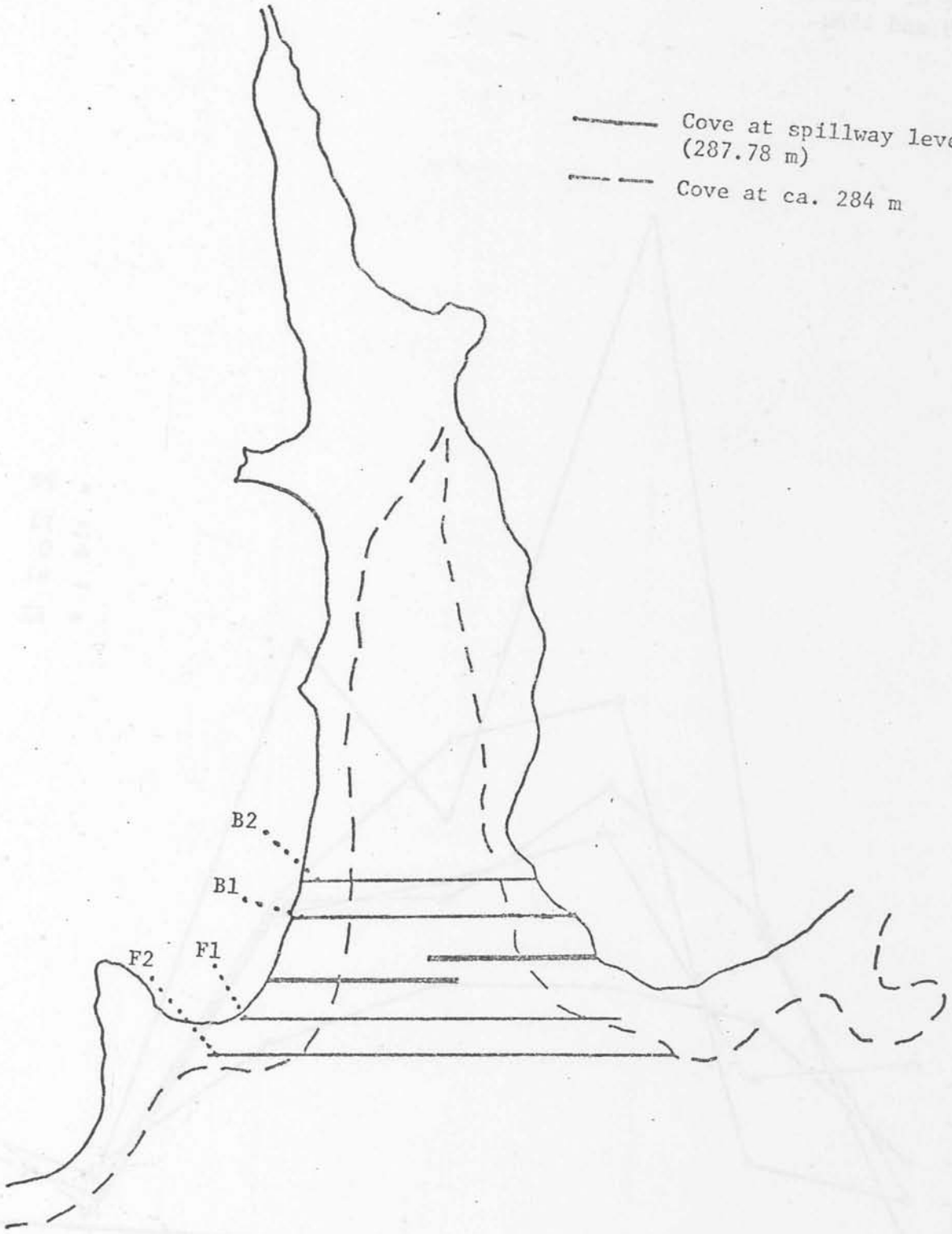


Figure 4. Number of invertebrates collected per Hester-Dendy sampler during 1979 and 1980.

