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THE SOUTH CAROLINA DEPARTMENT OF HEALTH
AND ENVIRONMENTAL CONTROL, AND THE
NUCLEAR REGULATORY COMMISSION

DAMES & MOORE

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SUMMARY

The monitoring programs being conducted at the present time are designed to meet the licensing requirements of the regulatory agencies.

The Federal Energy Regulatory Commission (FERC) requires five years of post operational data for the Fairfield Pumped Storage Facility. To satisfy the FERC requirements, water quality and biological parameters are monitored in the Broad River and in Parr and Monticello Reservoirs.

The monitoring program is also designed to meet the licensing requirements of the Nuclear Regulatory Commission (NRC) and the requirements of the National Pollution Discharge Elimination System (NPDES) permit for the Virgil C. Summer Nuclear Station (VCSNS) issued by the South Carolina Department of Health and Environmental Control (SCDHEC). These studies will provide for comparison between preoperational baseline conditions and postoperational impacts.

This report, which is the fifth one for the current monitoring program, will be submitted to FERC, NRC, and the SCDHEC. The report includes a summary of data for aquatic biology, surface water chemistry, and terrestrial data collected throughout 1981. The discussion of the data compares information collected during this reporting period with previous data, where applicable. The purpose of the environmental monitoring program is twofold: 1) to establish baseline conditions on Monticello Reservoir prior to the operation of the VCSNS, and 2) to determine what impacts, if any, are occurring to the biota in Parr and Monticello Reservoirs as a result of operating the Fairfield Pumped Storage Facility (FPSF). A detailed description of the history of the reservoirs, collecting stations, and other pertinent information were reported in Section 1 of the Environmental Monitoring Report, June through December 1978 (Dames & Moore, 1978).

The surface water temperatures at all stations during this reporting period were below the 32.2°C maximum temperature standard established by the SCDHEC, with the exception of a single hourly value of 32.4°C recorded during July at Station 11 (Neal Shoals Dam). Water temperatures generally followed seasonal trends and were highest in July and lowest in January. At the Broad River and Parr Reservoir Stations, no seasonal thermocline occurred; this was due to the shallow depths and the high current velocity. In Monticello Reservoir, stratification did occur and a thermocline was noted at the deeper stations from April through October.

The dissolved oxygen (DO) concentrations, along with temperature, followed seasonal trends. Higher DO values occurred during the colder months and lower values during the warmer months. At the Parr Reservoir and Broad River Stations, DO was found throughout the water columns in a sufficient concentration to support aquatic life. In Monticello Reservoir, DO concentrations at the surface and upper levels of the water column were generally greater than the minimal statutory limit (4.0 mg/l) established by the SCDHEC. There were, however, occasional periods during June through September that depressed oxygen levels were recorded at the United States Geological Survey (USGS) monitor at the FPSF intake. At the lower strata of the water column and at the bottom of most stations in Monticello Reservoir the DO values were also below the standards established by the SCDHEC. These depressed oxygen concentrations were due to the stratification and incomplete mixing of the water, a situation which was not found during the colder months when the reservoir "turned over" and complete mixing of the water occurred.

The pH values recorded at the stations in the Broad River and Parr Reservoir were within the range (6.0 to 8.5 units) of the values prescribed by the SCDHEC. In Monticello Reservoir the pH exceeded the state standard at the surface of certain stations during the spring and summer months, and in the subimpoundment during May. The high values

were attributed to photosynthetic activity and can be expected during the warm months. Below the thermocline in Monticello Reservoir, the pH fell below the state standard during several months of the year; this situation is not considered unusual in reservoirs that are stratified. In general, the pH followed seasonal trends in the water bodies. The higher values were recorded during the spring and summer months when photosynthesis of phytoplankton was at its peak; the lower (more neutral) values occurred during the colder months.

The water clarity, as indicated by higher transparency readings, was much better in Monticello Reservoir than in either the Parr Reservoir or the Broad River Stations. This increased transparency was due to settling of suspended particles characteristic of reservoirs as compared to the more turbid conditions that exist in lotic systems, such as the Broad River and Parr Reservoir.

In Parr Reservoir and the Broad River, nitrate values have ranged from 0.1 mg/liter to 5.7 mg/liter during 1978 through 1981. The mean value for this 4-year period was 1.85 mg/liter. The mean values for nitrate have shown very little fluctuation during these studies, ranging from 1.80 to 1.89.

At the Neal Shoals Dam station, during 1978 through 1981, nitrate values have ranged from 0.5 mg/liter to 4.8 mg/liter. The mean value during this 4-year period was 1.9 mg/liter.

In Monticello Reservoir nitrate values ranged from 0.1 mg/liter to 4.5 mg/liter during 1978 through 1981. The mean value for this 4-year period was 1.28 mg/liter. There has been no well defined pattern for nitrate values in Monticello Reservoir during this time. This pattern is not uncommon in new reservoirs that have been recently flooded, since nutrients are being leached from the soil. In addition the water quality in Monticello Reservoir is influenced by water that is pumped

up from the Broad River. Values of nitrate in the subimpoundment ranged from 0.1 mg/liter to 2.1 mg/liter during 1978 through 1981. The mean value during the 4-year period was 0.74 mg/liter. The trend for nitrate in the subimpoundment has been to generally increase; this increase in nitrate may be attributed in part to the addition of fertilizer as part of the management program for this water body.

Phosphate levels in Parr Reservoir and the Broad River ranged from 0.01 mg/liter to 0.92 mg/liter during 1978 through 1981. The mean value for the 4-year period was 0.33 mg/liter. The general trend showed a decrease in the mean value during 1981 (0.17 mg/liter) after a high mean value of 0.75 mg/liter was reached during 1980. At the Neal Shoals Dam station the range of phosphate values was from 0.09 mg/liter to 4.4 mg/liter; the mean value during the 4-year period was 0.64 mg/liter. In Monticello Reservoir phosphate values ranged from 0.01 mg/liter to 4.5 mg/liter. The mean value during the 1978 through 1981 period was 0.41 mg/liter. There was a general increase in phosphate from 1978 through 1980, and then the values decreased during 1981. In the subimpoundment the phosphate values ranged from 0.03 mg/liter to 2.1 mg/liter, with a mean phosphate value of 0.31 mg/liter. The values of phosphate in the subimpoundment have fluctuated, due in part to the application of fertilizer during several months of the year.

Ammonia values at stations in the Broad River and Parr Reservoir ranged from 0.1 mg/liter to 1.6 mg/liter during 1978 through 1981. The mean value for this 4-year period was 0.35 mg/liter. There was a general increase in ammonia from 1978 through 1980 and then a decrease in 1981. At the Neal Shoals Dam station the ammonia values ranged from 0.1 mg/liter to 1.1 mg/liter. The mean value during the period 1978 through 1981 was 0.34 mg/liter. In Monticello Reservoir ammonia values ranged from 0.1 mg/liter to 1.0 mg/liter. The mean value during the period 1978 through 1981 was 0.32 mg/liter. In the subimpoundment

ammonia values ranged from 0.1 to 2.2 mg/liter; the mean value for the period 1978 through 1981 was 0.6 mg/liter.

At all of the water bodies, at least once during the summer, the concentration of un-ionized ammonia exceeded the criterion recommended by the U.S. Environmental Protection Agency (USEPA) (1976). This condition occurred during 1980, but only in Monticello Reservoir. The criterion suggested for ammonia is based on the amount of un-ionized ammonia (NH3) present in solution, which is highly dependent on the temperature and pH of the water body being sampled. Although the concentrations of total ammonia (NH3 + NH4) were within the historical range occurring in the Broad River, the high pH values recorded at the surface resulted in a greater percentage of the total ammonia being in the un-ionized form. The un-ionized ammonia concentration recorded at the collecting stations is not considered unusual because the temperature, pH, and total ammonia values were within the ranges expected under natural conditions.

Concentrations of heavy metals in Parr Reservoir and the Broad River were detected in water samples but occurred in concentrations at or below the lower limit of the analytical procedure with the exception of copper, zinc, and iron. Copper exceeded the lower sensitivity limit at Station 5A (Broad River) during July; however, the value (0.03 mg/liter) was less than the maximum (0.06 mg/liter) recommended by the USEPA (1976) for the well being of aquatic species. Concentrations of zinc were detected at several stations, several times during the year. However in only one case (Station 2, October; 0.16 mg/liter), did the value exceed the maximum criterion (0.05 mg/liter) established by the USEPA (1976) for the well being of aquatic species. Concentrations of iron at the stations on the Broad River and in Parr Reservoir exceeded the recommended maximum (1.0 mg/liter) criterion established by the USEPA at least once during the year. These high values were attributed to

iron being a prime constituent of the soils in the area and were coincidental with runoff and high suspended solids values.

In the subimpoundment, the concentration of heavy metals was below the level of sensitivity of the analytical procedure. In Monticello Reservoir, the concentration of heavy metals throughout the current monitoring program, with the exception of iron and zinc, was below the level of sensitivity of the analytical procedure. The values of iron and zinc did not exceed recommended levels established by the USEPA. These metals are soluble constituents of the soil in the area and high values are to be expected in waters receiving runoff from these soils.

Copper values have ranged from <0.02 - 0.03 mg/liter at stations in the Broad River and in Parr Reservoir. At Stations 1 and 5A, values of 0.03 mg/liter were recorded twice during the period, once for each station. All of the other values recorded were between <0.02 or 0.02 mg/liter. At stations in Monticello Reservoir, values were either <0.02 or 0.02 mg/liter. Zinc values at stations in the Broad River and Parr Reservoir have ranged from 0.01 to 0.59 mg/liter from 1978 through 1981. The trend has been a decrease since 1978. During 1978 and 1979 the mean values for stations in the Broad River and Parr Reservoir were 0.02 mg/liter. During 1980 and 1981 the mean values were 0.01 mg/liter, with the exception of Stations 1 (1980) and 2 (1981), where the mean values were 0.02 mg/liter. In Monticello Reservoir zinc values have ranged from 0.01 to 0.52 mg/liter. The general trend has been a decrease in zinc concentrations from 1978 to the present. In 1978, 1979, and 1980 the mean values were generally 0.02 mg/liter while during 1981 all the stations recorded zinc values of 0.01 mg/liter. Iron values in Parr Reservoir and the Broad River during the past four years have ranged from 0.22 to 29.0 mg/liter. Mean values of iron concentrations have generally declined since 1978. The values recorded for 1978 and 1979 were 2.01 and 1.79 mg/liter, respectively; during 1980 the mean iron concentration was 2.53 mg/liter. It was during 1980 that the largest maximum values were recorded, 13, 20, and 29 mg/liter.

The reason(s) for these high values are unknown, but are probably due to rainfall runoff preceding the sampling period. During 1981 the iron values decreased and the mean concentration was 1.12 mg/liter. In Monticello Reservoir iron values have ranged from 0.02 to 0.86 mg/liter. The trend has been a slight decrease since 1978; the mean average has ranged from 0.32 mg/liter in 1978 to 0.28 mg/liter in 1981.

The vascular hydrophyte community in Parr Reservoir has become abundant. Much of the vegetation is located in backwater areas of the reservoir. The community of hydrophytes at the Neal Shoals Dam sampling station has shown very little change in species composition since 1978. Willows continue to be the dominant form of vegetation at this location. The subimpoundment contains the most diverse and abundant communities of hydrophytes, compared to the other sampling locations. The rich assemblage of flora may be attributed to the fertilization program being carried out at this location. In Monticello Reservoir, vegetative associations, especially within the coves, are continuing to show development. Communities of cattails, rushes, and willows dominate the coves; in these areas the substrate appears to be high in organic content, associated with the development of this vegetation.

The phytoplankton species composition in Parr Reservoir showed definite seasonal patterns during the past four years. An algal bloom was present during January at all stations in Parr Reservoir. During the next three collecting periods (April, July, October) a general decline in numbers was observed with the October samples showing the lowest numbers. Diatoms predominated the collections at all stations during every sampling period, with the exception of Station B. At Station B, phytoplankton samples were comprised primarily of green and blue green algae. At the Neal Shoals Dam station, diatoms were the most abundant phytoplankton group during all the sampling periods, except during July when the green algae were the most dominant. The lowest phytoplankton densities occurred during January and reached their peak during July. At the subimpoundment, phytoplankton densities were highest during

October and lowest in January. During January and July diatoms were the most abundant algal group at this station, making up more than half of the community. During April, chlorophytes were the most abundant group, comprising nearly two-thirds of the community, and during October the blue green algae were the most numerous. In Monticello Reservoir phytoplankton densities reached their peak at all stations during the July sampling period and then declined to their lowest level during November. During January there was an algal bloom on this reservoir. Diatoms were the most abundant group of organisms collected throughout the year with the exception of August and September; during August the green algae were the dominant group and in September diatoms and green algae were codominants.

An analysis of the zooplankton data during 1981 indicated that the species composition was similar to that reported during the 1978, 1979, and 1980 investigations. The distribution of taxa in the water bodies appeared to follow seasonal trends; this distribution also indicated that generally stable zooplankton communities existed, as compared with previous years' data. The rotifers were the dominant group collected throughout the study area. The overall densities and taxonomic diversities at the stations appeared to be similar to the historical data.

The larval fish collections made during 1981 revealed that each of the four major areas (Parr and Monticello Reservoirs, Neal Shoals, and the subimpoundment) harbored a distinct larval fish community. The ichthyofauna collected in Parr Reservoir were the most diverse among the areas sampled; eight taxa were collected here with the clupeids (gizzard shad) being the dominant species. At the Neal Shoals Dam station, six taxa were collected with the gizzard shad and crappie being the most abundant. The dominant ichthyofauna in the subimpoundment were the sunfishes; however, during 1981 the gizzard shad increased their numbers substantially, indicating that reproducing populations have become established. The subimpoundment also had the highest overall larval fish density of the collecting areas. In Monticello Reservoir

the percicthids (temperate basses) are becoming more abundant indicating that reproducing populations of these species are occurring. Collections from Monticello Reservoir showed the greatest overall increase in larval fish diversity, as compared to previous years. This increase is indicative of a developing fishery.

The benthic macroinvertebrate communities in all of the water bodies sampled illustrated stable conditions with respect to density and diversity of organisms. The only exception to this was at Station B in Parr Reservoir where there was a decline in ecological stability and complexity as compared to previous years. This station is in the tailrace canal and is subjected to daily, high current velocities. Thus, the substrate is scoured providing a poor habitat for benthic organisms. The benthic macroinvertebrate community at Neal Shoals Dam and Parr Reservoir was relatively unchanged from the previous studies, with the exception of Transect C in Parr Reservoir. At Transect C, during the past three years there has been a trend of declining numbers and diversity of benthic organisms. The reasons for the decline is due to the fluctuating water levels caused by the FPSF. This trend is still within the limits of natural variation in Parr Reservoir. At the Neal Shoals Dam station, the benthic community shows maintenance of ecological stability and complexity, compared with previous years. In the subimpoundment, the benthic community that is established continues to increase while no new organisms are colonizing the area; thus, there is a high density and a low diversity. The benthic community in Monticello Reservoir continues to increase in overall mean annual values for density and taxonomic composition, with the exception of the extreme northern area of Monticello Reservoir; this area maintained a benthic community structure in 1981 similar to that reported for 1980. The Asiatic clam continues to colonize new areas of Monticello Reservoir and has now been documented at all of the collecting areas with the exception of the subimpoundment.

The results of the fish sampling efforts indicated that the fish community of the water bodies in the study area was dominated by two groups: the clupeids (shad) and centrarchids (bream, bass, and crappie).

The clupeid family was represented by one species - gizzard shad. Gizzard shad were collected at least once during the year from every sampling station. The centrarchid family was represented by nine species, of which bluegill was the most common; this species was also collected at every sampling station at least once during the year. In Parr Reservoir, bluegill was the most numerous species collected and gizzard shad was second in abundance. Overall, the species composition of Parr Reservoir has remained virtually the same throughout the past four years. The groups that have been most abundant, such as the sunfish, shad, gar, carp, shiners, carpsuckers, and some species of catfish, have been found in collections every year, whereas those groups that have a relatively low population occurred sporadically from year to year; these groups included some bullheads, madtoms, yellow perch, and darters. Of special interest is the white bass that occurred in Parr Reservoir for the first time during 1981. This species is occurring in larger numbers in Monticello Reservoir and apparently was transported into Parr Reservoir through the FPSF. Age and growth studies indicated that five year classes of both gizzard shad and bluegill were found in Parr Reservoir. Growth of both species was somewhat slower than populations from similar habitats in the southeastern United States. Standing crop estimates from Parr Reservoir decreased from the previous year, which may have been attributed, in part, to the fluctuating water levels and the extremely low water conditions that prevailed during much of 1981. The most abundant species collected was the gizzard shad. At the Neal Shoals Dam sampling station, the least number of fish species (12) was collected during 1981 compared to previous years, when 19, 14, and 16 species were collected during 1978, 1979, and 1980, respectively. The species that were most common during 1981 included the sunfish and gizzard shad. The groups that have a small population do not appear in the collections every year and

include some of the suckers, catfish, including the bullheads, and perch. Age and growth studies indicated that five year classes of gizzard shad and four year classes of bluegill were found. Growth of both species was somewhat slower when compared to historical data from similar habitats. Standing crop estimates from the Neal Shoals Dam area decreased slightly from the previous year. The most abundant species collected was the largemouth bass which comprised more than 63 percent of the collection. In the subimpoundment, the species composition has been identical for the past three years. This consistency in the species composition throughout the years may be attributed to the subimpoundment being a closed system and to the management practices being employed by SCE&G. Bluegill was the most abundant species collected and the brown bullhead was next in total numbers collected. Gizzard shad are becoming more abundant every year in the subimpoundment. In addition, those individuals that are collected are much larger than from the other collecting areas. These larger individuals may be affecting population densities by being capable of producing more eggs. The larger size of these shad are attributed to the low population density, with reduced intraspecific competition, and the greater density of algae present in the subimpoundment. Age and growth studies indicated that four year classes of the gizzard shad and five year classes of the brown bullhead occurred. Growth of the brown bullhead was similar in the subimpoundment to that found in other comparable habitats. Growth of the bluegill in this reservoir was somewhat slower when compared to historical data. In Monticello Reservoir, the fish community was dominated by the sunfishes and gizzard shad, with a total of thirty species being collected during 1981; this is comparable to the previous years when 25, 31, and 27 species were collected in 1980, 1979, and 1978, respectively. Nine species of sunfish were identified with bluegill being the most abundant. Gizzard shad was second in numerical abundance. The spottail shiner was collected for the first time in the study area. This species is common in parts of South Carolina, and has been recorded from the Broad River watershed. During 1981 no gar were collected from Monticello Reservoir, although they

have been collected during previous years; their absence during 1981 indicates that their numbers are decreasing in this reservoir. Age and growth studies determined that four-year classes of bluegill and gizzard shad were found in the reservoir and that growth of both species was slower than other populations in similar habitats.

The results of the avian surveys indicated that the bird populations along the control and test auto survey routes were high in both density and diversity. Although the test route showed approximately the same number of birds for the 1980 and 1981 surveys (1980, 8.9 birds; 1981, 8.4 birds), the avian density was slightly greater than in most previous years (mean of 8.0 birds). The game birds, exemplified by bobwhite, were found to be at levels similar to previous years. The bobwhite population tends to be more sedentary than mourning doves and thus sampling results are not as influenced by flocks moving into the area during the survey as are the results for the mourning dove count. The avian surveys also identified two immature bald eagles in 1981; eagles have been sighted during the previous three years. It is possible that these immature birds could form a breeding pair in future years. The wide expanse of water offered by Monticello Reservoir and the abundant fish life present make this an ideal habitat for the eagles.

The waterfowl survey indicated that Monticello Reservoir is an important sanctuary for ducks and other aquatic bird species. During the peak of the migrating season (fall and winter), waterfowl were abundant in Parr Reservoir. Mallards, black ducks and blue-winged teal were the most common species. During the summer months few resident species were observed. The wood duck is the only resident duck that breeds here regularly, although mallards will occasionally occur in this region. However, wood ducks have not been abundant here since the reservoirs were constructed. They bred in the flooded portions of Monticello Reservoir before it was completely filled, and a pair of wood ducks was observed in Parr Reservoir during the summer of 1979. It appears that the fluctuating water levels in the reservoirs is

disturbing to this species, so that wood ducks have probably moved to more stable areas of the Broad River.

The interpretation of the 1981 aerial photographs indicated that there was no discernable evidence of decline or change in tree vigor in the site vicinity. The only land use changes noted during 1981 were areas of clear cutting for timber removal on private land.

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1.0 INTRODUCTION

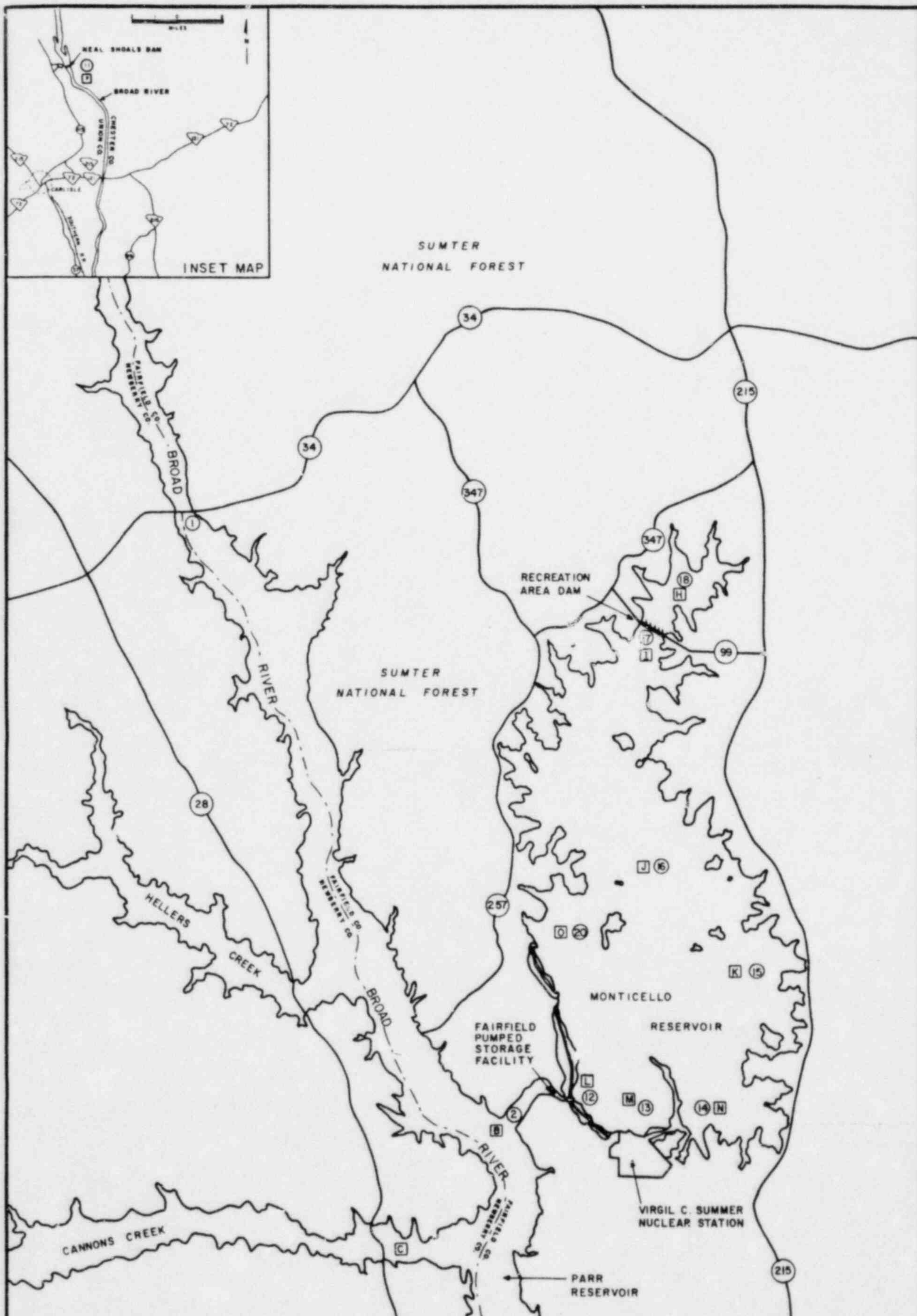
The present environmental monitoring program commenced in June 1978. At that time surface water and aquatic biological data were first collected on Monticello Reservoir, the subimpoundment, and at Neal Shoals Dam; aquatic biological and surface water data had been collected on Parr Reservoir for a number of years prior to 1978. Terrestrial biological data had also been collected in the site vicinity prior to 1978.

This report contains the results of the aquatic and terrestrial data collected for the Environmental Monitoring Program. The results of the surface water quality program include data taken by NUS Corporation; the biological data were collected by Dames & Moore. The reporting period for the surface water quality, the aquatic data, and the terrestrial data presented herein is for the year 1981; the data collected during 1981 are compared with earlier data where applicable. The purpose of the environmental monitoring program is twofold: 1) to establish baseline conditions on Monticello Reservoir prior to the operation of the VCSNS, and 2) to determine what impacts, if any, are occurring to the biota in Parr and Monticello Reservoir as a result of operating the FPSF. A detailed description of the history of the reservoirs, collecting stations, and other pertinent information may be found in Section 1 of the Environmental Monitoring Report, June through December 1978 (Dames & Moore, 1978).

2.0 AQUATIC SURVEY

2.1 SAMPLING LOCATIONS AND FREQUENCY

The sampling locations were documented in the 1978 Biologic. l Monitoring Report (Dames & Moore, 1978). The stations sampled during January through December 1981 are identical to those reported in 1978 and are ident.fied on Figure 2.1.1. The biological and surface water quality information has been collected from four major areas, including: Parr Reservoir, Neal Shoals Dam, the subimpoundment, and Monticello Reservoir. During the quarterly sampling programs (January, April, July, and October), all stations and all components of the aquatic ecosystem were sampled, including: phytoplankton, vascular hydrophytes, zooplankton, ichthyoplankton, benthic macroinvertebrates, and adult fish. In addition, the quarterly scope of work for the surface water quality program was carried out. During the monthly sampling program (January through December) phytoplankton were sampled at six locations in Monticello Reservoir, the surface water quality program was carried out, and ichthyoplankton were sampled according to the established schedule. Sampling for adult fish, in addition to the regularly scheduled quarterly program, occurred at Stations I and M in Monticello Reservoir, three weeks prior to and three weeks after e regularly scheduled spring sampling in April. A summary of biological and surface water collecting activities is shown in Figure 2.1.2.



South Carolina Electric & Gas Co.

Sampling Stations for the Aquatic Monitoring Programs

Figure 2.1.1

VIRGIL C. SUMMER NUCLEAR STATION AND FAIRFIELD PUMPED STORAGE PROJECTS

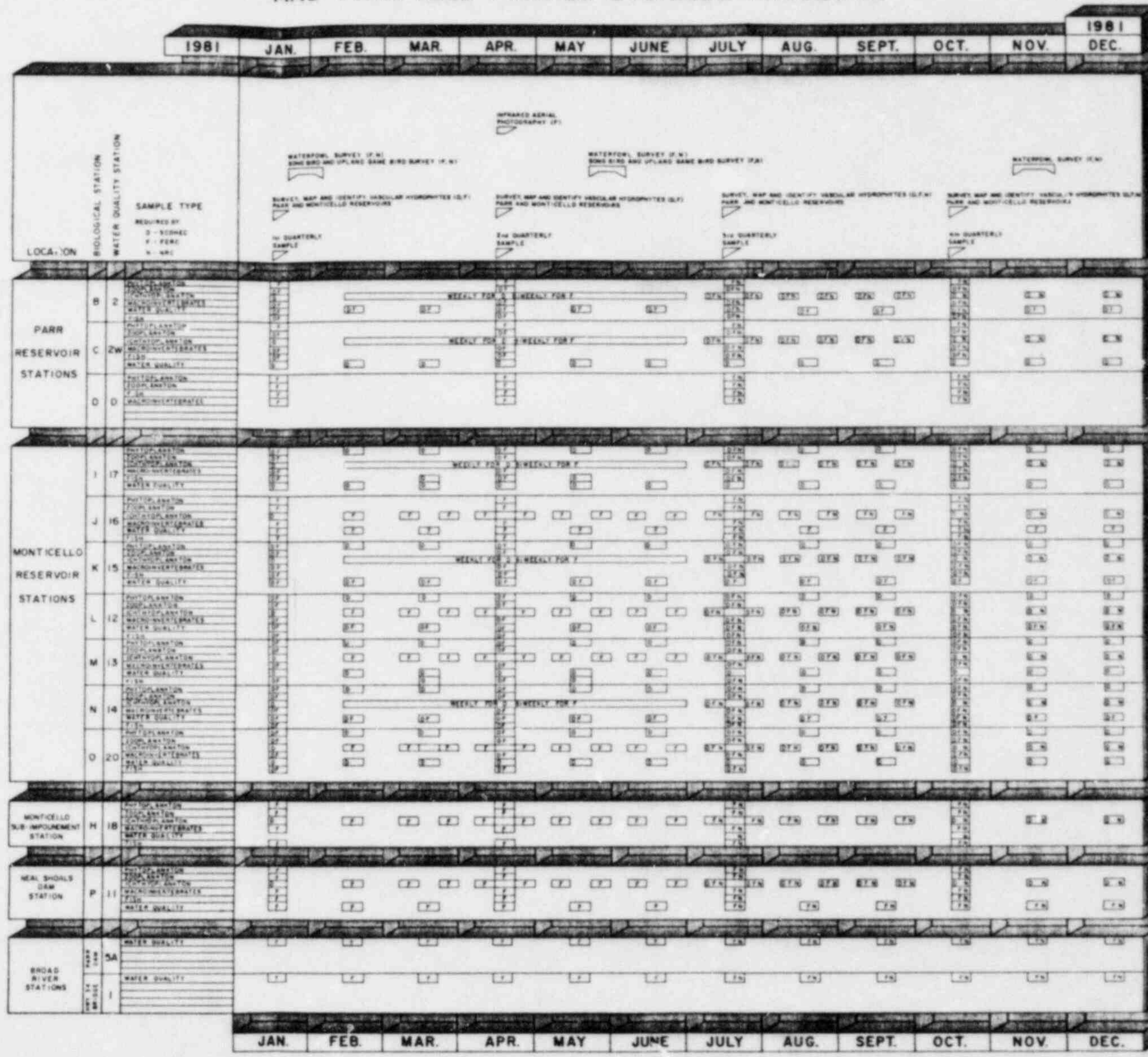


Figure 2.1.2. Environmental Sampling Program, January Through December 1981.

2.2 WATER QUALITY

2.2.1 Introduction

Water quality samples and physical measurements were obtained once a month at a series of stations in the Broad River, Parr Reservoir, and Monticello Reservoir from January 1981 through December 1981 as part of the Summer/Fairfield Environmental Monitoring Program Water Quality study.

The Water Quality study was designed to determine the baseline conditions on Monticello Reservoir prior to the operation of the VCSNS and to determine what changes, if any, are occurring in Parr and Monticello Reservoirs as a result of operating the FPSF. These data will also be used to determine if the existing water quality in the river and reservoirs meets the standards set by the South Carolina Department of Health and Environmental Control (SCDHEC) as well as the criteria suggested by the United States Environmental Protection Agency (USEPA). The information may also be useful in defining the cause of any changes that might occur in the communities of aquatic organisms.

2.2.2 Findings and Discussion

A summary of the results of temperature, dissolved oxygen, pH, conductivity, and transparency (Secchi disc) measurements are given by station and month in Table 2.2.1; bottom depth and approximate location of the thermocline are also indicated in this table. Results of the water quality chemical analyses are shown in Table 2.2.2. A summary of data (water temperature, pH, dissolved oxygen, and conductivity) recorded on the United States Geological Survey (USGS) continuous water quality monitor located at the FPSF intake on Monticello Reservoir is presented in Table 2.2.3.

Parr Reservoir and Broad River

Physical Measurements - During the 12-month sampling period, water temperatures in the Parr Reservoir and the Broad River (Stations 1, 2, 2W, 5A) ranged from 0.6°C at the bottom of Station 1 in January to 31.7°C in July at the surface of Station 1. Analysis of the data revealed a normal seasonal temperature pattern with the coldest water temperatures occurring during January and February and generally increasing temperatures through July followed by a decline to the low winter values. All temperatures taken at these stations were below the maximum standard of 32.2°C set by the SCDHEC (1977). No seasonal thermocline was observed at any of the stations sampled due to the shallow depths and high current velocity.

Dissolved oxygen (DO) concentrations also followed the expected seasonal trends, with higher levels generally occurring during the colder months and lower levels occurring during warmer periods. The maximum value was 14.1 mg/liter, recorded at Station 1 in January. The minimum concentration, recorded at the bottom of Station 2 in August, was 4.6 mg/liter. Most DO values fell within a range of 6.0 to 11.0 mg/liter. The SCDHEC standard for dissolved oxygen is 4.0 mg/liter.

The pH values at Stations 1, 2, 2W, and 5A ranged from 6.2 to 8.0 units. The minimum pH value was recorded at Station 2 in June. The maximum value occurred at Station 2W in January and February. All values were within the range of 6.0 to 8.5 units set by the SCDHEC (1977).

Conductivity values ranged from 65 μmhos/cm at Station 5A in July to 160 μmhos/cm at Station 1 in October.

Transparency, as measured with a Secchi disc, was lowest (0.1 m) at Station 1 in June. This low value resulted from a high concentration of suspended materials present in the water column that was probably caused by heavy rainfall and runoff during the period preceeding sampling. The highest transparency value was 1.9 meters recorded at

Station 2 in November. Transparency values at all Broad River and Parr Reservoir stations were lowest from June through September which is thought to be attributable to the higher precipitation level occurring during this period.

In general, physical values recorded between January 1981 through December 1981 at the Parr Reservoir and Broad River Stations are consistent with historical data collected under the present environmental monitoring program (Dames & Moore; 1978, 1979, 1979a, 1981). Water temperature and dissolved oxygen values conformed to the expected seasonal regime with low water temperatures and high dissolved oxygen concentrations recorded during the winter, and maximum water temperatures and minimum DO values occurring during the summer months. The pH values recorded during 1981 were within the range of historical values (6.2 to 8.5 units). The range of conductivity values was slightly higher during 1981 (65-100 μmhos/cm) than occurred in 1980 (50-100 μmhos/cm) and in 1979 (30-100 μmhos/cm). The range of transparency values recorded during this collection period was similar to that occurring in 1980.

Chemical Analyses - Ammonia values at Stations 1, 2, and 5A averaged 0.3 mg/liter. A maximum ammonia concentration of 0.6 mg/liter was observed at Station 1 in June. Mean nitrate concentrations varied from 1.7 mg/liter at Station 5A to 2.2 mg/liter at Station 1. The maximum nitrate value recorded was 2.9 mg/liter at Station 2 in March. Average total phosphate concentrations ranged from 0.11 to 0.27 mg/liter with a minimum value of less than 0.01 mg/liter at all three stations in June and a maximum of 0.57 mg/liter at Station 2 in July. Ammonia levels in the Broad River and Parr Reservoir are slightly less than those reported during 1980. Average nitrate and phosphate concentrations were similar to values reported in 1980.

Biochemical and chemical oxygen demands (BOD and COD) were generally low at all Broad River and Parr Reservoir stations; the BOD averaged 1.3 mg/liter at these stations, and the COD ranged from a mean of

5.0 mg/liter at Station 2 to 7.3 mg/liter at Station 1. An individual high reading of 21 mg/liter was recorded at Station 1. The BOD and COD values for 1981 are generally similar to those recorded during 1980.

The average mean value for total hardness recorded at Stations 1, 2, and 5A was 16.8 mg/liter; this value falls within the 0 to 75 mg/liter criterion defining soft water (USEPA, 1976). Hardness levels recorded from January through December 1981 are similar to levels which have occurred since June 1978.

Cadmium, chromium, lead, and mercury were detected in water samples collected from Parr Reservoir and the Broad River but occurred in concentrations at or below the sensitivity of the analytical procedures (i.e., they were present in concentrations too low to be adequately quantified). Copper concentrations of 0.03 mg/liter were recorded at Station 5A during July. However, this value is below the criterion (maximum of 0.1 times a 96-hour LC-50 as determined for a sensitive, resident aquatic species) recommended by the USEPA (1976). Using this criterion as determined from toxicity data for bluegill in soft water (Pickering and Henderson, 1966), a maximum permissible value of 0.06 mg/liter copper would apply.

