COASTAL FISHERIES INVESTIGATION

Federal Aid in Fish Restoration Project F-22

NORTH CAROLINA WILDLIFE RESOURCES COMMISSION

DIVISION OF INLAND FISHERIES

FINAL REPORT

STUDY: A Preliminary Survey of the Aquatic Vegetation in White Lake, North Carolina and its Value to the Fishery Resources.

Job 1. Water Quality Analysis

Job 2. Aquatic Vegetations Evaluation

Job 3. Fish Population Survey & Food Habits

Job 4. Aquatic Benthos

Job 5. Final Report

Project Type: Survey

Period Covered: May 1, 1978-September 30, 1979

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INTRODUCTION

White Lake is a 432.2 hectare (1068 acre) natural bay lake located eight kilometers (5 miles) east of Elizabethtown, North Carolina. This natural lake has a maximum depth of 3.18 meters (10.6 feet) an average depth of 2.25 meters (7.5 feet) and a shoreline length of 7.67 kilometers (4.77 miles). The lake's bottom composition is sand, fibrous peat and pulpy peat (Louder 1961).

The State of North Carolina owns the lake property to the mean high water mark, however, the land around the perimeter is in private ownership. The perimeter adjoining White Lake is extensively developed. This development includes motels, rooming houses, campgrounds, permanent residences, mobile home parks, summer homes and weekend cottages. The economy of White Lake is recreational and vacation oriented.

Concerns have been voiced by property owners, local residents, town officials and other individuals utilizing White Lake that the aquatic vegetation is restricting recreational uses and some action is needed to control the problem. The North Carolina Wildlife Resources Commission's Division of Inland Fisheries frequently has been called upon to comment on the aquatic vegetation problem and propose a logical solution.

Louder (1961) reported six species of aquatic vegetation present in White Lake: arrowhead, *Sagittaria sp*; filamentous algae, *Spirogyra sp.*; cabomba, *Cabomba caroliniana* Gray; bladderwort, *Utricularia sp.*; bald cypress, *Taxodium distichum* (L) Richard; and hairgrass, *Eleocharis sp.*. The current problem involves only the submerged rooted aquatic vegetation *Utricularia* and *Eleocharis* and the decomposing leaf litter associated with *Taxodium distichum*. *Utricularia* and *Eleocharis* will be referred to in the remainder of the study as the vegetation. The residents and users are concerned primarily with the degraded aesthetic conditions occurring in White Lake from these species of vegetation. The basic complaint was that the fragmented vegetation continuously washed upon their property creating an unpleasing appearance. The decaying detritus frequently was found in private swimming areas or washed up on the beaches.

Most property owners and users of White Lake believe that the North Carolina Wildlife Resources Commission should do something about the vegetation inasmuch as it regulates many water related activities in the lake such as boating, skiing, and fishing. The most common solution proposed by concerned citizens was to treat White Lake with an aquatic herbicide suitable to control the problem species of vegetation.

Cursory examination of random grab samples of aquatic vegetation present in White Lake revealed that a high macrobenthic population was associated with, or attached to, the vegetation. It appeared that these organisms provided a major source of food for game and nongame fish. This study was designed and implemented to determine the status of the aquatic vegetation in White Lake and its importance to macrobenthic and fish populations.

MATERIALS AND METHODS

A multifaceted approach was developed to investigate and evaluate the importance of the vegetation to the game fish population in White Lake. The investigation included identification of the problem species of aquatic vegetation, determination of their locations and densities in White Lake, determination of species compositions and standing crops of macrobenthic and fish populations and periodic monitoring of water quality conditions.

Previous field work on White Lake in 1972 provided some insight to the distribution of aquatic vegetation, however, this data was never published or documented. The densities of aquatic vegetation varied in White Lake and could be classified as heavy, moderate, and light zones. It was decided that these descriptive terms were suitable for use in this study in documenting the locations of different densities of vegetation.

Samples originally were scheduled to be collected on a bimonthly basis, starting in May 1978 and terminating in March 1979. Sampling was conducted on this schedule with the exception of the January 1979 sample period. This sample was not collected because high winds and inclement weather precluded field work. Samples of aquatic vegetation and benthic organisms were collected throughout White Lake on transect lines approximately 610 meters (2000 feet) apart, with sample sites located along each line at 305 meter (1000 feet) intervals. Samples were collected at a total of 20 sites (Figure 1).

Aquatic vegetation was sampled from a boat using an Eckman dredge. The 15.2 cm X 15.2 cm (6" X 6") Eckman dredge was modified in a manner so that it could be attached to a three meter (10 feet) wooden pole. The trip mechanism was activated using a 6 mm (¼") steel rod which extended from the dredge to above the water surface. This steel rod was secured to the wooden pole in such a manner that it did not interfere with activation of the dredge.

Each vegetation sample was thoroughly washed to remove any excess bottom material, labeled for proper identification and placed in a plastic bag. Upon return to the laboratory, each sample was sorted to species, blotted dry, and weighed in grams.

A map of areas affected by vegetation was developed by using a combination of aerial photographs of the entire lake, observations from a boat and examination of the vegetation sampling data (Figure 2). The lake was divided into zones according to the relative density of vegetation and classified as heavy, moderate or light. The total surface area contained in each zone was determined. This information and data generated from vegetation sampling was used to estimate the total standing crop of vegetation in each zone.

Aquatic invertebrate populations were sampled by using an Eckman dredge. The benthic samples were washed to remove excess detritus and associated bottom materials and preserved in 10% Formalin for later sorting, counting and identification in the laboratory. Identification of benthic organisms was made by using taxonomic keys developed by Pennak (1957) and Needham and Needham (1969). Identification of benthic organisms was made to either family, class, or order.

