Aquatic Ecology of the New Jersey Pinelands

prepared for

the New Jersey Pinelands Commission

by

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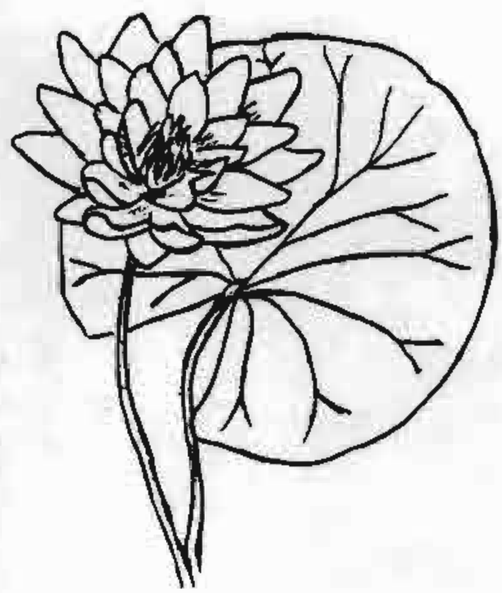

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EXECUTIVE SUMMARY

Aquatic life in the streams, lakes and bogs of the Pinelands National Reserve/Pinelands area has been investigated. The study area encompasses more than 2,000 square miles in Central and Southern New Jersey. It supports a relatively unique flora and fauna consisting of species adapted to the acid water and other environmental characteristics.

This study, which was performed for the State of New Jersey Pinelands Commission. is one of the inputs to a plan for the region being prepared by the Commission. The principal objectives of the aquatic ecology study were:

1) provide an inventory of aquatic life in all of the more important watersheds of the Pinelands area, and describe the composition of characteristic aquatic communities

2) identify specific areas which are believed to support "pristine" communities and therefore warrant protection

3) identify areas which appear to be degraded and specify, to the extent possible, factors which have deleterious effects on characteristic Pinelands aquatic communities

4) recommend various land and water management practices which would help to preserve or protect characteristic aquatic ecosystems.

Results of Inventory

Delaware River and Bay Drainage

Rancocas Creek. This is the largest stream system flowing out of the Pinelands to enter the Delaware River. Much of the North Branch east of Browns Mills supports characteristic aquatic communities. Pristine tributaries of the North Branch include the Greenwood Branch and McDonalds Branch which drain portions of Lebanon State Forest. Aquatic communities in the South Branch include many peripheral and in some cases pollution-tolerant species; species characteristic of typical acid water Pinelands communities are restricted for the most part to headwater tributaries in the eastern portion of the watershed.

Crosswicks Creek. Little information is available for the Pinelands portion of this watershed; lower reaches support non-Pinelands species.

Maurice River. Characteristic Pinelands species were found in Scotland Run and Little Ease Run, two tributaries to the upper mainstem. Manantico and Manumuskin Creeks support pristine communties upstream from Route 49; lower portions are tidal but relatively unmodified. Dennis Creek, Upper Dennis Creek, and several of its tributaries support characteristic communities.

Atlantic Coastal Drainage

Great Egg Harbor River: Four Mile and Hospitality Branches as well as the Tuckahoe River support characteristic species. Squankum Branch and the upper mainstem have been impacted by runoff from urban and agricultural areas. While the upper mainstem is degraded, pristine communities occur in some of the small tributaries and bogs in the area.

Mullica River. Most of the major tributaries to the Mullica support typical Pinelands communities: included are the Atsion and Batsto Rivers, Sleeper Branch, Albertson Brook and Great Swamp Branch of the Nescochague River. The lower Mullica and much of Bass River are tidal but show little biological evidence of disturbance. The Wading River (including the Oswego River) is the least disturbed of the watersheds investigated and resembles a truly "pristine" Pinelands stream most closely. In contrast, Hammonton Creek and the Nescochague River have been degraded by sewage and runoff from suburban areas and support modified communities.

Lesser Creeks of the Atlantic Drainage. Patcong, Absecon, Westecunk (at Stafford Forge) and Cedar Creeks all support characteristic Pinelands communities. This is also true for the headwaters region of Oyster Creek and Forked River west of the Garden State Parkway. The mainstem of Mill Creek and Toms River are significantly modified but some headwater tributaries in both streams are pristine.