Concentrations of zinc in excess of the analytical limit were recorded at one or more of the river and Parr Reservoir stations during February, June, October, and November. However, in only one case (Station 2, October: 0.16 mg/liter zinc), did the reported value exceed the 0.05 mg/liter criterion (maximum of 0.01 times the 96-hour LC-50 for bluegill in soft water, as per Pickering and Henderson, 1966) recommended by the USEPA (1976).

The USEPA criterion for total iron is 1.0 mg/liter. The mean concentration of iron exceeded this value at Station 1. The highest iron value recorded at Station 1 was 9.3 mg/liter in June. The concentration of iron at Station 1 also exceeded the criterion in August (2.8 mg/liter), September (1.1 mg/liter), and December (2.4 mg/liter). At Station 2, values exceeded the criterion in July (2.4 mg/liter) and

September (1.2 mg/liter). At Station 5A, values exceeded the limit in June (1.1 mg/liter) and August (1.6 mg/liter). In several cases, the high iron concentrations were coincidental with high suspended solids values. Because iron is a prime constituent of clay soils, such as those found in the study area, it is believed that these values were caused by runoff from heavy rainfall preceeding sampling. The other metals values that exceeded the recommended criteria are also believed to be due to leaching from the soil and are not considered unusual for the study area.

Daily observations were made of surface waters at Station 5A for the presence of oil and grease and odor. On May 19, July 5 and 9, and August 31, 1981, "trace" amounts of both oil/grease and odor were reported.

Neal Shoals Dam

Physical Measurements - Because of the shallow water depth (approximately 1 meter) at this station (11) temperature records at the surface and bottom generally were similar and no thermocline was observed. Normal seasonal fluctuations in water temperature occurred. The minimum temperature, (0.6°C) was recorded in January and the maximum (32.4°C) in July. This value was the only recorded instance during the 1981 sampling period when the maximum permissible water temperature of 32.2°C, set by the SCDHEC (1977), was exceeded.

Dissolved oxygen concentrations varied from 14.2 mg/liter in January to 4.9 mg/liter in August. These values are above the minimum value of 4.0 mg/liter established by the SCDHEC (1977).

Values of pH ranged from 6.7 (August) to 8.2 (July) units. These values are within the SCDHEC (1977) standards of 6.0 to 8.5 units. Conductivity values ranged between 80 (which was recorded several times during the year) and 130 (October) μmhos/cm. Secchi disc readings ranged from 0.1 to 1.1 meters, in September and March. respectively.

Chemical Analyses - Mean concentrations of ammonia, nitrate, and total phosphate were 0.3 mg/liter, 1.8 mg/liter, and 0.28 mg/liter, respectively. During July the concentration of un-ionized ammonia (0.6 mg/liter) exceeded the criterion recommended by the USEPA (1976). The criterion suggested for ammonia is based on the amount of un-ionized ammonia (NH3) present in solution, which is highly dependent on the temperature and pH of the water body being sampled. Although the concentrations of total ammonia (NH3 + NH4) were within the range normally occurring in the river, the high pH values recorded at the surface resulted in a greater percentage of the total ammonia being in the un-ionized form. The un-ionized ammonia concentration recorded at Neal Shoals is not considered unusual because the temperature, pH, and total ammonia values were within the ranges expected under natural conditions. Mean nutrient values at Neal Shoals have varied only slightly since 1978. The average ammonia concentration during 1981 was slightly less than occurred during 1980. Average ammonia values varied previously at this station from 0.3 to 0.4 mg/liter, mean nitrate values have varied from 1.8 to 2.2 mg/liter, and average phosphate values have varied from 0.30 to 0.39 mg/liter (Dames & Moore; 1978, 1979a, 1979b, 1981).

The mean BOD and COD values recorded during 1981 were 1.5 mg/liter and 8.5 mg/liter, respectively. The average total hardness level was 17.3 mg/liter, a value characterizing soft water (USEPA, 1977). The BOD and hardness levels are similar to those reported in the earlier surveys while COD values were somewhat higher than previously reported (Dames & Moore 1978, 1979a, 1979b, 1981).

Of the metals which occurred in detectable concentrations, only iron occurred in amounts greater than the criterion recommended by the USEPA (1976). The average iron concentration at Neal Shoals Dam was 1.4 mg/liter. The maximum iron value recorded was 4.7 mg/liter which occurred during June. The maximum iron value was coincidental with a moderately high suspended solids load in the river. The recommended

criterion for iron was also exceeded at Station 11 during August (2.0 mg/liter), September (2.3 mg/liter), October (1.6 mg/liter), and December (2.0 mg/liter). Previous studies have indicated that iron concentrations in the vicinity of Neal Shoals Dam are often greater than that recommended by the USEPA (Dames & Moore; 1978, 1979, 1981). As with the other stations located in the river and in Parr Reservoir, the elevated concentrations are believed to have resulted from leaching of iron from the soils in the region.

Subimpoundment

Physical Measurements - Water temperatures in the subimpoundment (Station 18) ranged from a low of 5.8°C on the surface in January to 30.3°C in July. The bottom temperature ranged from 5.0°C in January to 24.2°C in July. The results from these surveys indicate that the temperatures were within the range expected for the seasons encountered.

The dissolved oxygen (DO) concentrations ranged from a low of 6.7 mg/liter at the surface in June to 13.3 mg/liter in May. At the bottom the DO values ranged from a low of 5.7 mg/liter in October to 10.0 mg/liter in January; all of the values were above the prescribed limit established by the SCDHEC.

The pH was measured only at the surface at this station. The values for pH ranged from 6.3 to 9.5 and these were recorded during November and May, respectively. The pH limits established by the SCDHEC are a low of 6.0 and a high of 8.5. The high pH value recorded in May may have been caused by an algal bloom; no phytoplankton data are collected at this station in May but fertilization of the subimpoundment occurs during this month and a bloom in plankton could have caused a shift in the pH.

Conductivity values recorded at the surface range from 60 μmhos/cm in February to 119 μmhos/cm in May. Measurements made at the bottom ranged from a low of 66 μmhos/cm in January to 116 μmhos/cm in October.

The transparency values recorded ranged from 0.9 m in May to 2.1 m in March.

All of the physical measurements made during this reporting period appeared to follow seasonal trends for the area, and, except for the high pH value in May, fall within the prescribed limits established by the SCDHEC.

Chemical Analyses - The subimpoundment was sampled on a quarterly basis in January, April, July, and October. Ammonia concentrations from the four sampling periods ranged from 0.2 to 0.6 mg/liter. During April, because of high pH (8.9) occurring at Station 18, the concentration of ammonia (0.5 mg/liter) exceeded the criterion, based on the amount of un-ionized ammonia present in solution recommended by the USEPA (1976). Values for nitrate ranged from below detectable limits to 2.6 mg/liter during 1981. The concentrations of total phosphate varied from 0.05 to 0.11 mg/liter. The maximum and average ammonia concentrations were lower than occurred during 1980 but were similar to those recorded for other years at this station (Dames & Moore; 1978, 1979a, 1979b, and 1981). Nitrate and phosphate concentrations were similar to those reported for 1980.

BOD values during the four sampling periods ranged from less than 1 mg/liter to 3 mg/liter. Total hardness values ranged from 26 to 28 mg/liter and were within the range characteristic of soft water; however, the values were higher than those which occurred at the other sampling stations in Monticello and Parr Reservoirs as well as in the Broad River.

As with the 1979 and 1980 surveys, all concentrations of metals measured during the current reporting period were below the level of sensitivity of the analytical procedures.

Monticello Reservoir

Physical Measurements - All of the temperatures recorded in the Monticello Reservoir (Stations 12 through 17, and 20) were below the 32.2°C maximum limit for Class B waters set by the SCDHEC (1977). The highest temperatures recorded in the Monticello Reservoir were 29.1°C at the surface of Station 14 in July and 29.3°C at Station 17 in August. The lowest temperatures recorded were 5.4°C at the bottom of Station 12 in January, and 5.5 at Stations 13, 14, and 15 in February. The water temperatures taken above the thermocline followed the typical seasonal pattern. Water temperatures were generally highest in July and August and lowest in January and February. During the time that a thermocline was present, the water temperatures below the thermocline were from about 5 to 14°C cooler than those in the epilimnion.

A thermocline was observed at Station 20 from July through October. In July, it was located at depths between 26 and 29 meters, in August at depths between 27 and 29 meters, in September between 26 and 30 meters, and in October between 29 and 31 meters. The temperatures across the thermocline decreased by between 7.5°C and 11.0°C. The location of the thermocline during 1981 is generally consistent with those recorded at this station during previous surveys (Dames & Moore; 1978, 1979a, 1979b, 1981). During April at Station 20, thermal stratification was evident between the depths of 9 and 10 meters. Water temperatures decreased from 17.9 to 14.9°C between these depths. Station 12 is located in front of the FPSF intake and is approximately 30 meters in depth. In spite of the depth at this station, April was the only month when there was any evidence of water column stratification when water temperatures decreased from 15.6 to 13.6°C between 9 and 10 meters depth. Stratification was also evident during April at

Station 16 between 1 and 2 meters depth where water temperatures decreased from 16.9 to 14.9.°C.

During January, February, November, and December the difference between surface and bottom temperatures at all stations in the reservoir was less than 2°C.

Mean temperature ranges recorded in 1981 by the USGS monitor located at the FPSF intake are generally similar to the temperature ranges measured at other stations in the reservoir during this study. No recorded values exceeded the limit set by the SCDHEC (1977).

Dissolved oxygen concentrations recorded at the surface (30 cm) of the Monticello Reservoir ranged between 5.0 mg/liter and 12.9 mg/liter. The maximum surface DO concentration occurred at Station 13 in February. The minimum surface DO level was recorded at Station 13 in August. All surface values were greater than the 4.0 mg/liter standard set by the SCDHEC (1977).

Dissolved oxygen concentrations near the bottom of Monticello Reservoir ranged from 12.9 mg/liter at Stations 12 and 13 in February to very low values at Station 20 in August (0.2 mg/liter), September (0.0 mg/liter), and October (0.4 mg/liter). The DO levels near the bottom were below the SCDHEC standard at Station 20 during the months of June through November. Values below the standard were also recorded near the bottom at Station 12 in July, at Stations 12, 14, 16, and 17 in August, and at Stations 14, 16, and 17 in September. Low oxygen concentrations are considered typical of waters below the thermocline in deep fresh water ponds or lakes (Knight, 1965). This vertical stratification is believed to be the reason foı the depressed oxygen levels at Station 20 during the warm season.

At the USGS Monitor (sampling depth approximately 6 m) the daily mean DO values during the warm season were below the state standard (minimum

of 4 mg/liter) on three dates: August 5 and 6, and September 11. Daily mean values ranged from 3.9 to 7.8 mg/liter during August and from 3.5 to 7.8 mg/liter during September. A minimum hourly value of 3.0 mg/liter was recorded in September.

The pH standards for Class B waters, as set by the State of South Carolina (SCDHEC, 1977), range from 6.0 to 8.5 units. The pH values recorded in the Monticello Reservoir during 1981 ranged from a minimum of 2.8 units at the bottom of Station 20 in July to a maximum of 9.3 units at the surface of Station 20 in April. The pH values also were below the minimum state standard at the bottom of Station 12 in January and at the bottom of Station 20 in January, June, July, and September. Low pH values such as these are not considered unusual near the bottom of reservoirs that are stratified due primarily to the decomposition of organic material on the bottom. The maximum permissible pH value was exceeded in the photic zone at Stations 12, 16, and 17 in April and at Stations 16 and 17 in June. These high values are considered to be the result of the photosynthetic activity of phytoplankton. Photosynthesis removes carbon dioxide during daylight periods, shifting the system away from the production of carbonic acid and, consequently, to a less acidic state. This is especially true of soft water areas with low buffering capacity (such as Monticello Reservoir) where wide fluctuations in seasonal and daily pH values may be expected (Knight, 1965).

The daily, mean pH values recorded at the USGS Monitor in Monticello Reservoir ranged from 6.5 units in July to 7.8 units in April and May. The minimum hourly value recorded was 6.3 units and the maximum was 9.0 units. These values appear to be consistent with those recorded during the Water Quality Monitoring Study.

Conductivity values in Monticello Reservoir ranged from 60 μmhos/cm at Station 16 in August to 200 μmhos/cm at Station 20 in April. Most conductivity values recorded were between 80 and 100 μmhos/cm. Daily

mean conductivity values recorded at the USGS monitoring station in Monticello Reservoir ranged from 60 μmhos/cm in February to 95 μmhos/cm in September.

Water transparency measurements in the Monticello Reservoir ranged from a minimum of 0.4 m at Station 13 in June to a maximum of 2.0 m recorded at Station 17 in March.

Physical measurements taken in the Monticello Reservoir since June 1978 reveal seasonal patterns that are typical of deep freshwater lakes and ponds. Vertical temperature stratification occurs during the summer months while the reservoir is essentially isothermal in the winter. Dissolved oxygen levels have been generally highest during the winter months and lowest in the summer. The depressed DO values that have occurred in water below the thermocline are considered normal for water bodies of this type. High pH values can be expected in the photic zone during periods of high phytoplankton activity. Specific conductance has remained at a relatively low level throughout the study.

Chemical Analyses - Average ammonia values in the Monticello Reservoir ranged from 0.28 mg/liter at Station 15 to 0.32 mg/liter at Station 16. A maximum ammonia concentration of 0.50 mg/liter was recorded at Stations 12 (April, May, June), 14 (April), and 16 (January, April). Mean nitrate and total phosphate levels were within the narrow ranges of 1.1 to 1.4 mg/liter and 0.09 to 0.13 mg/liter, respectively, at the sampling stations in the reservoir. Ammonia and nitrate concentrations were lower during 1981 than occurred during 1980. Total phosphate concentrations were slightly higher than occurred in 1980 (Dames & Moore, 1981). In April, because of high pH values also occurring at Stations 12, 14, and 16, the concentrations of ammonia exceeded the criterion (based on the amount of un-ionized ammonia present in solution) recommended by the USEPA (1976). In July, because of high pH and water temperature values, the relatively low concentration of ammonia (0.20 mg/liter) at Station 14 also resulted in un-ionized NH_3 values

that exceeded the criterion. Although the concentrations of total ammonia (NH_3 + NH_4) were within the range normally occurring in the reservoir, the high pH values recorded at the surface resulted in a greater percentage of the total ammonia being in the un-ionized form. The un-ionized ammonia concentrations recorded from the reservoir are not considered unusual because the pH, water temperature, and total ammonia values were within the ranges expected in the reservoir under natural conditions.

Biochemical and chemical oxygen demands were low, as they were during the 1978, 1979, and 1980 study periods (Dames & Moore; 1978, 1979a, 1979b, 1981). BOD values averaged between 1.2 and 1.3 mg/liter. The range of mean COD levels was between 5.5 and 6.2 mg/liter. Total hardness values ranged from a maximum of 21 mg/liter to a minimum of 10 mg/liter; these values are characteristic of soft water.

Of the metals measured during 1981 in Monticello Reservoir, only iron and zinc occurred in detectable concentrations. However, concentrations of these metals did not exceed USEPA recommended criteria. Mean total iron values ranged from 0.20 to 0.36 mg/liter with a maximum concentration recorded of 0.56 mg/liter at Station 14 in March. Zinc values averaged 0.01 mg/liter at all of the reservoir stations with a maximum concentration of 0.04 mg/liter occurring at Station 14 in January. Iron and zinc are natural constituents of the clay soils in the area; therefore, periodic increases in their concentrations are not considered unusual. All of the other metals have remained at low levels throughout the 1978-1981 studies.

2.2.3 Summary

With one exception, water temperatures recorded during the 1981 water quality monitoring program were below the 32.2°C standard set by the SCDHEC (1977). The single occurrence of water temperature exceeding the standard was at the shallow (1 m) Neal Shoals station during July.

Dissolved oxygen concentrations in the Parr Reservoir and the Broad River exceeded the minimum state standard. However, in Monticello Reservoir the DO was somewhat reduced from June to September with concentrations below the standard of 4.0 mg/liter occurring near the bottom of several sampling stations. The USGS monitor in the FPSF intake indicated that, on rare occasions during this period, the daily mean DO level was below the minimum standard.

The maximum state standard of 8.5 for pH was exceeded in the photic zone of the Monticello Reservoir during the spring and summer months. These high values are attributed to natural photosynthetic activity and are expected during the warmer seasons. In several instances, pH values in bottom waters of the reservoir were below the standard. Because these values were recorded near the bottom, they are not considered unusual. Transparencies in Monticello Reservoir were generally higher than in Parr Reservoir or in the Broad River; the reduced turbidity is thought to be due to the greater depth and lentic characteristic of the Monticello Reservoir. Biochemical and chemical oxygen demands were low at all stations throughout the reporting period. Total hardness values at all stations conformed to the 0 to 75 mg/liter criterion for soft water set by the USEPA (1976). Hardness values in the subimpoundment were higher than those recorded from the other water quality sampling stations. Mean nitrate concentrations were slightly greater in Parr Reservoir and the Broad River than in Monticello Reservoir. Average total phosphate values were higher at the Broad River stations than in the Parr or Monticello Reservoirs. Ammonia concentrations were similar at all stations. Zinc and iron were the only metals that occasionally exceeded the criteria suggested by the USEPA (1976). These metals are typical constituents of soils in the watershed and, therefore, the concentrations observed are not considered unusual.

Table 2.2.1 Physical measurements (temperature, dissolved oxygen, pH, conductivity, Secchi disc) made during the month indicated. Bottom depth and approximate depth of thermocline are also given.

January 1981

Station	Temperature (°C)		Dissolved Oxygen (mg/liter)		pH		Conductivity (μmhos/cm)		Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	0.7	0.6	14.1	--[a]	7.6	7.3	70	70	NP	3.5	1.4
2	6.2	6.2	12.0	--[a]	7.8	7.5	90	90	NP	5	1.3
2W	4.4	4.4	12.8	--[a]	8.0	8.0	100	100	NP	5	0.9
5A	5.8	--[b]	13.0	--[b]	7.7	--[b]	70	--[b]	NP	<1	0.6
11	0.6	0.6	14.2	13.8	7.3	7.6	110	110	NP	1	1.0
12	5.8	5.4	12.3	12.2	7.5	3.4	70	80	NP	28	1.1
13	6.0	5.7	12.2	12.0	7.7	6.9	80	80	NP	12	1.2
14	6.2	6.0	11.8	11.7	7.6	6.6	70	70	NP	18	1.4
15	6.2	6.2	11.9	11.8	7.7	7.5	80	80	NP	3	1.4
16	6.5	6.4	12.0	11.9	7.6	7.0	70	80	NP	9.5	1.6
17	6.4	6.3	12.0	11.6	8.0	7.3	70	70	NP	11	1.2
18[c]	5.8	5.0	10.6	10.0	6.9	--[d]	65	66	--[d]	11	1.6
20	6.0	5.9	12.0	10.0	7.6	5.6	80	80	NP	31	1.2

NP - Not Present.

[a] - Instrument malfunction

[b] - Water depth less than 1m; only surface measurements made.

[c] - Data collected by Dames & Moore during the aquatic biology sampling.

[d] - Measurement not required.

February 1981

Station	Temperature (°C) Surface	Temperature (°C) Bottom	Dissolved Oxygen (mg/liter) Surface	Dissolved Oxygen (mg/liter) Bottom	pH Surface	pH Bottom	Conductivity (μmhos/cm) Surface	Conductivity (μmhos/cm) Bottom	Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
1	4.4	4.3	13.7	13.7	7.6	7.6	100	100	NP	2	1.3
2	5.5	5.5	12.5	12.5	7.6	7.7	90	90	NP	4.5	1.7
2W	5.3	5.4	12.7	12.9	8.0	6.9	100	100	NP	3	1.0
5A	6.2	--[a]	12.7	--[a]	6.7	--[a]	100	--[a]	NP	<0.7	(btm) 0.7
11	4.8	4.8	12.7	12.7	7.8	7.8	100	100	NP	1	(btm) 1.0
12	5.5	5.6	12.7	12.9	7.6	7.5	90	100	NP	31	1.8
13	5.7	5.5	12.9	12.9	7.6	7.6	90	90	NP	13	1.0
14	5.8	5.5	12.8	12.8	7.6	7.6	90	90	NP	18	1.9
15	5.5	5.5	12.8	12.8	7.6	7.6	90	90	NP	4	1.9
16	5.7	5.7	12.7	12.7	7.5	7.6	80	80	NP	11	1.9
17	5.9	6.0	12.5	12.6	7.4	7.4	80	80	NP	12	1.1
18[b]	8.0	--[c]	10.7	--[c]	6.7	--[c]	60	--[c]	--[c]	11	1.5
20	5.9	5.6	12.7	12.7	7.6	7.5	80	80	NP	30	1.8

NP - Not Present.

[a] - Water depth less than lm; only surface measurements made.

[b] - Data collected by Dames & Moore during the aquatic biology sampling.

[c] - Measurement not required.

Station	Temperature (°C) Surface	Temperature (°C) Bottom	Dissolved Oxygen (mg/liter) Surface	Dissolved Oxygen (mg/liter) Bottom	pH Surface	pH Bottom	Conductivity (μmhos/cm) Surface	Conductivity (μmhos/cm) Bottom	Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	March 1981										
1	9.6	9.6	10.8	10.8	7.4	7.4	90	90	NP	2.5	1.2
2	10.0	8.9	11.2	11.2	7.4	7.2	80	90	NP	5	1.1
2W	11.2	11.0	10.6	10.6	7.5	7.5	90	90	NP	4	0.5
5A	11.1	--[a]	11.1	--[a]	7.6	--[a]	90	--[a]	NP	1	(btm) 1.0
11	9.7	9.6	10.8	10.7	7.4	7.4	80	80	NP	1.1	(btm) 1.1
12	10.3	6.6	11.2	10.3	7.6	7.1	90	90	NP	28	1.4
13	10.3	9.6	11.2	10.7	7.6	7.4	90	90	NP	12	1.2
14	10.4	9.2	11.2	10.4	7.7	7.4	90	90	NP	16	1.[illegible]
15	10.4	9.8	11.2	11.2	7.7	7.6	90	90	NP	3.5	1.5
16	10.4	8.4	11.1	10.0	7.7	7.4	90	90	NP	12	1.8
17	10.3	8.3	11.2	9.9	7.6	7.4	90	90	NP	12	2.0
18[b]	12.0	--[c]	10.9	--[c]	7.2	--[c]	66	--[c]	--[c]	11	2.1
20	10.2	6.4	11.6	9.4	7.8	7.0	80	80	NP	31	1.4

NP - Not Present.

[a] - Water depth less than 1m; only surface measurements made.

[b] - Data collected by Dames & Moore during the aquatic biology sampling.

[c] - Measurement not required.

April 1981

Station	Temperature (°C) Surface	Temperature (°C) Bottom	Dissolved Oxygen (mg/liter) Surface	Dissolved Oxygen (mg/liter) Bottom	pH Surface	pH Bottom	Conductivity (μmhos/cm) Surface	Conductivity (μmhos/cm) Bottom	Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
1	20.9	20.9	8.0	8.0	7.2	7.2	90	90	NP	2	1.4
2	15.4	15.3	10.8	11.3	7.7	7.5	90	90	NP	5	1.0
2W	17.8	17.5	10.2	10.2	7.1	7.1	90	90	NP	3	0.8
5A	18.3	--[a]	10.2	--[a]	7.8	--[a]	80	--[a]	NP	<1	0.7
11	20.7	20.6	8.0	8.0	7.2	7.7	80	80	NP	1	0.9
12	17.7	11.0[b]	10.8	8.8[b]	9.2	7.2[b]	80	90[b]	9-10	28	1.4
13	17.4	16.2	9.2	8.8	7.7	7.6	80	80	NP	12	0.9
14	16.3	15.9	10.3	9.9	8.3	8.0	80	80	NP	11	1.4
15	15.8	15.4	9.7	9.4	7.9	7.8	80	80	NP	5	1.4
16	17.2	13.2	9.7	8.7	8.6	7.2	80	80	1-2	15	1.3
17	15.2	13.7	9.2	7.8	7.4	7.1	80	80	NP	12	1.4
18[c]	20.0	17.5	10.9	9.5	8.9	--[d]	84	80	--[d]	11	1.5
20	18.2	9.3	10.7	6.0	9.3	6.2	90	200	9-10	32	1.6

NP - Not Present.

a - Water depth less than 1m; only surface measurements made.

b - Bottom measurements believed to be affected by disturbed substrate; reported value made 1 m above bottom.

c - Data collected by Dames & Moore during the aquatic biology sampling.

d - Measurement not required.

Table 2.2.1 (Continued)

May 1981

Station	Temperature (°C)		Dissolved Oxygen (mg/liter)		pH		Conductivity (μmhos/cm)		Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	19.0	18.8	8.2	8.6	7.4	7.4	100	100	NP	2	1.2
2	20.1	18.3	7.6	7.5	7.0	7.0	90	90	NP	4.5	0.9
2W	18.8	18.4	7.8	7.7	7.2	7.2	90	90	NP	4	0.5
5A	20.0	--[a]	8.2	--[a]	7.6	--[a]	90	--[a]	NP	<1	0.5
11	19.3	19.3	8.4	8.5	7.2	7.2	80	90	NP	1	0.7
12	19.4	15.3	9.4	6.6	7.6	7.0	90	90	NP	29	1.9
13	18.9	18.6	8.0	7.8	7.3	7.2	90	90	NP	13	1.1
14	19.6	18.0	9.1	7.6	7.5	7.2	90	90	NP	14	1.9
15	19.1	18.7	8.9	8.6	7.6	7.5	90	90	NP	5	1.3
16	19.4	18.4	9.3	7.5	7.8	7.3	90	90	NP	12	1.6
17	19.3	18.2	9.0	7.2	7.6	7.3	80	80	NP	11	1.1
18[b]	22.8	--[c]	13.3	--[c]	9.5	--[c]	119	--[c]	--[c]	11	0.9
20	19.3	10.3	9.6	4.6	7.6	6.2	90	90	NP	31	1.5

NP - Not Present.

[a] - Water depth less than 1m; only surface measurements made.

[b] - Data collected by Dames & Moore during the aquatic biology sampling.

[c] - Measurement not required.

June 1981

Station	Temperature (°C)		Dissolved Oxygen (mg/liter)		pH		Conductivity (μmhos/cm)		Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	25.3	25.4	6.8	7.3	7.1	7.2	90	90	NP	3	0.1
2	21.4	21.2	6.4	6.4	7.0	6.2	100	100	NP	4	0.6
2W	24.4	23.4	6.4	6.1	7.0	7.0	90	90	NP	2.5	0.2
5A	25.4	--[a]	7.4	--[a]	7.1	--[a]	100	--[a]	NP	<1	0.4
11	25.1	24.7	6.1	6.1	7.0	7.0	90	90	NP	0.5	0.2
12	23.3	18.9	7.0	5.4	7.0	6.8	100	100	NP	29	0.5
13	23.0	22.6	6.5	6.2	7.0	7.0	100	100	NP	13	0.4
14	24.6	21.3	8.2	6.0	7.2	7.0	100	100	NP	18	0.9
15	25.7	25.7	8.5	8.5	8.1	8.0	100	100	NP	4	1.2
16	26.3	21.8	8.7	5.4	8.6	6.9	100	100	5-7	11	1.3
17	27.4	22.1	8.8	6.0	9.0	7.4	100	100	5-7	11	1.0
18[b]	29.0	--[c]	6.7	--[c]	8.0	--[c]	102	--[c]	--[c]	11	1.0
20	24.6	10.7	8.2	1.6	7.2	5.2	95	110	NP	32	0.9

NP - Not Present.

[a] - Water depth less than 1m; only surface measurements made.

[b] - Date collected by Dames & Moore during the aquatic biology sampling.

[c] - Measurement not required.

Table 2.2.1 (Continued)

July 1981

Station	Temperature (°C)		Dissolved Oxygen (mg/liter)		pH		Conductivity (µmhos/cm)		Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	31.7	30.8	7.1	6.7	7.2	7.3	90	80	NP	2	0.7
2	28.5	28.7	5.6	5.7	6.8	6.8	80	80	NP	3	0.4
2W	28.9	29.0	5.6	5.3	6.6	6.6	80	80	NP	2	0.3
5A	29.7	--[a]	5.2	--[a]	7.3	--[a]	65	--[a]	NP	<1	0.6
11	32.4	31.3	10.2	7.2	8.2	7.4	80	80	NP	1	0.6
12	27.8	24.6	7.0	2.3	7.1	7.0	80	80	NP	29	1.0
13	27.5	26.6	6.1	4.8	6.9	6.9	80	90	NP	11	0.7
14	29.1	26.5	8.4	5.2	8.4	6.7	80	80	NP	15	1.5
15	28.0	26.9	7.6	5.4	7.2	7.0	80	80	NP	5	1.2
16	28.0	26.4	7.8	4.8	7.3	6.8	80	80	NP	11	1.4
17	28.2	26.4	8.2	5.4	7.8	7.0	70	80	NP	10	1.4
18[b]	30.3	24.2	8.0	5.8	7.8	--[c]	106	101	--[c]	11	1.6
20	27.9	12.0	7.4	1.3	7.2	2.8	90	70	26-29	31	1.3

NP - Not Present.

[a] - Water depth less than 1m; only surface measurements made.

[b] - Data collected by Dames & Moore during the aquatic biology sampling.

[c] - Measurement not required.

Station	Temperature (°C)		Dissolved Oxygen (mg/liter)		pH		Conductivity (µmhos/cm)		Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	August 1981										
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	28.6	27.6	6.2	6.7	7.0	6.9	120	110	NP	2	0.3
2	26.8	26.8	4.8	4.6	6.7	6.6	110	100	NP	3	0.8
2W	27.8	27.5	5.0	4.9	6.4	6.3	85	85	NP	2	0.5
5A	27.8	--[a]	5.4	--[a]	7.0	--[a]	80	--[a]	NP	<1	0.5
11	28.6	28.1	5.0	4.9	6.7	6.7	120	120	NP	1	0.3
12	27.0	25.7	5.7	3.0	6.6	6.	80	90	NP	28	1.0
13	27.0	27.0	5.0	4.9	6.4	6.3	80	75	NP	15	0.7
14	27.7	26.6	8.0	3.5	7.2	6.3	80	50	NP	17	1.1
15	28.6	27.7	8.4	5.8	7.8	6.8	75	65	NP	4	1.5
16	28.5	26.7	8.0	2.5	7.6	6.4	60	65	NP	10	1.7
17	29.3	26.6	8.2	2.2	8.0	6.4	70	65	NP	12	1.4
18[b]	26.8	--[c]	8.4	--[c]	6.9	--[c]	94	--[c]	--[c]	11	1.1
20	27.3	15.9	6.8	0.2	6.8	6.5	80	100	27-29	29	1.1

NP - Not Present.

[a] - Water depth less than 1m; only surface measurements made.

[b] - Data collected by Dames & Moore during the aquatic biology sampling.

[c] - Measurement not required.

September 1981

Station	Temperature (°C)		Dissolved Oxygen (mg/liter)		pH		Conductivity (μmhos/cm)		Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	24.8	24.8	7.4	7.3	7.2	7.2	105	100	NP	2.5	0.5
2	26.0	25.4	6.4	5.8	6.8	6.8	100	100	NP	5	0.5
2W	25.8	25.8	5.2	5.0	6.6	6.6	90	90	NP	3.5	0.4
5A	26.9	--[a]	6.9	--[a]	7.4	--[a]	93	--[a]	NP	<1	0.8
11	24.6	24.4	7.0	6.8	7.0	7.0	80	80	NP	1	0.1
12	25.6	25.2	5.2	4.3	6.8	6.6	100	105	NP	31.5	0.9
13	25.6	25.5	5.3	5.2	6.8	6.8	90	90	NP	12.5	0.5
14	26.0	25.5	6.0	3.9	6.8	6.4	100	110	NP	18	1.3
15	26.2	26.0	7.0	6.8	7.1	7.0	90	90	NP	4	1.3
16	26.6	25.9	7.4	2.9	7.2	6.6	90	90	NP	12	1.4
17	27.3	25.8	8.2	2.1	7.9	6.8	90	90	NP	12	1.4
18[b]	28.0	--[c]	10.0	--[c]	7.8	--[c]	101	--[c]	--[c]	11	1.3
20	25.7	13.0	4.7	0	6.8	4.6	100	120	26-30	31	1.2

NP - Not Present.

[a] - Water depth less than 1m; only surface measurements made.

[b] - Data collected by Dames & Moore during the aquatic biology sampling.

[c] - Measurement not required.

October 1981

Station	Temperature (°C)		Dissolved Oxygen (mg/liter)		pH		Conductivity (µmhos/cm)		Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	16.5	16.4	8.9	8.8	7.6	7.5	160	160	NP	2	0.8
2	20.2	20.1	7.8	7.7	7.2	7.4	120	120	NP	5	1.2
2W	18.5	18.4	7.2	7.3	7.0	6.9	120	130	NP	4	0.6
5A	19.1	--[a]	7.8	--[a]	7.6	--a	125	--a	NP	<1	1.0
11	16.3	16.3	7.9	7.8	7.1	7.0	130	120	NP	1	0.2
12	21.1	20.5	6.4	6.4	7.0	6.7	100	100	NP	27.5	1.2
13	20.9	20.9	6.4	6.3	7.0	6.8	95	100	NP	8.5	1.3
14	21.1	21.1	6.2	6.1	6.8	6.5	95	95	NP	13	1.2
15	21.1	21.1	6.2	6.1	6.8	6.7	100	100	NP	5	1.3
16	20.9	20.7	5.8	5.8	6.8	6.6	90	90	NP	14	1.5
17	20.8	20.7	5.8	5.7	6.8	6.8	85	80	NP	9.5	1.2
18[b]	19.2	16.0	7.6	5.7	6.6	--c	83	116	--c	11	1.0
20	21.1	13.0	6.2	0.4	7.0	6.3	100	120	29-31	31	1.5

NP - Not Present.

[a] - Water depth less than 1m; only surface measurements made.

[b] - Data collected by Dames & Moore during the aquatic biology sampling.

[c] - Measurement not required.

November 1981

Station	Temperature (°C)		Dissolved Oxygen (mg/liter)		pH		Conductivity (μmhos/cm)		Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	12.4	12.3	9.1	9.0	7.3	7.0	100	100	NP	2	0.9
2	17.2	17.2	7.4	7.4	7.2	7.2	100	100	NP	5	1.9
2W	15.5	15.5	7.2	7.1	7.1	7.0	100	100	NP	4	1.0
5A	16.0	--[a]	8.8	--[a]	7.2	--[a]	100	--[a]	NP	1	(btm) 1.0
11	11.8	11.8	8.8	8.6	7.1	7.1	100	95	NP	1	0.6
12	17.0	16.7	8.4	7.8	7.1	6.6	100	100	NP	30.5	1.7
13	16.9	16.8	8.3	8.3	7.1	6.9	85	90	NP	7	1.7
14	17.1	17.0	8.4	8.3	7.0	6.8	100	100	NP	13	1.7
15	17.0	16.9	8.4	8.3	7.2	7.0	100	100	NP	5	1.7
16	17.2	16.9	8.1	8.0	7.1	6.6	100	100	NP	14.5	1.8
17	17.2	16.9	8.0	7.8	7.0	6.8	90	90	NP	11.5	1.3
18[b]	16.0	--[c]	7.1	--[c]	6.3	--[c]	79	--[c]	--[c]	11	1.2
20	17.1	16.1	8.3	2.4	7.2	6.5	100	100	NP	31.5	1.7

NP - Not Present.

[a] - Water depth less than 1m; only surface measurements made.

[b] - Data collected by Dames & Moore during the aquatic biology sampling.

[c] - Measurement not required.

Table 2.2.1 (Continued)

December 1981

Station	Temperature (°C)		Dissolved Oxygen (mg/liter)		pH		Conductivity (mhos/cm)		Approximate Thermocline Depth (m)	Bottom Depth (m)	Secchi Disc (m)
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	4.3	4.2	13.7	12.6	7.7	7.4	110	100	NP	3	0.2
2	10.5	10.5	10.7	10.6	7.1	7.1	100	100	NP	5	1.5
2W	9.2	7.4	11.0	11.1	7.4	7.5	100	105	NP	4	0.7
5A	8.9	--[a]	10.7	--[a]	--[b]	--[a]	105	--[a]	NP	<1	0.8
11	4.3	4.3	13.1	13.4	--[b]	--[b]	100	100	NP	1	0.3
12	10.2	8.7	10.8	--[b]	6.5[c]	--[b]	100	100	NP	28	1.5
13	10.1	8.8	10.4	9.9	6.5[c]	--[b]	100	100	NP	12.5	1.2
14	10.5	10.3	10.4	10.4	6.5	--[b]	100	100	NP	14	1.9
15	10.8	10.4	9.4	9.2	6.6[c]	--[b]	100	100	NP	4	1.9
16	10.9	10.5	9.6	9.8	--[b]	--[b]	100	100	NP	13	1.7
17	10.8	10.3	10.1	10.1	6.5[c]	--[b]	100	100	NP	11.5	1.3
18[d]	--	--	--	--	--	--	--	--	--	--	--
20	10.4	9.2	10.7	--[b]	6.5[c]	--[b]	100	100	NP	31.5	1.5

NP - Not Present.