The percent by number and the frequency of occurrence of each group of organisms in the samples were calculated, as described by Lagler (1956). The standing crop of each group of organisms in White Lake was also estimated by bimonthly periods. Differences in densities of benthic organisms between zones were tested using the Student "T" test described by Calhoun (1966).

Fish population samples were collected in September 1978 at two locations in the lake (Figure 1). One sample was collected within the heavily vegetated zone, while the second sample was collected in a zone of light vegetation density. Each sample site was 0.10 hectare (0.25 acre) in size and was enclosed with block nets on the day of the sample to prevent the ingress and egress of fish. Rotenone (fish toxicant) was applied at the rate of two parts per million within the sample area. A neutralizing agent, potassium permanganate, was applied outside the block nets to lessen any overkill. Potassium permanganate was also applied within the sample areas following the surfacing of distressed fishes. All fish were collected on the day of and the day following rotenone application. All specimens collected from each zone were identified by species, counted, weighed in grams or kilograms and measured in millimeters.

Stomachs were removed from yellow perch, largemouth bass, and yellow bullheads and preserved in 10% Formalin for later analysis. The invertebrate food items present in the stomachs were identified to the taxonomic level of order or family only, while fish food items were identified to the lowest taxonomic level possible. The percent by number and frequency of occurrence of all food items were calculated for each species (Lagler 1956).

Water quality parameters, pH, dissolved oxygen, temperature, total hardness, total alkalinity and secchi transparency, were measured bimonthly from May 1978 through March 1979. Samples were taken at A1, C4, and D4 (Figure 1). All water quality measurements, except the secchi transparencies, were made with a Hach Model AL 36B chemical kit.

RESULTS

Aquatic vegetation sampling indicated that three zones of different densities of vegetation were present. The estimated areas effected by aquatic vegetation in White Lake are as follows: heavy zone, 108.25 hectares (267.48 acres) or 25.05% of the lake; moderate zone, 241.18 hectares (595.95 acres) or 55.08% of the lake; and the light zone, 82.76 hectares (204.49 acres) or 19.15% of White Lake (Figure 2).

Only two genera of submerged rooted aquatics, hairgrass, *Eleocharis sp.* and bladderwort, *Utricularia sp.*, were collected during the sampling period.

The mean annual standing crop of all species of submerged rooted aquatic vegetation in White Lake was estimated to be 880.99 kg/ha in the heavily vegetated zone, 139.61 kg/ha in the moderate zone, and 0 kg/ha in the lightly vegetated zone (Table 1). Bladderwort comprised 32.99% of the standing crop of vegetation by weight in the heavy zone and 10.90% in the moderate zone. Hairgrass made up 67.00% of the vegetation in the heavy zone and 89.09% in the moderate zone. No submerged rooted aquatic vegetation was collected in the light zone (Table 1).

Amphipoda, Trichoptera, Diptera and Oligochaeta were the most numerous benthic organisms, respectively, in the heavy vegetative zone (Table 2). The greatest standing crop in the heavy zone occurred during the months of November and March. Amphipods were the only organisms present in the heavy zone during each sample period from May 1978 through March 1979.

The largest number of organisms occurred in the moderate zone (Table 3). Amphipoda, Diptera, Trichoptera, and Hirudinea were the most dominate organisms in decreasing order of abundance within the moderate vegetative zone. Diptera, Trichoptera and Amphipoda were present in the moderate zone of vegetation during each sample period. The greatest estimates of benthic standing crops occurred during October and November for this zone.

Diptera, Trichoptera, Amphipoda and Oligochaeta were the most numerous benthic organisms, respectively, in the light zone of vegetation (Table 4). The highest estimated standing crop of benthos occurred during the months of May and July. Trichopterans and dipterans occurred during each sample period from May 1978 through 1979.

The estimated mean standing crop of macrobenthic organisms for all sample periods in each vegetative zone is shown in Table 5. Amphipoda, Trichoptera, and Diptera were found to be the most numerous organisms during the study period. The total estimated standing crop of all benthic organisms is also indicated for each zone. The total estimated standing crop for the heavy vegetative zone was 2.09 times greater than the moderate zone while the moderate zone was 1.98 times greater than the light zone.

Food habits were determined for largemouth bass, yellow perch, and yellow bullhead collected in rotenone samples. A total of seven food items was observed in the six largemouth bass collected (Table 6). Fish, or fish remains, represented 73.67% by number of the contents observed. Crustaceans and insects comprised the remainder of the observed food items. The only insects identified in bass stomachs were dipterans and orthopterans.

Stomach contents of 32 yellow perch were examined. It was determined that fish or fish remains, and insects made up 6.53% and 91.74%, respectively, of food items utilized by yellow perch in White Lake. Trichoptera, Diptera and Odonata were the most utilized food items of yellow perch. Crustacea made up only 2.23% by number of the food contents. Decapods were found in 15.63% of the stomachs. Decapods ap pear to be a moderately important food item of yellow perch, however, no decapods were collected in the macrobenthic samples.

Only fish and fish remains were found in the stomachs of the four yellow bullheads collected in the September 1978 rotenone samples (Table 8). Although no aquatic invertebrates were found in bullhead stomachs, the small number of fish examined precludes drawing any firm conclusions regarding bullhead food habits.

A total of eight fish species was collected by rotenone sampling in September 1978 (Table 9). Four of these eight species (largemouth bass, warmouth, yellow perch, and yellow bullheads) provides recreational fishing in White Lake.

The estimated standing crop of game fish in the heavily vegetated area was 1.785 kg/ha while the standing crop of nongame fish was 3.66 kg/ha. In the lightly vegetated section, the estimated standing crop was 2.024 kg/ha of game fish and 0.35 kg/ha of nongame fish. The mean estimated standing crop from the two samples was 1.905 kg/ha game fish and 2.005 kg/ha nongame fish.

Bluespotted sunfish represented the greatest average percent by number of any species collected in the rotenone samples with 42.2%. However, this species has no angling importance in White Lake, yet does function as a forage fish for the other piscivorous species.