Results and Discussion

The inventory of aquatic plants and animals indicated that diversity is relatively high; even though most watersheds have not been sampled intensively, more than 350 species of algae, 62 species of aquatic macrophytes, 275 genera of macroinvertebrates and 91 species of fish have been recorded in Pinelands streams. Of these, certain taxa occur repeatedly in undisturbed streams. These are thought to characterize pristine waters. Characteristic species of each of the major Pinelands habitats (streams, lakes and bogs) are discussed.

The unique character of Pinelands communities is due to a combination of physical, chemical and biological factors. The most successful species are those capable of tolerating acid waters. Pristine streams are typically acid (pH less than 6.0), low in nutrients, darkly stained and sluggish. When Pinelands streams are contaminated, aquatic communities become modified; acid water species tend to be eliminated or reduced in numbers while other species capable of tolerating a wide range of pH become more prevalent. Maintenance of low pH is therefore seen to be the single most important factor for the protection of Pinelands aquatic communities.

Recommendations

As a result of the inventory, it was possible to identify watersheds or portions of watersheds which are known to support characteristic Pinelands communities and therefore warrant protection. These are:

1) entire Wading River watershed
2) entire Batsto River watershed
3) Westecunk Creek west of the Garden State Parkway
4) Cedar Creek west of the Garden State Parkway

Twelve other watersheds probably support pristine aquatic communities, but should be investigated more thoroughly since limited biological data were available. These include:

1) North Branch Rancocas Creek east of Browns Mills
2) Burrs Mill Brook upstream from its confluence with Gum Spring
3) Munumuskin River upstream from Route 49
4) Dennis Creek upstream from Route 47
5) entire Atsion River
6) entire Sleeper Branch
7) Landing Creek upstream from Route 30
8) entire Make Peace Stream
9) Absecon Creek west of Garden State Parkway
10) Patcong Creek west of Garden State Parkway
11) Oyster Creek west of Garden State Parkway
12) Forked River west of Garden State Parkway

In order to ensure the preservation of Pinelands aquatic communities in these areas, stringent land and water management measures must be instituted. These include the following:

- concentrate and cluster development

- locate development where soils, geology and topography are such that water quality will be least impaired

- establish standards for storm water and sanitary wastes based on ambient physical, chemical and biological conditions throughout the watershed

- encourage innovative techniques in wastewater management; prohibit wastewater discharges into surface waters of pristine (environmentally sensitive) areas

- prohibit sanitary sewage discharges into all lakes, even those located in areas not designated as environmentally sensitive

- discourage the use of fertilizers, pesticides and herbicides in lawns bordering surface waters

- preserve natural riparian and flood plain vegetation along streams and around lakes in order to buffer runoff from development.

Recommendations pertaining to agricultural and forestry are aimed at minimizing siltation and runoff containing fertilizers and toxic substances.

This study indicated that there are three general areas warranting additional investigation: watersheds suspected of being pristine should be surveyed; the biology and distribution of rare or endangered species should be investigated; and finally it is important to conduct studies which will define more accurately the relationship between land use, water quality and aquatic life.

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I INTRODUCTION

The Pinelands region in southern New Jersey is drained by five major systems and by numerous minor ones. Its major river systems are the Mullica, Great Egg Harbor, Wading, Maurice and Rancocas Rivers. The Pinelands region supports a relatively unique flora and fauna: characteristic species favor the acid, sluggish waters prevalent here and perpetuation of the typical Pinelands aquatic ecosystem depends on the maintenance of low pH and good water quality.

In order to help protect the Pinelands, the State of New Jersey Pinelands Commission is preparing a regional plan for an area designated as the Pinelands National Reserve/Pinelands area. Our study, one of many inputs to the plan, consisted of an investigation of algae, aquatic macrophytes, macroinvertebrates and fish. Our study area generally conformed with the Pinelands National Reserve/ Pinelands area but did not include the Atlantic coastal bays east of the Garden State Parkway. Hereinafter our study area is referred to as the "Pinelands area".

The principal objectives of this investigation were:

1) provide an inventory of aquatic life in all of the more important watersheds of the Pinelands area; describe the composition of characteristic aquatic communities

2) identify specific areas which are believed to support "pristine" communities and therefore warrant protection

3) identify areas which appear to be degraded and specify, to the extent possible, factors which have deleterious effects on characteristic Pinelands aquatic communities

4) recommend various land and water management practices which would help to preserve or protect characteristic aquatic ecosystems.