[a] - Water depth less than lm; only surface measurements made.

[b] - Instrument malfunction.

[c] - Data collected by Dames & Moore during the aquatic biology sampling.

[d] - Measurements not taken due to inclement weather.

Table 2.2.2 Annual summary of the results of chemical analysis of water samples taken at the station indicated during the period of: January 1981 through December 1981.

STATION 1 DEPTH = SURF

DETERMINATION-UNITS		MIN.	MAX.	RANGE	FREQ.	MEAN[a,b]	STANDARD DEV.
SODIUM	MG/L	6.30	18.00	11.70	12	10.69	2.81
CALCIUM	"	2.40	4.80	2.40	12	3.83	.84
MAGNESIUM	"	1.70	3.20	1.50	12	2.27	.54
CHLORIDE	"	5.00	13.00	8.00	12	7.83	2.21
SULFATE (SO 4)	"	4.00	21.00	17.00	12	10.08	4.91
TOTAL DISSOLVED SOLIDS	"	61.00	120.00	59.00	12	77.42	18.07
TOTAL SUSPENDED SOLIDS	"	2.00	130.00	128.00	12	24.50	36.68
MO - ALK	"	14.00	30.00	16.00	12	22.42	4.25
P - ALK (CACO 3)	"	0.00	0.00	0.00	12	0.00	0.00
AMMONIA (NH 3)	"	.10	.60	.50	12	.28	.16
BIOCHEMICAL OXYGEN DEMAND	"	1.00	2.00	1.00	12	1.25	.45
CADMIUM	"	< .01	< .01	0.00	12	< .01	0.00
CHEMICAL OXYGEN DEMAND	"	< 4.00	21.00	17.00	12	7.33	4.94
TOTAL CHROMIUM	"	< .03	< .03	0.00	12	< .03	0.00
COPPER	"	< .02	< .02	0.00	12	< .02	0.00
TOTAL HARDNESS (CACO 3)	"	17.00	24.00	7.00	12	18.92	1.98
TOTAL IRON	"	.48	9.30	8.82	12	1.70	2.52
LEAD	"	< .05	< .05	0.00	12	< .05	0.00
MERCURY	MICRO-GM/L	< .20	< .20	0.00	12	< .20	0.00
NITRATE (NO 3)	MG/L	.60	2.80	2.20	12	2.17	.63
ORTHO-PHOSPHATE	"	< .01	.44	.43	12	.19	.12
TOTAL PHOSPHATE	"	< .01	.51	.50	12	.27	.15
SILICA (SIO 2)	"	13.00	21.00	8.00	12	15.42	2.11
TURBIDITY	NTU	5.40	150.00	144.60	12	27.68	42.52
ZINC	MG/L	< .01	.02	.01	12	.01	.00
CARBON DIOXIDE	"	2.00	24.00	22.00	12	8.25	5.69
KJELDAHL N	"	NR[c]	NR	NR	NR	NR	NR
BORON	"	< .10	< .10	0.00	4	< .10	0.00

[a]In those cases where analyses showed concentrations to be below the detection limit of the analytical procedure, the value of the detection limit itself was used to calculate means.

[b]Values presented in the text have been rounded to the sensitivity of the analytical procedures.

[c]Measurement not required.

Table 2.2.2 (Continued)

STATION 2 DEPTH = SURF

DETERMINATION-UNITS		MIN.		MAX.	RANGE	FREQ.	MEAN[a,b]	STANDARD DEV.
SODIUM	MG/L		7.60		13.00	5.40	12	9.62	1.47
CALCIUM	"		1.60		4.40	2.80	12	2.90	.90
MAGNESIUM	"		1.40		3.60	2.20	12	2.09	.61
CHLORIDE	"		4.00		9.00	5.00	12	6.83	1.40
SULFATE (SO 4)	"		3.00		12.00	9.00	12	7.58	3.20
TOTAL DISSOLVED SOLIDS	"		44.00		80.00	36.00	12	67.08	10.28
TOTAL SUSPENDED SOLIDS	"	<	1.00		69.00	68.00	12	12.42	18.32
MO - ALK	"		17.00		22.00	5.00	12	19.92	1.56
P - ALK (CACO 3)	"		0.00		0.00	0.00	12	0.00	0.00
AMMONIA (NH 3)	"	<	.10		.50	.40	12	.32	.13
BIOCHEMICAL OXY-GEN DEMAND	"	<	1.00		2.00	1.00	12	1.25	.45
CADMIUM	"	<	.01	<	.01	0.00	12	< .01	0.00
CHEMICAL OXYGEN DEMAND	"	<	4.00		8.00	4.00	12	5.00	1.81
TOTAL CHROMIUM	"	<	.03	<	.03	0.00	12	< .03	0.00
COPPER	"	<	.02	<	.02	0.00	12	< .02	0.00
TOTAL HARDNESS (CACO 3)	"		12.00		25.00	13.00	12	15.92	4.08
TOTAL IRON	"		.22		2.40	2.18	12	.66	.61
LEAD	"	<	.05	<	.05	0.00	12	< .05	0.00
MERCURY	MICRO-GM/L	<	.20		.20	0.00	12	.20	0.00
NITRATE (NO 3)	MG/L		1.20		2.90	1.70	12	1.77	.59
ORTHO-PHOSPHATE	"	<	.01		.19	.18	12	.07	.06
TOTAL PHOSPHATE	"	<	.01		.57	.56	12	.14	.15
SILICA (SIO 2)	"		10.00		18.00	8.00	12	12.67	2.19
TURBIDITY	NTU		2.20		37.00	34.80	12	11.63	10.25
ZINC	MG/L	<	.01		.16	.15	12	.02	.04
CARBON DIOXIDE	"		3.00		17.00	14,00	12	7.33	4.36
KJELDAHL N	"		NR[c]		NR	NR	NR	NR	NR
BORON	"	<	.10	<	.10	0.00	4	< .10	0.00

[a]In those cases where analyses showed concentrations to be below the detection limit of the analytical procedure, the value of the detection limit itself was used to calculate means.

[b]Values presented in the text have been rounded to the sensitivity of the analytical procedures.

[c]Measurement not required.

STATION 5A DEPTH = SURF

DETERMINATION-UNITS		MIN.	MAX.	RANGE	FREQ.	MEAN[a,b]	STANDARD DEV.
SODIUM	MG/L	7.70	15.00	7.30	12	9.54	2.03
CALCIUM	"	1.60	4.80	3.20	12	2.97	1.03
MAGNESIUM	"	1.40	2.40	1.00	12	1.93	.36
CHLORIDE	"	4.00	11.00	7.00	12	7.08	1.83
SULFATE (SO 4)	"	4.00	14.00	10.00	12	8.67	3.26
TOTAL DISSOLVED SOLIDS	"	52.00	87.00	35.00	12	67.33	10.17
TOTAL SUSPENDED SOLIDS	"	4.00	19.00	15.00	12	10.83	4.63
MO - ALK	"	16.00	23.00	7.00	12	20.08	2.64
P - ALK (CACO 3)	"	0.00	0.00	0.00	12	0.00	0.00
AMMONIA (NH 3)	"	< .10	.50	.40	12	.33	.14
BIOCHEMICAL OXYGEN DEMAND	"	< 1.00	2.00	1.00	12	1.25	.45
CADMIUM	"	< .01	< .01	0.00	12	< .01	0.00
CHEMICAL OXYGEN DEMAND	"	< 4.00	10.00	6.00	12	5.17	2.17
TOTAL CHROMIUM	"	< .03	< .03	0.00	12	< .03	0.00
COPPER	"	< .02	.03	.01	12	.02	.00
TOTAL HARDNESS (CACO 3)	"	11.00	21.00	10.00	12	15.42	3.32
TOTAL IRON	"	.33	1.60	1.27	12	.70	.37
LEAD	"	< .05	< .05	0.00	12	< .05	0.00
MERCURY	MICRO-GM/L	< .20	< .20	0.00	12	< .20	0.00
NITRATE (NO 3)	MG/L	1.10	2.70	1.60	12	1.67	.44
ORTHO-PHOSPHATE	"	< .01	.11	.10	12	.06	.03
TOTAL PHOSPHATE	"	< .01	.16	.15	12	.11	.05
SILICA (SIO 2)	"	10.00	18.00	8.00	12	13.33	2.15
TURBIDITY	NTU	5.00	28.00	23.00	12	11.32	7.20
ZINC	MG/L	< .01	.04	.03	12	.01	.01
CARBON DIOXIDE	"	2.00	14.00	12.00	12	7.33	3.96
KJELDAHL N	"	NR[c]	NR	NR	NR	NR	NR
BORON	"	< .10	.10	0.00	4	.10	0.00

[a]In those cases where analyses showed concentrations to be below the detection limit of the analytical procedure, the value of the detection limit itself was used to calculate means.

[b]Values presented in the text have been rounded to the sensitivity of the analytical procedures.

[c]Measurement not required.

Table 2.2.2 (Continued)

STATION 11 DEPTH = SURF

DETERMINATION-UNITS		MIN.	MAX.	RANGE	FREQ.	MEAN [a,b]	STANDARD DEV.
SODIUM	MG/L	5.80	13.00	7.20	12	9.12	1.81
CALCIUM	"	2.40	4.80	2.40	12	3.57	.77
MAGNESIUM	"	1.20	2.40	1.20	12	2.03	.42
CHLORIDE	"	5.00	11.00	6.00	12	7.75	1.66
SULFATE (SO 4)	"	3.00	21.00	18.00	12	9.00	5.53
TOTAL DISSOLVED SOLIDS	"	51.00	95.00	44.00	12	70.83	12.39
TOTAL SUSPENDED SOLIDS	"	< 1.00	50.00	49.00	12	18.92	15.77
MO - ALK	"	16.00	23.00	7.00	12	19.17	1.75
P - ALK (CACO 3)	"	0.00	0.00	0.00	12	0.00	0.00
AMMONIA (NH 3)	"	< .10	.60	.50	12	.34	.16
BIOCHEMICAL OXYGEN DEMAND	"	< 1.00	4.00	3.00	12	1.50	.90
CADMIUM	"	< .01	< .01	0.00	12	< .01	0.00
CHEMICAL OXYGEN DEMAND	"	< 4.00	20.00	16.00	12	8.50	4.36
TOTAL CHROMIUM	"	< .03	< .03	0.00	12	< .03	0.00
COPPER	"	< .02	< .02	0.00	12	< .02	0.00
TOTAL HARDNESS (CACO 3)	"	15.00	20.00	5.00	12	17.33	1.72
TOTAL IRON	"	.49	4.70	4.21	12	1.41	1.23
LEAD	"	< .05	< .05	0.00	12	< .05	0.00
MERCURY	MICRO-GM/L	< .20	.20	0.00	12	.20	0.00
NITRATE (NO 3)	MG/L	.90	2.90	2.00	12	1.83	.64
ORTHO-PHOSPHATE	"	< .01	.40	.39	12	.16	.12
TOTAL PHOSPHATE	"	.09	.42	.33	12	.28	.10
SILICA (SIO 2)	"	10.00	19.00	9.00	12	14.08	2.23
TURBIDITY	NTU	5.00	100.00	95.00	12	24.86	27.75
ZINC	MG/L	< .01	.02	.01	12	.01	.00
CARBON DIOXIDE	"	0.00	15.00	15.00	12	6.42	4.34
KJELDAHL N	"	NR [c]	NR	NR	NR	NR	NR
BORON	"	< .10	.10	0.00	4	.10	0.00

[a] In those cases where analyses showed concentrations to be below the detection limit of the analytical procedure, the value of the detection limit itself was used to calculate means.

[b] Values presented in the text have been rounded to the sensitivity of the analytical procedures.

[c] Measurement not required.

STATION 12 DEPTH = SURF

DETERMINATION-UNITS		MIN.	MAX.	RANGE	FREQ.	MEAN[a,b]	STANDARD DEV.
SODIUM	MG/L	7.70	12.00	4.30	12	9.37	1.50
CALCIUM	"	1.60	4.40	2.80	12	2.83	.91
MAGNESIUM	"	1.20	2.40	1.20	12	1.96	.38
CHLORIDE	"	4.00	11.00	7.00	12	6.96	1.86
SULFATE (SO 4)	"	4.00	17.00	13.00	12	8.42	3.70
TOTAL DISSOLVED SOLIDS	"	59.00	79.00	20.00	12	65.00	6.28
TOTAL SUSPENDED SOLIDS	"	< 1.00	14.00	13.00	12	6.17	4.34
MO - ALK	"	14.00	23.00	9.00	12	19.33	2.53
P - ALK (CACO 3)	"	0.00	0.00	0.00	12	0.00	0.00
AMMONIA (NH 3)	"	< .10	.50	.40	12	.29	.15
BIOCHEMICAL OXY-GEN DEMAND	"	< 1.00	2.00	1.00	12	1.17	.39
CADMIUM	"	< .01	< .01	0.00	12	< .01	0.00
CHEMICAL OXYGEN DEMAND	"	< 4.00	10.00	6.00	12	5.50	2.28
TOTAL CHROMIUM	"	< .03	< .03	0.00	12	< .03	0.00
COPPER	"	< .02	.02	0.00	12	.02	0.00
TOTAL HARDNESS (CACO 3)	"	12.00	20.00	8.00	12	15.17	3.07
TOTAL IRON	"	.18	.53	.35	12	.36	.11
LEAD	"	< .05	< .05	0.00	12	< .05	0.00
MERCURY	MICRO-GM/L	< .20	< .20	0.00	12	< .20	0.00
NITRATE (NO 3)	MG/L	.70	2.10	1.40	12	1.44	.38
ORTHO-PHOSPHATE	"	< .01	.12	.11	12	.04	.03
TOTAL PHOSPHATE	"	< .01	.45	.44	12	.11	.11
SILICA (SIO 2)	"	10.00	15.00	5.00	12	12.17	1.40
TURBIDITY	NTU	2.60	17.00	14.40	12	7.96	5.44
ZINC	MG/L	< .01	.01	0.00	12	.01	0.00
CARBON DIOXIDE	"	0.00	18.00	18.00	12	6.58	5.50
KJELDAHL N	"	.30	.50	0.20	3	.37	.12
BORON	"	< .10	.10	0.00	4	.10	0.00

[a]In those cases where analyses showed concentrations to be below the detection limit of the analytical procedure, the value of the detection limit itself was used to calculate means.

[b]Values presented in the text have been rounded to the sensitivity of the analytical procedures.

STATION 14 DEPTH = SURF

DETERMINATION-UNITS		MIN.	MAX.	RANGE	FREQ.	MEAN[a,b]	STANDARD DEV.
SODIUM	MG/L	7.60	11.00	3.40	12	9.20	1.29
CALCIUM	"	1.60	4.40	2.80	12	2.77	.99
MAGNESIUM	"	1.60	2.40	.80	12	2.05	.32
CHLORIDE	"	4.00	11.00	7.00	12	7.00	1.81
SULFATE (SO 4)	"	4.00	13.00	9.00	12	7.50	3.15
TOTAL DISSOLVED SOLIDS	"	45.00	79.00	34.00	12	60.92	11.43
TOTAL SUSPENDED SOLIDS	"	3.00	11.00	8.00	4	6.00	3.83
MO - ALK	"	16.00	23.00	7.00	12	19.33	2.42
P - ALK (CACO 3)	"	0.00	0.00	0.00	12	0.00	0.00
AMMONIA (NH 3)	"	< .10	.50	.40	12	.29	.14
BIOCHEMICAL OXY- GEN DEMAND	"	< 1.00	3.00	2.00	12	1.33	.65
CADMIUM	"	< .01	< .01	0.00	12	< .01	0.00
CHEMICAL OXYGEN DEMAND	"	< 4.00	12.00	8.00	12	6.17	2.92
TOTAL CHROMIUM	"	< .03	< .03	0.00	12	< .03	0.00
COPPER	"	< .02	< .02	0.00	12	< .02	0.00
TOTAL HARDNESS (CACO 3)	"	12.00	21.00	9.00	12	15.58	3.23
TOTAL IRON	"	.10	.56	.46	12	.30	.12
LEAD	"	< .05	< .05	0.00	12	< .05	0.00
MERCURY	MICRO-GM/L	< .20	< .20	0.00	12	< .20	0.00
NITRATE (NO 3)	MG/L	< .10	1.90	1.80	12	1.16	.43
ORTHO-PHOSPHATE	"	< .01	.20	.19	12	.05	.06
TOTAL PHOSPHATE	"	< .01	.28	.27	12	.09	.07
SILICA (SIO 2)	"	9.60	15.00	5.40	12	11.97	1.59
TURBIDITY	NTU	2.50	13.00	10.50	12	4.92	2.76
ZINC	MG/L	< .01	.04	.03	12	.01	.01
CARBON DIOXIDE	"	1.00	26.00	25.00	12	6.58	7.42
KJELDAHL N	"	.30	1.00	.70	4	.58	.30
BORON	"	< .10	.10	0.00	4	.10	0.00

[a]In those cases where analyses showed concentrations to be below the detection limit of the analytical procedure, the value of the detection limit itself was used to calculate means.

[b]Values presented in the text have been rounded to the sensitivity of the analytical procedures.

Table 2.2.2 (Continued)

STATION 15 DEPTH = SURF

DETERMINATION-UNITS		MIN.	MAX.	RANGE	FREQ.	MEAN [a,b]	STANDARD DEV.
SODIUM	MG/L	7.70	12.00	4.30	12	9.32	1.53
CALCIUM	"	< .01	4.40	4.40	12	2.40	1.26
MAGNESIUM	"	1.00	2.90	1.90	12	1.96	.51
CHLORIDE	"	3.00	10.00	7.00	12	6.58	1.73
SULFATE (SO 4)	"	4.00	14.00	10.00	12	8.17	3.27
TOTAL DISSOLVED SOLIDS	"	49.00	75.00	26.00	12	60.25	8.36
TOTAL SUSPENDED SOLIDS	"	4.00	7.00	3.00	4	6.00	1.41
MO - ALK	"	15.00	22.00	7.00	12	18.92	2.50
P - ALK (CACO 3)	"	0.00	0.00	0.00	12	0.00	0.00
AMMONIA (NH 3)	"	< .10	.40	.30	12	.28	.12
BIOCHEMICAL OXYGEN DEMAND	"	< 1.00	2.00	1.00	12	1.17	.39
CADMIUM	"	< .01	< .01	0.00	12	< .01	0.00
CHEMICAL OXYGEN DEMAND	"	< 4.00	12.00	8.00	12	6.00	2.70
TOTAL CHROMIUM	"	< .03	< .03	0.00	12	< .03	0
COPPER	"	< .02	< .02	0.00	12	< .02	0.00
TOTAL HARDNESS (CACO 3)	"	10.00	21.00	11.00	12	15.08	3.45
TOTAL IRON	"	.10	.52	.42	12	.26	.10
LEAD	"	< .05	< .05	0.00	12	< .05	0.00
MERCURY	MICRO-GM/L	< .20	< .20	0.00	12	< .20	0.00
NITRATE (NO 3)	MG/L	.50	1.70	1.20	12	1.13	.31
ORTHO-PHOSPHATE	"	< .01	.28	.27	12	.07	.08
TOTAL PHOSPHATE	"	< .01	.64	.63	12	.13	.18
SILICA (SIO 2)	"	9.20	16.00	6.80	12	12.02	1.93
TURBIDITY	NTU	2.60	6.50	3.90	12	4.13	1.19
ZINC	MG/L	< .01	.01	0.00	12	.01	0.00
CARBON DIOXIDE	"	2.00	16.00	14.00	12	5.50	4.56
KJELDAHL N	"	.30	.90	.60	4	.65	.30
BORON	"	NR[c]	NR	NR	NR	NR	NR

[a]In those cases where analyses showed concentrations to be below the detection limit of the analytical procedure, the value of the detection limit itself was used to calculate means.

[b]Values presented in the text have been rounded to the sensitivity of the analytical procedures.

[c]Measurement not required.

STATION 16 DEPTH = SURF

DETERMINATION-UNITS		MIN.	MAX.	RANGE	FREQ.	MEAN [a,b]	STANDARD DEV.
SODIUM	MG/L	7.60	11.00	3.40	12	9.20	1.44
CALCIUM	"	2.00	4.00	2.00	12	2.77	.77
MAGNESIUM	"	1.20	2.40	1.20	12	1.88	.42
CHLORIDE	"	4.00	11.00	7.00	12	6.67	1.87
SULFATE (SO 4)	"	3.00	14.00	11.00	12	7.83	3.74
TOTAL DISSOLVED SOLIDS	"	40.00	79.00	39.00	12	61.08	10.53
TOTAL SUSPENDED SOLIDS	"	3.00	10.00	7.00	4	8.00	3.37
MO - ALK	"	15.00	24.00	9.00	12	19.58	2.57
P - ALK (CACO 3)	"	0.00	0.00	0.00	12	0.00	0.00
AMMONIA (NH 3)	"	< .10	.50	.40	12	.32	.13
BIOCHEMICAL OXY-GEN DEMAND	"	< 1.00	2.00	1.00	12	1.33	.49
CADMIUM	"	< .01	< .01	0.00	12	< .01	0.00
CHEMICAL OXYGEN DEMAND	"	< 4.00	12.00	8.00	12	5.75	2.63
TOTAL CHROMIUM	"	< .03	< .03	0.00	12	< .03	0.00
COPPER	"	< .02	< .02	0.00	12	< .02	0.00
TOTAL HARDNESS (CACO 3)	"	11.00	20.00	9.00	12	14.75	3.19
TOTAL IRON	"	.10	.28	.18	12	.20	.07
LEAD	"	< .05	< .05	0.00	12	< .05	0.00
MERCURY	MICRO-GM/L	< .20	< .20	0.00	12	< .20	0.00
NITRATE (NO 3)	MG/L	.60	1.70	1.10	12	1.07	.31
ORTHO-PHOSPHATE	"	< .01	.12	.11	12	.03	.03
TOTAL PHOSPHATE	"	< .01	.30	.29	12	.10	.09
SILICA (SIO 2)	"	7.60	15.00	7.40	12	12.03	2.20
TURBIDITY	NTU	2.00	4.40	2.40	12	3.23	.78
ZINC	MG/L	< .01	.02	.01	12	.01	.00
CARBON DIOXIDE	"	2.00	16.00	14.00	12	4.75	4.05
KJELDAHL N	"	.30	.70	.40	4	.48	.17
BORON	"	< .10	< .10	0.00	4	< .10	0.00

[a]In those cases where analyses showed concentrations to be below the detection limit of the analytical procedure, the value of the detection limit itself was used to calculate means.

[b]Values presented in the text have been rounded to the sensitivity of the analytical procedures.

STATION 18 DEPTH = SURF

DETERMINATION-UNITS		MIN.	MAX.	RANGE	FREQ.	MEAN[a,b]	STANDARD DEV.
SODIUM	MG/L	NR[c]	NR	NR	NR	NR	NR
CALCIUM	"	NR[c]	NR	NR	NR	NR	NR
MAGNESIUM	"	NR[c]	NR	NR	NR	NR	NR
CHLORIDE	"	NR[c]	NR	NR	NR	NR	NR
SULFATE (SO 4)	"	NR[c]	NR	NR	NR	NR	NR
TOTAL DISSOLVED SOLIDS	"	37.00	79.00	42.00	4	58.75	17.21
TOTAL SUSPENDED SOLIDS	"	2.00	6.00	4.00	4	4.25	1.71
MO - ALK	"	28.00	30.00	2.00	4	29.50	1.00
P - ALK (CACO 3)	"	0.00	4.00	4.00	4	1.00	2.00
AMMONIA (NH 3)	"	.20	.60	.40	4	.35	.19
BIOCHEMICAL OXYGEN DEMAND	"	< 1.00	3.00	2.00	4	1.50	1.00
CADMIUM	"	< .01	< .01	0.00	4	< .01	0.00
CHEMICAL OXYGEN DEMAND	"	NR[c]	NR	NR	NR	NR	NR
TOTAL CHROMIUM	"	< .03	< .03	0.00	4	< .03	0.00
COPPER	"	< .02	< .02	0.00	4	< .02	0.00
TOTAL HARDNESS (CACO 3)	"	26.00	28.00	2.00	4	26.75	.96
TOTAL IRON	"	NR[c]	NR	NR	NR	NR	NR
LEAD	"	< .05	< .05	0.00	4	< .05	0.00
MERCURY	MICRO-GM/L	< .20	< .20	0.00	4	< .20	0.00
NITRATE (NO 3)	MG/L	< .10	2.60	2.50	4	1.30	1.33
ORTHO-PHOSPHATE	"	< .01	.09	.08	4	.05	.03
TOTAL PHOSPHATE	"	.05	.11	.06	4	.08	.03
SILICA (SIO 2)	"	NR[c]	NR	NR	NR	NR	NR
TURBIDITY	NTU	1.60	4.00	2.40	4	2.40	1.10
ZINC	MG/L	NR[c]	NR	NR	NR	NR	NR
CARBON DIOXIDE	"	NR[c]	NR	NR	NR	NR	NR
KJELDAHL N	"	NR[c]	NR	NR	NR	NR	NR
BORON	"	< .10	< .10	0.00	4	< .10	0.00

[a]In those cases where analyses showed concentrations to be below the detection limit of the analytical procedure, the value of the detection limit itself was used to calculate means.

[b]Values presented in the text have been rounded to the sensitivity of the analytical procedures.

[c]Measurement not required.

Table 2.2.3 Summary of data taken from the USGS monitoring station at the Fairfield Pumped Storage Facility intake in Monticello Reservoir for the period January through December 1981.

	Temperature (°C)				Dissolved Oxygen (mg/liter)				pH				Conductivity (μmhos/cm)			
	Range		Daily Mean		Range		Daily Mean		Range		Daily Mean		Range		Daily Mean	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
January	2.6[a]	10.3[a]	5.2[a]	9.5[a]	10.1	13.5	11.1	13.2	7.4	7.8	7.4	7.6	66	72	66	71
February	4.3	12.9	6.4	11.0	5.2[a]	12.5[a]	8.1[a]	12.3[a]	6.8	7.6	7.1	7.5	56	68	60	66
March	8.9[a]	13.8[a]	9.6[a]	11.7[a]	7.7[a]	12.3[a]	7.9[a]	11.9[a]	7.1[a]	7.9[a]	7.1[a]	7.4[a]	59[a]	75[a]	63[a]	68[a]
April	11.4	21.0	12.8	18.2	8.2	13.4	9.2	11.7	6.9	9.0	7.0	7.8	57	84	62	72
May	17.9	24.7	18.4	21.9	6.9	11.7	7.8	10.4	6.8	8.8	6.9	7.8	66	84	72	77
June	20.8	30.2	22.0	27.7	5.0	10.5	5.6	8.0	6.6	8.5	6.7	7.4	64	91	69	81
July	24.8[a]	31.1[a]	25.6[a]	29.2[a]	3.8[a]	9.1[a]	4.3[a]	7.0[a]	6.5[a]	8.6[a]	6.5[a]	7.2[a]	74[a]	110[a]	77[a]	91[a]
August	23.8[a]	30.1[a]	25.8[a]	28.1[a]	3.2[a]	9.2[a]	3.9[a]	7.8[a]	6.5[a]	8.3[a]	6.6[a]	7.1[a]	76[a]	107[a]	79[a]	92[a]
September	23.0[a]	29.8[a]	24.3[a]	28.2[a]	3.0[a]	9.4[a]	3.5[a]	7.8[a]	6.3[a]	7.3[a]	6.6[a]	6.9[a]	77[a]	110[a]	86[a]	95[a]
October	15.6[a]	24.6[a]	18.6[a]	24.3[a]	6.4[a]	9.9[a]	6.9[a]	9.2[a]	6.7[a]	7.1[a]	6.7[a]	7.0[a]	82[a]	116[a]	87[a]	94[a]
November	10.9[a]	20.2[a]	13.5[a]	18.6[a]	8.3[a]	10.9[a]	8.4[a]	9.4[a]	6.8[a]	8.3[a]	6.9[a]	7.0[a]	82[a]	105[a]	84[a]	92[a]
December	4.3	14.1	8.7	14.0	9.0	12.6	9.1	11.8	6.6	7.1	6.8	7.0	51	88	67	86

[a] Data incomplete for the month.

2.3 VASCULAR HYDROPHYTES

2.3.1 Introduction

The vascular hydrophytes described in this study included those higher plants with specialized conductive or vascular tissue requiring a hydric habitat. Vegetation occupying xeric or mesic habitats was considered terrestrial. Hence, vegetation occurring near the shoreline was included as aquatic if it was an integral part of the littoral zone. The four major "forms" of hydrophytes included in this study, as defined by Sculthorpe (1967), are:

1. Emergents - These are rooted to the soil and are close to or below the water level for much of the year, but their leaves and reproductive organs are aerial.

2. Floating-leaved - These are rooted in submerged soils, with many of their leaves floating or completely aerial.

3. Free-floating - These are not normally attached but are often entangled in other plants. They may be either completely submerged, at the surface, or emergent from the surface.

4. Submergent - These are attached to submerged materials or surfaces by roots, rhizoids, or by the whole thallus. Their leaves and reproductive organs remain submerged throughout much of the year.

Use of these "forms" was considered both in the categorization of the plant as well as in describing the habitat to which it was confined.

The object of this study was to examine the vascular hydrophyte population in the study area and qualitatively assess its abundance and species distribution. A list of vascular hydrophytes found in this

study is presented in Table 2.3.1 along with growth form, location, relative abundance, and relative density.

2.3.2 Findings

A total of 57 hydrophyte species was found growing in the study area during 1981 (Table 2.3.1). Numbers of species in each reservoir varied. Monticello Reservoir had 18 species observed; Neal Shoals Dam, 10; Monticello Reservoir subimpoundment, 33; and Parr Reservoir had 44 (including adjacent inundated habitats).

Stand densities, referred to as abundant, moderately abundant, and sparse in Table 2.3.1 were determined by the growth habit of the species. For example, cattails (*Typha latifolia*) and softrush (*Juncus effusus*) occasionally grew in large monotypic stands described as "abundant," while many forbs such as beggar ticks (*Bidens frondosa*) and eclipta (*Eclipta alba*) generally occurred as small populations or as individuals, described as "sparse." The largest monotypic stands occurred either submerged or in standing water and are the result of rapid vegetative (asexual) reproduction. The most prominent of these species throughout the study area were the cattails, softrush, and black willow (*Salix nigra*).

The dominant vegetation throughout the littoral zone of the study area was emergent (Table 2.3.1). This vegetation form occurred consistently in areas with shallow water and gently sloping and non-shaded banks. The most extensive hydrophyte communities occurred in Parr Reservoir, either in backwater areas or on the islands. At the Neal Shoals Dam station, however, where the overhead canopy was very dense and the banks very steep, littoral vegetation was sparse; this lack of vegetation was expected due to the absence of sunlight and unsuitable substrate.

Monticello is a young reservoir which, unlike the subimpoundment, receives little nutrient subsidy (i.e., fertilizer). The development of

the littoral zone of this reservoir may depend on how well the vegetation can withstand wind and wave action. The vegetation of each reservoir is discussed in detail in the following subsections.

2.3.2.1 Parr Reservoir

Parr Reservoir continued to support an abundant hydrophyte assemblage. Much of the vegetation was located in backwater areas, resulting from overflow of the banks. These areas are rich in species and support dense populations of composites, grasses, and pickerel weed (Pontederia cordata). The heterogeneous substrate, along with the frequently fluctuating water levels, appeared to promote the growth of a diverse flora throughout much of Parr Reservoir. However, the sampling stations (littoral zone) were very rocky and steep and thus supported little or no vegetation. The shallow backwater area parallel to the railroad and perpendicular (going north) to the tailrace canal supported numerous aquatic species, including pondweed (Potamogeton diversifolius), which was not found growing elsewhere in the reservoir. A large, artificial marsh which is periodically flooded (north of railroad, Figure 2.1.1), also supported abundant hydrophytic vegetation and appeared to support numerous water fowl. The numerous islands in the reservoir are dominated by either black willow or grasses (principally Echinocloa spp.).

The Cannons Creek area supported a rich littoral zone, especially along the north side, where the confluence of a small tributary stream with the reservoir has resulted in a very densely vegetated, marsh-like habitat. Dominant species in this area were aneilema (Aneilema keisak) and Arthraxon hispidus var. cyptatherus.

The sampling station at Cannons Creek supported the most abundant vegetation of any of the sampling stations visited. Dominant species at this station included boltonia (Boltonia asteroides), spike rush (Eleocharis obtusa), and marsh-fleabane (Pluchea camphorata).

Much of the peripheral area around the Cannons Creek Station had an aspect dominance of bulrush, although other sedges were also numerous. Although some areas near the landing were periodically mowed, the Cannons Creek area supported a relatively stable and productive littoral community. A few cypress (Taxodium distichum) saplings have also been planted in this area.

2.3.2.2 Neal Shoals Dam

The Neal Shoals Dam area has shown very little change in species composition since the beginning of the monitoring period. The willow islands which occur in the cove where the central station is located have been occasionally sprayed with herbicides, but they continued to show some second growth. Most of the dead willows have been densely colonized by bryophytes and lichens. No hydrophytic vegetation occurred at the littoral zone sampling station.

2.3.2.3 Subimpoundment

The subimpoundment contained a very diverse and abundant community of vascular hydrophytes. This area has been frequently fertilized as a management practice, resulting in nutrient enrichment and accelerated eutrophication. This was manifested by a rapid development of the littoral zone. The coves were abundantly populated by softrush, cattail, and willow. Alder (Alnus serrulata) was occasionally associated with these species in moderate abundance.

Though extremely abundant in previous years, pondweed (Potamogeton diversifolius) was less dominant; it was only occasionally observed in moderately abundant stands in the subimpoundment. Instead, an unidentified filamentous alga appeared to dominate. The sampling station, though slightly exposed to wave action, appeared to maintain a relatively well-developed littoral community. Softrush was dominant here, although it occurred in small clumps rather than extensive stands.

2.3.2.4 Monticello Reservoir

Monticello Reservoir continued to show development of vegetative associations, particularly within the coves. Here, associations of cattails, softrush, bulrush, and willows typically dominated the ends of the coves. Spike rush (Eleocharis obtusa) was occasionally distributed as moderately abundant mats along the shores and in deeper water in these coves.

The substrate in the coves of Monticello Reservoir appeared to be high in organic content, whereas the banks outside the coves which were exposed to wave action, supported very little vegetation. The exposed shorelines were often very steep and had a clay, hardpan substrate, hindering colonization by hydrophytes. This condition persisted throughout the year and vegetation (kudzu) colonized only the upper edges of the eroded areas.

Individual sampling stations in the littoral zone of Monticello Reservoir were generally very sparsely populated. Most of the stations were located on exposed shorelines and therefore exhibited negligible vegetative development. Because of the relative instability of these areas, it is likely that this condition will persist.

2.3.3 Discussion

Vascular hydrophytes perform several important functions in aquatic ecosystems. As primary producers, they contribute to the supply of oxygen in the water, by photosynthesis, when submerged. In lentic (lake) ecosystems, hydrophytes are important contributors of organic matter to the detrital food chain. These plants also provide habitat, cover, and food for many species of animals, such as insect larvae, fish, birds, and mammals. Growth along reservoir edges can also protect the banks from erosion caused by wave action. This latter function is important in stabilizing the littoral zone and its associated faunal components.

The effects of lack of vegetation are particularly evident in Monticello Reservoir where gulleys devoid of vegetation are becoming eroded and could present problems in maintenance of a healthy aquatic community in the future.

The abundance of hydrophytes in restricted areas such as coves or backwaters is attributable to shallow water and the protection from wave action. Cattails and softrush, the dominant vegetative types in Monticello Reservoir and the subimpoundment, are capable of rapid vegetative reproduction in suitable habitats (i.e., the coves). Thus, these species are important in stabilization of shoreline substrates and in facilitating development of a littoral community. Organic sediment was abundant in these stands as a result of increased siltation, stressing their role in successional development. This type of succession is common in shallow areas of lakes (Sculthorpe, 1967).