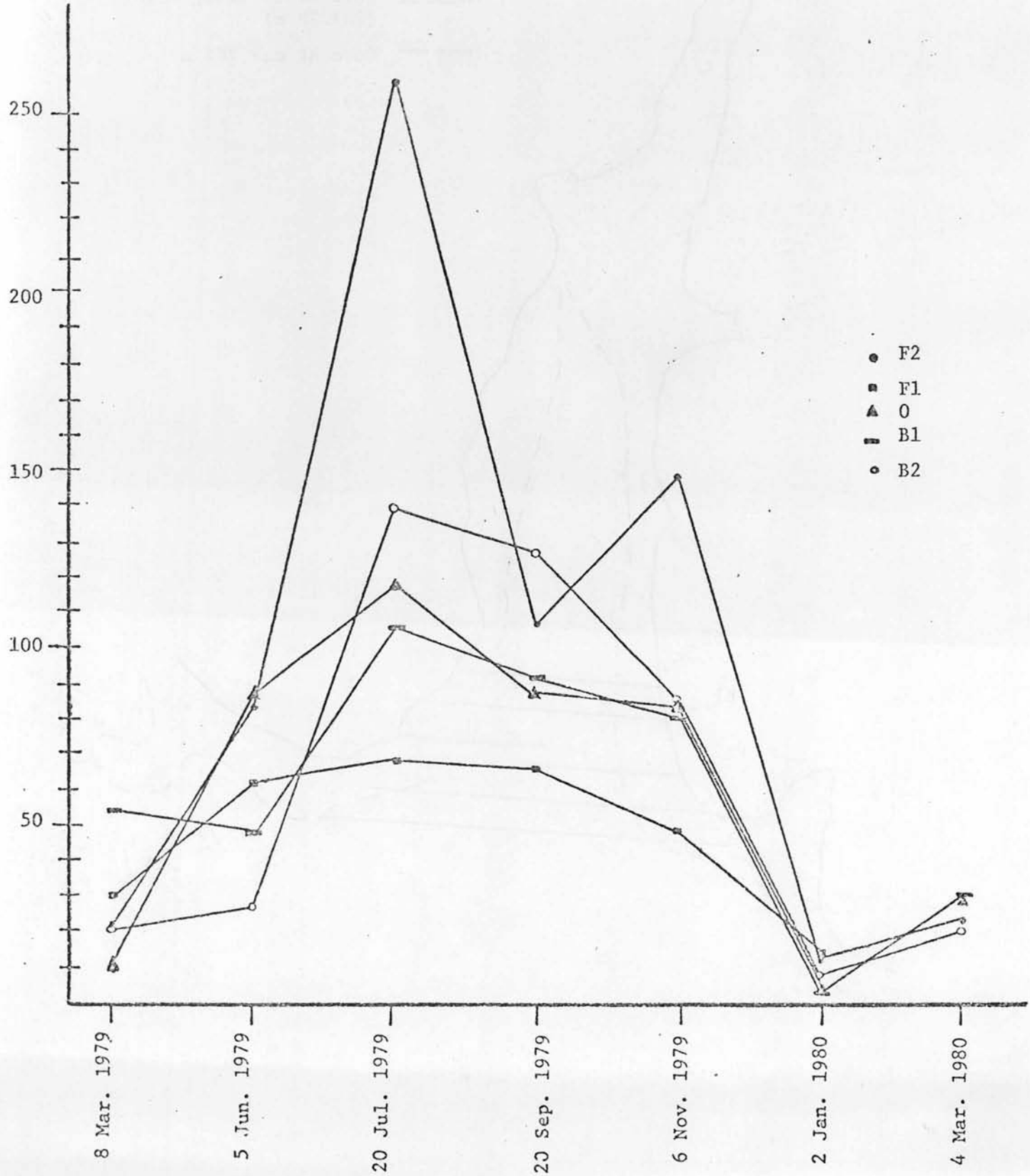


Figure 5. Percentage of fish collected on each transect while electrofishing during 1979 and 1980