II METHODS

A. General Methods

Data concerning aquatic plants and animals were obtained from published and unpublished sources and by searching nearby collections. No field studies were performed owing to the season of the year, budget and time limitations. For each group investigated, that is algae, aquatic macrophytes, macroinvertebrates and fish, lists were prepared on the distribution of individual taxa by watershed. The lists are presented in Appendix A, B, C and D and the flora and fauna of individual watersheds are described in the text. With one exception, only watersheds within the Pinelands area were inventoried; however, in a few instances data were included from points just beyond the boundary. Also, it should be noted that except for fish, collections in brackish waters east of the Garden State Parkway were not included in this inventory.

The inventory was used to assess the degree of disturbance in Pinelands streams. To do this, a list of species characteristic of Pinelands communities was prepared. Aquatic macrophytes and fish were most useful for this purpose because the list of characteristic species is relatively short for each group. Algae and macroinvertebrates were less useful as indicators of pristine conditions because undisturbed streams support large numbers of species in both groups. Also, their taxonomy is not as well known as for fish. For example, macroinvertebrate identifications were carried out only to the generic level in many instances and this precluded a list of characteristic species. Nevertheless, it was possible to identify a number of algae tolerant of acid waters and to formulate a list of macroinvertebrate genera with widespread distribution in Pinelands waters. These genera, however, are not considered to be indicative of Pinelands waters, since nearly all of them are found in other areas where habitats are similar.

Four watersheds were identified as "pristine" by relying primarily on fish data. With few exceptions, the fish fauna of streams included in this category were limited to the 14 species considered to be characteristic of the Pinelands (see page 32). These same streams probably support characteristic aquatic macrophytes (see Appendix B) as well as algae and macroinvertebrates tolerant of acid water; however, in preparing this inventory, few of the studies reviewed contained information for more than one group at a specific location.

In addition to the 4 watersheds listed as "pristine", 12 others are listed as "potentially pristine". The data for these watersheds are inconclusive but suggestive of pristine conditions. Absecon Creek, for example, is listed as a "potentially pristine" watershed on the basis of macroinvertebrate data. Some information was found for algae but none for either aquatic macrophytes or fish. Watersheds listed as "potentially pristine" warrant additional investigation along with other candidate areas identified in other phases of the Pineland Commission's study.

Two kinds of maps were submitted to the Pinelands Commission: Species Distribution Maps and a Synthesis Map. Species Distribution Maps at a scale of 1" = 2000' (7½ minute USGS Quadrants) were prepared for selected species of aquatic macrophytes and fish. No maps were prepared for the distribution of either algae or macroinvertebrates owing to limited site-specific data. The Synthesis Map portrays areas which are known or thought to support pristine Pinelands communities.

B. Specific Methods and Sources of Information

Algae

Information on the algae of the Pinelands area was collected from a number of sources. The recent work by Moul and Buell (1979) was used extensively as it is believed to be the most comprehensive work on Pinelands algae. Included in their work are most published records of Pinelands algae as well as a compilation of Rutgers University collection records. Other published records include Patrick et al (1979), Britton (1889), Drouet (1956, 1968, 1973, 1978, in press), and the Academy of Natural Sciences of Philadelphia (1973). Non-published sources were collected by contacting local institutions and agencies and by reviewing the algal collection records housed in the Academy of Natural Sciences of Philadelphia (ANSP) herbararia.

The survey of available algal data for the New Jersey Pinelands was compiled by watershed. A number of problems occurred in doing this because of the lack of continuity and standardization in collection and because of reporting methodologies. In many cases specific collecting sites and habitats were not given. For many of the earlier collections, only the nearest town is listed as the collection site. In other cases, the river name is listed but no location. However, in spite of the difficulty in evaluating this type of information, it has been included because it is believed that the data are valuable in providing information of a general nature about the algal flora in the Pinelands.

A second consideration in the data compilation is the age of the information. Some of the available published data were collected in the late 1800's. This information is considered important and is included for two reasons. First, it provides an historical perspective as to the makeup of the algal community against which current and future data can be compared; and second, in many cases these data are indicative of the present algal community. When ecological conditions remain stable, the biotic community is not apt to change significantly. An example of both points can be seen in the data included. In the ANSP Rhodophyta (red algae) herbarium, two collections of _Batrachospermum_ sp. were recorded for the same specific sampling location. One sample was collected in 1890, the second sample in 1965.

Another problem in assessing the Pinelands algae is the lack of information concerning species abundance, species associations and seasonality. That is, a species may be known to exist, or have existed at a particular site, but there is no information as to other species that occurred with it, how much was present, or if it was only present specific times of the year.