Other significant factors limiting development of littoral zones, besides water depth and wave action, are steep banks and a dense overhead canopy. The results of these factors are particularly evident at the Neal Shoals Dam station, where a dense overstory of willows, cottonwoods, and red maple, along with steep banks, severely limit herbaceous vegetation along the shoreline. Fluctuating water levels, along with high turbidity, have probably also been contributing factors limiting the distribution and abundance of vascular hydrophytes in the study area.

Morphological adaptations of vascular hydrophytes frequently provide compensating mechanisms to enable establishment of aquatic vegetation. These adaptations include a high degree of phenotypic plasticity of leaves such as in pondweed and arrowhead (Sagittaria latifolia); rapid lateral growth by underground stems (rhizomes); and the production of spongy tissues (aerenchyma) which facilitate oxygen metabolism in relatively anaerobic conditions. Thus, many of those species colonizing the shorelines throughout the study area are preadapted to a stressful environment.

Most of the species found in the study area are emergent hydrophytes (Table 2.3.1) and, therefore, are less affected by the water-related limiting factors such as depth, turbidity, and fluctuations of water level.

Submerged hydrophytes are more likely to be influenced by increases in turbidity than emergent hydrophytes, not only because of reduced light penetration but also as a result of abrasive effects which can damage the leaves.

The cause of the decline in abundance of pondweed in the subimpoundment is uncertain, but competition from stress-tolerant algae, along with occasional oxygen depletion (based on field measurements) associated with eutrophication, may be contributing factors.

Table 2.3.2 presents dominant vegetation communities, relative fish and wildlife value, probable successional changes, and factors most evident in limiting the hydrophytes in each reservoir.

2.3.4 Summary

A total of 57 species of vascular hydrophytes were found growing in the study area. No significant increases in diversity were noted over previous surveys, although the abundance of several species continued to increase. Species which increased in abundance included softrush, cattail, grasses (Echinocloa spp.), and willows (in Monticello Reservoir only). The subimpoundment continues to show eutrophic conditions, although the pondweed population has decreased in abundance. The major factors limiting growth of the littoral vegetation along all banks appeared to be shading by canopy vegetation and steep banks which did not provide a suitable area for colonization. Other significant factors affecting plant development were turbidity, deep water, fluctuating water levels, and wave action.

Table 2.3.1. Vascular hydrophytes found during shoreline surveys of Parr and Monticello Reservoirs, Neal Shoals Dam, and the subimpoundment, 1981.

Scientific Name	Common Name	Form[a] (Habitat)	Location[b]	Stand Densities[c]	Distribution[d]
Alisma subcordatum	Water-plantain	E	P	S	R
			S	S	R
Alnus serrulata	Alder	E	S	MA	O
			NS	S	R
Ammania coccinea	Ammania	E	S	S	R
			M	S	R
Aneilema keisak	Aneilema	E,S	P	A	O
			CC	A	O
Arthraxon hispidus var. cryptatherus	Grass	E	CC	MA	R
Aster sp.	Aster	E	P	MA	C
			CC(St.C)	MA	C
			NS	S	R
			M	S	R
			S	MA	O
Bacopa monneiri	Water-hyssop	E	M	S	R
Bidens frondosa	Beggar ticks	E	M	S	O
			S	S	O
			P	S	O
			CC	S	O
Boltonia asteroides	Boltonia	E	P	MA	O
			CC(St.C)	MA	R
Carex lurida	Caric sedge	E	S(St.H)	MA	O
Cephalanthus occidentalis	Buttonbush	E	CC(St.C)	S	O
			P	S	O
Chasmantium latifolium	Inland seaoats	E	S	S	R
			NS	S	R
			P	S	R
Cicuta maculata	Water hemlock	E	P	S	R
			CC	S	R
Cyperus erythrorhizos	Flat-top sedge	E	S(St.H)	MA	O
Cyperus iria	Flat-top sedge	E	P	S	R
			CC(St.C)	MA	O
			M(St.K)	S	R
Cyperus virens	Flat-top sedge	E	P	S	O
Diodia virginiana	Buttonweed	E,S	P	S	O

Scientific Name	Common Name	Form[a] (Habitat)	Location[b]	Stand Densities[c]	Distribution[d]
Echinocloa colonum	Barnyard-millet	E	S(St.H)	MA	O
			P	A	C
			CC	MA	C
Echinocloa crusgalli	Barnyard-millet	E	M	S	O
			S	S	C
			P	A	C
			CC	MA	O
Eclipta alba	Eclipta	E	M	S	R
			P	S	R
Eleocharis obtusa	Spike rush	E,S	P	S	R
			S	MA	O
			CC(St.C)	MA	O
			M	MA	O
Eleocharis quandrangulata	Spikerush	E	S	MA	R
Erianthus giganteus	Sugarcane plumegrass	E	M	MA	C
			S	MA	C
			P	S	O
			CC	S	O
Fuerina squarrosa	Umbrella-grass	E	S(St.H)	S	R
			CC	S	R
Hibiscus moscheutos	Hibiscus	E	S	S	O
			NS	S	R
			P	S	R
			CC	S	O
Hydrolea quadrivalvis	Hydrolea	E	P	S	O
Hypericum mutilum	St. John's wort	E	M	S	R
			P	S	R
Juncus acuminatus	Bog-rush	E	S	S	R
			P	S	O
			CC	S	O
Juncus dichotomus	Bog-rush	E	S(St.H)	MA	O
Juncus effusus	Soft rush	E	M	MA	O
			S	A	C
			CC	MA	O
Juncus polycephalus	Bog-rush	E	S	S	R
Leersia oryzoides	Cut grass	E	S	MA	R
Lindernia dubia	False pimpernel	E	P	S	R
			NS	S	R
Ludwigia alternifolia	False-loosestrife	E,S	S	S	O
Ludwigia alterniflora	False-loosestrife	E	S(St.H)	S	O
Ludwigia glandulosa	False loosestrife	E	CC(St.C)	S	O
Ludwigia palustris	False-loosestrife	E,S	M	S	R
			S	S	R

Table 2.3.1 (Continued)

Scientific Name	Common Name	Form[a] (Habitat)	Location[b]	Stand Densities[c]	Distribution[d]
Mimulus ringens	Monkey-flower	E	M	S	R
			S	S	O
			P	S	O
Mollugo virticillata	Carpet-weed	E	P(St.B)	S	R
Paspalum notatum	Paspalum	E	S(St.H)	S	O
			P	S	O
Penthorum sedoides	Ditch stone crop	E	P	S	R
Pluchea camphorata	Marsh-fleablane	E	M(St.M)	S	R
			CC	S	O
			NS	S	R
			P	S	O
			CC(St.C)	MA	O
			M(St.O)	MA	O
Polygonum hydropiperoides	Smartweed	E	S		C
			NS		R
			CC	MA	O
			P	MA	O
Polygonum lapathifolium	Pale smartweed	E	NS	S	R
			P	S	R
Polygonum sagittatum	Tearthumb	E	P	MA	O
			CC	MA	O
Pontederia cordata	Pickerelweed	E	S	S	O
			P	S	O
			CC	MA	C
Potamogeton diversifolius	Pondweed	S,FL	S	S	O
			P	MA	R
Ptilimnium capillaceum	Mock Bishop's weed		CC(St.C)	MA	R
Rhynchospora corniculata	Horned rush	E	CC(St.C)	S	O
			P	S	R
Rotala ramosior	Tooth-cup	E,S	NS	S	R
			S	MA	O
Sagittaria latifolia	Arrowhead	E	CC	S	O
Salix nigra	Black willow	E	P	A	O
			CC	M	O
			NS	A	C
			M	MA	O
			S	MA	C
Saururus cernuus	Lizard's tail	E	P	S	R
			CC(St.C)	S	R
Scirpus cyperinus	Woolgrass bulrush	E	S	A	C
			CC	MA	C
			P	MA	R
			M(St.I,K)	MA	O

Table 2.3.1 (Continued)

Scientific Name	Common Name	Form[a] (Habitat)	Location[b]	Stand Densities[c]	Distribution[d]
Scirpus validus	Soft-stem bulrush	E	S	MA	O
			P	S	R
Taxodium distichum	Bald cypress	E	CC	S	O
			M(St.I)	S	R
			S	S	R
Typha latifolia	Cattail	E	M(St.M)	MA	O
			S	A	C
			CC	MA	O
			P	S	O

[a] Symbols for form (or habitat) of plants are as follows:

E = Emergent
S = Submerged
FL = Floating leaved

[b] Symbols for locations of populations are as follows:

M = Monticello Reservoir
P = Parr Reservoir
S = Subimpoundment
CC = Cannons Creek
NS = Neal Shoals Reservoir
St._ = individual station corresponding to nearest littoral benthic macroinvertebrate sampling location.

[c] Symbols for stand densities are as follows:

A = Abundant (a great number of individuals/stand)
MA = Moderately abundant
S = Sparse (one or two individuals/stand)

[d] Symbols for distribution are as follows:

C = Common
O = Occasional
R = Rare

Table 2.3.2. Dominant vegetation, fish and wildlife value, expected succession, and probable major limiting factors of the littoral communities of the water bodies in the study area, 1981.

Location	Dominant Vegetation	Fish and Wildlife Value	Expected Succession	Probable Major Limiting Factors
Cannons Creek	Diverse; cattails, soft rush, boltonia, and sedges.	Moderate to high in the marshy areas.	No significant change likely.	Steep banks; deep, turbid water, fluctuating water levels.
Subimpoundment	Diverse; cattails and soft rush; pondweed in coves.	High	Trend is toward eutrophication.	Fertilizer accelerating growth; limited by steep banks and shading.
Parr Reservoir	Abundant willow stands, smartweed, and grasses, especially on islands and backwater areas.	High	Uncertain; succession appears attenuated by limiting factors.	Fluctuating water level, shading, steep banks, and turbid water.
Monticello Reservoir	Cattails and soft rush in coves.	Moderate	Continued development of littoral zone in areas where erosion is not significant.	Steep, clay banks, wave action.
Neal Shoals	Primarily willows, very little herbaceous growth along littoral zone.	Low to moderate.	Little succession expected in near future.	Steep banks, deep water, heavy shading from canopy.

2.4 PHYTOPLANKTON

2.4.1 Introduction

Phytoplankton are microscopic, free-floating plants which make up an important component of the aquatic ecosystem. They occupy the lowest trophic level in the food web within the aquatic environment and are consumed by many types of higher life forms, including invertebrates, fish, and occasionally, vertebrates such as waterfowl. Thus, the general health and physical well-being of these consumers are directly or indirectly dependent on phytoplankton.

In addition to the biotic relationships of phytoplankton, there are numerous abiotic factors which are also of importance. Knowledge of phytoplankton species composition is useful in interpreting water quality and predicting potential problems concerning nuisance algal growths. Nuisance algae can cause water taste and odor problems, and bio-fouling in filters, screens, pumps, and other types of water handling equipment.

2.4.2 Findings and Discussion

Parr Reservoir

Stations in Parr Reservoir (Stations B, C, and D) were sampled during January, April, July, and October. The complex phytoplankton assemblage showed definitive quarterly (temporal) patterns. These patterns were exemplified by evaluating mean total densities, collectively, from Stations B, C, and D. These density data are provided in Table 2.4.1.

Mean total densities in Parr Reservoir ranged from 3,712/ml in October to 72,988/ml in January. An algal bloom was evident at all of the Parr Reservoir stations during January, with densities ranging from 115,481 cells/ml at Station B to 18,581 cells/ml at Station D. Phytoplankton populations exhibited a general decline in numbers through the next

three sampling efforts, with October densities ranging between 4 and 35 times lower than those found in January.

Except at Station B in April, diatoms (Bacillariophyta) were the predominant algal group at all of the Parr Reservoir stations for every sampling effort. This group of organisms comprised between 97 and 54 percent of the phytoplankton community throughout the year at all of the stations, except at Station B; diatoms represented only 41 percent of the total community there in April. Green algae (Chlorophyta) were present in samples from each of the sampling stations during all of the months surveyed. Fifty-six and twenty-seven percent, respectively, of the algal population sampled at Stations B and D in April (9,088 cells/ml and 4,179 cells/ml, respectively) were chlorophytes; green algae represented between about 18 and 24 percent of the phytoplankters collected at Stations C and D in April and July as well as at Station C in October. Blue-green algae (Cyanophyta) were also well represented at the Parr Reservoir stations in October, with 25 percent of the community at Stations B and C and 12 percent at Station D.

During the course of the quarterly sampling, algal groups other than the diatoms, green, and blue-green algae were generally uncommon. Other algal groups, made up less than 7 percent of the densities during the four surveys.

The species diversity and number of taxa reported during the quarterly surveys fluctuated independently of the total densities. Collections in July yielded the greatest number of taxa (12.3). The number of taxa collected during the other three quarterly surveys ranged from an average 11.3 (April) to 8.7 (January). The average species diversity (a measure of the distribution of taxa among the number of individuals per taxon) was highest during April through October when average diversity values were between 2.15 and 2.61, and lowest during January (0.96).

During each sampling period, the predominant species were quite similar in Parr Reservoir. In January, Melosira was, by far, the dominant organism, comprising from 53 percent of the phytoplankton community at Station D to 89 and 93 percent of the communities, respectively, at Stations C and B. The diatom, Cyclotella, and a blue-green, Anabaena, were also important components of the phytoplankton community at these stations in January.

During April, Melosira and Cyclotella were again among the predominant species at the Parr Reservoir stations, with the green alga Chlamydomonas also becoming a very important part of the phytoplankton community. Cyclotella was the most abundant organism at Stations C and D, comprising 33 percent and 40 percent, respectively, of the community there; Chlamydomonas was the most prevalent species at Station B, comprising more than 37 percent of the organisms collected there.

Synedra, a diatom, was the predominant alga at all of the Parr Reservoir stations in July, representing from 71 percent (Station B) to almost 43 percent (Station D) of the phytoplankton communities in July. Synedra was also a very important component of the algal community in October, when it comprised from 48 percent of the community at Station B to 20 percent at Station D. Cyclotella and Melosira were also abundant at Station D, while Lyngbya (a blue-green alga) was the second most prevalent species at Station B.

Total phytoplankton biomass in Parr Reservoir during 1981 cannot be correlated with total phytoplankton densities. When the average biomass was highest during April (11.7 mg/liter), the phytoplankton density was much lower than during January (when the average densities were much higher). The lack of correlation between these data may be caused by suspended solids in the water column, which affects both turbidity and biomass. Turbidity affects phytoplankton production by restricting light penetration into the water and, therefore, reducing primary productivity by lowering rates of cell growth and reproduction.

In addition, solids in the water will add non-phytoplankton biomass to samples, resulting in apparent biomass increases where no appreciable increase occurs in the density of plankton organisms.

Evaluation of the phytoplankton communities observed at the three Parr Reservoir stations showed apparent dissimilarities during 1981. The range of values and mean annual phytoplankton density were highest at Station B and lowest at Station D. The inverse of these findings was observed for mean biomass and species diversity. The highest average number of taxa was found at Station C, and the lowest at Station D. These data suggest that, although Stations B, C, and D are all within the boundaries of Parr Reservoir, each undergoes independent ecological succession.

In past studies (Dames & Moore; 1978, 1979, 1979a), Station B consistently accounted for the lowest phytoplankton density, taxonomic richness, biomass, and species diversity. Station C, located in the Cannons Creek embayment area, was consistent in producing the highest phytoplankton density, species diversity, and number of taxa. Station D was ranked between these two stations in the above characteristics, except for biomass. This latter station generally showed higher biomass levels than at the other stations. During 1981, only the station trend for biomass levels did not change with regard to previous trends.

Neal Shoals Dam

The phytoplankton density increased to a high of 29,961 cells/ml in July from a January low of 5,583 cells/ml, and then declined to 12,901 cells/ml in October.

As at the Parr Reservoir stations, in January, April, and October diatoms were most abundant; these organisms made up approximately 44,

93, and 63 percent of the total density, during the respective months. During July, the green algae were predominant (58 percent), but diatoms (37 percent) were also abundant. Green algae were also numerous during January (25 percent) and October (22 percent).

During January, 63 percent of the phytoplankton population at Station P was evenly distributed among the following genera: Spirogyra (a green alga), Navicula (a diatom), and Anabaena (a blue-green alga). In April, Synedra comprised 31 percent of the population but, as in Parr Reservoir, Cyclotella and Melosira were also abundant. The July sampling effort yielded Dispora (a green alga) as the most abundant species (40 percent), followed by Synedra (25 percent), which was also abundant in Parr Reservoir. Synedra remained at a level of 25 percent of the population in October, but was rivaled in abundance by Chlamydomonas and Cyclotella (both almost 20 percent).

The species diversity indices at Station P were very similar throughout the entire year; the values recorded ranged from a low of 2.77 in October to a high of 3.07 in January, and the mean for the four sampling periods was 2.87. The biomass data reflected the phytoplankton densities throughout the year; the highest biomass (16.8 mg/liter) occurred in July, and the lowest (5.2 mg/liter), in January.

Subimpoundment

Phytoplankton densities in the subimpoundment were highest in October (24,737 cells/ml) and lowest in January (9,387 cells/ml), but the trend was not toward greater density over the year since April populations were higher than those reported for July.

During January and July, diatoms were the most abundant algal group at Station H, representing 57 and 52 percent of the population, respectively. The blue-green algae were also important during the

January (27 percent) and July (26 percent) periods, with green algae also forming a large portion of the phytoplankton community in July (22 percent). During April, the chlorophytes were the most abundant group (64 percent) and, in October, the blue-greens were most numerous (52 percent). In both April and October, diatoms remained an important component of the community, representing 32 and 36 percent of the community during those respective months.

A total of 15 taxa was collected from Station H from April through October, while 12 taxa were collected in January. Species diversity ranged between 3.13 (July) and 2.14 (January), averaging 2.66 for the year. In January, Melosira (51 percent) and Anabaena (26 percent) were the most abundant species. Chlamydomonas accounted for 43 percent of the community, but another green alga, Chlorococcales (13 percent), and the diatom Asterionella (13 percent) were also important during April. During the summer period, the blue-green Oscillatoria formed the most abundant component (25 percent) of the algal community, but Synedra (19 percent), Melosira (15 percent), and Chlamydomonas (12 percent) were present in relatively high concentrations also. Lyngbya, a species not found in the July samples, bloomed to 41 percent of the October population, with Synedra remaining at a level (22 percent) similar to that seen in July, and Cymbella increasing to 12 percent of the community.

Monticello Reservoir

Phytoplankton densities generally showed characteristic trends during every season except summer. In the winter, mean densities at all stations increased from 3,537 cells/ml during November to 41,567 cells/ml in January. A decline of 30,562 cells/ml occurred in February from January's winter high, but mean densities increased during the spring from March (15,960 cells/ml to May (38,918 cells/ml). June phytoplankton densities decreased to an average of 22,470 cells/ml for the Monticello Reservoir stations. This decrease in the mean phyto-

plankton density was followed in July by an increase to the highest mean level recorded for 1981, 47,791 cells/ml. From late summer (August) to October, densities decreased from 11,746 cells/ml to 3,284 cells/ml.

Mean densities for phytoplankton at all of the Monticello Reservoir stations indicated that diatoms were the most numerous group, forming 94 (January) to 53 (April) percent of the community, during every month except August and September. In August, the diatoms were second in abundance (38 percent) to the green algae (58 percent); diatoms and green algae were almost equally abundant, as an average, with 38 percent and 36 percent of the community, respectively, during September. Green algae were also important components of the algal community in Monticello Reservoir during March (46 percent) and April (51 percent). Station J was the only station where diatoms dominated the phytoplankton community year-around, but the chlorophytes were very important (43 percent) at this station during April. At the other Monticello Reservoir stations, green algae were dominant or co-dominant with the diatoms from one time (Station I in August, Station M in September) to four times (Stations N and O in March, August, September, and December) times during the year.

Melosira was the most abundant organism at all stations during January and February. Although still an important component of the phytoplankton community in March, Cyclotella, Chlorococcales, and Chlamydomonas were also abundant at all of the stations sampled. By April, Melosira and Chlamydomonas remained important at all stations, and Fragillaria showed a strong increase at Station I. A Fragillaria bloom was evident at all stations during May and June, but by July this diatom had almost disappeared from the community, being replaced by a Synedra bloom at all stations. In August, dominance was spread among different genera at each station, but in September, Lyngbya was the dominant at Station I and Chlamydomonas was dominant at all other stations. In October, Melosira reappeared as the dominant genus at four

stations, with Synedra dominant at Stations J and L and Fragillaria most abundant at Station K. Melosira continued to be a very important component of the Monticello Reservoir phytoplankton community in November, with Synedra also being abundant at Station I and Cyclotella being most numerous at Station M. In December, Cyclotella was most abundant at Stations I through N, but was codominant with Melosira at Stations K and M and codominant with an unidentified chlorophyte at Station N. The unidentified chlorophyte was the predominant species at Station O in December.

Mean species diversity at the Monticello Reservoir stations was lowest (0.61) in January but increased during the next two months until it reached 2.75 in March. The diversity then decreased to its second lowest value (1.17) in May before rising to its highest level (3.03) in August. By the end of the three following months, the diversity had declined to 1.82. It remained relatively constant (1.95) in December before dropping to the January low.

The highest mean number of taxa (10.7 to 14.7) occurred between February and September. The lowest number of taxa (6.5) was recorded in December, but November and January showed a similarly low number, (6.7) for each month.

Mean total phytoplankton biomass from the samples collected in Monticello Reservoir was highest between April (12.0 mg/liter) and July (11.6 mg/liter), with the highest biomass recorded in June (22.6 mg/liter). After this peak period, the mean biomass declined from 8.0 mg/liter in August to 6.2 mg/liter in December. During eight of the sampling periods, density and biomass increased and decreased synchronously. However, in February, when densities had decreased to one-fourth of January levels, the biomass showed a slight increase. In March, the biomass declined by 1.9 mg/liter from February while the density increased 1.5 times over February collections. In June, although the mean phytoplankton density had decreased significantly

from the May levels, the biomass increased by 9.0 mg/liter. July also showed an inverse correlation between biomass and density. Discrepancies in biomass-density relationships may be due to contamination from non-planktonic biomass during periods of high turbidity.

Although the monitoring results sometimes differed noticeably among the Monticello Reservoir stations for the monthly sampling efforts, none of the stations appeared to exhibit a continual, monthly pattern of higher or lower biomass, density, diversity, or taxa number levels than any of the other stations. However, in general, the southern Monticello Reservoir stations (L, M, N) appeared to have lower mean densities than the other stations. Such a trend was not evident for the other parameters measured. Station J showed the greatest range in density measurements. Station I had the highest mean annual species diversity (2.35), and Stations J (1.73) and N (1.80), the lowest.

In addition, although the dominant genera and representative genera sometimes differed among sampling stations and individual sampling efforts, there was an over-all similarity in the phytoplankton composition among stations. For example, although Chlamydomonas was the most abundant phytoplankter at all stations during September, with the exception of Station I (where it was exceeded in numbers by Lyngbya and Cymbella), this genus still comprised an important part of the community at Station I (almost 11 percent). In addition, during the same sampling period Cymbella formed an important part of the phytoplankton community at Stations M, N, and O (12 to 13 percent), and Lyngbya was relatively numerous (13 to 22 percent) at Stations K, M, and O.

2.4.3 Summary

During previous studies (Dames & Moore, 1978, 1979a, 1979b, 1980), parameters measured for the phytoplankton communities in Parr Reservoir were observed to be similar to those found at the Neal Shoals Dam sampling site; additionally, the subimpoundment was found to exhibit

phytoplankton community characteristics similar to those recorded for Monticello Reservoir. With the exception of species composition, during 1981, the phytoplankton sampling results from Parr Reservoir showed little similarity to those from the Neal Shoals Dam station. The same dissimilarities, again with the exception of generic composition, were evident between the Monticello Reservoir and subimpoundment stations.

During the quarterly surveys in Parr Reservoir, biomass generally fluctuated inversely to phytoplankton biomass while a positive biomass-density relationship occurred in Monticello Reservoir during eight of the twelve samplings. These relationships have been observed during previous studies of phytoplankton in the two reservoirs. The opposing patterns seem to be largely caused by the influence of relatively high turbidity in Parr Reservoir and generally lower values in Monticello Reservoir. In Parr Reservoir, the high biomass values are not considered to be accurate indicators of biomass due to non-planktonic contamination.

The monthly fertilization program being carried out from March through August in the subimpoundment appears to have prolonged the period of highest phytoplankton production during 1981. Although Monticello Reservoir experienced a phytoplankton bloom in January and was characterized by decreasing phytoplankton numbers from August through October, the subimpoundment populations were at their lowest recorded level in January before initiation of the fertilization program and peaked in October following termination of the program. In spite of the artificial nutrient input into the subimpoundment, however, phytoplankton densities at Station H were, except in October, lower than the mean densities in Monticello Reservoir. However, fertilization appears to have shifted the generic composition since green and blue-green algal comprised a greater proportion of the phytoplankton community in the subimpoundment than in Monticello Reservoir. A shift

in species abundance as a result of inorganic fertilization has been documented in the literature (Bennett, 1970).

As in the 1980 study (Dames & Moore, 1980), a high degree of similarity in the phytoplankton community was observed among the Monticello Reservoir stations. The ecological variables measured in the phytoplankton communities were generally quite uniform throughout Monticello Reservoir, although mean densities seemed to be, on the average, somewhat lower at stations in the lower reservoir. The generally higher variation in range of phytoplankton densities near the FPSF noted during the 1980 effort was not evident during 1981.

Table 2.4.1 Density, biomass, number of taxa, and taxonomic diversity of phytoplankton collected during 1981 at Parr Reservoir, Neal Shoals Dam, Monticello Reservoir, and the subimpoundment.

Area	Parr Reservoir												Neal Shoals Dam			
Station	B				C				D				P			
Density (cells/ml)	J	A	JL	O	J	A	JL	O	J	A	JL	O	J	A	JL	O
Chlorophyta	1212	9088	506	85	376	5229	7470	513	364	4179	823	172	1396	1185	17511	2783
Euglenophyta	--	369	0	0	--	0	0	0	--	141	0	0	--	0	0	0
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pyrrophyta	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chrysophyta	0	0	0	0	94	0	2158	0	0	0	165	0	225	0	1245	1012
Bacillariophyta	111952	6648	12930	3248	80855	20506	21746	1281	16395	11264	3462	3612	2431	14525	11205	8094
Cyanophyta	2317	--	422	1111	3577	--	0	598	1822	--	0	516	1531	--	0	1012
Total	115481	16105	13858	4444	84902	25735	31374	2392	18581	15584	4450	4300	5583	15710	29961	12901
Biomass (mg/l)	7.1	9.6	9.0	8.1	7.4	13.0	13.1	10.7	7.6	12.6	10.8	15.1	5.2	14.6	16.8	12.6
Species Diversity Index	.55	2.54	1.50	2.16	.74	2.73	2.15	2.45	1.58	2.55	2.79	2.96	3.07	2.84	2.78	2.77
No. of Taxa	11	10	10	10	10	14	14	7	6	10	13	9	12	13	17	9

[a] Shannon-Wiener species diversity index (Pielou, 1966).

Table 2.4.1 (Continued)

Area	Subimpoundment				Monticello Reservo!-											
Station	H							I								
Taxa	J	A	JL	O	J	F		A	M	JU	JL	A	S	O	N	D
Chlorophyta	1186	10969	2352	2863	90	284	5639	7081	2756	1092	7728	10772	2248	341	340	2992
Euglenophyta	--	0	84	95	--	--	--	160	--	--	0	0	0	0	--	--
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pyrrophyta	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chrysophyta	305	740	0	0	3783	0	--	0	0	0	0	427	86	0	--	--
Bacillariophyta	5354	5517	5628	8980	43421	4563	8102	8205	47842	19238	46032	8466	5709	5728	2890	7952
Cyanophyta	2542	--	2856	12799	0	2854	--	--	0	0	0	171	4846	683	0	0
Total	9387	17226	10920	24737	47294	7701	13741	15446	50598	20330	53760	19836	12889	6752	3230	10944
Biomass (mg/l)	8.3	10.0	7.6	6.7	8.6	9.9	7.0	10.6	10.1	20.3	13.0	7.5	8.1	7.8	5.4	6.6
Species Diversity Index[a]	2.14	2.76	3.13	2.62	0.63	2.45	3.01	2.16	1.05	1.63	1.77	3.16	2.75	2.89	4.16	2.56
No. of Taxa	12	15	15	15	5	14	14	8	11	12	13	19	15	12	10	11

[a] Shannon-Wiener species diversity index (Pielou, 1966).

Area	Monticello Reservoir															
Station	J				K											
Taxa	J	A	JL	O	J	F	M	A	M	JU	JL	A	S	O	N	D
Chlorophyta	505	14174	7311	170	477	1451	6761	15083	14024	9309	2142	6241	4869	84	680	259
Euglenophyta	--	412	0	0	--	--	--	587	--	--	0	85	885	0	--	--
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pyrrophyta	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chrysophyta	0	0	510	0	0	70	0	65	--	115	659	85	530	0	--	--
Bacillariophyta	44155	18166	92160	2820	42617	12501	11154	15477	34481	38511	6185	7097	3010	2365	5271	6057
Cyanophyta	0	--	0	256	0	35	--	--	0	0	0	85	2657	84	85	0
Total	44660	32752	99811	3246	43094	14057	17915	22130	48505	47935	8986	13593	11951	2533	6036	6316
Biomass (mg/l)	7.6	10.4	9.0	6.6	8.1	8.4	7.2	10.7	12.8	24.0	8.2	6.4	10.7	6.6	6.8	4.6
Species Diversity Index[a]	0.62	2.27	1.54	2.48	0.51	1.08	2.93	2.44	1.63	2.14	2.73	3.30	2.95	2.33	1.94	1.29
No. of Taxa	8	13	12	9	7	13	14	17	11	16	14	19	14	8	11	4

[a] Shannon-Wiener species diversity index (Pielou, 1966).

Table 2.4.1 (Continued)

Area	Monticello Reservoir											
Station					L							
Taxa	J	F	M	A	M	JU	JL	A	S	O	N	D
Chlorophyta	404	566	1681	15486	576	166	4753	830	2052	252	85	860
Euglenophyta	--	--	--	303	--	--	164	0	170	0	--	--
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--
Pyrrophyta	--	--	--	--	--	--	--	--	--	--	--	--
Chrysophyta	0	0	0	0	--	0	655	83	0	0	--	--
Bacillariophyta	38763	10269	7112	12369	25981	2739	52959	3154	1965	1008	1403	2925
Cyanophyta	202	496	--	--	0	0	0	0	0	0	0	0
Total	39369	11331	8793	28158	26557	2905	58531	4067	4187	2160	1488	3785
Biomass (mg/l)	7.9	8.7	6.1	12.9	13.3	18.5	13.7	8.1	9.6	5.2	7.4	7.3
Species Diversity Index[a]	0.59	1.86	2.77	2.64	0.97	0.99	1.64	2.72	3.01	2.28	0.63	2.07
No. of Taxa	8	12	13	17	10	4	17	11	12	7	3	7

[a] Shannon-Wiener species diversity index (Pielou, 1966).

Table 2.4.1 (Continued)

Area	Monticello Reservoir											
Station	M											
Taxa	J	F	M	A	M	JU	JL	A	S	O	N	D
Chlorophyta	95	320	5845	5152	327	412	2324	854	870	510	84	170
Euglenophyta	--	--	--	0	--	--	0	0	0	0	--	--
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--
Pyrrophyta	--	--	--	--	--	--	--	--	--	--	--	--
Chrysophyta	0	71	--	0	0	0	415	0	0	255	--	--
Bacillariophyta	28351	10807	7540	9425	15404	9485	20085	1965	957	1785	588	2210
Cyanophyta	0	535	--	--	572	82	0	598	261	170	0	1190
Total	28466	11733	13385	14577	16303	9979	22824	3417	2088	2720	672	3570
Biomass (mg/l)	12.6	12.7	9.6	13.1	14.6	27.4	13.1	7.1	6.6	6.4	7.3	6.4
Species Diversity Index[a]	0.42	1.73	2.79	2.24	1.72	1.60	2.08	2.90	2.47	2.50	1.88	2.07
No. of Taxa	6	15	14	9	11	9	16	10	7	7	5	5

[a] Shannon-Wiener species diversity index (Pielou, 1966).

Area	Monticello Reservoir											
Station	N											
Taxa	J	F	M	A	M	JU	JL	A	S	O	N	D
Chlorophyta	81	418	16720	14529	1384	14359	2180	11424	4153	85	340	1360
Euglenophyta	--	--	--	279	--	--	0	0	86	0	--	--
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--
Pyrrophyta	--	--	--	--	--	--	--	--	--	--	--	--
Chrysophyta	0	0	0	69	--	0	323	0	86	0	--	--
Bacillariophyta	39351	8378	12097	7609	29328	26305	17888	3696	2681	2805	5951	1445
Cyanophyta	0	34	--	--	0	0	0	420	778	0	0	0
Total	39432	8830	28817	22486	30712	40664	20391	15540	7784	2890	6291	2805
Biomass (mg/l)	9.2	8.1	6.7	14.0	18.4	22.9	10.8	9.9	7.9	3.3	6.5	5.5
Species Diversity Index[a]	0.49	1.20	2.42	1.78	0.83	2.54	1.43	3.28	3.18	1.47	1.32	1.76
No. of Taxa	6	9	12	11	10	18	13	16	15	4	6	6

[a] Shannon-Wiener species diversity index (Pielou, 1966).

Area	Monticello Reservoir											
Station	0											
Taxa	J	F	M	A	M	JU	JL	A	S	O	N	D
Chlorophyta	61	790	7035	5454	3196	680	6678	10817	3613	513	171	1275
Euglenophyta	--	--	--	347	--	--	0	338	516	0	--	--
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--
Pyrrophyta	--	--	--	--	--	--	--	--	--	--	--	--
Chrysophyta	0	68	0	0	--	85	814	338	172	85	--	--
Bacillariophyta	35942	9804	6073	8876	57555	12242	62740	2535	4042	2821	3335	1105
Cyanophyta	C	1720	--	--	0	0	0	0	1635	170	0	0
Total	48674	12382	13108	14677	60832	13007	70232	14028	9978	3589	3506	2380
Biomass (mg/l)	8.3	8.6	8.4	12.0	12.4	22.7	13.3	9.2	6.0	7.5	5.8	6.9
Species Diversity Index[a]	1.06	2.26	2.63	2.65	0.84	1.49	1.22	2.86	3.04	2.76	0.99	1.92
No. of Taxa	7	16	10	13	11	11	13	13	15	10	5	6

[a] Shannon-Wiener species diversity index (Pielou, 1966).

2.5 ZOOPLANKTON

2.5.1 Introduction

Zooplankton form the animal constituent of the plankton community. These organisms are primary consumers which feed directly on the phytoplankton and form a portion of the food chain base for the higher organisms.

Replicate samples of zooplankton were collected in January, April, July, and October 1981 at the aquatic biology stations indicated in Figure 2.1.1. Organisms were identified to the lowest practicable taxon and enumerated for each replicate. The findings were averaged for each station and collection period and summarized in Table 2.5.1. In presenting these findings, quantitative comparisons were made between stations for number of taxa, densities, distribution of the taxa within the four major sampling areas, and species diversity. Taxa comprising 10 percent or more of the collection were considered codominants in the community. The species enumerated from the samples were referenced to two crustacean orders, Cladocera and Copepoda, and the phylum, Rotatoria (rotifers). Unidentified eggs and other immature stages of zooplankton, excluding copepod, naupliar, and copepodite forms, were omitted from these analyses.

2.5.2 Findings and Discussion

Parr Reservoir

The biological survey conducted in Parr Reservoir included the collection of zooplankton at three stations (Figure 2.1.1). The average density for total zooplankton, obtained from the mean densities of all three sampling locations, ranged from 5.03/liter in January to 31.78/liter in April. The largest mean density occurred at Station C during each of the four sampling periods. Highest total numbers at Station C

during April (37.74/liter) were concurrent with the greatest densities (31.36/liter) for members of the phylum Rotatoria observed from Parr Reservoir samples.

Community composition was generally similar for the four sampling periods. The rotifers were the most abundant organisms identified and enumerated from samples collected at the three stations. These zooplankters accounted for an average of 80 percent of the total zooplankton community for the four collecting periods. During 1980, rotifers also predominated in the January, April, July, and October collections, comprising an overall average of 74 percent of the total zooplankton community (Dames & Moore, 1980). According to Chengalath, et al. (1971), the rotifers are perhaps the most common animals found in standing waters, and, in many cases, constitute the numerically dominant fauna in zooplankton.