Unidentified centrachids had the next highest mean percent by number with 35.5%. This group of fishes were $\leq$ 4 cm TL and included specimens of blackbanded sunfish, bluespotted sunfish, warmouth and representatives of the genus *Lepomis*. While no angling importance can be given to this size group, they are important as a forage base in White Lake. Also, those individuals in the genus *Lepomis* may in time reach angling importance as they attain a larger size.

Yellow perch comprised 70% by weight of the mean standing crop and accounted for 5.6% by number of the mean estimated standing crop. Yellow bullhead was the only species for which a sport fishery exists which exceeded yellow perch in percent by numbers of the mean estimated standing crop with 8.0%. Yellow bullhead represented 8.6% by weight of the estimated standing crop.

Largemouth bass comprised 0.5% by number and 8.7% by weight of the estimated standing crop. While largemouth bass may be the most sought after species in White Lake, yellow perch is the most numerous and important from an angler's viewpoint.

The heavily vegetated area contained 93.02% of all fish collected from the rotenone samples. The remaining 6.97% were collected from the lightly vegetated zone. The estimated standing crop of fish in the heavy vegetative zone is 5.21 times greater than that of the light vegetative zone.

Water quality was monitored during the period May 1978 through March 1979 at three sample sites (Figure 1). The seasonal changes in various parameters monitored are indicated in Table 10. All values recorded are within those ranges considered acceptable to warmwater fish production and survival.

DISCUSSION

The various user groups have voiced concern over the aquatic vegetation problem existing in White Lake since 1968, according to available records. Many solutions have been proposed during the years with little formal thought or study given to the problem or cause. Some of these solutions were application of copper sulfate, stocking of Israeli carp and restricting the use of motor powered boats on White Lake.

Some of the user groups of White Lake may contribute directly to the problem of fragmented and decaying vegetation that litters beaches and swimming areas. The two species of submergent rooted aquatic vegetation, *Eleocharis sp.* and bladderwort, observed during this study are relatively fragile plants. Each of these species as well as *Cabomba caroliniana* described by Louder (1961) have small slender stems which may be easily broken. These slender fragile stems undoubtedly become broken, dislodged and fragmented during periods of intensive use on White Lake. The summer recreational periods generate an excessive use of this body of water by water skiers pulled by high performance inboard and outboard motor boats. The submergent aquatic vegetation may become broken and dislodged by the internal and external seiches generated from the boating activity. The dislodged aquatic vegetation is then deposited around the shoreline periphery of White Lake, thus worsening the vegetation problem. The deposition of the detritus or organic particles within the swimming areas may also be a result of boating activity and the internal and external seiches this activity produces (Ruttner 1966).

The entrance of leaf litter into White Lake is a function of nature through discharging or dropping of the damaged, diseased or dead leaves. This litter, in addition to the fragmented aquatic vegetation, undergoes normal biological decomposition to form the detritus present in the lake bottom.

Marzolf and Benson (1978) discuss the role of leaf litter in an aquatic situation.

> "Upon falling into the stream, the leaves exhibit an initial rapid loss of weight, presumably the soluble and easily leached organic fractions. McDowell and Fisher (1976) found that nearly 17% of litter input was released to the water as dissolved organic matter (DOM) within three days of entry. Bacteria and fungi invade leaves of any given species rapidly, and further weight loss (decomposition) takes place at a rate which is dependent upon temperature (Petersen and Cummins 1974). Hynes and Kaushir (1969) showed that the nitrogen and protein content of leaves in controlled laboratory experiments increased in the early stages of decomposition if a source of inorganic or organic nitrogen was added. Hynes (1970) suggested that other nutrients, such as phosphate, can be implicated in this effect. Presumably, the activities of the microflora increase available protein in the resource. Aquatic insect detritivores, both shredders and scrapers, are likely to utilize the "enhanced" resource, but the relative importance of the leaf itself and/or microflora for food has not been fully resolved. Shredders, however, cannot grow on sterile leaves, and different microbial species on leaves yield different growth rates by some detritvores (Baerlochso and Kendrick 1973)."

Louder (1961) reported six species of aquatic vegetation present in White Lake. The six dominant species described in decreasing order of abundance were arrowhead, *Sagittaria sp.*; filamentous algae, *Spirogyra sp.*; *Cabomba caroliniana* Gray; bladderwort, *Utricularia sp*; bald cypress, *Taxodium distichum* (L) Richard; and hair-grass, *Eleocharis sp.* Two of the three species of submerged rooted aquatic vegetation reported were collected during the present study. *Cabomba caroliniana* was not observed or collected during this study. The reason for the absence of this plant is not known, however, it may be due to sampling error or a possible change in habitat over the last 20 years. There were no estimates provided in Louder's report of the amount of vegetation per acre or per hectare, therefore there is no baseline of data for comparison. The only baseline data available is an undocumented observation made in 1972 of vegetated areas (Nichols 1972). These estimates were made by observing the lake bottom from a boat and then mapping vegetative zones using this information. There does not appear to have been any noticeable increase or decrease in the amount of area affected since 1972 when compared to the data generated by the present study.

Eleocharis sp. represents the greatest percentage of the submergent rooted aquatic vegetation present within the heavy and moderate zones (Table 1). This genus had a total estimated standing crop in White Lake of 714.72 kg/ha. Bladderwort had a total estimated standing crop of 305.88 kg/ha in White Lake.

The heavy zone included 108.25 ha or 25.05% of White Lake and had an estimated mean annual standing crop of 880.99 kg/ha of vegetation. The heaviest standing crop occurred in October 1978 with 2185 kg/ha in the heavy zone.