We are reluctant to categorize the algal species as "characteristic" or "non-characteristic" of the Pinelands because the species are so numerous and many are very widespread in occurrence. However, there are a number of genera which are common to many Pinelands watersheds and these organisms are delineated and discussed beginning on page 30. Algal species are recorded by watershed in Appendix A. In addition, data concerning habitat type, ecological information and abundance estimates were included in the Appendix if this information was available. Appendix A was prepared using the same format as Moul and Buell (1979).

Aquatic Macrophytes

For aquatic macrophytes, Glassboro State College, Stockton and Ryder Colleges, the State Museum, State University and the State Department of Transportation were contacted. Information dealing with specific site locations came primarily through herbaria searches conducted at the Rutgers Herbaria located in Camden and New Brunswick (Chrysler Herbarium). The Herbarium at the Academy of Natural Sciences was closed and therefore could not be searched. Other site-specific data were obtained from state and private collections and from previous field studies performed by the authors. Knowledgeable individuals also were contacted.

Both old and recent data were found, but with few exceptions, only data from the 1930's and onwards were used. Collections which were thought not to be representative of conditions today were either not included or, if they were included, a notation was made concerning their possible obsolescence.

Vascular plant species included in this inventory require an association with water for existence. Since many plants grow in moist substrates but not usually within the boundaries of a lake or stream, criteria were needed to classify "true" aquatic macrophytes. The criteria selected were defined after Sculthrope (1967).

1) Submerged aquatic macrophytes are those that occur on submerged substrates and have leaves that are usually submerged or just reach the water surface.

2) Emergent aquatic macrophytes are those that occur on submerged substrates, but project the vegetative organs above the surface of the water.

Implicit in these definitions is the fact that aquatic macrophytes are almost always found within or along the edge of a watercourse.

With few exceptions, information concerning specific habitats in the Pinelands of New Jersey was not available and therefore it was necessary to consult general botanical references to determine habitat preference, range and factors affecting the distribution of individual species. These references include Muerscher (1944), Fassett (1957), Fernald (1950) and Gleason and Cronquist (1963). Specific Pinelands taxa are best covered by Stone (1910), but these data were subject to the same limitations as Britton's (1889) algal data were, i.e., age and non-specific collection locations.

The Pinelands area supports at least 62 species of aquatic macrophytes, as recorded in this inventory. They are tabulated in Appendix B, with the appropriate growth from designation ("submergent" or "emergent") and discussed in the text.

Macroinvertebrates

Data for macroinvertebrates (aquatic insects, crustaceans, etc.) were obtained mostly from unpublished sources and from personal collections. Except for work by Smith (1909), no early publications of macroinvertebrates were found, and correspondence with local institutions indicated that collections of macroinvertebrates from the Pinelands are meager or non-existent. Nearly all of the data were obtained from water quality monitoring programs such as the one being conducted by the New Jersey Division of Water Resources (Brzozowski, 1978) and from special studies prepared for environmental impact assessments.

Macroinvertebrate data were compiled in a phylogenetic list and tabulated by watershed. Macroinvertebrate distribution is presented in Appendix C. This list was used as a basis for identifying macroinvertebrate genera common to most watersheds and thus characteristic of Pinelands waters.

Several problems are associated with the investigation of macroinvertebrates. First, data obtained from monitoring studies must be considered with care, because a variety of sampling techniques were employed and each technique produces somewhat different results. In most studies, artificial substrates or some type of bottom sampler were employed. Such studies provide data which can be compared over time, but the collections almost never represent all species present at the time of sampling. This is because not all species colonize artificial substrates and because statistical analyses have shown that in order to obtain a representative sample using either a dredge or square foot sampler, many more "grabs" must be made than is usually feasible with limited time and personnel. Diversity amongst macroinvertebrates, therefore, probably is much higher than indicated in Appendix C.

Second, while it is possible to identify genera common to most watersheds, it is not possible to identify species. This is because the taxonomy of many macroinvertebrates is difficult and in many cases identifications are carried out only to the generic level. Many genera include species capable of existing under a broad range of environmental conditions.

Fish

Fish data were obtained primarily from collections made by R.W. Hastings and from unpublished sources. A considerable amount of information was obtained from published and unpublished data from the New Jersey State Freshwater Fisheries Laboratory at Lebanon and from reports prepared by State fishery personnel at the Nacote Creek Laboratory.