The mean relative abundance for copepods and cladocerans represented approximately 15 and 5 percent of the total zooplankton community, respectively. The highest number for copepods, 4.60/liter, was recorded during April at Station C. Cladoceran densities were generally low and ranged from 0.10/liter at Station D during January to 1.78/liter at Station C in April.

For the four sampling periods, the overall codominant zooplankton species recorded from Parr Reservoir samples were the rotifers Polyarthra sp., Synchaeta sp., and Keratella cochlearis and the copepod nauplii. These taxa were also the most numerous zooplankters collected at all three sampling locations in January, April, and October 1980 (Dames & Moore, 1980). Additional codominant species of the present study were: Asplanchna sp. at Station C during April and Bosmina longirostris at Station D during July.

Several other species, although less abundant, occurred at all three stations. The mean number of taxa collected was 15 in January, 11 in

April, 20 in July, and 15 in October; the range was from 10 in April to 23 in July at Stations B and D, respectively. Similarly, the Shannon-Wiener diversity values ranged from 2.21 in April to 3.27 in July, at Stations B and D, respectively.

Zooplankton biomass was determined for all sampling periods, with values averaging 0.028 mg/liter for January, 0.004 mg/liter for April, 0.004 mg/liter for July and 0.005 mg/liter for October samples. The greatest biomass was measured at Station D (0.031 mg/liter) during January.

Neal Shoals

Zooplankton samples were collected from one station (Figure 2.1-1) in the Neal Shoals Dam area. The mean density for total zooplankton increased from low levels in January (0.47/liter) and April (1.81/liter) to 241.00/liter in July before declining to 60.72/liter in October. The high densities observed during July were the largest recorded for the 12 stations sampled during the 1981 survey.

The rotifers were the most abundant organisms observed, accounting for 93 percent of the total zooplankton community for the four collecting periods. These zooplankters also predominated in the samples collected during 1980, comprising an average of 82 percent of the total zooplankton community (Dames & Moore, 1980).

Species of Cladocera and Copepoda were observed in all samples during the collecting periods, except in January when cladocerans were not present in the samples. Their densities, however, were generally low and comprised approximately 1 and 6 percent, respectively, of the zooplankton community for the 1981 survey. Copepods were highest in densities during October (14.38/liter) and accounted for almost 24 percent of the collection for that month.

Codominant taxa recorded from samples collected at the station were the rotifers: Synchaeta sp., Keratella cochlearis, and Polyarthra sp. during January; Polyarthra sp. and Synchaeta sp. during April; Brachionus angularis, Asplanchna sp., and Filinia longiseta during July; and Synchaeta sp., Conochilus unicornis, and Polyarthra sp. during October. During an earlier study conducted in 1980, these rotifers (with the exception of B. angularis) were also observed as codominants (Dames & Moore, 1980). Although B. angularis was recorded only from the July collections of the present study, the mean density of this rotifer was the highest reported for any taxa for the 12 stations sampled during the survey. In addition, the copepod nauplii were codominant in January, April, and October.

The number of taxa collected during January, April, July, and October were 12, 13, 16, and 11, respectively. During the previous year, collections yielded 22, 18, 20, and 13 taxa from the four sampling periods.

During the 1981 study, zooplankton species diversity ranged from 2.11 during April to 2.76 in January. Diversity values recorded during 1980 ranged from 2.24 in October to 3.06 in July. Diversity values reported in July (2.52) and October (2.40) during 1979 were the lowest reported for the entire study area (Dames & Moore, 1979).

Zooplankton biomass for 1981 was 0.005 mg/liter in January, 0.006 mg/liter in April, 0.037 mg/liter in July, and 0.016 mg/liter in October. The values recorded at this station were comparable to those recorded in Parr Reservoir during April, but were much higher during July and October; they were somewhat lower during January (Dames & Moore, 1981).

Subimpoundment

The average density for total zooplankton collected ranged from 3.55/liter in July to 111.31/liter during April. Mean densities for the rotifers and copepods accounted for approximately 83 and 14 percent, respectively, of the total zooplankton community for the four sampling periods. Mean densities for the cladocerans ranged from 0.01/liter during July to 5.26/liter in April. The densities obtained for the cladocerans never represented more than 5 percent of the total zooplankton community for each sampling period.

Codominant taxa observed in samples collected from the subimpoundment were the rotifers: Polyarthra sp., Keratella cochlearis, and Kellicottia bostoniensis during January; K. cochlearis and Conochilus unicornis during April; Brachionus angularis, and Synchaeta sp. during July; and Polyarthra sp., Synchaeta sp., and C. unicornis during October.

During previous investigations conducted in 1980, K. cochlearis and the copepod nauplii were the codominant taxa for the four sampling periods (Dames & Moore, 1980). K. cochlearis alone comprised 50 percent of the zooplankton recorded from samples collected in July 1979 (Dames & Moore, 1979a). In the present study, K. cochlearis accounted for 60 percent of the April collection. According to Stemberger (1979) Keratella is perhaps the most common limnetic rotifer in fresh water.

The number of taxa collected during January, April, July, and October was 17, 15, 12, and 13, respectively.

Zooplankton species diversity was highest in January (2.75). The lowest diversity in the subimpoundment occurred in July (1.42); this was also the lowest value reported for the entire study area for all four sampling periods.

Biomass was determined for all sampling periods and was highest in April (0.016 mg/liter). The high volume coincides with phytoplankton productivity associated with fertilization of the subimpoundment.

Monticello Reservoir

Zooplankton samples were collected from Monticello Reservoir at seven stations (Figure 2.2.1) during the four sampling periods. The average density for total zooplankton, obtained from the mean densities of all seven sampling locations ranged from 1.84/liter during October to 32.94/liter in April. Mean densities for individual sampling stations ranged from a low of 1.24/liter at Station L in October to a high of 60.25/liter at Station N during April. The cumulative average densities of major taxa among the seven stations sampled were highest for the rotifers, cladocerans, and copepods during April.

The rotifers were the most numerous zooplankters in samples collected during January, April, and July. The greatest density observed for these individuals, 49.36/liter, was recorded at Station N in April. Overall, the occurrences of the rotifers represented an average of 65 percent of the total zooplankton community for the four sampling periods.

Average densities for the two crustacean orders, Copepoda and Cladocera, accounted for 26 and 10 percent, respectively, of the total zooplankton identified from the Monticello Reservoir samples. During July and October, however, the copepods comprised 42 and 59 percent, respectively, of the total zooplankton population.

The codominant taxon which was observed in all sampling periods was the copepod nauplii. This taxon alone accounted for 38 and 43 percent of the total zooplankton community during July and October, respectively. Additional codominant taxa for individual sampling periods were: Synchaeta sp. and Keratella cochlearis during January; Polyarthra sp.,

Synchaeta sp., Asplanchna sp., and B. longirostris during April; K. cochlearis and Polyarthra sp. during July; and B. longirostris during October.

In addition to these codominants, several species were frequently observed throughout the samples collected in the Monticello Reservoir, although in lower overall densities. The number of zooplankton taxa enumerated at the sampling stations ranged from: 9 to 17 during January; 11 to 15 during April; 17 to 22 during July; and 13 to 17 during October.

Zooplankton species diversity ranged from 2.19 during July to 3.11 in October, both extremes occurring at Station I. Overall, however, the average species diversity was slightly higher in April (2.62) than in January (2.50), July (2.49), and October (2.56).

Values for biomass were higher during January, averaged 0.023 mg/liter and ranged from 0.013 mg/liter at Station O to 0.037 mg/liter at Station K.

2.5.3 Summary

The zooplankton communities observed during January, April, July, and October 1981 did not indicate any unusual trends. Based on assessments of taxonomic composition, densities, distribution among the stations, and species diversity, these zooplankton populations appeared to be progressing through normal seasonal changes. The species composition of zooplankton at the twelve stations in the study area was similar to that reported during the 1978, 1979, and 1980 investigations. The rotifers were, overall, the dominant organisms collected during this study; these organisms are characteristic of limnetic habitats such as that found throughout the study area. The distribution of taxa indicated that generally stable zooplankton communities exist. The frequency of zooplankter occurrence at the various stations indicated

that few differences seemed to occur within each major study area, particularly Parr and Monticello Reservoirs. Overall densities and taxonomic diversities at the stations for all areas did not appear to change significantly from previous years.

Table 2.5.1 Zooplankton collected in January, April, July, and October 198[illegible], represented by numbers of organisms per major taxonomic category[a] species diversity[b], and biomass.[c]

Area	Parr Reservoir			$\bar{x}$ of B-D	Neal Shoals	Sub-Impoundment	Monticello Reservoir							$\bar{x}$ of I-O
Station	B	C	D		F	H	I	J	K	L	M	N	O	
January														
Rotatoria	3.34	5.13	3.7[illegible]	4.07	0.38	11.05	4.05	2.[illegible]9	4.70	1.42	2.89	2.20	1.68	2.78
Cladocera	0.27	0.12	0.10	0.16	0.0[illegible]	0.37	0.81	0.44	0.09	0.08	0.08	0.14	0.10	0.25
Copepoda	0.85	0.69	0.88	0.80	0.09	[illegible].38	0.62	0.30	0.88	0.25	0.59	0.45	0.31	0.49
Total Density	[illegible]	5.93	4.70	5.03	0.47	19.80	5.48	3.23	5.67	1.75	3.56	2.78	2.10	3.51
Total Taxa	13	13	19	15	12	17	12	14	9	15	15	13	17	14
Species Diversity	2.65	2.47	2.65	2.59	2.76	2.75	2.27	2.23	2.39	2.64	2.52	2.67	2.81	2.50
Biomass	0.029	0.024	0.031	0.028	0.005	0.006	0.025	0.028	0.037	0.015	0.023	0.022	0.013	0.023
April														
Rotatoria	28.32	31.36	19.06	26.25	0.99	94.09	6.[illegible]	14.03	38.16	14.95	22.76	49.36	14.07	22.76
Cladocera	1.74	1.78	1.02	1.15	0.04	5.26	5.[illegible]	5.81	1.99	2.34	1.89	5.01	2.45	3.59
Copepoda	3.96	4.60	3.51	4.02	0.78	11.95	7.[illegible]	13.95	4.82	4.48	3.77	5.88	5.58	6.59
Total Density	34.02	37.74	23.60	31.78	1.81	111.31	19.32	33.79	44.97	21.76	28.41	60.25	22.10	32.94
Total Taxa	10	13	11	11	13	15	15	15	11	14	13	13	13	13
Species Diversity	2.21	2.50	2.24	2.32	2.11	2.06	2.67	2.90	2.38	2.73	2.54	2.42	2.69	2.62
Biomass	0.002	0.007	0.004	0.004	0.006	0.016	0.011	0.013	0.011	0.005	0.005	0.011	0.005	0.009

Table [illegible].5.1 (Continued)

Area	Parr Reservoir			$\bar{x}$ of B-D	Neal Shoals	Sub-Impoundment	Monticello Reservoir							$\bar{x}$ of [illegible]
Station	B	C	D		P	H	I	J	K	L	M	N	O	
July														
Rotatoria	2.66	17.24	0.71	6.87	235.73	3.51	13.54	6.65	11.18	1.97	1.91	2.38	1.54	5.60
Cladocera	0.80	0.86	0.23	0.63	3.44	0.01	0.37	0.35	0.[illegible]7	0.72	0.55	0.81	0.48	0.49
Copepoda	3.32	2.12	0.44	1.96	1.84	0.03	8.73	7.31	2.36	3.16	1.95	4.46	2.91	4.41
Total Density	6.79	20.21	1.39	9.46	241.00	3.55	22.64	14.32	13.72	5.58	4.41	7.65	4.94	10.50
Total Taxa	20	16	23	20	16	12	17	22	19	18	18	19	20	19
Species Diversity	2.81	3.23	3.27	3.10	2.40	1.42	2.19	2.38	2.55	2.54	2.62	2.58	2.57	2.49
Biomass	0.007	0.005	0.001	0.004	0.037	0.009	0.004	0.004	0.005	0.002	0.003	0.006	0.001	0.004
October														
Rotatoria	1.18	30.16	4.50	11.95	46.04	20.12	0.67	0.33	0.36	0.26	0.36	0.42	0.24	0.38
Cladocera	0.21	0.67	0.53	0.47	0.30	0.07	0.29	0.31	0.40	0.21	0.64	0.35	0.48	0.38
Copepoda	0.83	4.22	2.17	2.41	14.38	0.72	0.87	0.66	1.59	0.76	1.51	1.09	1.11	1.08
Total Density	2.22	35.05	7.21	14.83	60.72	20.91	1.82	1.30	2.35	1.24	2.51	1.87	1.83	1.84
Total Taxa	15	16	15	15	11	13	17	17	13	14	14	15	15	15
Species Diversity	2.72	2.33	2.62	2.56	2.60	1.97	3.11	2.79	2.38	2.52	2.20	2.45	2.45	2.56
Biomass	0.003	0.003	0.008	0.005	0.016	0.002	0.001	0.001	0.001	0.0004	0.001	0.001	0.001	0.0009

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[a] Counts are in numbers of organisms per liter.

[b] Shannon-Wiener species diversity index (Pielou 1966).

[c] Biomass is in mg/liter of ash-free, dry weight.

2.6 ICHTHYOPLANKTON

2.6.1 Introduction

Ichthyoplankton, comprised of the egg and larval component of the ichthyofauna, are of fundamental importance in assessing fishery success for two reasons:

1. Ichthyoplankton are the products of a species' reproductive efforts; therefore, ichthyoplankton abundance and survival bear directly on the reproductive success of a species.

2. Ichthyoplankton, particularly of forage species such as gizzard shad, provide a valuable food resource to a number of desirable fish species.

In temperate areas, most spawning takes place in spring and summer; therefore, ichthyoplankton are collected most abundantly in these seasons. The presence of early life history stages of fish often indicates that a water body is being used as a nursery and/or nursery area by adult fish.

Because of their limited mobility, eggs and larvae are particularly susceptible to being affected by the operation of power generating stations. These effects, which are dependent on specific engineering variables, include impingement upon water intake structures, entrainment through condenser cooling systems, and entrainment in the heated effluents discharged during power generation (Battelle, 1974). Thermal stress can kill organisms (Marcy, 1971; 1973), weaken them and thus make them more vulnerable to predation (Schubel et al., 1978), or, in the case of eggs, cause abnormal development of the embryo which often results in death soon after hatching (Koo and Johnston, 1978). Mechanical stress can also weaken or kill exposed organisms (Marcy, 1973).

Ichthyoplankton samples were collected throughout 1981 at eleven stations: two stations in Parr Reservoir (Stations B and C), one control station in the Broad River upstream from Neal Shoals Dam (Station P), one station in the subimpoundment of Monticello Reservoir (Station H), and seven stations in Monticello Reservoir (Stations I, J, K, L, M, N, and O). Collections were made at the surface and at mid-depth at all stations except C (Parr Reservoir) and P (Neal Shoals). At these two stations, only surface samples were taken because of the shallow water.

Data provided by these sampling efforts are described below for each of the four study areas (Section [illegible].2) and then related to the present and developing fisheries in these areas (Section 2.6.3). The following characteristics are desc[illegible]bed by these data: 1) species composition, 2) relative abundance, 3) spatial distribution and frequency, and 4) temporal distribution.

2.6.2 Findings

Mean monthly ichthyoplankton densities are presented in Table 2.6.1 for March through September 1981. No ichthyoplankton were found in samples collected in January, February, October, November, or December of 1981.

Parr Reservoir

Two distinctly different habitats were sampled in Parr Reservoir. Station B is located in the tailrace canal for the FPSF and is subject to high velocity and scouring currents. Most ichthyoplankton found at Station B were probably derived from Monticello Reservoir via the FPSF. In contrast, Station C is in a cove formed by the mouth of Cannons Creek. This protected area harbors a resident larval fauna.

At Station B, patterns of increase and decline followed those of Monticello Reservoir. This is to be expected because most larvae collected at Station B probably come from Monticello Reservoir via the FPSF. Clupeids were the most abundant larvae collected; second in abundance were sunfishes. Clupeid densities reached 67.6/100 m^3, and total sunfish abundance did not exceed 2.4/100 m^3. Densities for these predominant organisms were highest in May and showed a declining trend in June, July, and August. Other taxa collected at Station B included minnows (Cyprinidae), suckers (Catostomidae), white bass, crappie, and darters. Mean monthly densities for each of these taxa never exceeded 1.6/100 m^3. Larval fish were first collected at Station B in April and included catostominae, Morone spp., and clupeids.

At Station C, the highest monthly mean densities collected in 1981 occurred in May (150.3 larvae/100 m^3) and June (152.2/m^3), and consisted mostly of clupeids (144.9 to 146.1/100 m^3) during these respective months.

Other taxa which were collected at Station C during May and June included minnows (Cyprinidae), crappie (Pomoxis spp.), temperate bass (Morone spp.), and sunfishes (Lepomis spp.) and an unidentified centrarchid. Moderately high clupeid densities initially occurred at Station C in April (97.4/100 m^3), then peaked in May and June. In July, clupeid abundance declined to less than 1.3/100 m^3 and in August, clupeids failed to appear in the samples. Sunfish (Lepomis spp.) followed the same relative trend April through August; densities peaked in April then declined in May and occurred sporadically in June, July, and August. Lepomis spp. densities did not exceed 2.6/100 m^3. Darters (Percidae) were the first larvae obtained from the entire study area, appearing in March.

Neal Shoals

Neal Shoals, Station P, is a control station removed from the influence of the FPSF and its attendant fluctuations in water level. Two peaks in larval densities were observed at Neal Shoals in May and July. The first peak was produced as a result of the presence of numerous clupeids (158.7/100 m^3) and the second peak occurred mostly because of the abundance of Lepomis spp. (132.1/100 m^3). Low densities of minnows, crappie, and darters were also present in these samples. Densities declined sharply in June and August, with only unidentified sunfish occurring in September (0.9/100 m^3). The larval fauna at Station P consisted of low densities, exclusive of clupeids; densities of other taxa were never greater than 4.7/100 m^3, and most often were less than 1.1/100 m^3. The less numerous taxa included darters, minnows, and crappie.

Subimpoundment

Station H is located in a subimpoundment at the northern end of Monticello Reservoir. The fertilization program being carried out in the subimpoundment is responsible for maximizing the development of a desirable fishery in this area. Unlike the other areas studied, clupeids were not the numerically predominant larval fish collected from the subimpoundment. In April, the first taxa collected were crappie and clupeids, both taxa being comprised of similar numbers, 17 to approximately 23/100 m^3 in surface collections. In May, very few crappie were taken in collections, but sunfish larvae were present in moderate abundance (maximum 26.9/100 m^3) in surface and mid-depth samples. Maximum clupeid density reached 220.2/100 m^3 at mid-depth, and clupeids were present in moderate abundance at the surface (29.1/100 m^3). Sunfish abundances increased to even higher levels in June (mean at surface was 86.3/100 m^3; mean at mid-depth was 6.0/100 m^3) while clupeid densities declined to only 1/100 m^3. Sunfish densities declined to moderate abundance in July and low

abundance in August. In most months, there was a noticeable trend for sunfish to be more abundant in surface samples.

Monticello Reservoir

The seven stations (I, J, K, L, M, N, and O) sampled in Monticello Reservoir were all located in open water, as opposed to protected coves, and were sampled at both surface and mid-depth. For the reservoir as a whole, larval fish first appeared in April with a mean density of approximately 10 organisms/100 m^3, increased in abundance in May to 50 organisms/100 m^3, then decreased from June through September from 30 to less than 1 organism/100 m^3. From April through July, all stations collectively showed higher larval fish densities in surface samples. The frequency of taxa occurring in 84 possible surface and mid-depth samples from April through September ranged from one for Ictaluridae (catfish) to 55 for Clupeidae. The next most frequently occurring taxa were Lepomis spp. (35), Percidae (19), and Cyprinidae (14), and suckers, Morone spp., and crappie (from 6 to 9 occurrences each).

Densities of larval fish at all stations, except Station L, increased in May and decreased in June with clupeids dominating the collections. At Station L, the highest ichthyoplankton density occurred in June, 119.0/100 m^3, with clupeids being the most abundant group. In May, the highest density, 111.3/100 m^3, was found in surface samples at Station M; the lowest, 12.2/100 m^3, was found at mid-depth at Station L. Densities at both surface and mid-depth were atypically low at Station L in May. Averaged surface and mid-depth densities of clupeids were similar in May and slightly higher at the surface than at mid-depth during June for all stations. Other taxa collected during May and June generally did not exceed 2.0/100 m^3 and included crappie, suckers. darters, cyprinids, and white bass, which were generally more numerous in May than June. In June, total densities declined, associated with a decline in clupeid abundance, while a general increase

in sunfish abundance was noted. Percidae frequency and abundance decreased significantly from May to June. Sunfish were generally distributed evenly in both the surface and mid-depth samples.

In July, densities continued to decline with no station having a mean monthly density higher than 10/100 m^3, and most showing densities less than 3/100 m^3. Sunfish and clupeids were the most abundant larvae collected at all stations, with average clupeid density being slightly higher. Additional taxa collected in July included minnows and unidentified Centrarchidae. In August, averaged densities were the lowest recorded during 1981, and only two taxa, sunfish and clupeids, were collected. Sunfish were the most abundant at Stations I, J, K, L, and M. Clupeids occurred only at Stations K and M. The highest mean larval fish density in August was recorded at Station L, mid-depth (6.4/100 m^3) and Station M, surface (6.1/100m^3). The only Ictaluridae to be collected in the entire study area were present in the September samples at Monticello Reservoir, Station M, mid-depth, their density was less than 1 organism/100 m^3.

2.6.3 Discussion

A rather typical seasonal succession of fish larvae was observed in the study area during 1981. The first larvae to appear were the Percidae, then crappie, clupeids, temperate bass, and minnows, followed by sunfish and suckers and, finally, by ictalurids. This succession is expected, based upon available information on preferred spawning temperatures of the adult fish of these taxa.

Shallow water areas, especially Stations C and P, with morphometric features conducive to influencing increased water temperature, were the first to produce relatively high abundances of larval fish. (This comparison excludes the artificially enhanced fishery in the subimpoundment.) The reason for these areas to produce larval fish early in the season was likely due to a rapid but stable increase in water temperature in these shallower, protected areas, resulting in the earlier

attainment of preferred spawning temperatures. The earlier occurrence of percid larvae in March, and the higher larval fish densities in samples collected during April, indicated earlier spawning activity in 1981 than in 1980. During the 1981 sampling program, overall monthly larval fish densities peaked higher than 1980 densities in Monticello Reservoir. This could possibly indicate more favorable environmental conditions for fish and fish spawning and rearing.

Each of the four major study areas (Parr Reservoir, Neal Shoals, the subimpoundment, and Monticello Reservoir) harbored distinct larval fish communities for the sampling periods during 1981.

Parr Reservoir was composed of 8 ichthyoplankton taxa comprised predominantly of Clupeidae, _Lepomis_ spp., and Cyprinidae. The ichthyoplankton community at the Neal Shoals Dam station was composed of 6 taxa comprised predominantly of Clupeidae, _Lepomis_ spp., and Percidae, while Monticello Reservoir samples were composed of 10 taxa made up mostly of Clupeidae, _Morone_ spp., _Lepomis_ spp., Catostomidae and Percidae. The subimpoundment contained 3 larval fish taxa and, ranked in order of high to low abundance included Clupeidae, _Lepomis_ spp., and _Pomoxis_ spp. Overall, the number of larval fish taxa collected monthly was lower at Neal Shoals than at Parr Reservoir; was the highest at Monticello Reservoir, and the lowest at the subimpoundment. Comparatively, the subimpoundment had the highest average larval fish density, Neal Shoals was second, Parr Reservoir third, and Monticello Reservoir was fourth. This presently makes the subimpoundment the most productive and, in part, verifies the success of SCWMRD program to establish a recreational fishery here. The moderately high densities and variety of larval fish collected from Parr Reservoir and Neal Shoals reflect their relative mature development. The overall low densities in Monticello Reservoir likely reflect it being a new impoundment and a less developed ecosystem, while that of the subimpoundment has obviously

been artificially enhanced for high productivity of fish and other types of aquatic life.

Further evaluation of larval fish distributed among Monticello Reservoir stations showed that the greatest number of taxa was collected during 1981 at Stations K, L, and M. This high diversity may be due in part to the relatively shallower, somewhat protected environments at K and M compared to the other stations in the reservoir. The overall favorable larval fish diversity at Station L is likely affected by the FPSF. Thus, larvae from nearby habitats of Parr and Monticello Reservoirs, may be carried into the sampling area, potentially increasing the number of taxa collected here. Sunfish populations in Monticello Reservoir during 1981 were relatively low considering the numerically abundant adult population. Lower densities of sunfishes may be due to fluctuating water levels in Monticello, caused by the operation of the FPSF, which interferes with reproduction by nest building species such as centrarchids. Snyder (1971) found that only a limited area was used by nest builders in another pumped storage facility with similar fluctuations in water level. It is also possible that these species are missed because areas where they are likely to occur most abundantly are not sampled, such as the numerous protected and shallow areas of the many coves around the periphery of Monticello Reservoir.

The abundance of clupeid larvae in nearly all areas of Monticello Reservoir provides a valuable food resource to several recreationally important species (largemouth bass, crappie, and white bass) which, both as larvae and adult, prey upon the larvae of forage species such as gizzard shad (Clark and Pearson, 1979). This may be especially true for the recreational fishery in Monticello Reservoir where the greatest potential for increasing fish populations probably exists.

The trends evident in the 1981 data are quite similar to those observed in previous years (Dames & Moore; 1978, 1979, 1979a, 1980). The early peaks in densities at Stations C and P in 1981, although varying in

time by several weeks, were apparently the result of an unusually warm period in early spring at favorable environmentally oriented stations. Clupeid larvae were more abundant throughout the study areas in 1981 than in previous years. Steady increases in most other larval fish diversities and overall abundance are also evident from data from Monticello Reservoir. This trend should continue until Monticello Reservoir approaches maturity.

2.6.4 Summary

A typical succession of larval fish species was observed in the study area in 1981. Percidae were the first taxa to appear in March and clupeids the first to occur in notable abundance. The presence of these taxa was followed by that of crappie and sunfish.

Except for the subimpoundment, clupeids dominated collections in all areas. The numerical abundance and wide distribution of clupeids in the study area make it an important forage fish which provides a valuable food resource to some of the recreationally important fish species present in the area. In the subimpoundment, sunfish and crappie were proportionally more abundant than in other collections; this is presumed to be the result of directed management of this water body for recreational fishing. The subimpoundment also had the highest overall larval fish densities. Parr Reservoir and Neal Shoals produced the highest densities of clupeid fish but also maintained a relatively diverse larval fish assemblage among areas sampled. Total larval fish densities were moderately high, with the lower densities observed in Monticello Reservoir and highest densities in the subimpoundment. Monticello Reservoir showed the greatest overall increase from 1980 in larval fish diversity, although overall abundance was lowest compared to Parr Reservoir, Neal Shoals, and the subimpoundment during 1981. Parr Reservoir and Neal Shoals showed some characteristics typical of a mature fishery whereas Monticello Reservoir was typical of a naturally

developing fishery and the subimpoundment of an enhanced or managed fishery.

Table 2.6.1 Mean monthly densities of larval fish (number/100 m^3) collected in net tows, March through September 1981.

MARCH 1981		Area	Parr		Neal Shoals	Sub-Impoundment	Monticello						
Scientific Name	Common Name	Station	B	C [a]	P [a]	H	I	J	K	L	M	N	O
Dorosoma spp.	Herring	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Clupeidae, Unid.	Herring	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Cyprinus carpio	Carp	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Cyprinidae	Minnows	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Catostominae	Suckers	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Catostomidae, Unid.	Suckers	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Morone spp.	Temperate bass	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Lepomis spp.	Sunfish	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Pomoxis spp.,	Crappie	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Centrarchidae, Unid.	Sunfish	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Percidae	Darters	Sfc	-	1.0	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Damaged, Unid.		Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Total		Sfc	-	1.0	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)

Note: Sfc = Surface Samples; Mid = Mid-depth

[a] Only surface samples taken at Stations C and P

Table 2.6.1 (Continued)

APRIL 1981		Area	Parr		Neal Shoals	Sub-impoundment	Monticello						
Scientific Name	Common Name	Station	B	C [a]	P [a]	H	I	J	K	L	M	N	O
Dorosoma spp.	Herring	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Clupeidae, Unid.	Herring	Sfc	5.3	97.4	18.7	17.4	-	3.4	6.1	16.3	12.4	3.2	3.2
		Mid	(7.8)	(-)	(-)	(20.0)	(0.9)	(6.1)	(13.2)	(1.4)	(15.0)	(4.3)	(1.9)
Cyprinus carpio	Carp	Sfc	-	-	-	-	-	-	-	-	-	-	1.1
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Cyprinidae	Minnows	Sfc	-	-	-	-	-	-	-	2.0	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Catostominae	Suckers	Sfc	0.9	0.9	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Catostomidae, Unid.	Suckers	Sfc	-	-	-	-	-	-	-	5.6	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Morone spp.	Temperate bass	Sfc	0.9	2.7	-	-	-	-	1.0	4.1	1.2	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(4.4)
Lepomis spp.	Sunfish	Sfc	-	2.6	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Pomoxis spp.,	Crappie	Sfc	-	1.5	-	22.8	-	-	1.0	-	-	-	-
		Mid	(-)	(-)	(-)	(4.4)	(2.8)	(-)	(-)	(-)	(-)	(-)	(-)
Centrarchidae, Unid.	Sunfish	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Percidae	Darters	Sfc	-	-	4.7	-	-	1.1	1.2	3.4	-	0.9	1.6
		Mid	(-)	(-)	(-)	(-)	(1.3)	(-)	(-)	(-)	(-)	(-)	(-)
Damaged, Unid.		Sfc	-	2.4	13.5	-	-	-	-	2.0	-	0.9	1.1
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(1.0)	(-)	(1.2)
Total		Sfc	7.1	107.5	36.9	40.2	-	4.5	9.3	33.4	13.6	5.0	7.0
		Mid	(7.8)	(-)	(-)	(24.4)	(5.0)	(6.1)	(13.2)	(1.4)	(18.9)	(4.3)	(7.5)

Note: Sfc = Surface Samples; Mid = Mid-depth

[a] Only surface samples taken at Stations C and P

Table 2.6.1 (Continued)

MAY 1981		Area	Parr		Neal Shoals	Sub-impoundment	Monticello						
Scientific Name	Common Name	Station	B	C [a]	P [a]	H	I	J	K	L	M	N	O
Dorosoma spp.	Herring	Sfc	-	-	1.0	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Clupeidae, Unid.	Herring	Sfc	63.2	144.9	158.7	29.1	54.0	82.2	25.1	14.8	111.3	13.7	14.3
		Mid	(67.6)	(-)	(-)	(220.2)	(32.7)	(70.2)	(51.0)	(12.2)	(82.3)	(43.0)	(29.0)
Cyprinidae, Unid.	Minnows	Sfc	1.1	0.8	-	-	1.0	-	-	-	-	1.3	-
		Mid	(0.9)	(-)	(-)	(-)	(-)	(-)	(2.5)	(-)	(-)	(-)	(-)
Catostomidae, Unid.	Suckers	Sfc	1.2	-	-	-	-	0.9	-	-	0.9	-	-
		Mid	(0.9)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(0.9)	(-)	(-)
Morone spp.	Temperate bass	Sfc	-	0.9	-	-	-	-	-	1.0	-	-	-
		Mid	(0.9)	(-)	(-)	(-)	(-)	(1.0)	(-)	(-)	(1.1)	(-)	(-)
Lepomis spp.	Sunfish	Sfc	2.2	0.8	1.9	25.8	-	1.0	1.0	3.5	2.5	1.0	2.8
		Mid	(1.0)	(-)	(-)	(26.9)	(-)	(-)	(-)	(-)	(1.2)	(-)	(-)
Pomoxis spp.,	Crappie	Sfc	0.9	2.9	1.0	-	0.9	-	-	-	1.5	1.3	-
		Mid	(-)	(-)	(-)	(1.5)	(-)	(-)	(-)	(0.9)	(1.5)	(-)	(1.1)
Centrarchidae, Unid.	Sunfish	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Percidae, Unid.	Darters	Sfc	1.6	-	1.0	-	4.6	0.9	1.0	2.0	1.0	1.1	1.0
		Mid	(-)	(-)	(-)	(-)	(1.1)	(1.0)	(1.0)	(-)	(-)	(-)	(-)
Damaged, Unid.		Sfc	2.4	-	1.4	2.4	1.6	3.0	1.7	-	2.4	2.4	1.9
		Mid	(-)	(-)	(-)	(2.4)	(-)	(-)	(1.2)	(-)	(1.9)	(2.4)	(1.3)
Total		Sfc	72.6	150.3	165.0	57.3	62.1	88.0	28.8	21.3	119.6	20.8	20.0
		Mid	(71.3)	(-)	(-)	(251.0)	(33.8)	(72.2)	(55.7)	(13.1)	(88.9)	(45.4)	(31.4)

Note: Sfc = Surface Samples; Mid = Mid-depth

[a] Only surface samples taken at Stations C and P

Table 2.6.1 (Continued)

JUNE 1981

Scientific Name	Common Name	Area / Station	Parr B	Parr C [a]	Neal Shoals P [a]	Sub-Impoundment H	Monticello I	Monticello J	Monticello K	Monticello L	Monticello M	Monticello N	Monticello O
Dorosoma spp.	Herring	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Clupeidae, Unid.	Herring	Sfc	13.3	146.1	41.2	1.0	4.8	10.1	20.8	119.0	27.8	42.1	22.8
		Mid	(15.1)	(-)	(-)	(-)	(9.0)	(15.7)	(33.3)	(13.2)	(11.5)	(27.9)	(36.4)
Cyprinus carpio	Carp	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Cyprinidae	Minnows	Sfc	1.1	-	-	-	-	-	-	1.0	-	1.0	0.9
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(0.9)	(-)
Catostominae	Suckers	Sfc	-	-	-	-	0.9	1.0	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Catostomidae, Unid.	Suckers	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Morone spp.	Temperate bass	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Lepomis spp.	Sunfish	Sfc	2.1	1.9	-	86.3	1.0	1.0	1.5	3.8	1.3	2.1	0.9
		Mid	(-)	(-)	(-)	(6.0)	(1.1)	(0.9)	(0.9)	(-)	(1.4)	(2.4)	(-)
Pomoxis spp.,	Crapple	Sfc	-	2.5	-	-	-	-	1.0	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Centrarchidae, Unid.	Sunfish	Sfc	-	0.8	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Percidae	Darters	Sfc	-	-	-	-	-	-	1.0	1.0	-	1.0	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Damaged, Unid.		Sfc	1.0	0.9	1.0	1.6	-	-	1.0	-	-	-	-
		Mid	(-)	(-)	(-)	(1.1)	(-)	(-)	(1.3)	(-)	(-)	(0.8)	(-)
Total		Sfc	17.5	152.2	42.2	88.9	6.7	12.1	25.3	124.8	29.1	46.2	24.6
		Mid	(15.1)	(-)	(-)	(7.1)	(10.1)	(16.6)	(35.5)	(13.2)	(12.9)	(32.0)	(36.4)

Note: Sfc = Surface Samples; Mid = Mid-depth

[a] Only surface samples taken at Stations C and P

Table 2.6.1 (Continued)

JULY 1981		Area	Parr		Neal Shoals	Sub-impoundment	Monticello						
Scientific Name	Common Name	Station	B	C [a]	P [a]	H	I	J	K	L	M	N	O
Dorosoma spp.	Herring	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Clupeidae, Unid.	Herring	Sfc	1.0	1.3	12.9	1.0	1.2	-	-	10.0	1.0	1.1	1.9
		Mid	(0.9)	(-)	(-)	(-)	(1.2)	(1.4)	(-)	(3.4)	(1.3)	(2.3)	(3.9)
Cyprinus carpio	Carp	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Cyprinidae	Minnows	Sfc	1.0	-	1.1	-	-	-	-	1.1	-	-	1.0
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(2.3)	(1.3)	(-)	(-)
Catostominae	Suckers	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Catostomidae, Unid.	Suckers	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Morone spp.	Temperate bass	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Lepomis spp.	Sunfish	Sfc	-	-	132.1	28.0	1.1	-	2.7	2.1	1.1	-	2.9
		Mid	(0.9)	(-)	(-)	(3.5)	(1.0)	(-)	(1.2)	(-)	(1.1)	(-)	(1.1)
Pomoxis spp.,	Crappie	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Centrarchidae, Unid.	Sunfish	Sfc	-	-	-	-	-	-	-	-	1.0	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Percidae	Darters	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Damaged, Unid.		Sfc	-	0.8	-	2.2	-	-	0.9	1.1	1.1	1.5	1.0
		Mid	(0.9)	(-)	(-)	(2.7)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Total		Sfc	2.0	2.1	146.1	31.2	2.3	-	3.6	14.3	4.2	2.6	6.8
		Mid	(2.7)	(-)	(-)	(6.2)	(2.2)	(1.4)	(1.2)	(5.7)	(3.7)	(2.3)	(5.0)

Note: Sfc = Surface Samples; Mid = Mid-depth

[a] Only surface samples taken at Stations C and P

Table 2.6.1 (Continued)

AUGUST 1981		Area	Parr		Neal Shoals	Sub-Impoundment	Monticello						
Scientific Name	Common Name	Station	B	C [a]	P [a]	H	I	J	K	L	M	N	O
Dorosoma spp.	Herring	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Clupeidae, Unid.	Herring	Sfc	0.8	-	-	-	-	-	-	-	-	-	-
		Mid	(1.1)	(-)	(-)	(5.4)	(-)	(-)	(1.6)	(-)	(1.2)	(-)	(-)
Cyprinus carpio	Carp	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Cyprinidae	Minnows	Sfc	1.0	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Catostominae	Suckers	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Catostomidae, Unid.	Suckers	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Morone spp.	Temperate bass	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Lepomis spp.	Sunfish	Sfc	1.4	1.9	2.9	5.9	0.9	1.2	2.1	4.7	6.1	-	-
		Mid	(2.4)	(-)	(-)	(7.5)	(-)	(-)	(1.6)	(6.4)	(-)	(-)	(-)
Pomoxis spp.,	Crappie	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Centrarchidae, Unid.	Sunfish	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Percidae	Darters	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Damaged, Unid.		Sfc	-	-	-	0.9	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Total		Sfc	3.2	1.9	2.9	6.8	0.9	1.2	2.1	4.7	6.1	-	-
		Mid	(3.5)	(-)	(-)	(12.9)	(-)	(-)	(3.2)	(6.4)	(1.2)	(-)	(-)

Note: Sfc = Surface Samples; Mid = Mid-depth

[a] Only surface samples taken at Stations C and P

Table 2.6.1 (Continued)

SEPTEMBER 1981		Area	Parr		Neal Shoals	Sub-Impoundment	Monticello						
Scientific Name	Common Name	Station	B	C [a]	P [a]	H	I	J	K	L	M	N	O
Dorosoma spp.	Herring	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Clupeidae, Unid.	Herring	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Cyprinus carpio	Carp	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Cyprinidae	Minnows	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(0.9)	(-)	(-)
Catostominae	Suckers	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Catostomidae, Unid.	Suckers	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Morone spp.	Temperate bass	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Lepomis spp.	Sunfish	Sfc	-	-	-	1.09	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Pomoxis spp.,	Crapple	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Centrarchidae, Unid.	Sunfish	Sfc	-	-	0.9	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Percidae	Darters	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Ictaluridae	Catfish	Sfc	-	-	-	-	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(0.9)	(-)	(-)
Total		Sfc	-	-	0.9	1.09	-	-	-	-	-	-	-
		Mid	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(1.8)	(-)	(-)

Note: Sfc = Surface Samples; Mid = Mid-depth

[a] Only surface samples taken at Stations C and P

2.7 BENTHOS

2.7.1 Introduction

Benthic macroinvertebrates are bottom-dwelling organisms which inhabit underwater substrates during part or all of their life cycle. These organisms are large enough to be retained by a 0.595 mm sieve and may be seen by the unaided eye. Many species are important biological indicators of the physical and chemical quality of an aquatic ecosystem. The benthic macroinvertebrate community may also provide an indication of important trophic or food chain relationships with higher life forms, especially fish, within the aquatic environment. Certain aspects of these relationships are evaluated using numerical analyses (mean annual values) as described herein.