The moderate zone represents 241.80% ha or 55.80% of the lake and had a yearly mean of only 139.61 kg/ha of vegetation. The highest estimated standing crop occurred in the moderate zone in March 1979. There was no submergent rooted aquatic vegetation present within the light zone.

It does not appear that these densities are great enough to impair angler use of White Lake at this point in time. The only impairment occurring is the nuisance, or unpleasing aesthetics, that the fragmented vegetation causes along the shoreline. This problem varies from day to day depending on the amount of boating activity and direction of the prevailing winds.

Cursory examination of random grab samples of aquatic vegetation during the winter of 1977-1978 revealed that a high macrobenthic population was associated with submerged plants. Macrobenthic organisms constitute a major source of food for game fish and nongame fish in White Lake, therefore the determination of their importance to the fish population of White Lake and their association with submerged plants was essential criteria for evaluating the aquatic vegetation problem.

The importance of the vegetation to the macrobenthic community can be easily observed by comparing the annual mean standing crop of benthos between the respective vegetative zones. The annual mean estimated standing crop of benthos in the heavy vegetative zone is 2.09 times greater than that in the moderate zone. However, the moderate zone area is 2.2 times greater in size than the heavy vegetative area. The annual mean estimated standing crop of benthos in the moderate zone is 1.98 times greater than that of the light vegetative zone. The total annual mean estimated standing crop was 27,905,886 organisms. The total number of organisms present in the heavy zone represented 58.2%, the moderate zone composed 27.7% and the light zone included the remaining 13.9% of the yearly estimated standing crop. Amphipods, Trichoptera, Diptera, and Oligochaeta were the most dominate organisms in each vegetative zone, except within the moderate zone where Hirudinea replaced Oligochaeta. These four groups represented 94.47% of the total mean estimated standing crop of macrobenthos in White Lake.

The numbers of Amphipoda, Trichoptera, Diptera and Odonata in the samples were compared between zones using the T test as described by Calhoun (1966). These data were compared to determine if different densities of vegetation influenced the macrobenthic standing crop.

Amphipod numbers were significantly higher in the heavily vegetated zone than in the light zone ($t = 1.51$, $\alpha = 0.05$). However, there was no significant difference in Amphipod numbers between the heavy zone and the moderate zone or between the moderate zone and the light zone.

There were significantly more trichopterans in the heavy zone than in the moderate zone ($t = 3.26$, $\alpha = 0.05$) or in the light zone ($t = 2.66$, $\alpha = 0.05$). There was no difference in Trichopteran numbers between the moderate and the light zones.

Dipterans were also more numerous in the heavy zone than in the moderate zone ($t = 5.57$, $\alpha = 0.01$). There was no significant difference in the number of dipterans between the heavy or the moderate and the light zones. There were no significant differences in the numbers of Odonata between any of the three vegetative zones.

The total numbers of all benthic organisms collected in the samples from White Lake were also compared by zone. The total number of benthic organisms in the heavy zone was significantly higher than in the moderate zone ($t = 3.04$, $\alpha = 0.05$) or in the light zone ($t = 2.96$, $\alpha = 0.05$). There was no difference in the total number of benthic organisms between the moderate and the light zones.

It is obvious that macrobenthic populations are considerably higher in those areas supporting vegetative growth. Further, it appears that macrobenthic populations are higher in those areas that are heavily vegetated as compared to the more moderately vegetated areas of White Lake. These data indicate that the population numbers of certain selected benthic organisms, particularly those organisms that have been demonstrated to be vital to the diet of yellow perch, are directly related to the relative density of vegetation.

Food habit information indicated that fish and fish remains represented 73.67% of the largemouth bass food in White Lake and that insects made up 21.04%. Crustaceans were represented by Decapoda and composed only 5.26% by number of the food items observed. These percentages were derived from observed food habits of only six largemouth bass collected in the White Lake rotenone samples.

The insect families Trichoptera, Odonata, and Diptera were the most numerous food items found in the stomachs of yellow perch, one of the primary species of angling importance in White Lake. Trichopterans alone were found in 46.88% of the stomachs examined and they accounted for 78.43% by number of all food items in the stomachs. Trichopterans and dipterans were both significantly more numerous in the benthos samples collected from the heavily vegetated zone than in those collected from the moderate or light zones. Overall, yellow perch utilized benthic organisms for almost 94% of their diet. It appears that yellow perch are directly dependent on benthic organisms, particularly insects in the families Trichoptera, Diptera, and Odonata for forage in White Lake. Since these organisms are often directly associated with vegetation, and have been documented to be much more abundant in the areas of vegetation, especially heavy vegetative growth, it is apparent that the yellow perch fishery is somewhat dependent on and is certainly benefited by the beds of rooted submergent aquatic plants in White Lake.

The absence of macrobenthic organisms in yellow bullhead stomachs may be due to the small sample size, time of sample, season, or other unknown variables. Harlan and Speaker (1969) and Trautman (1957) reported that yellow bullhead utilize macrobenthic food items. Trautman (1957) also documents the close association yellow bullheads had to aquatic vegetation in Indian Lake and the subsequent decline of this fishery following habitat alterations which decreased the aquatic vegetation.

In analyzing the various factors and interrelationships presented in this study, one can see the role of the aquatic vegetation is an important factor to the well being of the fishery resource in White Lake. The aquatic macrobenthic organisms which utilize or are associated with the aquatic macrophytes are important food items in the diet of yellow perch, and possibly yellow bullhead and largemouth bass. The aquatic vegetation also serves as cover for other nongame and game fish species present in the lake. These same areas function as spawning sites and nursery areas for other fishes present in White Lake.