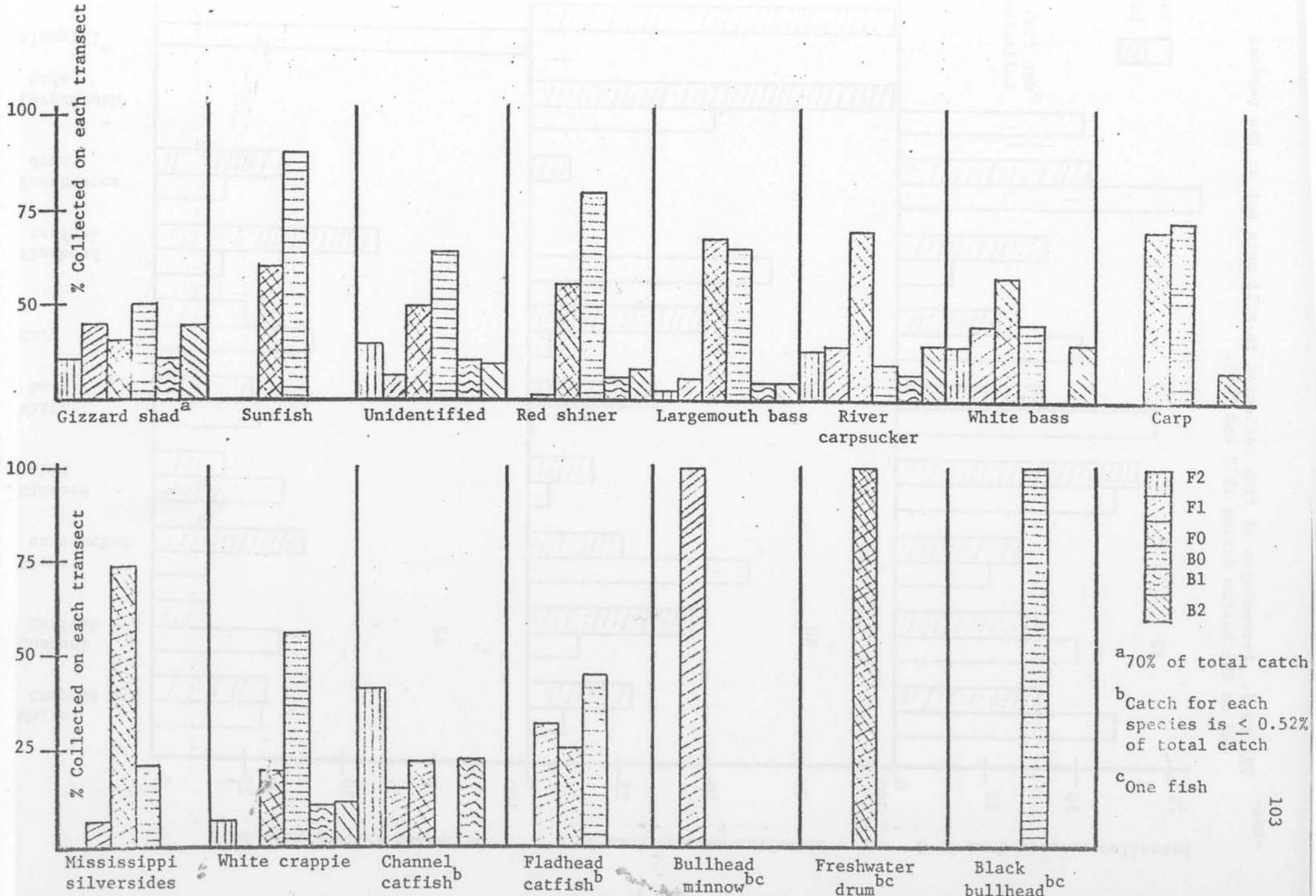


Figure 6. Percentages of fish collected in gill nets set at the surface and on the bottom during 1979 and 1980.