The resulting numerical relationships, which are emphasized in this section, provide indications of overall ecological conditions and trends that are often better than evaluations provided by single indicator species, or single community component (number of taxa, densities, biomass, diversity, or equitability) evaluations (Tables 2.7.1 and 2.7.2). The component of density provides information on the upper and lower limits of the number of organisms per square meter of a particular taxon or complete community. Biomass data supplements density measurements with weight per square meter measurements and also shows upper and lower limits for specific taxa and entire communities. The community components of diversity and equitability provide evaluations of taxonomic richness or variety, and evenness or the apportionment of individuals among taxa. Higher diversity and equitability values generally indicate more complex food chains (numerous functional feeding groups present at different trophic levels) and increased community stability (reduced oscillations or moderation from extreme variations of density, biomass, and taxonomic makeup).

Frequently, subtle changes reflected in the benthic macroinvertebrate communities cannot be completely assessed with short-term data collection. Under these circumstances it is possible that either natural variation or artificial changes may be the cause. Environmental changes resulting from natural variation are likely to be caused by temporal and/or spatial changes, or influences on the benthic community. For objective evaluations of these types of changes in the aquatic environment, long-term studies may be required to complete an ecological assessment.

The emphasis of this section was to evaluate the benthic data collected quarterly during 1981 and to assess important ecological trends and relationships which have occurred since June 1978. Evaluation and comparison of the benthic macroinvertebrate data were based on variables among the transects sampled and mean annual values calculated from composite quarterly survey data. The numerical relationships (mean annual values) depicting general ecological relationships were calculated for each transect and include density, biomass, number of taxa, diversity, and equitability. Distribution, and frequency of important taxa were considered separately. Mean annual values were calculated from triplicate samples at each transect, collected quarterly (January, April, July, and October). The data from which mean annual values were calculated for 1981 are presented in Table 2.7.2. The 1978, 1979, and 1980 data are provided in the respective Environmental Monitoring reports (Dames & Moore; 1978, 1979, 1979a, 1980).

2.7.2 Findings

Parr Reservoir

During 1981, the benthic macroinvertebrate communities in Parr Reservoir showed similar trends to those from previous surveys (Dames & Moore; 1978, 1979, 1979a, 1980). During 1981 mean annual taxonomic diversity ($\bar{d}$) was 1.31 for Transect B, 1.99 for Transect C, and 3.35 for Transect D; equitability was 0.48, 0.58, and 0.83, respectively. The

mean annual number of taxa was 6.5, 11.5, and 17.0 for Transects B, C, and D, respectively. Mean annual density was $882/m^2$, $1817/m^2$, and $1204/m^2$ for Transects B, C, and D, respectively. Biomass was 44.49 g/m^2 at Transect B, 12.78 g/m^2 at Transect C and 26.94 g/m^2 at Transect D. Transect B showed the most significant changes since the 1978 survey.

Community characteristics, as indicated by the improvement of selected overall mean annual values, showed some moderation from a developing trend toward previously lower extreme values at Transect B. The moderation experienced at Transect B was from an earlier trend toward lower numbers of taxa, and lower diversity and equitability, but with significant increases in density and biomass (1978 through 1980) indicating a less stable, less complex benthic community. During the 1981 survey, mean annual density and equitability remained similar and biomass, number of taxa, and diversity increased. Since increases in the number of taxa and diversity indicate greater stability in aquatic ecosystems, it is considered a slight improvement in the benthic macroinvertebrate community at Transect B. Further monitoring should help determine the significance of the beneficial changes that occurred during 1981.

Transect C and especially Transect D, showed ranges characteristic of the mean annual values obtained during previous surveys (Dames & Moore; 1978, 1979, 1979a, 1980).

Although the benthic community at Transect C showed characteristic density and above normal biomass values, as compared to previous data, a gradual trend toward decreased number of taxa, diversity, and equitability were indicated. These changes suggest a slightly decreased community complexity since 1978. This trend was most pronounced in 1981 when fewer benthic macroinvertebrate taxa occurred which subsequently reduced the mean annual values for taxonomic diversity and equitability. The reduction in number of taxa may be caused by repeated drawdown in

Parr Reservoir and, in part, may also result from natural variation. Studies in 1982 may provide findings which will help define this trend and establish further rationale for the causes.

The slightly increased taxonomic variability at Transect B suggests a slightly improved benthic community during 1981. The indicator values, however, were still considerably below mean values for 1978, indicating that the tailrace area is a physically stressed environment. Benthic density and biomass continue to increase predominantly due to the presence of the Asiatic clam (Corbicula manilensis) at Transect B and are presently much higher than pre-1979 values.

During 1981, Parr Reservoir showed mean annual benthic macroinvertebrate density ($1301/m^2$), and diversity (2.22) to be higher than observations obtained from 1976 through 1981 (Dames & Moore; 1976, 1977, 1978, 1979, 1979a, 1980, and 1981). Mean annual density, from 1976 through 1981, ranged from $381/m^2$ to $1633/m^2$, and diversity ranged from 1.92 to 2.78. The mean annual values calculated for the same period were $1197/m^2$ for density and 2.20 for diversity. The indication is that unlike Transects B and C, the benthic community at Transect D has become more diverse. Based on statistical data, this improvement has been of a magnitude to easily differentiate the subtle and possible adverse trend described at Transect C.

Benthic macroinvertebrate biomass at all Parr Reservoir stations was higher than for any previous year. This increased biomass results from the collection of both higher numbers and larger Asiatic clams, depending on the specific sampling area. Overall, benthic density did not increase during this survey year. The data for other benthic organisms indicated that biomass for all except the Asiatic clam has probably stabilized.

Although there has been significant variability in Asiatic clam densities since these studies began in Parr Reservoir in 1978, the overall trend indicates increased abundance from June 1978 through January 1980;

decreased densities from April 1980 through July 1981, and a return to higher densities in October 1981. The Asiatic clam abundance continues to show the greatest variation at Transects B and C and the least variation at Transect D. The highest densities for the Asiatic clam in Parr Reservoir for a single benthic sample occurred at Transect B ($3014/m^2$) in January 1980, and Transect C ($2497/m^2$) in October 1980. The highest Asiatic clam density during the 1981 survey also occurred at Transects B and C, with $860/m^2$ and $732/m^2$, respectively.

The most abundant taxa collected from Transects C and D in Parr Reservoir during 1981 were primarily midges, mayflies, and tubificid worms. Many of these taxa were also predominant during earlier studies. The predominant organisms, which also are useful indicator species, were Hexagenia limbata, Coelotanypus spp., Cryptochironomus spp., Tanytarsus spp., Dicrotendipes spp., Procladius spp., Branchiura sowerbyi, and the Asiatic clam, Corbicula manilensis. These aquatic macroinvertebrates appeared frequently in the benthic samples at Transects C and D.

The benthic macroinvertebrate community at Transect B provided further evidence of habitat alteration since impoundment of Monticello Reservoir and operation of the FPSF. This alteration was expected and has been discussed in the previous reports (Dames & Moore; 1978, 1979, 1979a, 1980). Dominant benthic species present at Transect B included tubificid and naidid worms, and the Asiatic clam. Although other species of benthic macroinvertebrates were occasionally present, they occurred infrequently. The slight increase in diversity during 1981 was due to increases in the frequency of previously uncommon taxa occurring in benthic samples. The Asiatic clam made up from 32.1 to 89.5 percent of the benthic density at Transect B and continues to be the most important biomass component.

Neal Shoals Dam

Benthic macroinvertebrate samples have been collected from the Neal Shoals Dam station since 1978; at this location, the benthic community has remained stable, based on samples collected through 1981. Mean annual values for densities increased slightly while those for taxonomic composition, biomass, diversity, and equitability decreased slightly during 1981, as compared to previous studies.

Mean annual diversity (2.61) in 1981 reflected a complex community comprised of high numbers of taxa (mean, 14.3) and high densities (mean, $1786/m^2$). These characteristics reflected a mean annual equitability index of 0.69. The predominant benthic fauna were similar to that observed at Transects C and D in Parr Reservoir. The Asiatic clam was more abundant during 1981 than during previous surveys at Neal Shoals Dam; and during July and October the Asiatic clam densities were higher than at the Parr Resevoir transects.

Benthic macroinvertebrate biomass, as expressed by mean annual values ($0.89\ g/m^2$), remained consistent during 1981 as compared to previous surveys in 1979 and 1980, but was much less than the 1978 measurement of $5.70\ g/m^2$.

Subimpoundment

The benthic macroinvertebrates communities at Transect H have changed considerably in species, density, biomass, diversity, and equitability from 1978 through 1981. This community has increased its mean annual density by a factor of nearly 24 during that period. Mean annual taxonomic composition doubled from 1978 through 1980 and decreased during 1981. Taxonomic diversity increased from 1.9 in 1978 to 2.98 in 1980, and then decreased to 2.15 during 1981. This decrease was due primarily to very high densities of Chaoborus sp. ($7003/m^2$) and Chironomus sp. ($3171/m^2$) taxa during 1981. Biomass increased slightly

from 1979 through 1981. These data indicate that the benthic communities achieved a very high growth rate through 1980 and may have reached, at least temporarily, a growth plateau.

Monticello Reservoir

Monticello Reservoir benthic communities have shown an overall increase in all parameters surveyed from 1978 through 1981. Densities calculated from the 1981 study were higher than the results from previous years at all transects. Taxonomic diversity was generally stable or had increased at most transects. Collectively for all transects, there has been an increase in mean annual diversity (from 1978 through 1981) from 1.80 to 2.74 in Monticello Reservoir.

Benthic macroinvertebrate community characteristics may be assessed using the mean annual values calculated for each transect during 1981. For example, the highest densities occurred at Transects L and M ($2180/m^2$ and $2084/m^2$, respectively), while moderate densities ($1460/m^2$ and $1770/m^2$) occurred at Transects N and K, respectively. The remaining transects showed benthic densities between $917/m^2$ (Transect I) and $1182/m^2$ (Transect J). Corbicula manilensis, tubificid worms, Hexagenia limbata, Nais sp., and occasionally Dero sp., Dicrotendipes spp. and Chironomus sp. were typically found in samples with the highest densities.

The transect with the highest mean number of taxa was K (15.8); Transects J and L had 14.8 and 15.0 taxa, respectively, and Transects M and O had 14.5 taxa each. Transects N (13.0) and I (13.8) had the least number of taxa. Taxonomic diversity ($\bar{d}$) indicated that the most diverse benthic community occurred at Transects L (2.88) and O (2.86), while slightly less diverse communities occurred at Transects I, J, and K (2.79, 2.76, 2.75, respectively). The lowest taxonomic diversities occurred at Transects M and N, 2.58 and 2.61, respectively.

Equitability values were between 0.67 and 0.78, with Transect I being highest and Transect M being the lowest.

The most frequent insect taxa occurring in Monticello Reservoir were present at six combinations of the seven transects during each quarterly survey. These included the following insect taxa: Hexagenia limbata, Dicrotendipes spp., Coelotanypus spp., Procladius spp., Pseudochironomus sp., Cryptochironomus spp., and Chironomus spp. The following non-insect taxa also occurred: Asiatic clam, tubificid worms (Tubificidae), Dero spp., and Nais spp. For the first time since 1978, the Asiatic clam was present at all transects. All of the above taxa increased their frequency of occurrence since 1979 and expanded their distribution throughout most of the reservoir. Overall, the taxonomic component within Monticello Reservoir continued to show a greater assortment of benthic organisms than during previous years.

Evaluation of benthic macroinvertebrate biomass data in 1981 indicated substantial increases throughout Monticello Reservoir. This was especially true for Transects J, K, L, and N. The Asiatic clam continues to add substantially to biomass at Transects L and M. Transects M, O, and I continued to show increases in biomass, but during 1981 these increases were not as large as those exhibited by Transects J, K, L, and N. The Asiatic clam continues to be the predominant biomass contributor, aiding in the increase in overall mean annual benthic biomass of approximately 23 times in this reservoir from 1980 through 1981. Increases of this magnitude in the future will largely depend on the distribution, frequency, and potential population size of the Asiatic clam; their densities are expected to increase in Monticello Reservoir, however, not at the rate experienced during the 1981 study.

2.7.3 Discussion

Several important observations may be made by comparing the data collected during the past four years. These observations reflect the

overall quality of the aquatic environment in which the benthic organisms live.

Three trends are apparent from a review of the benthic macroinvertebrate data collected from Parr and Monticello Reservoirs, the subimpoundment, and the control station at Neal Shoals. These trends have been observed through objective evaluations of short- and long-term changes in benthic macroinvertebrate community components. These trends are characterized as: 1) declining ecological stability and complexity at Transect B in Parr Reservoir; 2) maintenance of ecological stability and complexity at Neal Shoals Dam, Transects C and D in Parr Reservoir, and Transect I in Monticello Reservoir; and 3) increasing ecological stability and complexity in the subimpoundment and six transects in Monticello Reservoir. Each of these observations are discussed below.

Transect B in Parr Reservoir has the only benthic community showing a significant overall trend towards reduced ecological stability and a more simplified community structure. This trend has been recognized in previous Dames & Moore reports (1978, 1979, 1979a, 1980) and is evidenced by decreasing community diversity, fewer taxa, and a simplified community structure; the trend moderated somewhat during 1981. On the other hand, specific taxa such as the Asiatic clam are tolerant of these environmental stresses, and are increasing in numbers of organisms and concomitant biomass.

The trend towards maintenance of ecological stability and complexity during 1981 is apparent at Neal Shoals Dam, Parr Reservoir Transects C and D, and for Transect I in Monticello Reservoir. Transect C in Parr Reservoir, showed a slight decline in the overall complexity of the macroinvertebrate community. This slight decline is attributed primarily to natural variation and, for this reason, Transect C has been categorized as maintaining ecological stability. This is not intended to disregard the possible adverse affects of drawdown on this benthic community. The 1982 benthic data should provide more insight towards

defining this trend and establishing further rationale for potential causes.

The six Monticello Reservoir transects that showed increased ecological stability and complexity were J, K, L, M, N, and O. The variability was substantial between stations; however, all showed improved ecological characteristics. Each of these transects has unique habitat features which probably account for most variability among the stations. These include both abiotic and biotic factors which are reviewed to determine basic limnological characteristics of the sampling areas studied.

Transect H, located in the subimpoundment, has shown the most dramatic changes in the ecological stability and complexity of its benthic macroinvertebrate community over the past three years. Based on the 1981 data and a perspective of previous studies, the benthic community reached at least a temporary plateau in which standing crop increased but the number of taxa, diversity, and equitability decreased.

2.7.4 Summary

The benthic macroinvertebrate data obtained from the 1981, and earlier surveys mimicked the somewhat predictable environmental conditions found in the four major study areas. As expected, in Parr Reservoir, only Transect B has shown a significant decline in ecological stability and complexity. During 1981 this change was not as apparent as reported for earlier surveys; however, the relative level of physical stress due to the station's close proximity to the FPSF, was still observed.

The remaining transects in Parr Reservoir (C and D) continue to have diverse benthic macroinvertebrate communities, illustrative of ecological stability and complexity. The 1981 data for Transect C, however, continues to show a trend over the past three years of slightly declining environmental conditions. This trend is believed to be within the limits of natural variation in Parr Reservoir. However, the potential

adverse affects of repeated drawdown on benthic communities in Parr Reservoir cannot be disregarded at this time. Further data collection and evaluation will define the significance, if any, of the trend observed at Transect C during the previous three years. The benthic community of Transect P (Neal Shoals Dam) also demonstrated maintenance of ecological stability and complexity.

The macroinvertebrate communities in Monticello Reservoir continue to show increases in mean annual values for density, taxonomic composition and diversity, equitability, and biomass. This increase in biological productivity and community complexity is expected to continue in Monticello Reservoir, although more variability may occur at those transects located closer to the FPSF. Transect I was the only station in Monticello Reservoir which did not show substantive increases in parameters measured and appears to have attained stable community development.

The benthic community in the subimpoundment continues to show increases in density and biomass while showing a lower number of taxa and reduced diversity. This trend is expected to continue as long as intensive fertilization continues. The subimpoundment is the only area sampled to date in which the Asiatic clam have not been reported.

Table 2.7.1 Summary of benthic macroinvertebrate data collected from twelve stations during the 1981 monitoring program.

Area	Parr Reservoir			Neal Shoals	Sub-Impoundment	Monticello Reservoir						
JANUARY Station	B	C	D	P	H	I	J	K	L	M	N	O
Taxonomic Abundance (No/m^2)												
Bryozoa	--	--	--	--	14	--	--	--	--	--	--	--
Coelenterata	--	--	--	--	14	--	--	--	--	--	--	--
Turbellaria	--	--	29	--	--	--	14	--	--	--	--	--
Nematoda	--	--	--	--	--	14	--	--	29	29	--	--
Oligochaeta	57	1,306	316	330	4,391	28	330	1,263	615	270	431	416
Hirudinea	--	--	--	--	--	--	14	57	--	--	--	--
Gastropoda	--	--	--	43	--	--	--	--	--	--	--	14
Bivalvia	603	488	157	14	--	--	143	230	215	1162	459	531
Diptera	14	114	156	1,176	5,926	57	1,231	157	430	517	487	243
Ephemeroptera	--	--	158	29	86	43	43	14	57	732	72	186
Megaloptera	--	--	14	--	--	--	--	--	--	--	--	--
Odonata	--	--	--	--	--	--	--	14	--	--	--	--
Trichoptera	--	--	--	--	14	--	14	--	--	--	--	42
TOTAL	674	1,908	803	1,592	10,445	142	1,789	1,735	1,346	2,710	1,449	1,246

Table 2.7.1 (Continued)

APRIL	Area	Parr Reservoir			Neal Shoals	Sub-impoundment	Monticello Reservoir						
	Station	B	C	D	P	H	I	J	K	L	M	N	O
Taxonomic Abundance (No/m^2)													
Coelenterata		14	--	--	--	--	--	--	--	--	--	--	129
Nematoda		14	--	--	--	--	14	--	--	--	--	--	14
Oligochaeta		689	257	459	387	1,966	86	101	402	1,866	286	531	387
Hirudinea		--	--	--	--	--	--	--	57	--	--	--	--
Bivalvia		388	746	71	--	--	29	29	301	1,134	1,004	244	531
Diptera		14	70	660	1,469	4,103	1,061	229	228	144	271	272	456
Ephemeroptera		--	--	143	14	57	115	--	29	--	416	--	29
Odonata		--	--	--	--	--	--	14	--	--	--	--	14
Trichoptera		--	14	--	--	--	--	14	14	--	--	--	--
Hydracarina		--	--	--	--	--	--	--	14	--	--	--	--
TOTAL		1,119	1,087	1,333	1,870	6,126	1,305	387	1,045	3,144	1,977	1,047	1,560

JULY	Parr Reservoir			Neal Shoals	Sub-Impoundment	Monticello Reservoir						
Station	B	C	D	P	H	I	J	K	L	M	N	O
Taxonomic Abundance (No/m^2)												
Bryozoa	--	--	--	--	--	--	--	14	--	--	--	--
Coelenterata	--	--	--	--	--	--	--	--	--	--	--	--
Nematoda	14	--	43	--	--	14	14	--	--	--	--	--
Oligochaeta	344	1,234	416	372	301	473	14	789	558	789	144	28
Bivalvia	301	57	100	703	--	14	86	703	230	861	603	158
Diptera	14	70	285	416	3,257	128	558	300	443	156	300	417
Ephemeroptera	--	43	--	--	--	14	--	14	--	--	--	--
Megaloptera	--	--	14	14	--	--	--	--	--	--	--	--
Trichoptera	--	--	29	--	--	--	--	14	--	14	28	14
Coleoptera	14	--	--	--	--	--	--	--	--	--	--	--
TOTAL	687	1,404	887	1,505	3,558	643	672	1,834	1,231	1,820	1,075	617

Table 2.7.1 (Continued)

OCTOBER	Parr Reservoir			Neal Shoals	Sub-Impoundment	Monticello Reservoir						
Station	B	C	D	P	H	I	J	K	L	M	N	O
Taxonomic Abundance (No/m^2)												
Bryozoa	--	--	--	--	--	--	14	--	--	--	--	--
Turbellaria	--	--	--	--	--	--	--	14	--	--	--	--
Nematoda	--	--	14	--	--	--	--	72	--	14	14	14
Gastropoda	--	--	--	--	--	--	--	14	244	--	--	--
Bivalvia	860	631	158	1,378	--	273	574	847	631	646	129	100
Oligochaeta	100	387	660	359	718	431	42	759	1,564	574	1,378	43
Hirudinea	--	--	14	--	--	--	--	--	--	--	--	--
Diptera	57	286	571	387	11,911	371	974	601	544	258	489	559
Ephemeroptera	--	1,535	330	14	43	474	258	158	14	86	14	129
Megaloptera	--	14	--	29	--	--	--	--	--	--	--	--
Trichoptera	29	14	14	--	--	--	14	--	--	--	14	--
Hydracarina	--	--	--	--	--	14	--	--	--	--	--	--
TOTAL	1,046	2,867	1,761	2,167	12,672	1,563	1,876	2,465	2,997	1,578	2,038	845

Table 2.7.2 Summary of mean annual values for benthic macroinvertebrates obtained during the 1981 monitoring program.

Area	Parr Reservoir			Neal Shoals	Sub-Impoundment	Monticello Reservoir						
Station	B	C	D	P	H	I	J	K	L	M	N	O
Density No/m^2 Jan	674	1908	803	1592	10445	142	1789	1735	1346	2710	1449	1246
April	1119	1087	1333	1670	6126	1305	387	1045	3144	1977	1047	1560
July	687	1404	887	1505	3558	643	672	1834	1231	1820	1075	617
Oct	1046	2867	1761	2167	12672	1563	1876	2465	2997	1578	2038	845
Mean Annual	882	1817	1204	1786	8201	917	1182	1770	2180	2084	1460	1115
Biomass g/m^2 Jan	0.11	0.98	23.18	0.85	1.93	0.04	0.67	0.74	7.07	50.87	0.35	8.88
April	57.60	19.04	10.59	0.71	1.42	0.71	0.17	0.55	25.08	65.52	0.53	4.10
July	33.62	3.57	20.44	1.69	0.34	0.31	0.76	17.93	12.70	77.02	19.81	4.07
October	86.62	27.52	53.56	0.30	1.34	4.50	16.10	23.44	106.97	81.93	11.06	8.86
Mean Annual	44.49	12.78	26.94	0.89	1.26	1.39	4.43	10.67	37.96	68.84	7.94	6.48
Number of Taxa Jan	3	7	12	12	22	6	22	13	16	17	15	17
April	9	13	16	20	17	22	12	18	14	15	13	22
July	8	10	16	11	9	11	9	15	14	13	11	7
October	6	16	24	14	13	16	16	17	16	13	13	12
Mean Annual	6.5	11.5	17.0	14.3	15.3	13.8	14.8	15.8	15.0	14.5	13.0	14.5
Mean Species[a] Diversity ($\bar{d}$) Jan	0.57	2.02	2.91	2.73	3.10	2.37	3.00	2.39	3.44	2.55	3.14	3.11
April	1.78	1.97	3.49	3.39	2.43	3.75	3.38	3.25	2.30	2.63	2.58	3.18
July	1.81	1.76	3.27	2.41	1.23	2.20	1.95	2.49	2.82	2.48	2.21	2.05
October	1.07	2.19	3.71	1.92	1.83	2.85	2.70	2.87	2.95	2.67	2.52	3.10
Mean Annual	1.31	1.99	3.35	2.61	2.15	2.79	2.76	2.75	2.88	2.58	2.61	2.86
Equitability (e)[b] Jan	0.36	0.72	0.81	0.76	0.69	0.92	0.67	0.65	0.86	0.62	0.80	0.76
April	0.56	0.53	0.87	0.78	0.59	0.84	0.94	0.78	0.60	0.67	0.70	0.71
July	0.60	0.53	0.82	0.70	0.39	0.63	0.61	0.64	0.74	0.67	0.64	0.73
October	0.41	0.55	0.81	0.50	0.50	0.71	0.67	0.70	0.74	0.72	0.68	0.87
Mean Annual	0.48	0.58	0.83	0.69	0.54	0.78	0.72	0.69	0.74	0.67	0.71	0.77

[a] Index used is Shannon-Wiener (Pielou, 1966).
[b] Index used is presented in USEPA (1973).

2.8 FISH

2.8.1 Introduction

Fish are important and visible components of the aquatic ecosystem. Fish rank high as a source of food and recreation for man. Species that are not of special interest for man as a recreational or food source serve as food for other, more valuable fish species. Also, because of their sensitivity to changes in their environment many species may be useful indicators of stress in the aquatic ecosystem.

The purpose of this investigation was to identify important characteristics of the fish community in the water bodies of the study area according to: species composition and relative abundance, standing crop, diet, and condition factors and age distribution. The relative abundance was expressed as the percent of the total yearly catch for a species from all of the stations in that reservoir.

Mean condition factors and fish lengths at annulus formation were calculated for dominant species (those that comprised five percent or more of the total 1981 catch). The condition factor (K) is a means of comparing the relative well being of fish. The heavier a fish is at a given length, the larger the factor and, by implication, the better the "condition" of the fish. The factor is expressed in the form $K = W \times 10^5/L^3$ where W is the weight of the fish in grams, L is the total length of the fish in mm and 10^5 is a factor to bring the value of K near unity.

For growth determinations the scale (spine) radius and fish length data were fitted by linear regression using raw data and log-transformed ($\log_{10}$) data. The particular relationship used for back-calculation was determined by the goodness of fit based on the regression correlation coefficient (r); the higher the r value, the better the fit. The Lee Method (Lagler, 1969) of back-calculation was used to estimate

total body length at each annulus for species in which the higher r value was obtained using raw data. The Monastyrsky Method (Lagler, 1969) was used for species in which the higher r value was obtained using log-transformed data. For the Lee Method fish body lengths were estimated according to the formula $L = m S + b$, where L represents the length of the fish in mm and S represents the scale (spine) radius in mm multiplied by 43 (60), the magnification at which the scale (spine) was viewed; m and b are constants derived from the data. The formula for the back-calculation of lengths using the Monastyrsky Method is $L = bS^m$.

2.8.2 Findings and Discussion

A total of 32 fish species were collected from all the stations during the 1981 sampling periods, utilizing gill nets and a boom electrofisher. The most numerous group of fish collected from all impoundments was the centrarchid family (sunfish), which was represented by several species, particularly bluegill, largemouth bass, and black crappie. The next most abundant group was the clupeid family (shad) represented by one species, gizzard shad, which occurred in all the impoundments. Ictalurids (catfish), cyprinids (minnows), and catostomids (suckers) were found in all the impoundments in varying degrees of abundance.

Species composition of 1981 collections was similar to observations in previous years (Dames & Moore, 1978, 1979, 1979a, 1980), with minor exceptions. Exceptions to previous years included the first time collection of the spottail shiner, which was captured in Monticello Reservoir. Other exceptions indicated passage of fish between Monticello and Parr Reservoirs through the penstocks of the Fairfield Pump Storage Facility (FPSF). The tessellated darter, observed in Parr Reservoir in 1978 and 1980, was collected for the first time in Monticello Reservoir in 1981. Whitefin shiner and white bass, previously collected only from Monticello Reservoir, were collected for the first time in Parr Reservoir.

A detailed description of the fishery investigation follows and is presented by reservoir. Species composition, relative abundance, condition factors, and age distributions are described for the combined 1981 sampling periods.

Parr Reservoir

Species Composition and Relative Abundance. A total of 22 species were collected in Parr Reservoir utilizing both gill nets and a boom electrofisher (Table 2.8.1). During 1981, the centrarchid (sunfish) family was the dominant group. It represented 66 percent of the total catch and was represented by 8 species, of which the bluegill was most numerous. The next most abundant group was the clupeid (shad) family. This group comprised 34 percent of the total catch and was represented by one species, gizzard shad. The remaining groups of fish obtained in these collections, with the percent of the catch, included: five members of the catostomid (sucker) family, three percent; three members of the ictalurid (catfish) family, three percent; two members of the cyprinid (minnow) family, one percent; and one member of the lepisosteid (gar) family, one percent. Whitefin shiner and white bass were collected in Parr Reservoir for the first time. These species were previously found in Monticello Reservoir (Table 2.8-2) and their occurrence in Parr Reservoir indicated a movement through the penstocks of the FPSF.

The fish composition of Parr Reservoir has changed little since 1978 (Table 2.8-2). Of 32 species collected since 1978, 21 have been collected in at least 3 of the 4 collecting years. Species at apparently low population levels, including shorthead redhorse, yellow bullhead, tadpole madtom, and tessellated darter, were infrequently collected. Four species, creek chubsucker, snail bullhead, flier, and swamp darter, have not been collected since 1978.

Condition Factor and Age Distribution

Condition factors and lengths at annulus formations (based on the Monastyrsky Method) for gizzard shad, bluegill, and largemouth bass are:

Species	Mean Condition Factor	Mean Length (mm) at Annulus Formation						
		1	2	3	4	5	6	7
Gizzard shad	0.960	114	182	228	281	327	--	--
Bluegill	1.665	47	88	117	138	158	--	--
Largemouth bass	1.422	127	214	287	350	386	411	378

Gizzard shad exhibited slightly slower growth than fish from waterbodies in other areas of the southeastern U.S. (Carlander, 1969) and the condition factor was average compared to fish from other bodies of water reported by Jester and Jensen (1971). In general, growth of bluegill at Parr Reservoir was slower than other bluegill populations from the Southeast (Carlander, 1977). The condition factor was considered average when compared to data for other bluegill populations compiled by Carlander (1977). For the average largemouth bass from Parr Reservoir, recruitment into the fishery, at approximately 305 mm (12 in), occurred during the fourth year of life, as it did for most largemouth bass from the Southeast (Carlander, 1977). However, growth appeared to be slower for Parr Reservoir largemouth bass than other populations. The mean condition factor was average in comparison to other largemouth bass populations in the Southeast (Carlander, 1977).

Standing Crop Estimates. The standing crop is the poundage of fish present in a body of water at a specific point in time. Standing crop estimates at Station C were made by block netting an area of 0.07 ha (hectare). The results are shown in Table 2.8.3. A total of 5.3 kg/ha, represented by 3 species, occurred at this cove in 1981, as compared with 142.8 kg/ha, represented by 17 species, that occurred during 1978; 11.3 kg/ha, represented by four species in 1979; and 54.9 kg/ha,

represented by 15 species in 1980 (Dames & Moore; 1978, 1979a, 1981). The most abundant species collected (by weight) during 1981 was gizzard shad. The decreased abundance since 1980 at the cove near Station C may be attributed in part to the fluctuating water levels and the extremely low water conditions that prevailed during 1981.

Neal Shoals Dam

Species Composition and Relative Abundance. A total of 12 fish species was collected from Neal Shoals Dam utilizing the electrofisher during the 1981 collecting periods (Table 2.8.1). The centrarchid family was numerically the dominant group of fish comprising 78 percent of all fish collected. This family was represented by 7 species, of which bluegill was the most numerous (38 percent of the total catch). The clupeid, represented by gizzard shad, was the second most numerous group (20 percent of the total catch).

The species composition of fish collections at Neal Shoals Dam have generally been consistent since 1978 (Table 2.8-2). Of 23 species collected from the reservoir, 13 have been collected in at least three of the last four collecting years. Four species, silver redhorse, shorthead redhorse, white catfish, and pumpkinseed, have been collected infrequently. Black bullhead, mosquito fish, redbreast, and yellow perch have not been collected since 1978. Creek chubsucker, common in the subimpoundment and Monticello Reservoir, was collected for the first time in 1981.

Condition Factor and Age Distribution. Presented below are the condition factors and mean fish lengths at annulus formation for the dominant species in the 1981 collections. The Lee Method was used for back-calculation of gizzard shad, bluegill, and redear and the Monastyrsky Method was used for white crappie and black crappie (Lagler, 1969).

Species	Mean Condition Factor	Mean Length (mm) at Annulus Formation					
		1	2	3	4	5	6
Gizzard shad	0.924	127	184	220	257	293	--
Bluegill	1.700	43	87	119	141	--	--
Redear	1.562	98	137	158	192	183	--
White crappie	1.220	88	140	192	252	301	319
Black crappie	1.148	74	115	150	178	215	245

Growth of bluegill was slow. Typically, bluegill from the Southest reach a harvestable size of 152 mm (6 in) by the fourth growing season (Carlander, 1977) but the average bluegill from Neal Shoals Dam will not reach harvestable size until the fifth growing season. The growth of gizzard shad was slow compared to other populations in the Southeast (Carlander, 1969).