Louder (1961) collected rotenone samples in the same general vicinity of White Lake in 1957, 1958, and 1959 on 0.2 hectare sites (0.5 acre). In the three consecutive years that he sampled, a standing crop of 552 fish/ha with a weight of 9.73 kg/ha was estimated. Calculations from rotenone samples collected in the present study provided an estimated standing crop of 838 fish/ha with a weight of 21.05 kg/ha. This is a 151.81% increase in standing crops (fish/ha) and a 216.54% increase in the weight of fish/ha over the last 20 years. In summation, this increase may be directly linked to the available vegetation that serves as feeding areas and areas of cover. However inasmuch as Louder fails to describe the exact technique used for rotenone sampling and to document whether block nets were utilized, the calculations made from his data can only be used to make broad, generalized statements in comparison with this study's data, and not used as a baseline data.

The only species collected in 1978 for which sport fisheries exist were yellow perch, largemouth bass, yellow bullhead, and warmouth. During the three consecutive years that Louder (1961) conducted rotenone samples, yellow perch had a mean estimated standing crop of 58 fish/ha and a weight of 4.45 kg/ha. Calculations from the rotenone samples taken in this study showed that the number of yellow perch per hectare decreased to 47 fish/ha with the weight increasing to 14.75 kg/ha. Largemouth bass also decreased in the number of fish per hectare by 35.72% or from seven fish/ha in Louder's samples to four fish/ha in September 1978. The weight of largemouth bass per hectare increased by 494.59%, or from 0.37 kg/ha to 1.83 kg/ha. The reverse, however, occurred with the yellow bullhead. Its estimated standing crop increased from 43 fish/ha in Louder's samples to 67 fish/ha in September 1978, while the weight of yellow bullheads per hectare decreased from 2.44 kg/ha to 1.82 kg/ha.

This increase-decrease type of relationship, and vice versa, may be a direct result of population density in relation to the carrying capacity of the body of water (Carlander 1977) and the life cycles of the species involved. That is, a massive number of individuals in a given area would experience reduced growth through increased competition of food and space. This negative effect would be offset by increased mortality, lower nativity and/or any other circumstances that would decrease the number of individuals in a given area, thereby increasing the growth rate by lessening the competition for food and space. This type of relationship may have occurred with all species in White Lake, thereby accounting for a portion of the increase in both the number of fish/ha and the weight of the fish/ha that has occurred in White Lake over the previous twenty (20) years.

The water throughout White Lake maintains a certain degree of continuity in quality. The thorough mixing of the water which causes this continuity may be attributed to a number of factors, both natural and artificial, with the natural factors being shallow depth, oval shape and wave action (Louder 1961), and the artificial factors being the users of the lake (i.e., motorboats, skiers, swimmers, etc.).

Water quality parameters conducted by Steve Tedder, Environmental Research Specialist with the Department of Natural Resources and Community Development (1977), revealed that the heavy metals and other toxic substances present in White Lake were well below the water quality criteria established by the Federal Water Pollution Control Administration (1968). In a personal letter from Tedder dated November 30, 1977, he states, "In reviewing this data, I have found no water quality violations."

Because of its slightly infertile water with low pH values, the productivity of White Lake is probably somewhat lower than most lakes in the State of North Carolina. Even though the water quality of White Lake is not ideal for warmwater fish production, all values recorded fell within those ranges considered to be acceptable for warmwater fish propagation and survival.

According to the lake classification scheme presented by Welch (1952), White Lake best fits the productivity classification as a dystrophic lake. This also parallels the mesotrophic description proposed by Uttormark and Wall (1974) in classifying Wisconsin lakes by trophic levels.

Uttormark and Wall (1974) devised a lake classification system based on productivity capabilities and usage. A system similar to this could be developed for White Lake and other bay lakes. They reported that the Wisconsin Department of Natural Resources (1968) established criteria to minimize user conflicts and provide a high quality recreational experience by specifying minimum space requirement for various forms of recreational uses of lakes. While these are somewhat arbitrary and subject to debate they are based on logical rationale, and when applied with judgment, they can be used to calculate use rates for lakes.

Activity	**Space Requirement**
Swimming	185 swimmers/acre
Fishing	8 acres/boat
Boating	15 acres/boat
Water skiing	20 acres/boat

White Lake has a surface area of 1068 acres, so a maximum of 53 boats would be the maximum number of boats which could be used on White Lake at any one time and still meet the criteria established by Uttormark and Wall (1974) to minimize user conflicts and provide a high quality recreational experience. The N. C. Department of Natural Resources and Community Development, Division of State Parks and Lakes (unpublished data), collected data on the boating usage of White Lake during the summer of 1979. According to their survey, an average of 48 boats per day were launched at the public boating ramps during Saturdays and Sundays of each week from April 1, 1979 through September 10, 1979. On 16 of the 48 days that the survey was conducted, the number of boats launched exceeded 53 boats. In addition, there are 235 power boats moored permanently at private boat docks and piers around the perimeter of White Lake during the recreational season. Most of these permanently based boats are used on the lake at least once per week during the warm months, and many are used three to four times per week. Most of the boats used on White Lake are for the purpose of water skiing. This activity could easily contribute to the vegetation problem by causing the stems of vegetation to fragment, thereby allowing them to drift to new locations where they may settle, become rooted and establish beds of vegetation at new locations around the lake.

Yousef (1974) studied the effects of water quality by boating activity in selected Florida lakes. From this study, he determined: (1) Dissolved oxygen profiles and turbidity measurements generally indicated a mixing of the water column following boating activity. (2) Under test conditions, the mixing depth appears to vary directly with horsepower of the motor. The effective mixing depth reached up to 15 feet below the surface with a 50 hp motor. (3) Resuspension of solids from the bottom and aquatic macrophytes was observed following boating activity. Changes in turbidity were dependent on horsepower, depth, operational time and type and nature of bottom sediments. Changes occurred within five minutes in shoreline areas less than five feet deep. (4) Turbidity levels decreased in one hour following cessation of boating activity.

Based on the above references, it does appear that White Lake may be impacted by extremely high boating use and that this activity probably significantly contributes to the vegetation-people problem.