A total of 91 species were recorded in this inventory and are tabulated in Appendix D. They have been divided into six categories based upon habitat preference and distribution patterns in New Jersey. These categories are defined as follows:

1. Characteristic Pinelands - Restricted Distribution. Fishes in this category are most typical of the Pinelands region in New Jersey. They are generally indicative of relatively unmodified or pristine Pinelands waters. Although not exclusively confined to the Pinelands area, their distribution elsewhere in New Jersey is significantly limited, and they tend to be rare in most parts of the State except for the Pinelands. Seven species are placed in this category.

2. Characteristic Pinelands - Widespread Distribution. Fishes in this category are distributed throughout most of New Jersey and include some of the most abundant species in the State. They are generally quite numerous at Pinelands locations, but also at other locations outside the Pinelands area. Thus they are to be expected at typical Pinelands locations, but usually also occur at locations where water conditions may be modified. Eight species are placed in this category.

3. Peripheral Pinelands - Fishes placed in this category appear to have limited tolerance to acid water, or other characteristics of the Pinelands aquatic habitats, and thus are generally excluded from typical Pinelands waters. They are generally widespread in northern New Jersey, and in the Inner Coastal Plain on the west side of the State. In the Pinelands area, they are usually restricted to waters at the periphery, or in modified areas where water pH is elevated or other limiting factors are involved. Their distribution in such modified Pinelands areas is also correlated in many cases with past stocking practices. Eighteen species are in this category.

4. Anadromous - These are marine species which move up into freshwater streams to spawn. Four species are in this category.

5. Introduced - Fishes placed in this category are not native to New Jersey but have been introduced into waters of the State during various stocking programs, usually intended to improve angling. Twelve species are included in this category, 8 of which are apparently well-established as self-perpetuating populations.

6. Marine - Fishes placed in this category are characteristic of marine waters but may occasionally or commonly move upstream into coastal freshwater streams. In this inventory 42 marine species were recorded, mostly associated with downstream, tidal portions of the Maurice, Tuckahoe, Great Egg Harbor and Mullica Rivers.

A discussion of all fishes inventoried in the Pinelands is found beginning on page 32. This section also includes a list of characteristic Pinelands fishes, as defined above, on page 32.

Personnel

This study was directed by Mr. Thomas Lloyd who was assisted by the following:

Jacquelyn G. White-Reimer - Algae
Joseph and Catherine Arsenault - Aquatic Macrophytes
Robert W. Hastings - Fish
Marianne Merritt - General Research

III RESULTS OF INVENTORY

A. Delaware River and Bay Drainage

Rancocas Creek (Ran. C)

Rancocas Creek is the largest system flowing westward out of the Pinelands to enter the Delaware River. The watershed encompasses 360 mi^2 within Burlington, Camden and Ocean Counties. Its two major tributaries, the North and South Branches, flow together outside the Pinelands near Mount Holly. The North Branch (NBRan. C) is approximately 23 miles long and drains the Mount Holly-Pemberton area while the South Branch (SBRan. C) is about 20 miles long and drains the Medford-Vincentown area. According to the U.S. Fish and Wildlife Service, about half of the watershed is used for residential, industrial or agricultural purposes and the remainder is forested (U.S.F.W.S., 1978). Suburban development is concentrated in the Mount Holly, Fort Dix and Medford areas. Most agricultural land is located in the center of the watershed and most forested land in the eastern and southern portions.

Characteristic Pinelands aquatic communities occur in the headwaters of both branches (see discussion of "characteristic" communities beginning on page 29). The headwaters of the North Branch are acid as indicated by pH values less than 5.0 (B.C.M., 1980). Downstream, in the more developed portion of the watershed, pH is 6.0 or above. According to Betz, Converse, Murdoch, Inc., a few tributaries of the South Branch are typically acid with pH measurements near 4.5 (B.C.M., 1980); however, several of the lakes, such as Upper and Lower Birchwood Lakes, as well as the Southwest Branch in the vicinity of Medford Township have considerably higher pH with readings of at least 6.5 (ANSP, 1973; and B.C.M., 1980).