The condition factor of gizzard shad was low and, for bluegill, was average when compared to values reported by Jester and Jensen (1971) for gizzard shad and Carlander (1977) for bluegill. Growth and condition of black crappie was slightly below average when compared to crappie populations from similar habitats (Carlander, 1977) Growth and condition of white crappie and redear was average when compared with other areas of the Southeast (Carlander, 1977).

Standing Crop Estimates. The standing crop estimates from the control station was made by block netting an area of 0.07 ha and applying rotenone. A complete kill was assumed and the results are illustrated in Table 2.8.3. A total of 23.8 kg/ha of fish were collected, represented by 10 species. Largemouth bass and bluegill (15.2 and 5.9 kg/ha, respectively) accounted for the greatest biomass. Other species listed in order of abundance included: warmouth, black crappie, and redear sunfish. The standing crop estimates for 1981 were about one half of that recorded during the previous year (Dames & Moore, 1980). The reason for this decline may be attributed to the low water conditions that prevailed during much of 1981. The low water may have caused the fish to migrate out of the area.

Subimpoundment

Species Composition and Relative Abundance. A total of 13 species were collected from the subimpoundment during the 1981 collecting periods utilizing gill nets and a boom electrofisher (Table 2.8.1). The centrarchid family, which comprised 53 percent of all fish collected, was the dominant group. This family was represented by eight species, of which bluegill was the most numerous (23 percent of all fish collected). The ictalurid was the second most numerous group; it was represented by the brown and yellow bullhead, and comprised 36 percent of the fish collected.

Of 20 species collected in the subimpoundment since 1978, 12 have been collected in three of the past four collecting years. Silvery minnow and black bullhead have been collected infrequently and are probably at low population levels. Black crappie was collected for the first time in the subimpoundment in 1981. Three species, redfin pickerel, lake chubsucker, and white catfish, have not been collected since 1978.

Condition Factor and Age Distribution. Presented below are the mean condition factors and mean fish lengths at annulus formation (Monastrysky Method) for the dominant species in the 1981 collections.

Species	Mean Condition Factor	Mean Length (mm) at Annulus Formation					
		1	2	3	4	5	6
Gizzard shad	1.004	191	273	298	332	--	--
Brown bullhead	1.178	175	242	258	269	272	--
Warmouth	2.043	62	118	154	167	--	--
Bluegill	1.842	32	90	134	149	158	168
Largemouth bass	1.256	135	196	243	263	--	--

Growth of the gizzard shad was faster than described by Carlander (1969) and Jester and Jensen (1977) for populations in the Southeast. Growth of the brown bullhead was faster than described by Carlander (1969) for

other brown bullhead populations. Compared to growth data of warmouth from North Carolina lakes compiled by Carlander (1977), warmouth from the subimpoundment grew at a faster rate. Similar to bluegill from Parr Reservoir and other waterbodies from the Southeast, the average bluegill from the subimpoundment reached harvestable size, approximately 152 mm (6 in) in their fourth growing season. However, growth appeared to be slower in bluegill from the subimpoundment than in populations from other areas in the Southeast (Carlander, 1977). Mean condition for bluegill was higher than bluegill from Parr Reservoir but within the range of values for bluegill from similar habitats (Carlander, 1977).

No largemouth bass older than age four were collected from the subimpoundment in 1981. On the average, largemouth bass have not yet attained harvestable size by their fourth growing season. Generally the growth rate and condition of largemouth bass from the subimpoundment was lower than for other largemouth bass from similar latitudes (Carlander, 1977).

Monticello Reservoir

Species Composition, Relative Abundance, and Diversity. A total of 30 fish species were collected from Monticello Reservoir utilizing gill nets, boom electrofisher, and a seine in the 1981 collecting periods (Table 2.8.1).

For all stations and collecting periods combined, the centrarchid family was the dominant group of fish; it was represented by nine species and comprised 66 percent of the fish captured. Bluegill was the most numerous species (54 percent of the fish captured). The next most numerous group was the clupeid, comprising 20 percent of all samples, and was represented by one species, gizzard shad. The remaining groups of fish obtained in these collections, with the percent of the total catch, included: seven members of the ictalurid (catfish) family, ten percent; five members of the catostomid (sucker) family, three percent; five

members of the cyprinid (minnow) family, one percent; one member of the percichthyid (temperate bass) family, 0.02 percent.

The fish composition in Monticello Reservoir has changed little since 1978 (Table 2.8.2). Of 32 fish species collected since 1978, 26 have been collected in at least three of the last four collecting years. Green sunfish and lake chubsucker have been collected infrequently and redfin pickerel is the only species that has not been collected from the reservoir since 1978. The tessellated darter was collected for the first time in 1981; this species was previously collected in Parr Reservoir and may represent movement of fish through the penstocks of the FPSF.

Condition Factor and Age Distribution. Presented below are the mean condition factors and fish lengths at annulus formation calculated for gizzard shad and bluegill using the Monastyrsky Method and largemouth bass using the Lee Method.

Species	Mean Condition Factor	Mean Length (mm) at Annulus Formation						
		1	2	3	4	5	6	7
Gizzard shad	0.888	120	187	228	275	--	--	--
Bluegill	1.628	48	87	115	139	--	--	--
Largemouth bass	1.241	127	199	280	348	410	449	488

These species generally exhibited slower growth than populations in areas of similar habitats (Carlander, 1977; Jester and Jensen, 1971). However, largemouth bass were recruited into the sportfishing population by their fourth growing season; this is common in the Southeast. Compared to populations in the southeastern United States the condition factor of gizzard shad from Monticello Reservoir was low (Jester and Jensen, 1971) and average for bluegill and for largemouth bass (Carlander, 1977).

Standing Crop Estimates. Standing crop estimates from coves near Stations I and K were made by block netting an area of 0.07 ha and

applying roten--: a complete kill was assumed. The results are presented in Table 2.8.3. A total of 5.9 kg/ha was obtained at the cove near Station I and 1.6 kg/ha was collected at the cove near Station K. At Station I, gizzard shad was the most abundant species; this was followed by bluegill and largemouth bass. At Station K, bluegill was the most abundant species; it was followed by pumpkinseed and largemouth bass.

The standing crop estimates for the 1981 samples were lower than the previous year. The results from the 1978 study showed that coves near Station I and K produced 83.5 and 84.5 kg/ha, respectively, and during 1979, 6.6 and 5.4 kg/ha, respectively (Dames & Moore; 1978, 1979). The 1980 data suggest that the fish were utilizing the littoral zone as they were during 1978, while the 1981 data indicate that the fish were not using the littoral zone as frequently, following the 1979 trend. The fluctuating water levels in the littoral zone increases turbidity and may account for this area not being frequented by fish.

2.8.3 Summary

The fish populations of Parr Reservoir were comprised primarily of the centrarchid-gizzard shad species. Bluegill was the most numerous species collected and gizzard shad was second in numerical abundance. Five year classes of gizzard shad and five year classes of bluegill were found. Growth of both species, as determined from back-calculated lengths, was slightly slower than other populations in various areas of the southeastern United States.

The fish data from Neal Shoals Dam indicated that centrarchids and gizzard shad numerically dominated the fish fauna. Seven species of centrarchids were collected with bluegill being the most numerous. Gizzard shad was second in numerical abundance. Four year classes were found for both bluegill and five year classes for gizzard shad. Growth

of both species was slightly slower than populations in other areas of the Southeast.

The fish populations of the subimpoundment were numerically dominated by centrarchid-ictalurid species. Bluegill was the most numerous of the eight centrarchid species collected and brown bullhead was the most numerous of the two ictalurid species collected. Four year classes of of gizzard shad and five year classes of brown bullhead were found. Growth of the brown bullhead was similar to fish in other southeastern areas and growth of bluegill was slightly slower.

The fish populations in Monticello Reservoir were also numerically dominated by centrarchid-gizzard shad species. Nine species of centrarchids were identified and bluegill was the most numerous. Gizzard shad was second in numerical abundance in the collections. Four year classes of bluegill and gizzard shad were found in the reservoir. Growth of both species was slower than populations in other areas of the southeastern United States.

Table 2.8.1 Numbers of fish, and their percent abundance (%), collected by electrofisher and gill net during the 1981 sampling program.

		Area	Parr Reservoir			Neal Shoals	Sub-impoundment	Monticello Reservoir						
Common Name	Scientific Name	Station	B	C	D	P	H	I	J	K	L	M	N	O
Gar	Lepisosteidae													
Longnose gar	Lepisosteus osseus		4	7	3									
		(%)	(0.9)	(2.6)	(1.1)									
Shad	Clupeidae													
Gizzard shad	Dorosoma cepedianum		80	62	91	94	65	284	152	162	19	262	146	19
		(%)	(18.1)	(23.4)	(32.4)	(19.7)	(9.0)	(27.7)	(45.5)	(46.2)	(1.7)	(28.7)	(43.7)	(1.7)
Minnows	Cyprinidae													
Carp	Cyprinus carpio			8		5						2	1	
		(%)		(3.0)		(1.1)						(0.2)	(0.3)	
Silvery minnow	Hybognathus nuchalis					1		2		1	1	7	2	2
		(%)				(0.2)		(0.2)		(0.3)	(0.1)	(0.8)	(0.6)	(0.2)
Golden shiner	Notemigonus crysoleucas			12		2	9	2		1	2	1		1
		(%)		(4.5)		(0.4)	(1.2)	(0.2)		(0.3)	(0.2)	(0.1)		(0.1)
Whitefin shiner	Notropis niveus		1		1			22	1	2		4	12	
		(%)	(0.2)		(0.4)			(2.1)	(0.3)	(0.6)		(0.4)	(3.6)	
Spottail shiner	N. hudsonius										1			
		(%)									(0.1)			
Sucker	Catostomidae													
Quillback carpsucker	Carpiodes cyprinus		2	11	5			6	15	30	10	18	11	2
		(%)	(0.5)	(4.2)	(1.8)			(0.6)	(4.5)	(8.5)	(0.9)	(2.0)	(3.3)	(0.2)
River carpsucker	C. carpio			3								1		
		(%)		(1.1)								(0.1)		
Highfin carpsucker	C. velifer				1							1		
		(%)			(0.4)							(0.1)		
Silver redhorse	Moxostoma anisurum		1		8			1	4	1		20		1
		(%)	(0.2)		(2.8)			(0.1)	(1.2)	(0.3)		(2.2)		(0.1)
Shorthead redhorse	M. macrolepidotum				1									
		(%)			(0.4)									
Creek chubsucker	Erimyzon oblongus					1	4				1	4		6
		(%)				(0.2)	(0.6)				(0.1)	(0.4)		(0.5)
Catfish	Ictaluridae													
White catfish	Ictalurus catus		3	10	3			12	17	3	18	26	11	12
		(%)	(0.7)	(3.8)	(1.1)			(1.2)	(5.1)	(0.9)	(1.6)	(2.9)	(3.3)	(1.1)
Yellow bullhead	I. natalis						6				3	4		8
		(%)					(0.8)				(0.3)	(0.4)		(0.7)

Common Name	Scientific Name	Area / Station	Parr Reservoir B	Parr Reservoir C	Parr Reservoir D	Neal Shoals P	Sub-Impoundment H	Monticello Reservoir I	Monticello Reservoir J	Monticello Reservoir K	Monticello Reservoir L	Monticello Reservoir M	Monticello Reservoir N	Monticello Reservoir O
Brown bullhead	I. nebulosus		2	5	1	4	256	220	3	6	4	16	2	5
		(%)	(0.5)	(1.9)	(0.4)	(0.8)	(35.3)	(21.5)	(0.9)	(1.7)	(0.4)	(1.8)	(0.6)	(0.4)
Channel catfish	I. punctatus		4		6			5		2	1	3	1	3
		(%)	(0.9)		(2.1)			(0.5)		(0.6)	(0.1)	(0.3)	(0.3)	(0.3)
Flat bullhead	I. platycephalus							3		6	4		1	2
		(%)						(0.3)		(1.7)	(0.4)		(0.3)	(0.2)
Snail bullhead	I. brunneus							1			43	28		27
		(%)						(0.1)			(3.9)	(3.1)		(2.4)
Margined madtom	Noturus insignis											2		
		(%)										(0.2)		
Temperate bass	Percichthyidae													
White bass	Morone chrysops		2									1		
		(%)	(0.5)									(0.1)		
Sunfish	Centrarchidae													
Flier	Centrarchus macropterus						6		1	1	2	5		
		(%)					(0.8)		(0.3)	(0.3)	(0.2)	(0.5)		
Redbreast	Lepomis auritus		15		1		2	1	2		22	20		32
		(%)	(3.4)		(0.4)		(0.3)	(0.1)	(0.6)		(2.0)	(2.2)		(2.8)
Warmouth	L. gulosus		3			3	71	12	3		20	24	2	29
		(%)	(0.7)			(0.6)	(9.8)	(1.2)	(0.9)		(1.8)	(2.6)	(0.6)	(2.6)
Bluegill	L. macrochirus		125	72	79	179	166	325	83	90	874	385	117	919
		(%)	(28.2)	(27.2)	(28.1)	(37.6)	(22.9)	(31.9)	(24.9)	(25.6)	(78.3)	(42.2)	(35.0)	(81.0)

Table 2.8.1 (Continued)

Common Name	Scientific Name	Area / Station	Parr Reservoir B	Parr Reservoir C	Parr Reservoir D	Neal Shoals P	Sub-Impoundment H	Monticello Reservoir I	Monticello Reservoir J	Monticello Reservoir K	Monticello Reservoir L	Monticello Reservoir M	Monticello Reservoir N	Monticello Reservoir O
Pumpkinseed	L. gibbosus		12	19	8		14	22	8	12	16	7	14	18
		(%)	(2.7)	(7.2)	(2.8)		(1.9)	(2.1)	(2.4)	(3.4)	(1.4)	(0.8)	(4.2)	(1.6)
Redear sunfish	L. microlophus		13	22	6	28	1		4	4		2	1	
		(%)	(2.9)	(8.3)	(2.1)	(5.9)	(0.1)		(1.2)	(1.1)		(0.2)	(0.3)	
Largemouth bass	Micropterus salmoides		110	20	28	9	122	83	40	24	57	59	13	49
		(%)	(24.8)	(7.5)	(10.0)	(1.9)	(16.8)	(8.1)	(12.0)	(6.8)	(5.1)	(6.5)	(3.9)	(4.3)
White crappie	Pomoxis annularis			11	3	24						3		
		(%)		(4.2)	(1.1)	(5.0)						(0.3)		
Black crappie	P. nigromaculatus		65	3	36	126	3	11	1	4	18	6		
		(%)	(14.7)	(1.1)	(12.8)	(26.5)	(0.4)	(1.1)	(0.3)	(1.1)	(1.6)	(0.7)		
Perch	Percidae													
Yellow perch	Perca flavescens							13		2				
		(%)						(1.3)		(0.6)				
Tesselated darter	Etheostoma olmstedi											1		
		(%)										(0.1)		
	Total number captured		443	265	281	476	725	1025	334	351	1116	912	334	1135

Table 2.8.2 Fish species collected in 1978, 1979, 1980, and 1981.

	Area	Parr Reservoir				Neal Shoals Dam				Subimpoundment				Monticello Reservoir			
Common Name	Scientific Name (Year)	1978	1979	1980	1981	1978	1979	1980	1981	1978	1979	1980	1981	1978	1979	1980	1981
Gar	Lepisosteidae																
Longnose gar	Lepisosteus osseus	x	x	x	x									x	x	x	
Shad	Clupeidae																
Gizzard shad	Dorosoma cepedianum	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pickerel	Esocidae																
Redfin pickerel	Esox americanus									x				x			
Minnows	Cyprinidae																
Carp	Cyprinus carpio	x	x	x	x		x	x	x					x	x	x	x
Silvery minnow	Hybognathus nuchalis	x	x	x		x		x	x		x			x	x	x	x
Golden shiner	Notemigonus crysoleucas	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Whitefin shiner	Notropis niveus				x											x	x
Sandbar shiner	N. scepticus																x
Carpsucker	Catostomidae																
Quillback carpsucker	Carpiodes cyprinus	x	x	x	x										x	x	x
River carpsucker	C. carpio	x	x	x	x	x	x	x						x	x		x
Highfin carpsucker	C. velifer		x	x	x										x		x
Silver redhorse	Moxostoma anisurum	x	x	x	x	x								x	x	x	x
Shorthead redhorse	M. macrolepidotum	x			x		x	x							x		
Lake chubsucker	Erimyzon sucetta									x				x	x		
Creek chubsucker	E. oblongus	x							x		x	x	x	x	x	x	x
Catfish	Ictaluridae																
White catfish	Ictalurus catus	x	x	x	x	x		x		x				x	x	x	x
Yellow bullhead	I. natalis	x	x			x					x	x	x	x	x	x	x
Brown bullhead	I. nebulosus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Channel catfish	I. punctatus	x	x	x	x	x	x	x						x	x	x	x
Flat bullhead	I. platycephalus	x	x											x	x	x	x

Table 2.8.2 (Continued)

Common Name	Scientific Name	Parr Reservoir				Neal Shoals Dam				Subimpoundment				Monticello Reservoir			
		1978	1979	1980	1981	1978	1979	1980	1981	1978	1979	1980	1981	1978	1979	1980	1981
Snail bullhead	*I. brunneus*	x													x	x	x
Black bullhead	*I. melas*					x				x	x			x	x		x
Margined madtom	*Noturus insignis*														x		
Tadpole madtom	*N. gyrinus*	x															
	Poeciliidae																
Mosquito fish	*Gambusa affinis*					x											
Temperate Bass	Percichthyidae																
White bass	*Morone chrysops*				x										x	x	x
Sunfish	Centrarchidae																
Flier	*Centrarchus macropterus*	x								x	x	x	x	x	x	x	x
Redbreast	*Lepomis auritus*	x	x	x	x	x				x	x	x	x	x	x	x	x
Warmouth	*L. gulosus*	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bluegill	*L. macrochirus*	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pumpkinseed	*L. gibbosus*	x	x	x	x		x	x		x	x	x	x	x	x	x	x
Redear sunfish	*L. microlophus*	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
Longear sunfish	*L. megalotis*													x			
Green sunfish	*L. cyanellus*														x		
Hybrid sunfish	*Lepomis* sp.									x				x			
Largemouth bass	*Micropterus salmoides*	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
White crappie	*Pomoxis annularis*	x	x	x	x	x	x	x	x			x		x	x		x
Black crappie	*P. nigromaculatus*	x	x	x	x	x	x	x	x				x	x	x	x	x
	Percidae																
Yellow perch	*Perca flavescens*					x										x	x
Swamp darter	*Etheosoma fusiforme*	x															
Tessellated darter	*E. olmstedi*	x															x
Total Number of Species		28	22	20	22	19	14	16	12	15	13	13	13	27	31	25	30

Table 2.8.3 Standing crop (kg/ha) estimates of fishes from Parr and Monticello Reservoirs and the Neal Shoals Dam, 1981.[a]

Common Name / Stations	Monticello Reservoir I	Monticello Reservoir K	Parr Reservoir C	Neal Shoals P
Gizzard shad	3.8		4.3	
Silvery minnow				0.2
Whitefin shiner	0.04			
Channel catfish		0.3		
White catfish		0.06		
Pumpkinseed		0.2		
Warmouth				0.9
Bluegill	1.8	0.8	0.8	5.9
Redear sunfish				0.6
Largemouth bass	0.2	0.2	0.2	15.2
White crappie				0.08
Black crappie				0.9
Tessellated darter	0.04			
Swamp Darter				0.01
Total	5.9	1.6	5.3	23.8

[a] Fish collections made by rotenone.

3.0 TERRESTRIAL SURVEY

3.1 PHOTOGRAMMETRIC ANALYSIS OF THE BROAD RIVER/MONTICELLO RESERVOIR STUDY AREA

An analysis of the false-color infrared aerial photography of the Broad River Study Area indicated that little change has occurred in land use between April 1980 and April 1981. Seven areas evidenced changes in vegetative cover (Figure 3.1.1). In all of these areas, the modifications consisted of clear-cutting for timber removal. This is a common timber management practice in the southeastern United States and results in the creation of relatively large areas of open habitat which, until pine trees again dominate the area, are very good wildlife habitat.

The areas cleared in 1981 ranged in size from 9 to 44 acres and totaled 123 acres. Two of the areas (B and C) could erode into Parr and Monticello Reservoirs respectively, but the potential for this is not high.

A comparison of the 1981 photographs with those taken in earlier years does not indicate any change or loss of vigor.

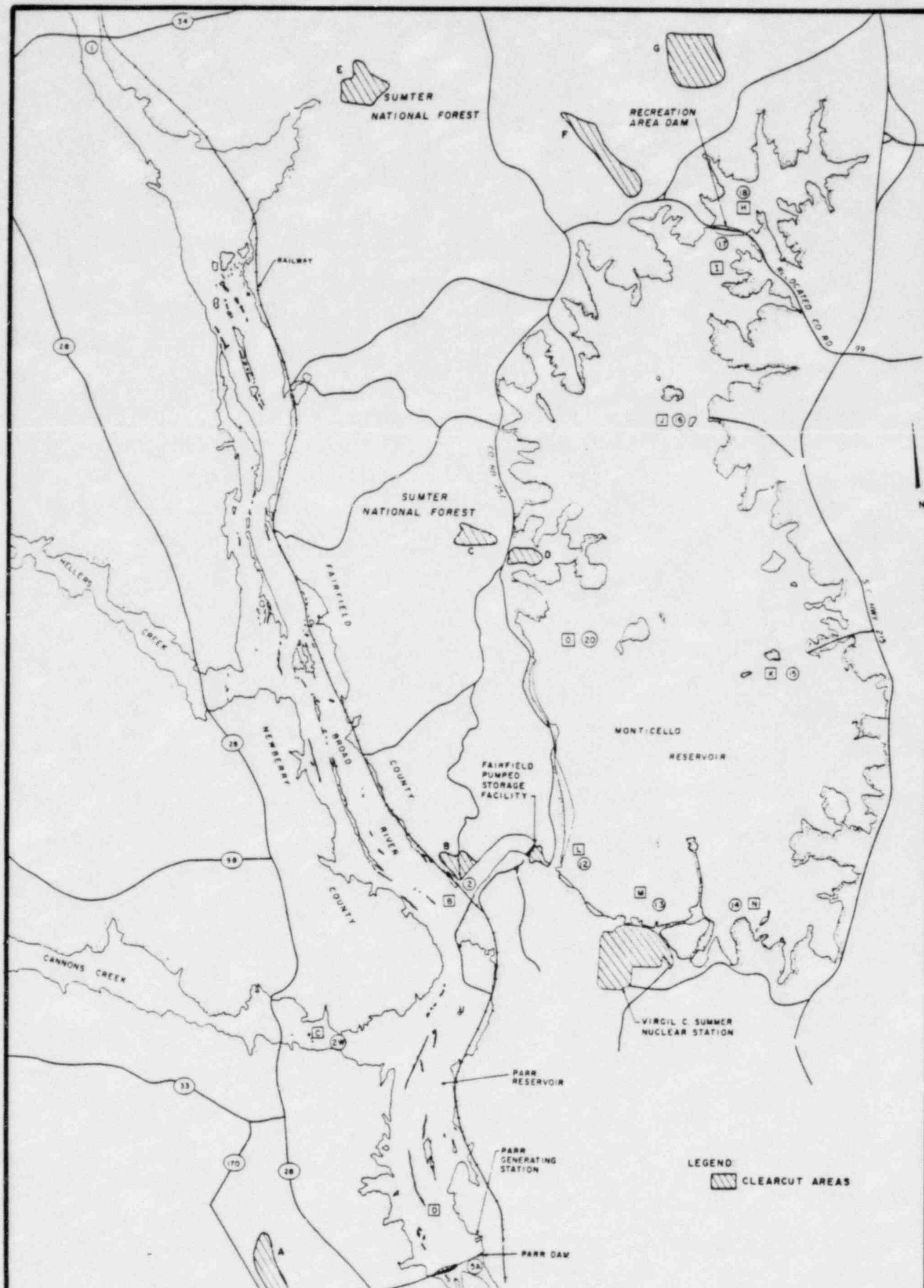


Figure 3.1-1. Land Modification in Study Area from 1980 to 1981.

3.2 BIRDS

3.2.1 Avian Auto Survey

3.2.1.1 Introduction

The Auto Survey was conducted along two separate series of roads during both the winter and summer seasons (Figure 3.2.1). One series of roads was located around the perimeter of Monticello Reservoir, near the areas of influence of the generating facilities (Routes ABC), while the other was located away from this area (Route D). The land use along the two routes is superficially similar with approximately equal amounts of wooded versus open land occurring on the routes. However, Route D is more urbanized than Routes ABC. Numerous single-family houses occur along this route, while houses along Routes ABC are less common. The undisturbed habitat present on Route D occurs in smaller patches than on Routes ABC.

The surveys were conducted during both the winter and summer seasons. The summer survey was timed to coincide with the U.S. Fish and Wildlife Service's Game Bird Call Count. All birds seen or heard at designated stops were counted; a separate count of bobwhite and mourning dove was made for the Game Bird Call Count during the summer survey.

3.2.1.2 Findings and Discussion

A list of species observed during the summer and winter auto surveys is presented in Tables 3.2.1 and 3.2.2. The number of birds observed along both the control and the test routes decreased from the levels recorded in 1980 (Figure 3.2.2). However, as has been noted since 1973, there were more individuals along the test route than along the control route (Figure 3.2.2). A daily average of 8.4 birds per stop was observed during the summer survey along the test routes (ABC) while the average along the control route was 5.4. This relationship was further demonstrated by the results of a χ^2 test conducted on the

number of individuals of certain indicator species which occurred on the two routes. The indicator species which were abundant enough on both routes during the summer survey to be included in the analysis were the mocking bird, eastern meadowlark, cardinal, rufous-sided towhee, Carolina chickadee, and mourning dove. The χ^2 generated was significant at the 95 percent level, indicating that a significant difference did exist in the abundance of these species on the two routes. For all but the cardinal and chickadee, the numbers of individuals recorded on the test route were higher than on the control.

A similar relationship between the test and control routes occurred during the winter survey. The test route had an average of 9.5 birds per stop per day, while Route D had only 7.6. The χ^2 calculated for indicator species was not significant. However, only the cardinal, Carolina chickadee, and rufous-sided towhee were abundant enough to be included in the analysis, resulting in an analysis which was less powerful as the analysis conducted on the summer data. On the other hand, during the winter survey, both towhees and chickadees were more abundant on the test than on the control route.

Twenty-five bobwhite were recorded along the test route during the two summer mornings of the Game Bird Call Count. During the same period, twenty-five bobwhites were also recorded along the control route (Figure 3.2.3). A comparison of the 1981 data with data from previous years indicates that the bobwhite populations along both routes have been fairly stable since 1977.

Eight mourning doves were recorded along the test route during the Game Bird Call Count while five were recorded along the control route. Since 1978, the test route has consistently had higher numbers of mourning doves than the control route. This relates to the degree of urbanization along the control route. Although doves occur regularly around houses, larger flocks occur in the less disturbed habitats along Routes ABC, thus accounting for the observed differences.

3.2.2 Waterfowl Survey

3.2.1.1 Introduction

Waterfowl surveys were conducted on Monticello Reservoir and on Parr Reservoir and its tributaries, Frees Creek, and Cannons Creek. Observations were made of all ducks and other waterfowl, wading birds, and shorebirds which utilized these areas during the winter, summer, and fall seasons of 1981.

3.2.2.2 Findings and Discussion

Waterfowl observed during the 1981 surveys are listed in Table 3.2.3. The fall and winter surveys documented the occurrence of migrating species utilizing the aquatic habitats of the study area. The summer survey was performed to document the occurrence of resident waterfowl species.

During the fall survey, ducks were abundant in Parr Reservoir and its tributaries, with mallards, black ducks, and blue-winged teal being the most common species seen. During this survey, the great blue heron was particularly abundant in Parr Reservoir, with 37 individuals observed in the reservoir and its tributaries. A small flock of Canada geese was also seen in Cannons Creek during the fall survey. The fall survey of Monticello Reservoir indicated that mallards were the only common, migrating duck species, although the large, resident flock of Canada geese was present. Numerous gulls and great blue herons, as well as three common loons were also seen on Monticello Reservoir.

During the winter survey, a large number of ducks was present in Parr Reservoir and its tributaries. Mallards were abundant in the dredge spoil area south of Frees Creek on the east bank of Parr Reservoir. Great blue herons and killdeer were also common there. This area is somewhat protected from the boat traffic on the reservoir and offers

attractive habitat in the form of open, shallow water broken up by marshy areas vegetated with willows and aquatic plants. A large flock of mallards was found in the slough which runs north from the tailrace canal parallel to the Broad River. Gulls also were numerous here as were great blue herons. Gulls occurred in Cannons Creek during this survey. Fewer ducks were observed on Monticello Reservoir than on Parr Reservoir during the winter period. Mallards and scaup were the most common. There were high winds on the lake during the winter census period, and it appeared that many ducks found the more sheltered habitat of Parr Reservoir more suitable than the open water of Lake Monticello. The flock of Canada geese transplanted by the South Carolina Wildlife and Marine Resources Department during 1979 seemed to be doing well in Monticello Reservoir.

The summer survey censused resident species that occurred in the area. The wood duck is the only resident duck that breeds here regularly, although mallards will occasionally occur in this region. Only a single wood duck was seen in Parr Reservoir. Wood ducks have not been abundant here since the reservoirs were constructed. They bred in the flooded portions of Monticello Reservoir before it was completely filled, and a pair of wood ducks was observed in Parr Reservoir during the summer of 1979. It appears that the condition of fluctuating water levels in the reservoirs is not attractive to this species, so that wood ducks have probably moved to more stable areas of the Broad River. The only other aquatic birds seen in Parr Reservoir during the summer survey were three great blue herons, a common egret, and a woodcock. Other than the transplanted geese, the only species seen in Monticello Reservoir were the great blue heron and the double-crested cormorant.

3.2.3 Strip Census

3.2.3.1 Introduction

Avian strip censuses were conducted at six sites in the study area during the winter and summer of 1981. Three sites were designated as test sites and were located within an area of possible influence of the generating facilities; the other three sites were designated as controls, and were located outside of any area of influence. A survey test and control site were located in each of the following habitats, which were the major vegetative types in the study area: pine, selectively-cut pine, and deciduous forests.

3.2.3.2 Findings and Discussion

Twenty species of birds were observed on the three test sites during the 1981 surveys (Table 3.2.4). Thirty-two species were recorded on the control sites (Table 3.2.5). A graphic presentation of avian density (birds per acre) on test and control sites during the periods 1974 through 1977 and 1979 thru 1981 is provided in Figure 3.2.4. Avian diversity (number of species per site) is given in Figure 3.2.5.

A comparison of the data from winter 1981 with that from 1979-1980 showed that the pine habitat exhibited an increased density and diversity of species in the winter of 1981. The increase in density on the control site (Transect 1) was due to the presence of numerous cardinals and towhees, both of which were uncommon on the test strip. Differences between the control and test sites were observed during the summer survey. Both the density and diversity of birds on the control site during summer were over twice as great as the density and diversity of birds on the test site. The summer bird community on the control site contained numerous summer tanagers, vireos, and warblers, which were rare on the test site.

The selectively-cut pine sites were altered by harvesting certain sized pines several years ago. This is a common practice in pine forested areas managed for timber. Initially, this harvesting practice opens the habitat to additional sunlight and allows a more diverse plant community to become established on the forest floor. Species such as bobwhite will move into these areas until the remaining pines grow to a size at which the canopy once again shades out the sunlight, and the area reverts back to a nearly monotypic pine stand. Both of the study sites in this habitat have passed the "open" stage and are now similar to pine-dominated sites.

The density of birds on both the control and test, selectively-cut pine stands was much lower in the winter of 1981 than during winter 1980. However, the density recorded in 1980 was heavily influenced by flocks of kinglets which inflated the density estimates. These flocks were not present in 1981, and the densities recorded were similar to the 1979 levels. Diversity was higher on the test site during the winter, with nearly twice as many species seen as on the control. Avian density and diversity during the summer surveys was equal on both test and control sites and was similar to the levels recorded in 1980.

The deciduous control site was located in a heavily wooded stream bottom while the test site was located in an area where a transmission line was constructed directly through a stream bottom. Since the establishment of the transmission line, the species found on the test site have included birds common to bottomland areas as well as those found in fields and hedgerows.

The winter community observed on the deciduous control site was similar in both density and diversity to the levels recorded during 1980. No one species was particularly common, but a fairly large number of species was seen. However, the winter community on the test site was greatly reduced both in density and diversity from previous surveys, with only two species seen, the hermit thrush and the towhee.

There is presently no explanation for the reduced numbers of birds on this strip.

Similar results occurred during the summer survey. The populations on the deciduous control site were similar both in density and diversity to populations observed in previous years. However, the populations on the test strip were greatly reduced in number and diversity. Again, there is no apparent explanation for this. Currently, the reduction in numbers on the test strip cannot be attributed to the operation of the generating facilities. However, this test area should receive particular attention during future surveys to determine if a trend is apparent.

3.2.4 Unusual Observations

During the 1981 surveys, two species listed as endangered by the U.S. Department of the Interior were observed within the study region. During each of the waterfowl surveys of Parr Reservior, two immature southern bald eagles were seen. Eagles have been reported from both Monticello and Parr Reservoirs in past years and it appears that the habitat created by these impoundments is quite suitable for this species.

A much more unusual sighting occurred during the summer 1981 avian roadside census when an eastern cougar was seen crossing the road just south of Hellers Creek. This species is also listed as endangered and is much rarer than is the bald eagle. Although the habitat surrounding Parr Reservoir is suitable for this species, there is no evidence that it is a resident.

3.2.5 Summary

Avian populations along the control and test auto survey routes were high in both density and diversity. The test route, although showing

somewhat reduced numbers of birds from the 1980 survey period, was still higher in avian density and diversity than in most previous years. The control route exhibited an even greater decrease in avian density and diversity when compared to the 1979 levels, but was still at the same level as recorded in 1977-78. The decrease on the control route appears directly related to the greater degree of urbanization along this route. The larger number of homes along the control route tends to create a patchiness of habitat on this route. The habitat along the test route is less patchy and does not have the influence of human disturbance, thus accounting for the higher population levels.

The Game Bird Call Count demonstrated that both bobwhite quail and mourning dove populations are similar in size, and fairly stable along both the control and test routes. The mourning dove population tends to fluctuate more widely than the quail population, but this is due to the migratory nature of mourning doves and their tendency to form flocks. Bobwhite quail are more sedentary and thus, the call count is not as influenced by flocks moving into an area during the survey as is the mourning dove count.

The waterfowl survey indicated that Monticello Reservoir is an important sanctuary for ducks and other aquatic bird species. Parr Reservoir was utilized heavily by migrant species during the fall and winter, but few resident species were found there during the summer. The fluctuating water levels in both Parr and Monticello Reservoirs have caused a decline in resident breeding populations of such species as the wood duck and kingfisher. However, the great blue heron appeared to be as common in 1981 as in previous studies and may have increased in numbers. Species such as gulls, killdeer, and loons, which first appeared after construction was completed, were still present. The efforts to establish a resident population of Canada geese seems to have been very successful, and some breeding and nesting has been observed.

In general, the bird populations surveyed in the avian strip counts demonstrated slight reductions in numbers from the 1980 levels. These reductions occurred in all habitats during both seasons, indicating that there was an overall reduction in bird use of the study area in 1981. The reductions were particularly evident in several of the test sites. The reasons for the reduced population are unknown at this time.

The two immature bald eagles seen during the 1981 surveys could form a breeding pair in future years. Eagles do not breed until they are 7 to 10 years old, but they form pairs at an earlier age. Thus, it is possible that, in future years, eagle nesting could occur near the reservoirs. The eastern cougar which was seen near Hellers Creek could remain in the area, but these animals require very large home ranges, and it is not yet possible to predict whether the animal is or will become a resident of the study region.

Table 3.2.1 Birds observed during the auto survey - summer 1981.