CONCLUSIONS

1. Yellow perch have the highest standing crop by weight of any species of angling importance, and they may be the primary supporters of the sport fishery in White Lake.

2. Macrobenthic organisms, particularly the insect families Trichoptera, Diptera, and Odonata are primary food items in the diet of yellow perch.

3. Macrobenthic organisms, especially those most utilized as forage by yellow perch and other species, are more abundant in heavily vegetated areas than in the moderate or lightly vegetated areas. Therefore, the vegetation in White Lake is beneficial to the sport fishery because it is essential habitat for the production of forage for game and some nongame species.

4. Estimated standing crop of submergent rooted aquatic vegetation present in White Lake was 880.9 kg/ha in the heavy zone; 139.61 kg/ha in the moderate zone; 0.0 kg/ha in the light zone.

5. Two primary genera of rooted submergent aquatic vegetation are present in White Lake, *Eleocharis sp.* and *Utricularia*.

6. The moderate vegetative zone had the greatest diversity of macrobenthic organisms.

7. Fish population data indicated that the fishery is closely associated with vegetative zones of White Lake; 93.02% of all fish collected were taken from the heavily vegetated zone. The remaining 6.97% were collected from the lightly vegetated zone.

8. The mean estimated game fish standing crop was 17.85 kg/ha, while the mean nongame fish standing crop was 3.66 kg/ha.

9. White Lake does not appear to have a vegetation problem resulting from over enrichment or a eutrophication condition. The existing water quality is within acceptable standards.

10. The existing vegetation problem as described by concerned individuals may be a result of overutilization of the lake by high performance inboard and outboard motorboats pulling skiers and pleasure riding on White Lake.

RECOMMENDATIONS

1. No chemical, biological or mechanical techniques should be used in White Lake to control vegetation.

2. Strong considerations should be given to reducing the total number of boats using White Lake.

3. Horsepower restrictions should also be strongly considered.

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Table 1. Estimate standing crop in kilograms/hectare of aquatic vegetation by species and zone collected in White Lake, N. C. from May 1978 through March 1979.

	HEAVY ZONE						
	MAY KG/HA	JULY KG/HA	OCT. KG/HA	NOV. KG/HA	MAR. KG/HA	MEAN KG/HA	PERCENT KG/HA
Eleocharis	282.05	363.95	1222.00	0.00	1363.03	590.34	67.00
Bladderwort	141.02	328.59	963.22	2044.90	0.00	290.65	32.99
Total	423.07	692.44	2185.22	2044.90	1363.03	880.99	99.99
	MODERATE ZONE						
Eleocharis	28.91	0.00	264.42	64.16	264.42	124.38	89.09
Bladderwort	0.00	0.00	0.00	76.15	0.00	15.23	10.90
Total	28.91	0.00	264.42	140.31	264.42	139.61	99.99
	LIGHT ZONE						
Eleocharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bladderwort	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2. Estimated standing crop of macrobenthic organisms per hectare collected by Eckman dredge hauls by family, order, or class by month in the heavy zone in White Lake, N. C., May 1978 - March 1979.

HEAVY ZONE

SPECIES	MAY	JULY	OCT.	NOV.	MAR.	MEAN
Oligochaeta	0.0	1,865,345.0	0.0	284,161.0	0.0	429.901.0
Hirudinea	0.0	0.0	861,094.0	430,547.0	430,547.0	344,438.0
Amphipoda	572,628.0	2,436,896.0	2,006,349.0	30,612,863.0	8,753,021.0	8,876,351.0
Ephemeroptera	0.0	0.0	0.0	0.0	0.0	0.0
Odonata	0.0	0.0	0.0	0.0	0.0	0.0
Hemiptera	0.0	0.0	0.0	0.0	0.0	0.0
Megaloptera	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera	0.0	2,583,282.0	2,725,363.0	9,041,488.0	8,722,474.0	4,534,521.0
Coleoptera	47,360.0	0.0	430,547.0	0.0	0.0	95,581.0
Diptera	1,575,802.0	0.0	1,078,538.0	5,020,178.0	2,152,735.0	1,965,451.0
Total	2,195,790.0	6,885,523.0	7,101,891.0	45,389,237.0	19,658,777.0	16,246,243.0

Table 3. Estimated standing crop of macrobenthic organisms per hectare collected by Eckman dredge hauls by family, order, or class by month in the moderate zone in White Lake, N. C., May 1978 - March 1979.

MODERATE ZONE

SPECIES	MAY	JULY	OCT.	NOV.	MAR.	MEAN
Oligochaeta	0.0	180,830.0	0.0	176,524.0	21,527.0	114,525.0
Hirudinea	0.0	357,354.0	396,103.0	714,708.0	430,547.0	379,742.0
Amphipoda	645,821.0	142,081.0	5,308,645.0	8,787,465.0	4,339,914.0	3,844,785.0
Ephemoptera	0.0	34,444.0	0.0	0.0	0.0	6,889.0
Odonata	0.0	68,888.0	447,769.0	0.0	0.0	103,331.0
Hemiptera	0.0	0.0	0.0	357,354.0	0.0	71,471.0
Megaloptera	0.0	0.0	350,354.0	0.0	0.0	71,471.0
Trichoptera	787,901.0	607,091.0	2,079,542.0	2,329,259.0	1,399,278.0	1,440,610.0
Coleoptera	0.0	107,637.0	215,274.0	215,274.0	722,910.0	172,219.0
Diptera	1,772,188.0	861,094.0	1,218,448.0	1,648,995.0	2,294,816.0	1,549,108.0
Total	3,155.910.0	2,359,399.0	10,023,135.0	14,229,579.0	8,808,992.0	7,754,151.0

Table 4. Estimated standing crop of macrobenthic organisms per hectare collected by Eckman dredge hauls by family, order, or class by month in the light zone in White Lake, N. C., May 1978 - March 1979.