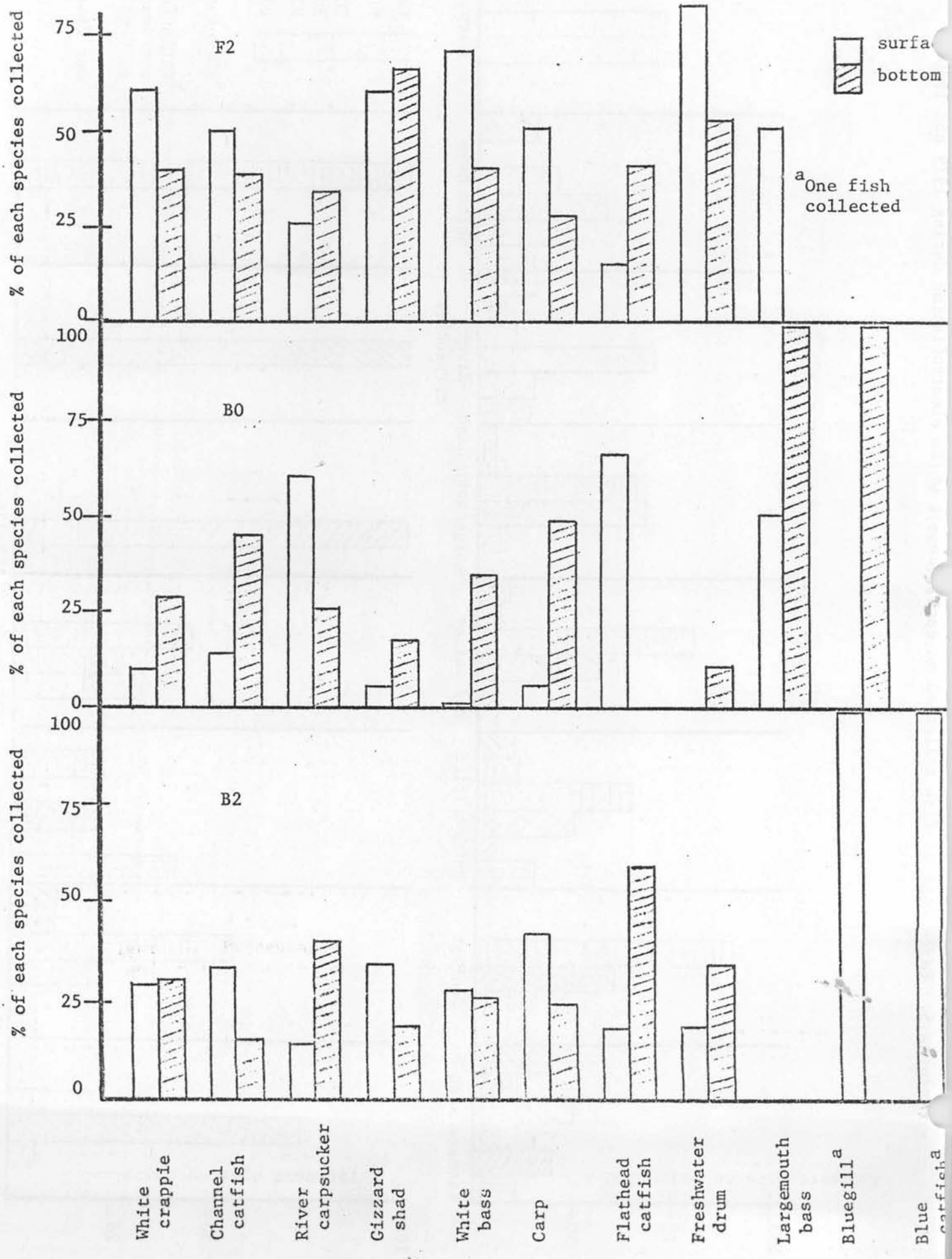
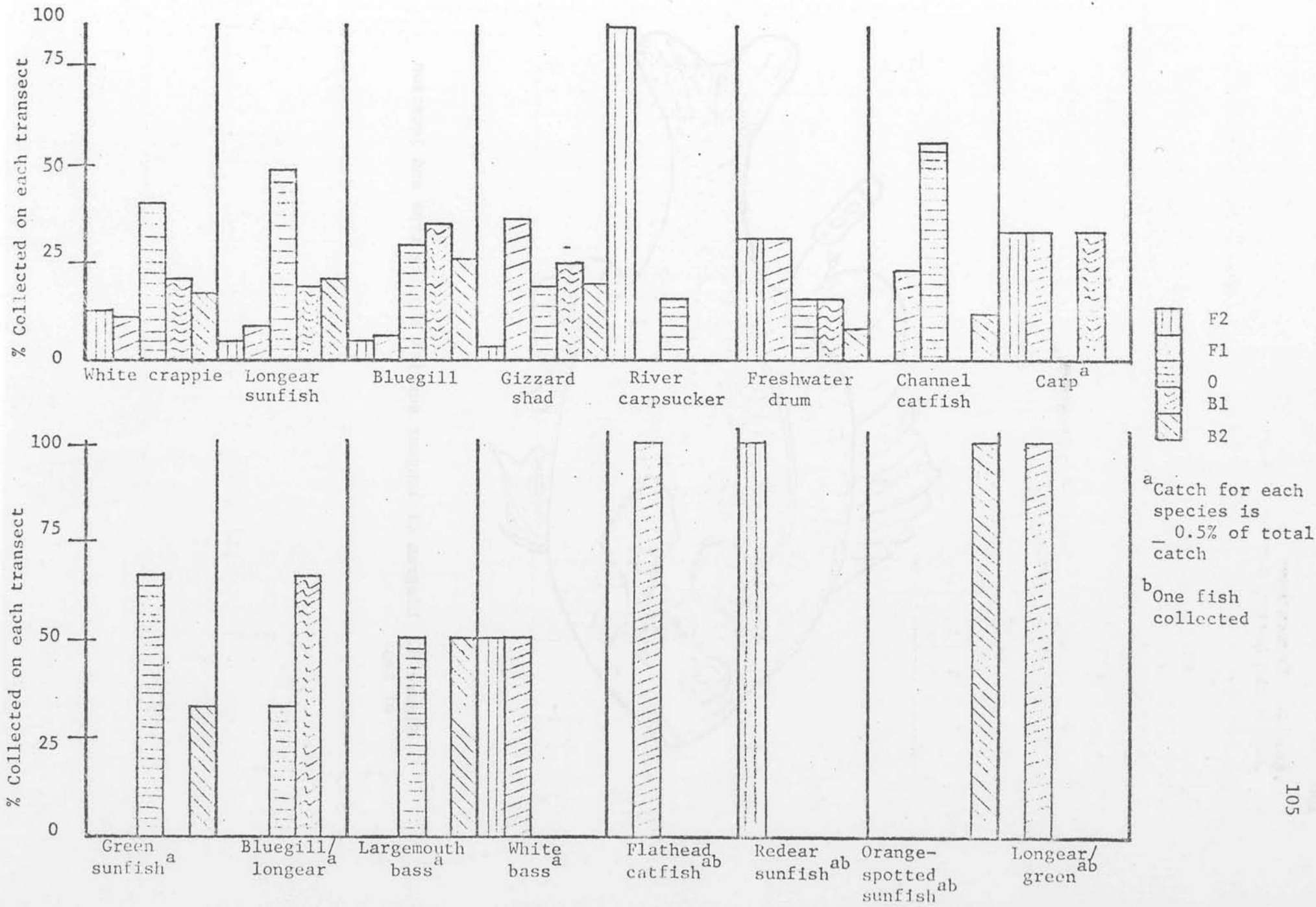