Common Name	Scientific Name	Route Where Observed[a] ABC	D	Status[b]
Turkey vulture	*Cathartes aura*		X	P
Red-shouldered hawk	*Buteo lineatus*		X	P
Mourning dove	*Zenaida macroura*	X	X	P
Yellow-billed cuckoo	*Coccyzus americanus*	X		S
Chimney swift	*Chaetura pelagica*		X	S
Common flicker	*Colaptes auratus*	X		P
Red-bellied woodpecker	*Melanerpes carolinus*	X	X	P
Eastern kingbird	*Tyrannus tyrannus*	X	X	S
Great crested fly-catcher	*Myiarchus crinitus*	X		S
Barn swallow	*Hirundo rustica*	X	X	S
Purple martin	*Progne subis*	X	X	S
Blue jay	*Cyanocitta cristata*	X	X	P
Common crow	*Corvus brachyrhynchos*	X	X	P
Carolina chickadee	*Parus carolinensis*	X	X	P
Tufted titmouse	*Parus bicolor*	X	X	P
Brown-headed nuthatch	*Sitta pusilla*	X	X	P
Rough-winged swallow	*Stelgidopteryx ruficollis*	X	X	S
Loggerhead shrike	*Lanius ludovicianus*	X		P
Cattle egret	*Bubulcus ibis*		X	S
Broad-winged hawk	*Buteo platypterus*		X	S
Mockingbird	*Mimus polyglottos*	X	X	P
Brown thrasher	*Toxostoma rufum*	X	X	P
Robin	*Turdus migratorius*	X	X	P
Wood thrush	*Hylocichla mustelina*	X	X	S

Common Name	Scientific Name	Route Where Observed[a] ABC	D	Status[b]
Starling	*Sturnus vulgaris*	X		P
White-eyed vireo	*Vireo griseus*	X	X	S
Pine warbler	*Dendroica pinus*	X	X	P
Prairie warbler	*Dendroica discolor*	X	X	S
Yellow-breasted chat	*Icteria virens*	X	X	S
Eastern meadowlark	*Sturnella magna*	X	X	P
Red-winged blackbird	*Agelaius phoeniceus*	X	X	P
Common grackle	*Quiscalus quiscula*	X	X	P
Brown-headed cowbird	*Molothrus ater*	X	X	P
Summer tanager	*Piranga rubra*	X	X	S
Cardinal	*Cardinalis cardinalis*	X	X	P
Blue grosbeak	*Guiraca caerulea*	X	X	S
Indigo bunting	*Passerina cyanea*	X		S
Parula warbler	*Parula americana*		X	S
Yellow-throated warbler	*Dendroica dominica*		X	S
Tennessee warbler	*Vermivora peregrina*		X	S
Rufous-sided towhee	*Pipilo erythrophthalmus*	X	X	P
	Total Number of Species	33	35	

[a] Routes are illustrated in Figure 3.2.1

[b] P = Permanent Resident
S = Summer Resident
W = Winter Resident

Table 3.2.2 Birds observed during the auto survey - winter 1981.

Common Name	Scientific Name	Route Where Observed[a] ABC	D	Status[b]
Turkey vulture	Cathartes aura	X	X	P
Red-tailed hawk	Buteo jamaicensis	X		P
Killdeer	Charadrius vociferus	X		P
Common flicker	Colaptes auratus	X	X	P
Pileated woodpecker	Dryocopus pileatus		X	P
Red-bellied woodpecker	Melanerpes carolinus	X	X	P
Downy woodpecker	Picoides pubescens		X	P
Blue jay	Cyanocitta cristata	X	X	P
Common crow	Corvus brachyrhynchos	X	X	P
Carolina chickadee	Parus carolinensis	X	X	P
Tufted titmouse	Parus bicolor	X		P
Slate-colored junco	Junco hyemalis	X	X	W
Northern harrier	Circus cyancus		X	W
Red-shouldered hawk	Buteo lineatus		X	P
Mockingbird	Mimus polyglottos	X		P
Robin	Turdus migratorius	X	X	P
Hermit thrush	Catharus guttatus	X		W
Eastern bluebird	Sialia sialis		X	P
English sparrow	Passer domesticus	X		P
Eastern meadowlark	Sturnella magna	X		P
Common grackle	Quiscalus quiscula	X	X	P
Cardinal	Cardinalis cardinalis	X	X	P
Rufous-sided towhee	Pipilo erythrophthalmus	X	X	P
Chipping sparrow	Spizella passerina	X	X	P
White-throated sparrow	Zonotrichia albicollis		X	W
	Total Number of Species	19	18	

[a] Routes are illustrated in Figure 3.2.1

[b] P = Permanent Resident
S = Summer Resident
W = Winter Resident

Table 3.2.3 Results of 1981 waterfowl surveys.

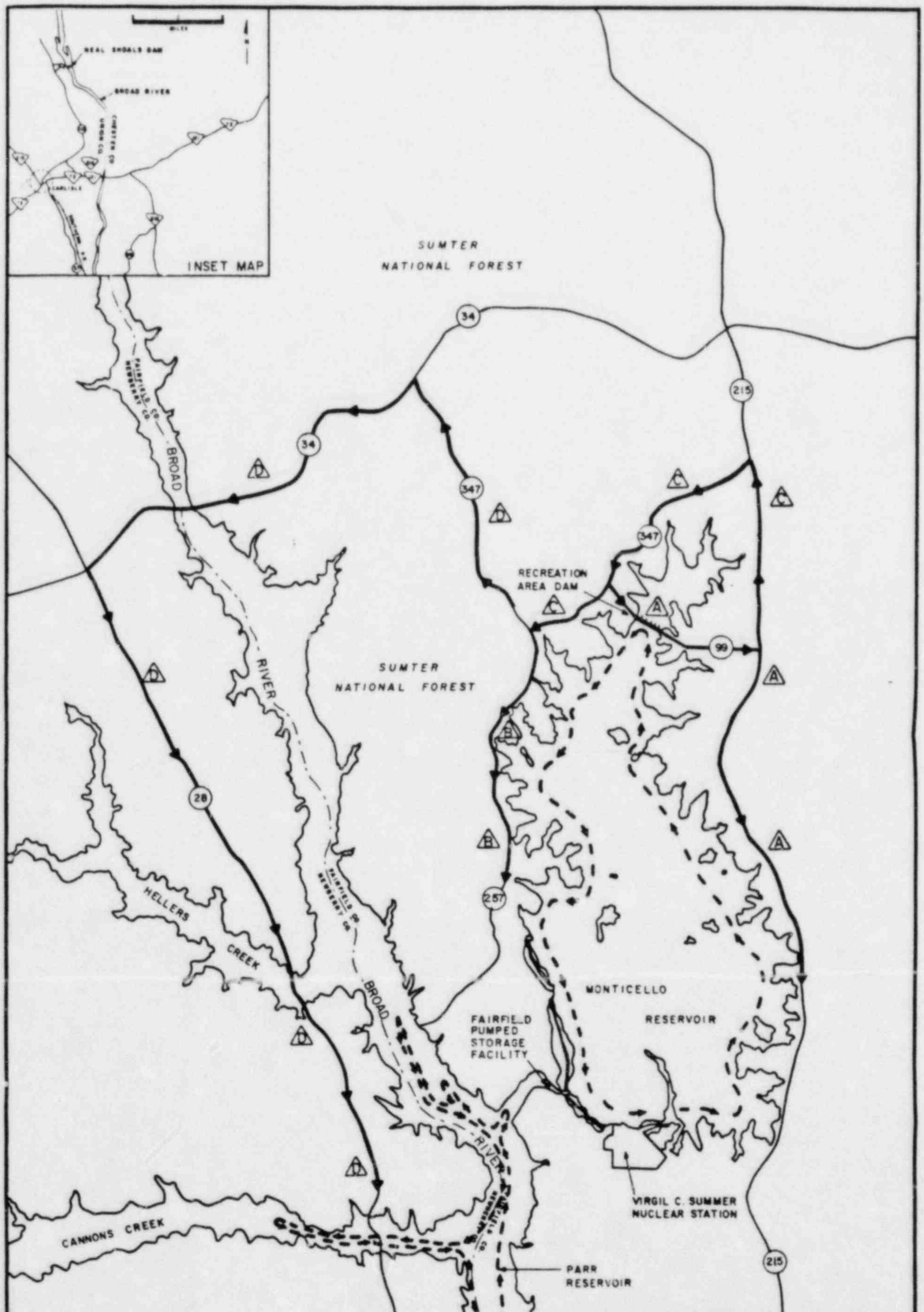
Common Name	Dredge Spoil/ Frees Creek			Cannons Creek			Parr Reservoir			Monticello Reservoir		
	Winter	Summer	Fall	Winter	Summer	Fall	Winter	Summer	Fall	Winter	Summer	Fall
Canada goose						18				210	240	215
Mallard	105		100				453		33	6		199
Black duck			150				2		5			
Wood duck								1				
Greater scaup									1	20		18
Pintail									1			
Shoveler									54			
Red-breasted merganser									2			
Blue-winged teal			150				15			7		
Common coot										9		
Common loon												3
Pied-billed grebe												1
Great blue heron	21		6	3		6	17	3	25	1	10	13
Belted kingfisher						2	1					1
Double-crested cormorant									1		7	1
Common Egret					1							
Gull (ring-billed/herring)	12			16						12		80
Woodcock								1				
Killdeer	3											
Total Ducks	105	0	400	0	0	18	470	1	96	252	240	435
Total Shore Birds/ Wading Birds	36	0	6	19	1	8	18	4	26	13	17	96
Total Individuals	141	0	406	19	1	26	488	5	122	265	257	531
Total Species	4	0	4	2	1	3	5	3	8	7	3	9

Table 3.2.4 Results of avian strip census conducted in different habitats on test sites during winter and summer of 1981.

Common Name	Pine		Selectively Cut Pine		Deciduous	
	Winter	Summer	Winter	Summer	Winter	Summer
Cardinal	1	2	2	2	1	
Rufous-sided towhee		2		1		
Blue jay		1	1	1		1
Tufted titmouse			3	1		1
Common crow	1					
Carolina chickadee	1		2	3		1
Mourning dove	1					
Hermit thrush	1		1		1	
Wood thrush						
Summer tanager		1		2		
White-eyed vireo						
Common flicker	1		1			
Slate-colored junco	4					
Downy woodpecker			1			
Brown headed nuthatch			1			
Winter wren			1			
Prairie warbler				1		
Blue grosbeak				1		
Red-eyed vireo				2		
Parula warbler				1		
Numbers of Individuals	10	6	13	15	2	3
Number of Species	7	4	9	10	2	3

Table 3.2.5 Results of avian strip census conducted in different habitats on control sites during winter and summer 1981.

Common Name	Pine		Selectively Cut Pine		Deciduous	
	Winter	Summer	Winter	Summer	Winter	Summer
Cardinal	4	4	2	1	1	1
Rufous-sided towhee	4	1		1	1	3
Blue jay	1	2	1	3		
Tufted titmouse	2	1		2		
Carolina chickadee	1	1	3	3	4	1
American goldfinch	2					
Mourning dove	1	1		1		
Hermit thrush	1				2	
Wood thrush		1				1
Summer tanager		4				
White-eyed vireo		1		1		2
Red-eyed vireo						3
Bobwhite quail		1				
Yellow-throated warbler		1				
Yellow-billed cuckoo				1		
Pine warbler				2		
Red-bellied woodpecker					2	1
Eastern bluebird					1	
Blue-gray gnatcatcher					2	
Downy woodpecker					1	
Parula warbler						1
Brown-headed nuthatch						1
Number of Individuals	16	18	6	15	14	14
Number of Species	8	11	3	9	8	9



South Carolina Electric & Gas Co.

Terrestrial Sampling Locations and Survey Routes

Figure 3.2.1

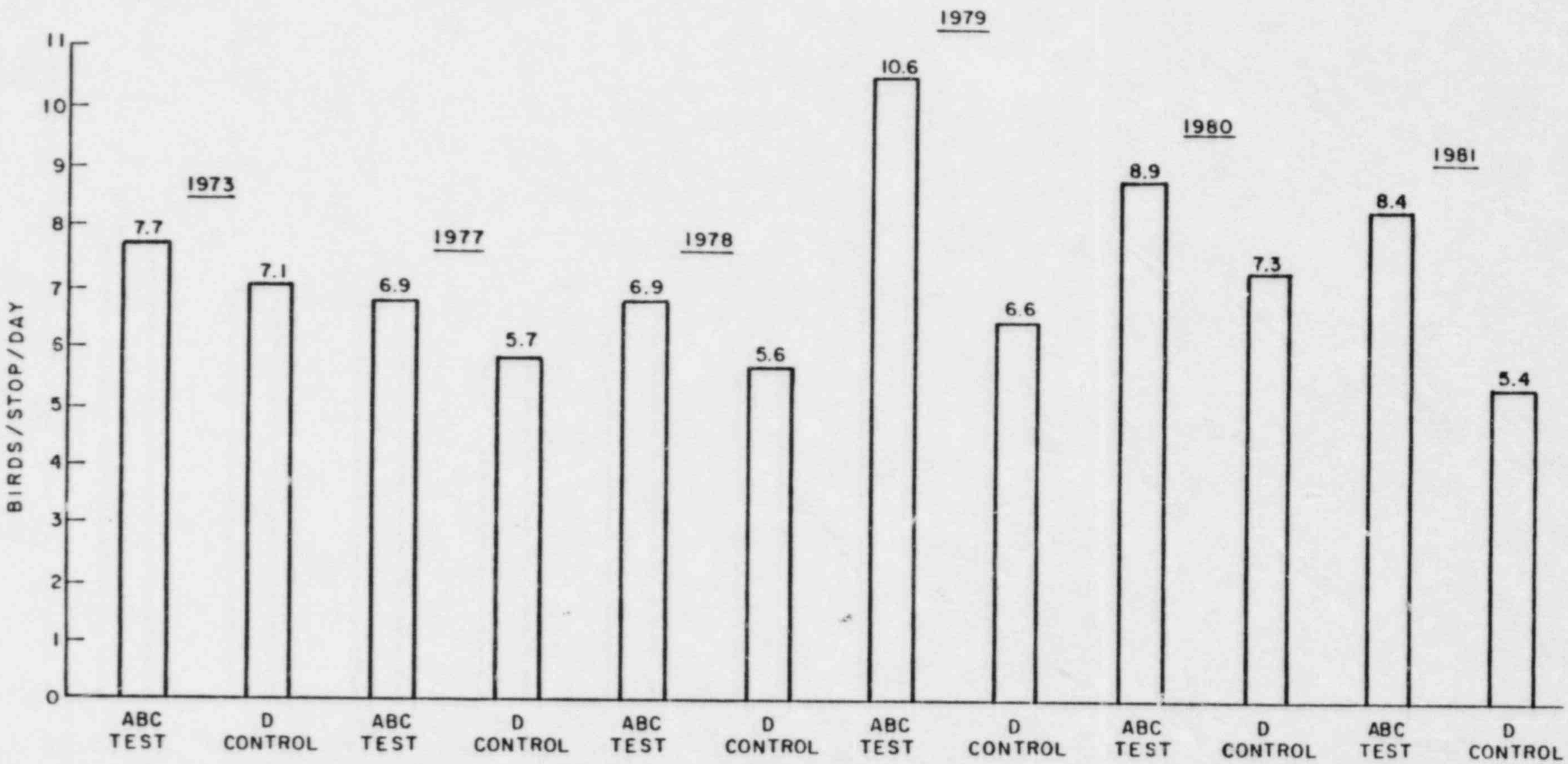


Figure 3.2.2. Average Number of Birds Recorded on Summer Avian Survey Routes.

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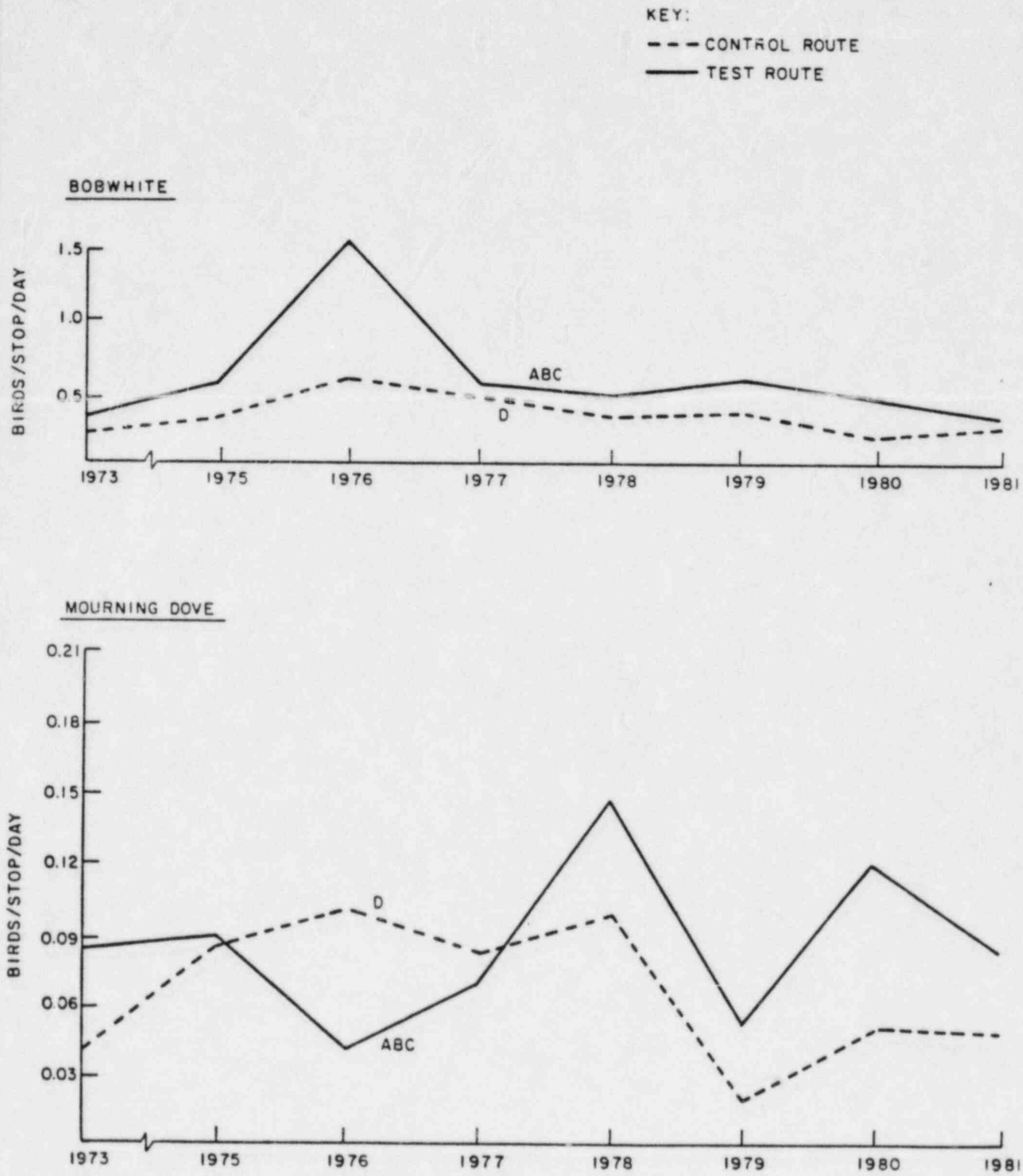

Figure 3.2.3. Comparison of Game Bird Call Counts on Avian Survey Routes.

DAMES & MOORE

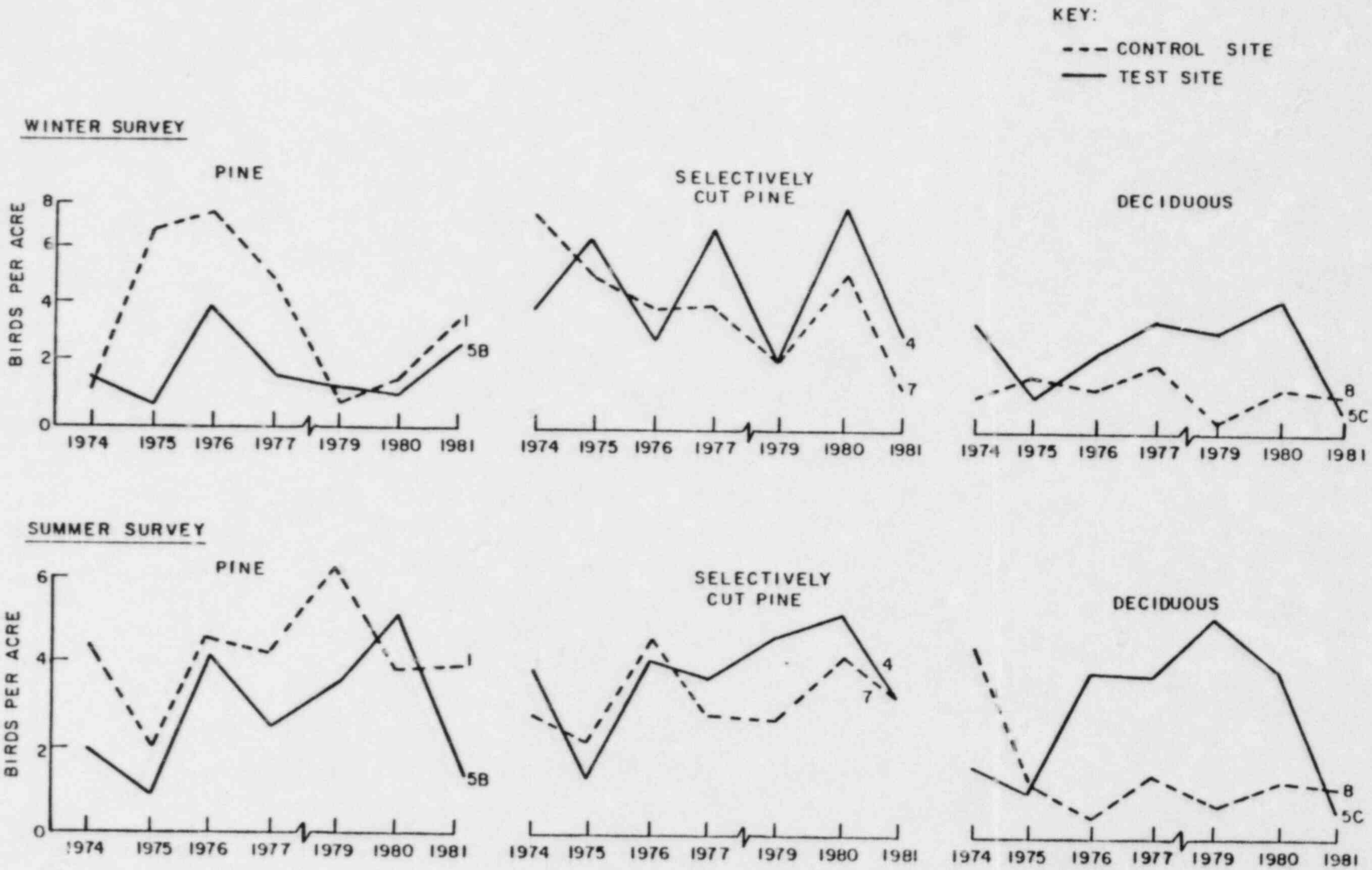

Figure 3.2.4. Avian Density in Selected Habitats During Strip Censuses.

DAMES & MOORE

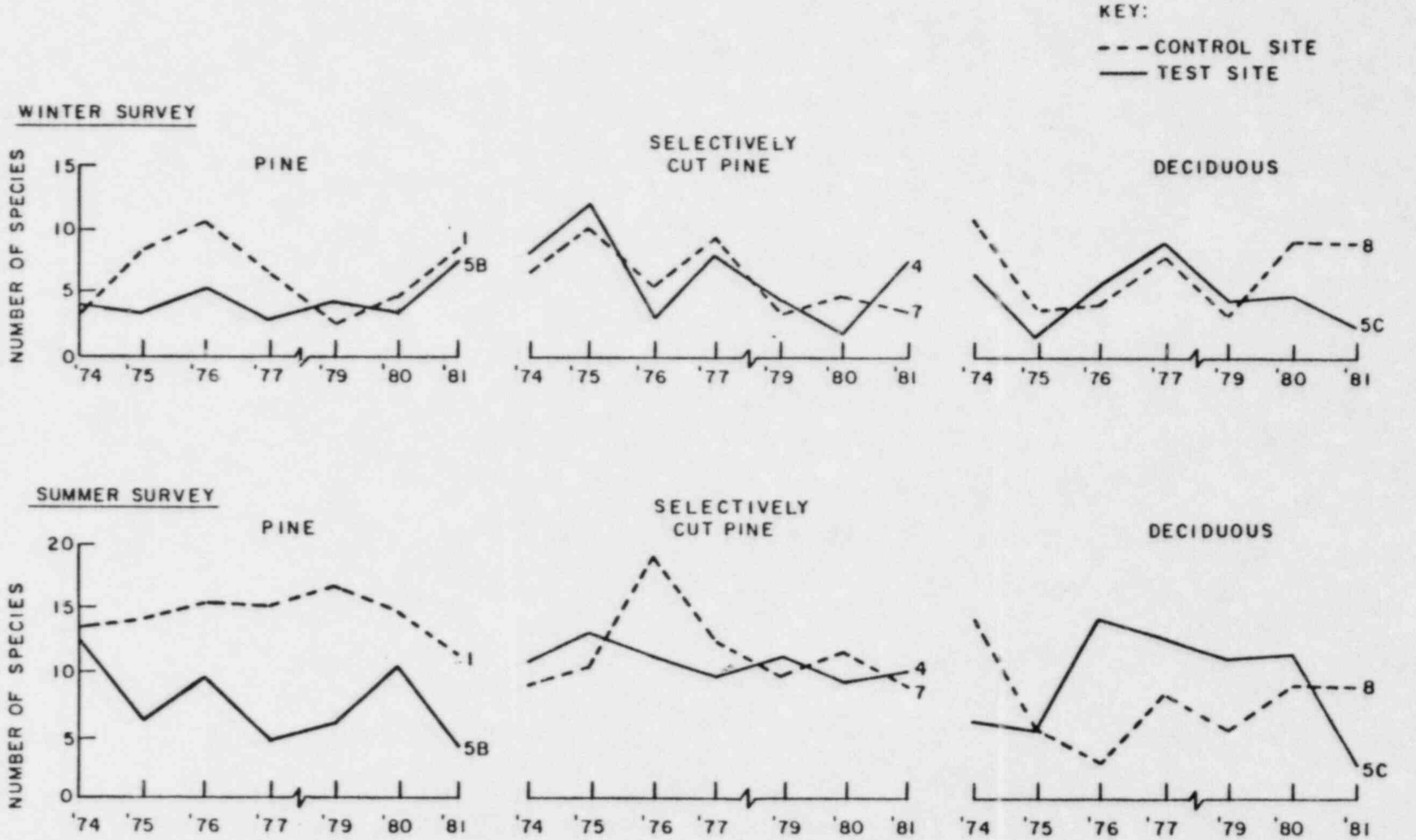

Figure 3.2.5. Avian Diversity in Selected Habitats During Strip Censuses.

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APPENDIX A

METHODS

Water quality sampling was conducted monthly, during the two-day period following the second Monday in each month, and was concurrent with the biological sampling. Sampling dates and locations are indicated in Table A-1.

The schedule for monthly and quarterly physical measurements and water quality sampling is in Tables A-2 and A-3.

Physical measurements were made in situ at the surface (30 cm) and at 1 m intervals to the bottom using electronic instruments with remote probes as follows: Temperature measurements were made using a Montedoro-Whitney TF10 or TC-5C thermistor, dissolved oxygen with a YSI Model 51 dissolved oxygen meter, pH with an AMI Model 107 pH meter, and conductivity with a GLI Model 708 conductivity meter. All instruments were given time to stabilize before the readings were recorded at each depth. Transparency was determined using a Secchi disc. Appropriate calibrations of all instruments were carried out several times during each sampling day.

Surface water samples were collected for determination of select chemical parameters using plastic bottles. The samples were preserved in the field according to approved procedures and shipped on ice to the analytical laboratory.

The methods used for chemical analysis of water samples are listed in Table A-4. Inspection for oil and grease residue and unusual odor was conducted daily below Parr Dam (Station 5A) by SCE&G personnel.

Table A-1 Water quality sampling locations and sampling dates for the Summer/Fairfield Environmental Monitoring Program, January 1981 through December 1981.

AREA	STATION NUMBER	LOCATION
Broad River	1	Broad River at Highway 34 Bridge
	5A	Broad River below Parr Dam
Parr Reservoir	2	Broad River at Frees Creek Trestle
	2W	Cannons Creek near Highway 28 Bridge
Neal Shoals Dam	11	Broad River above Neal Shoals Dam
Subimpoundment	18	Monticello Reservoir Recreation Impoundment
Monticello Reservoir	12	Monticello Reservoir at Fairfield Intake
	13	Monticello Reservoir at Summer Intake
	14	Monticello Reservoir at Summer Discharge
	15	Monticello Reservoir Western Section
	16	Monticello Reservoir Near Old Highway 99
	17	Monticello Reservoir Northern Tip
	20	Monticello Reservoir Eastern Section

SAMPLING DATES

January 13-14, 1981
February 10-11, 1981
March 10-11, 1981
April 14-15, 1981
May 12-13, 1981
June 9-10, 1981
July 14-15, 1981
August 11-12, 1981
September 15-16, 1981
October 13-14, 1981
November 10-11, 1981
December 15-16, 1981

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	13	Monticello Reservoir at Summer Intake
	14	Monticello Reservoir at Summer Discharge
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July 14-15, 1981
August 11-12, 1981
September 15-16, 1981
October 13-14, 1981
November 10-11, 1981
December 15-16, 1981

Table A-2. Monthly sampling schedule for the Summer/Fairfield water quality study.

Station Number:	1	2	5A	11	12	14	15	16	18
A. LABORATORY ANALYSES (surface sample only)									
Sodium Hardness	X	X	X	X	X	X	X	X	NR
Calcium Hardness	X	X	X	X	X	X	X	X	NR
Magnesium	X	X	X	X	X	X	X	X	NR
Chloride	X	X	X	X	X	X	X	X	NR
Sulfate (SO_4)	X	X	X	X	X	X	X	X	NR
TDS	X	X	X	X	X	X	X	X	NR
TSS	X	X	X	X	X	NR	NR	NR	NR
Mo-Alkalinity	X	X	X	X	X	X	X	X	NR
P-Alkalinity ($CaCO_3$)	X	X	X	X	X	X	X	X	NR
Ammonia (NH_3)	X	X	X	X	X	X	X	X	NR
BOD	X	X	X	X	X	X	X	X	NR
Cadmium	X	X	X	X	X	X	X	X	NR
COD	X	X	X	X	X	X	X	X	NR
Total Chromium	X	X	X	X	X	X	X	X	NR
Copper	X	X	X	X	X	X	X	X	NR
Total Hardness ($CaCO_3$)	X	X	X	X	X	X	X	X	NR
Total Iron	X	X	X	X	X	X	X	X	NR
Lead	X	X	X	X	X	X	X	X	NR
Mercury	X	X	X	X	X	X	X	X	NR
Nitrate (NO_3)	X	X	X	X	X	X	X	X	NR
Ortho-Phosphate	X	X	X	X	X	X	X	X	NR
Total Phosphate	X	X	X	X	X	X	X	X	NR
Silica (SiO_2)	X	X	X	X	X	X	X	X	NR
Turbidity	X	X	X	X	X	X	X	X	NR
Zinc	X	X	X	X	X	X	X	X	NR
Carbon Dioxide	X	X	X	X	X	X	X	X	NR
Kjeldahl Nitrogen	NR	NR	NR	NR	NR	NR	NR	NR	NR
Boron	NR	NR	NR	NR	NR	NR	NR	NR	NR

NR: Not required

B. IN SITU MEASUREMENTS (1 Meter Intervals Surface to Bottom)

Temperature
Dissolved Oxygen — Stations 1, 2, 2W, 5A, 11, 12, 13, 14, 15, 16, 17, 20
pH
Conductivity

C. IN SITU MEASUREMENT (Surface)

Transparency (Secchi Disc) — Stations 1, 2, 2W, 5A, 11, 12, 13, 14, 15, 16, 17, 20

Table A-3. Quarterly sampling schedule for the Summer/Fairfield water quality study.

Station Number:	1	2	5A	11	12	14	15	16	18
A. LABORATORY ANALYSES (surface sample only)									
Sodium Hardness	X	X	X	X	X	X	X	X	NR
Calcium Hardness	X	X	X	X	X	X	X	X	NR
Magnesium	X	X	X	X	X	X	X	X	NR
Chloride	X	X	X	X	X	X	X	X	NR
sulfate (SO_4)	X	X	X	X	X	X	X	X	NR
TDS	X	X	X	X	X	X	X	X	X
TSS	X	X	X	X	X	X	X	X	X
Mo-Alkalinity	X	X	X	X	X	X	X	X	X
P-Alkalinity ($CaCO_3$)	X	X	X	X	X	X	X	X	X
Ammonia (NH_3)	X	X	X	X	X	X	X	X	X
BOD	X	X	X	X	X	X	X	X	X
Cadmium	X	X	X	X	X	X	X	X	X
COD	X	X	X	X	X	X	X	X	NR
Total Chromium	X	X	X	X	X	X	X	X	X
Copper	X	X	X	X	X	X	X	X	X
Total Hardness ($CaCO_3$)	X	X	X	X	X	X	X	X	X
Total Iron	X	X	X	X	X	X	X	X	NR
Lead	X	X	X	X	X	X	X	X	X
Mercury	X	X	X	X	X	X	X	X	X
Nitrate (NO_3)	X	X	X	X	X	X	X	X	X
Ortho-Phosphate	X	X	X	X	X	X	X	X	X
Total Phosphate	X	X	X	X	X	X	X	X	X
Silica (SiO_2)	X	X	X	X	X	X	X	X	NR
Turbidity	X	X	X	X	X	X	X	X	X
Zinc	X	X	X	X	X	X	X	X	NR
Carbon Dioxide	X	X	X	X	X	X	X	X	NR
Kjeldahl Nitrogen	NR	NR	NR	NR	X	X	X	X	NR
Boron	X	X	X	X	X	X	NR	X	X

NR: Not required

B. IN SITU MEASUREMENT (1 Meter Intervals Surface to Bottom)

Temperature
Dissolved Oxygen
pH
Conductivity

Stations 1, 2, 2W, 5A, 11, 12, 13, 14, 15, 16, 17, 20

C. IN SITU MEASUREMENT (Surface)

Transparency (Secchi Disc) Stations 1, 2, 2W, 5A, 11, 12, 13, 14, 15 16, 17, 20

Table A-4 Procedures used in chemical analysis of water quality samples taken between January 1981 and December 1981 for the Environmental Monitoring Program.[a]

Parameter	Detection Limits	Procedure
Sodium	0.01 mg/liter	AA - SM
Calcium	0.08 mg/liter	ASTM D1126-67B
Magnesium	0.5 mg/liter	ASTM D1126-67B
Chloride	0.4 mg/liter	SM
Sulfate (SO_4)	1 mg/liter	ASTM D516-68B
Total Dissolved Solids	1 mg/liter	ASTM D1887-67A
Total Suspended Solids	1 mg/liter	ASTM D1888-67A
MO-Alk	2 mg/liter	ASTM D1067-70C
P-Alk ($CaCO_3$)	2 mg/liter	ASTM D1067-74B
Ammonia (NH_3)	0.1 mg/liter	ASTM D1426-74B
Biochemical Oxygen Demand	1 mg/liter	SM 507
Cadmium	0.01 mg/liter	EPA
Chemical Oxygen Demand	4 mg/liter	EPA
Total Chromium	0.03 mg/liter	EPA
Copper	0.02 mg/liter	EPA
Total Hardness ($CaCO_3$)	2 mg/liter	ASTM D1126-67B
Total Iron	0.02 mg/liter	EPA
Lead	0.05 mg/liter	EPA
Mercury (μg/l)	0.2 μg/liter	EPA
Nitrate (NO_3)	0.2 mg/liter	SM 419-D
Ortho-Phosphate (PO_4)	0.01 mg/liter	ASTM D-515-72B
Total Phosphate	0.01 mg/liter	ASTM D-515-72B
Silica (SiO_2)	0.04 mg/liter	ASTM D859-68D
Turbidity	0.01 NTU	ASTM D1889-71
Zinc	0.01 mg/liter	EPA
Carbon Dioxide	1 mg/liter	SM-407-A
Kjeldahl N	1 mg/liter	EPA
Boron	0.2 mg/liter	SM 107B (1971 ED)

[a] Analysis Procedures taken from:

SM - Standard Methods for the Examination of Water and Wastewater, 1976, 14th ed. Publ. by American Publ. Health Assoc., Amer. Water Works Assn., Water Poll. Control Fed., Washington, D.C., 1193 pp.

ASTM - American Society for Testing and Materials, 1975. Annual Book of ASTM Standards, Part 31.

EPA - U.S. Environmental Protection Agency, 1974, Methods for Chemical Analysis of Water and Wastes. EPA-625-6-74-003.

AA - Atomic Absorption