LIGHT ZONE

SPECIES	MAY	JULY	OCT.	NOV.	MAR.	MEAN
Oligochaeta	0.0	86,109.0	0.0	516,656.0	861,094.0	292,772.0
Hirudinea	0.0	0.0	1,119,422.0	86,109.0	86,109.0	258,328.0
Amphipoda	1,291,641.0	1,205,572.0	1,205,532.0	249,717.0	0.0	790,484.0
Ephemoptera	0.0	0.0	0.0	0.0	0.0	0.0
Odonata	0.0	0.0	0.0	0.0	0.0	0.0
Hemiptera	0.0	0.0	0.0	0.0	0.0	0.0
Megaloptera	0.0	0.0	86,109.0	0.0	0.0	17,222.0
Trichoptera	3,013,829.0	688,875.0	430,547.0	1,119,422.0	688,875.0	1,118,310.0
Coleoptera	0.0	0.0	0.0	86,109.0	0.0	17,222.0
Diptera	3,691,941.0	1,377,751.0	430,547.0	861,094.0	344,438.0	1,347,154.0
Total	7,997,411.0	3,358,267.0	3,272,157.0	2,919,107.0	1,980,516.0	3,905,492.0

Table 5. Yearly mean estimated standing crop (number/hectare) of benthic organisms in White Lake by family (insects), class (annelids), or order (crustaceans), by zone.

ORGANISMS	HEAVY ZONE	MODERATE ZONE	LIGHT ZONE	TOTAL
Oligocheata	429,901	114,525	292,772	837,198
Hirudinea	344,438	379,742	258,328	982,508
Amphipoda	8,876,351	3,844,785	790,484	13,511,620
Empheroptera	0	6,889	0	6,889
Odonata	0	103,331	0	103,331
Hemiptera	0	71,471	0	71,471
Megaloptera	0	71,471	17,222	88,693
Trichoptera	4,534,521	1,440,610	1,188,310	7,163,441
Coleoptera	95,581	172,219	17,222	285,022
Diptera	1,965,451	1,549,108	1,341,154	4,855,713
Total	16,246,243	7,754,151	3,905,492	27,905,886

Table 6. Food habits of six largemouth bass collected in rotenone samples from White Lake in September 1978.

FOOD ITEM	NUMBER	PERCENT BY NUMBER	FREQUENCY OF OCCURRENCE
Crustacea			
Decapoda	1	5.26	16.66
Insecta			
Diptera	1	5.26	16.66
Orthoptera	1	5.26	16.66
Unidentified Insect Fragment	2	10.52	33.33
Osteichthyes			
Lepomis sp.	11	57.89	33.33
Tessellated Darter	2	10.52	33.33
Unidentified Fish Remains	1	5.26	16.66
Totals	19	99.97	

Table 7. Food habits of 32 yellow perch collected in rotenone samples from White Lake in September 1978.

FOOD ITEM	NUMBER	PERCENT BY NUMBER	FREQUENCY OF OCCURRENCE
Crustacea			
Eubranchiopoda	3	0.51	3.13
Amphipoda	4	0.69	9.38
Decapoda	6	1.03	15.63
Insecta			
Collembola	6	1.03	9.38
Ephemeroptera	5	0.86	6.25
Odonata	41	7.02	18.75
Orthoptera	1	0.18	3.13
Megaloptera	1	0.18	3.13
Trichoptera	458	78.43	46.88
Diptera	17	3.05	18.75
Unidentified Insect Fragments	4	0.69	12.50
Osteichthyes			
Lepomis sp.	30	5.14	15.63
Etheostoma sp.	8	1.38	18.75
Empty	-	-	12.50
Total	584	100.19	

Table 8. Food habits of four yellow bullhead collected in rotenone samples from White Lake in September 1978.

FOOD ITEM	NUMBER	PERCENT BY NUMBER	FREQUENCY OF OCCURRENCE
Osteichthyes			
Lempomis sp.	4	66.66	50.0
Bullhead	1	16.66	25.0
Tessallated darter	1	16.66	25.0
Total	6	99.98	

Table 9.

SAMPLE SITE	HEAVILY VEGETATED				LIGHTLY VEGETATED				MEAN			
Area in Acres	0.25				0.25				0.25			
Area in Hectares	0.10				0.1				0.10			
	NO.	WT (G)			NO.	WT (G)			NO.	WT (G)		
Total Game Fish/ha	1365	1785			86	2024			725.5	1905		
Total Nongame Fish/ha	195	3660			31	350			113.0	2005		

SPECIES	PER HECTARE		% TOTAL		PER HECTARE		% TOTAL		PER HECTARE		% TOTAL	
	NO.	WT (G)	NO.	WT (G)	NO.	WT (G)	NO.	WT (G)	NO.	WT (G)	NO.	WT (G)
Black Banded Sunfish	3.0	10	0.19	0.04	0.0	0.0	0.0	0.0	1.5	5.0	0.1	0.02
Blue Spotted Sunfish	696.0	2,700	44.6	12.5	13.0	30	11.1	0.1	354.5	1,365	42.2	6.4
Warmouth	40.0	790	2.5	3.6	0.0	0.0	0.0	0.0	20.0	395	2.3	1.8
Yellow Perch	24.0	9,770	1.5	45.4	70.0	19,730	59.8	95.8	47	14,750	5.6	70.0
Largemouth Bass	6.0	3,190	0.3	14.8	3.0	480	2.5	2.3	4.5	1,835	0.5	8.7
Centrarchids	596.0	1,390	38.2	6.4	0.0	0.0	0.0	0.0	298.0	695	35.5	3.3
Tessellated Darter	15.0	T	0.9	T	2.0	T	1.7	T	8.5	T	1.0	T
Yellow Bullhead	125.0	3,420	8.0	15.8	10.0	220	8.5	1.0	67.5	1,820	8.0	8.6
Tadpole Madtom	55.0	240	3.5	1.1	19.0	130	16.2	0.6	37.0	185	4.4	.87
Total	1560	21,510	99.69	99.64	117	20,590	99.8	99.8	838.5	21,050	100.6	99.69
		21.510 kg/ha				20.59 kg/ha				21.05 kg/ha		

Table 10. Water quality values collected from White Lake, May 1978 - March 1979.