Figure 7. Percentage of fish collected on each transect in hoop nets during 1979 and 1980.



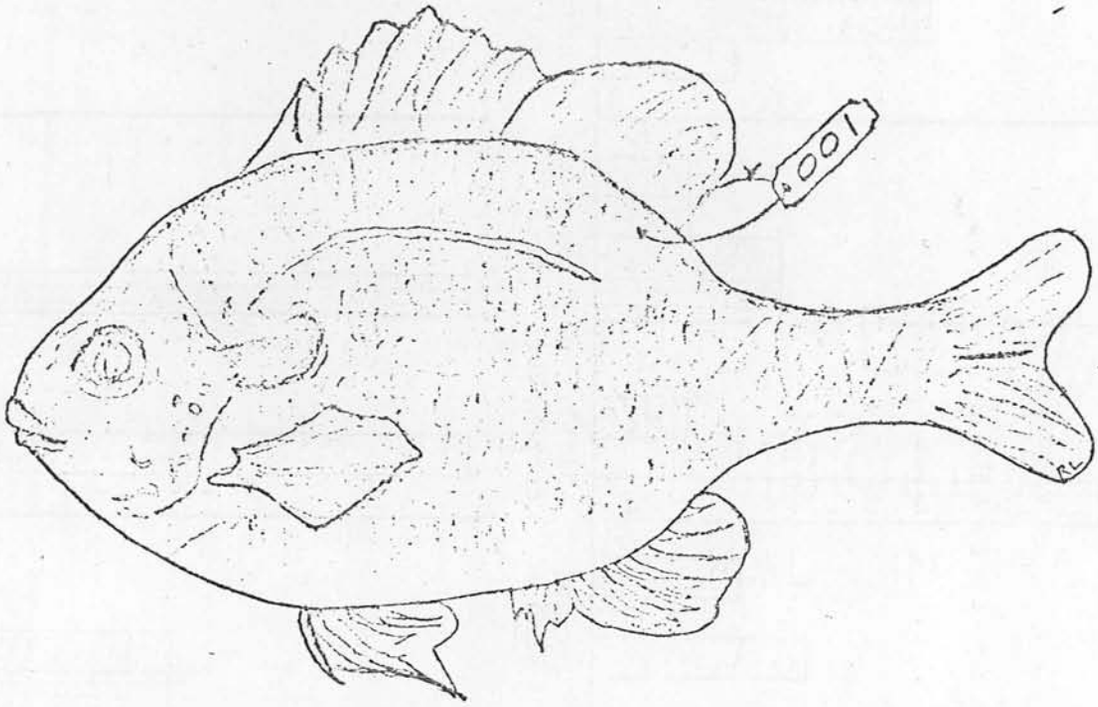


Figure 8. Diagram of longear sunfish showing type and location of tag.