	MONTH														
	MAY			JULY			OCTOBER			NOVEMBER			MARCH		
SAMPLE SITE	A_1	C_4	D_4	A_1	C_4	D_4	A_1	C_4	D_4	A_1	C_4	D_4	A_1	C_4	D_4
Parameter															
Dissolved Oxygen*	8.5	10.0	9.0	7.0	8.0	8.0	11.0	10.0	11.0	10.0	13.0	13.0	10.0	9.0	9.0
Total Hardness*	17.1	17.1	17.1	34.2	34.2	17.1	51.3	68.1	51.3	51.3	51.3	51.3	17.1	17.1	17.1
Total Alkalinity*	17.1	17.1	17.1	17.1	17.1	17.1	34.2	34.2	51.3	34.2	34.2	34.2	17.1	17.1	17.1
PH	5.3	5.5	5.5	5.3	5.5	5.5	6.6	6.5	6.5	6.5	6.3	6.0	6.0	6.0	6.0
Temperature °C	20.6	21.1	21.1	28.9	26.7	27.2	16.7	17.2	17.2	15.0	16.7	16.7	15.0	15.0	15.0
Secchi (cm)	278.5	298.5	270.2	213.5	276.0	152.6	198.2	198.0	274.3	200.0	200.0	200.0	167.64	137.1	137.1

*Expressed as parts per million (ppm).

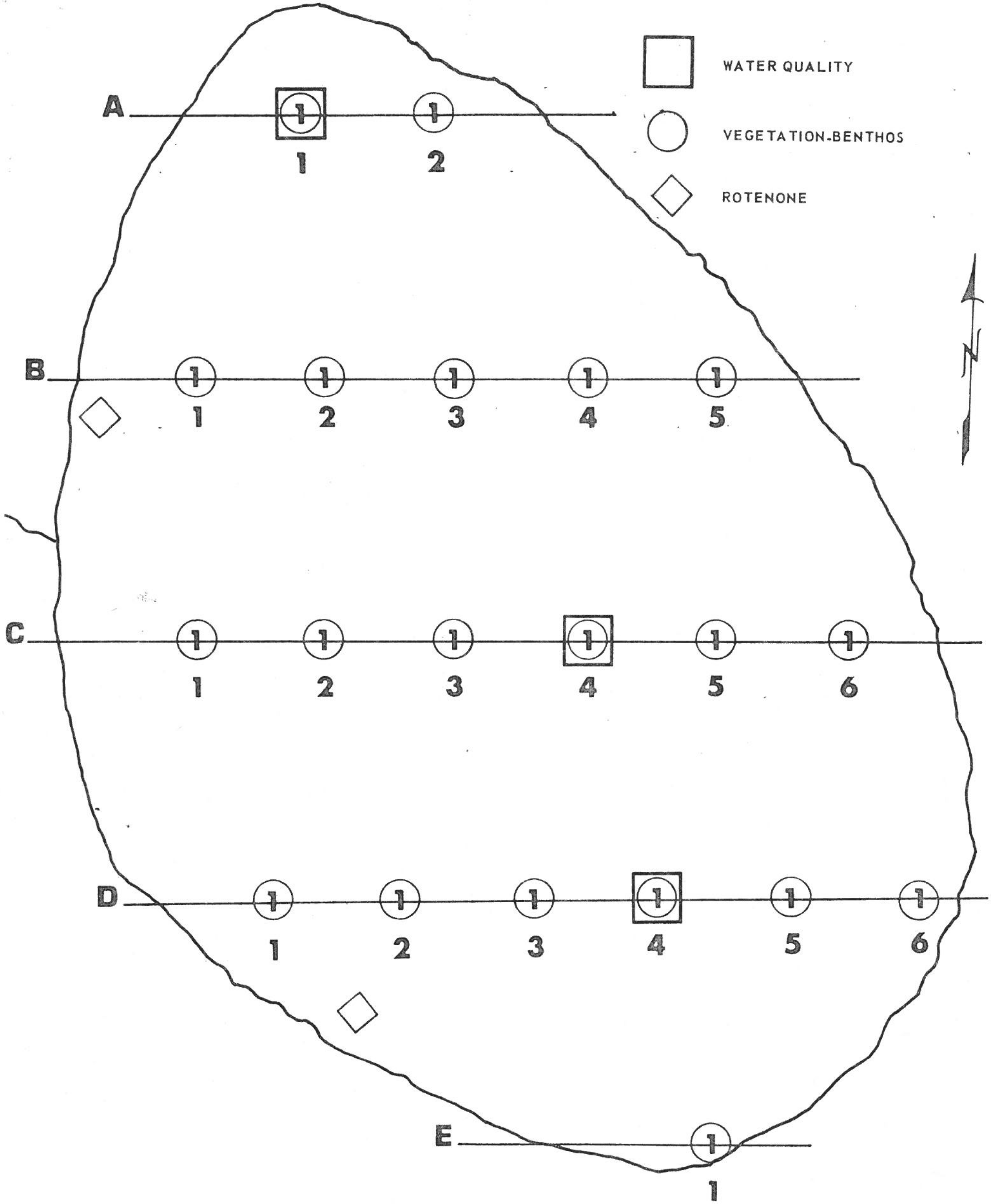

Figure 1. White Lake, N. C., indicating transect sample lines and stations.

Figure 2. Estimated area affected by vegetation.