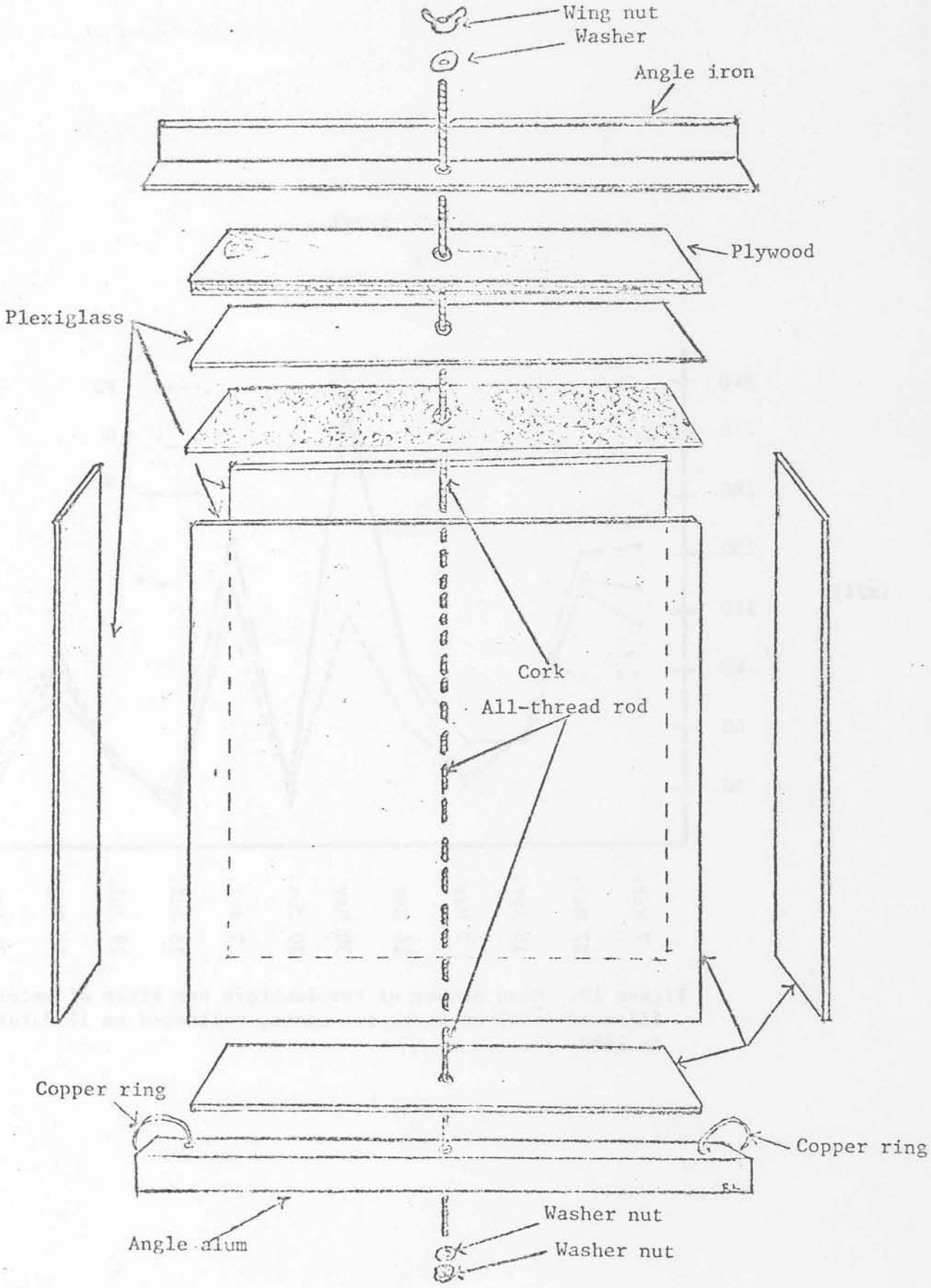


Figure 9. Diagram of plexiglas box.

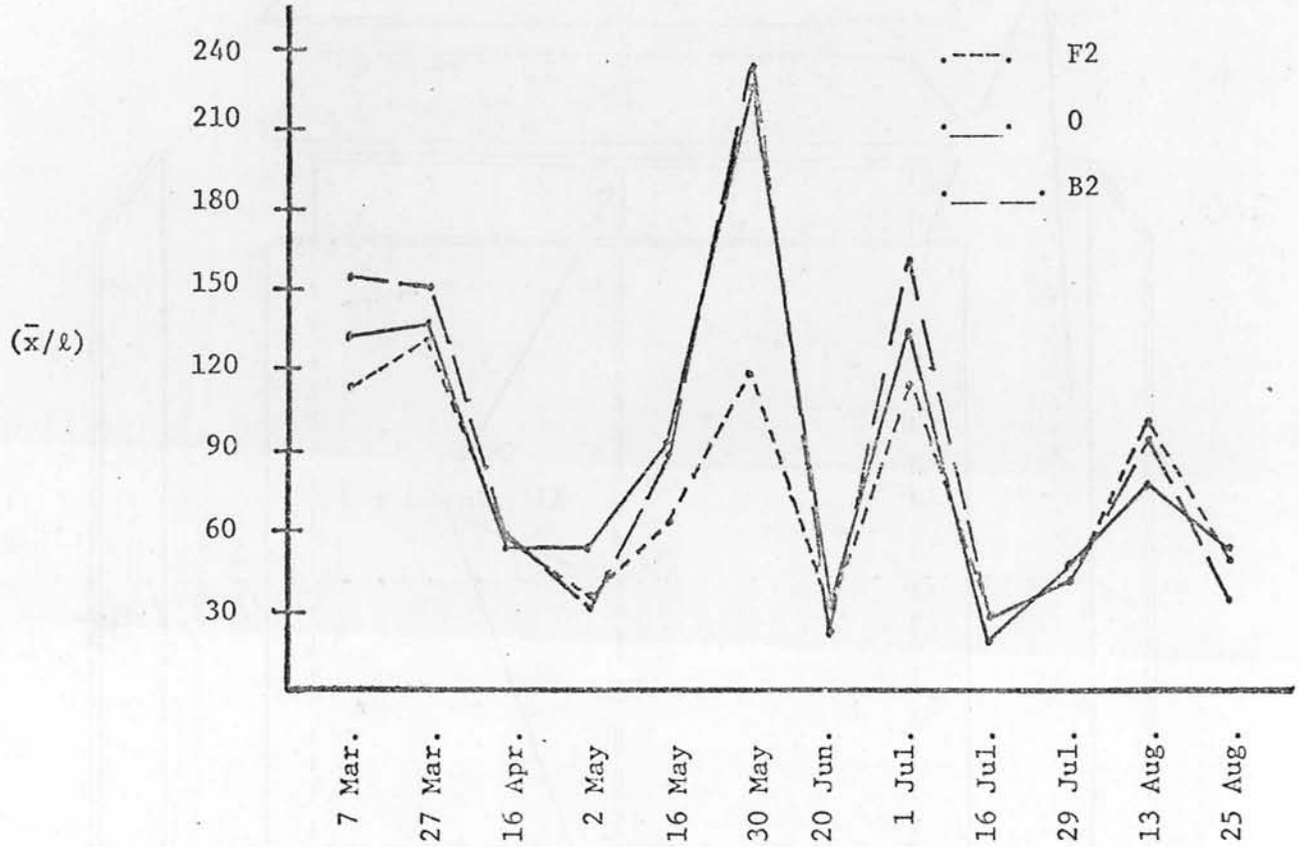


Figure 10. Mean number of zooplankters per liter of water filtered ($\bar{x}/\ell$) on three transects, collected on 12 dates in 1980.

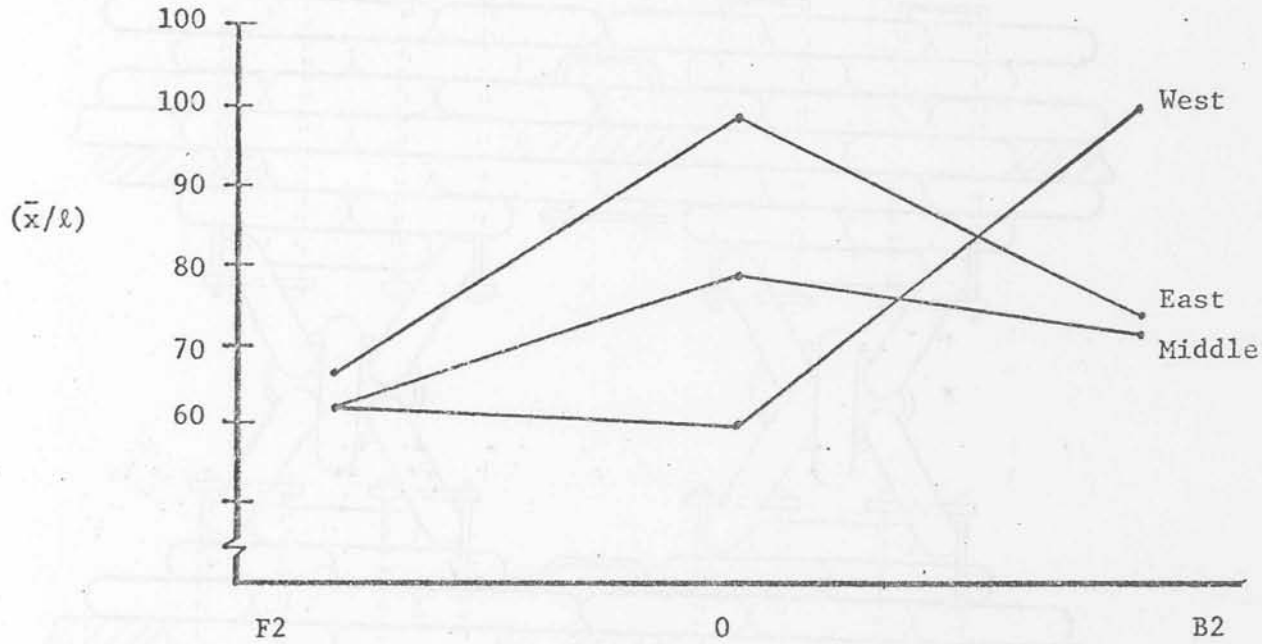


Figure 11. Mean number of zooplankters per liter of water filtered ($\bar{x}/\ell$) for twelve dates during 1980. West, middle, and east were geographical sections of the transects.

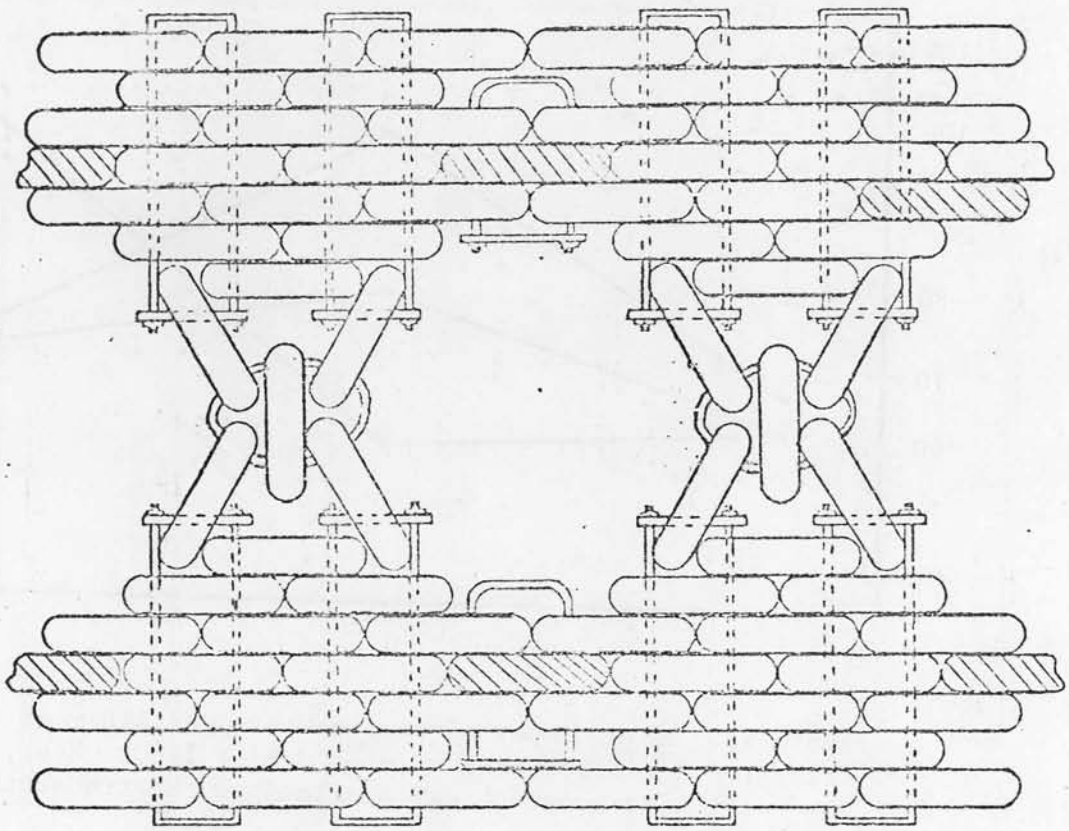


Figure 12. Arrangement of two rows of 18-tire modules and interconnecting U-bolts.

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.

APPENDIX B

The following monthly water levels for Lake Carl Blackwell were selected from observations 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 oliveris* (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.