In general, the species found in the North Branch upstream from Browns Mills are indicative of acid water conditions. The algal community is diverse and contains numerous species of desmids and diatoms. A number of new desmid species were identified by Woole from the Brown Mills region

(Moul and Buell, 1979). McDonalds Branch in Lebanon State Forest, where samples were collected over a number of years at a site adjacent to a gauging station, provides one of the best series of algal data. Several species of algae indicative of the Pinelands area were present here at virtually all sampling times. These algae include the red algae Batrachospermum spp., the diatom Actinella punctata and species of Frustulia, Fragilaria, Eunotia and Pinnularia. Green algae genera included Mougeotia, Zygogonium, Zygnema and Spirogyra as well as numerous desmid species from most of the known genera (Moul and Buell, 1979).

In the South Branch, acid water algal communities do occur, but in partially developed areas such as Medford Township both characteristic and modified communities are present (see discussion of "modified communities" beginning on page 41). Most lakes in the Medford area are typical brown water lakes; however, Upper and Lower Birchwood Lakes, Lake Mishe-Mokwa and Braddock Mill Pond showed some effects of sanitary wastes or organic enrichment (ANSP, 1973). Collections from these lakes included acid water species such as Actinella punctata, Frustulia rhomboides, Surirella delicatissima and several species of Eunotia and Pinnularia. Species characteristic of a wider pH range were also collected, particularly in the lakes with an elevated pH such as those with a higher organic content (Patrick et. al., 1979).

The aquatic macrophytes found at various locations in the headwaters of both major branches commonly occur in acid waters. Golden club (Orontium aquaticum) has been reported from the Pole Ridge Branch west of Whiting and from McDonalds Branch where bladderwort (Utricularia intermedia) also occur. Additionally, Pakim Pond in Lebanon State Forest supports characteristic species.

Upper and Lower Birchwood Lakes (Medford Township) support large populations of fanwort (Cabomba carolinana), which is not a true Pinelands species. Other lakes, however, support characteristic species such as various bladderworts (Utricularia spp.), bullhead lily (Nuphar variegatum), fragrant water lily (Nymphaea odorata) and others.

Relatively little data for macroinvertebrates were found for Rancocas Creek. The New Jersey Division of Water Resources has two monitoring stations located outside the Pinelands area near the mouth of each branch. Thirty-three taxa were found in the North Branch; midge larvae (Polypedilum spp. and Pentaneura) and mayflies (Caenis) were most common (Brzozowski, 1978). A total of 25 taxa were found in the South Branch where aquatic earthworms (Nais communis), beetles, various midge larvae and mayflies (Stenonema) were the principal groups present.

In Mason's Creek, a tributary of the lower South Branch, Drake and Wichser (1978) found a low diversity amongst macroinvertebrates. Midge larvae and aquatic earthworms were dominant, just as reported by Brzozowski(1978) for the mainstem of the South Branch.

In the Medford Lakes area, many of the lakes sampled by the Academy of Natural Sciences (ANSP, 1973) supported large populations of dragon and damselflies, caddisflies and midge larvae. The most impacted lakes had large populations of snails, oligochaete worms and, in one, leeches. Studies performed by Smith (1961) in Turkey Lake, then an uncontaminated lake located just south of Mishe-Mokwa, showed that the principal macroinvertebrates were oligochaetes, midge larvae, dragonflies, true bugs (hemipterans) and beetles.

Characteristic Pinelands fish species occur in several tributaries of the North Branch. These include mud, blackbanded and banded sunfishes (*Acantharchus pomotis*, *Enneacanthus chaetodon* and *E. obesus*, respectively); yellow bullhead (*Ictalurus natalis*) and chain pickerel (*Esox niger*). Much of the Greenwood Branch draining Lebanon State Forest also supports such species. Fowler (1906) reported the ironcolor shiner (*Notropis chalybaeus*) at Browns Mills, but it has not been reported from the Rancocas in recent years and it may now be extinct from this drainage.

The mainstem North Branch coming out of the Browns Mills-Ft. Dix area is slightly modified, mostly by the addition of centrarchids (sunfish family) which have been stocked as game or panfish. As the North Branch passes out of the Pinelands area, extreme changes in the fish fauna are apparent: two-thirds of the fish species recorded at Smithville and Mt. Holly are peripheral or introduced species.

In the South Branch, the eastern tributaries (Cedar Run, Burrs Mill Brook) appear to be populated by characteristic Pinelands species, with little or no modification. In contrast the Southwest Branch which drains Medford is quite modified. Most of the lakes in this part of the system have been stocked with various non-Pinelands species, and some have been treated with lime or limestone to neutralize acidity (Stewart, 1971).

Crosswicks Creek (Cro. C)

The Crosswicks Creek watershed has a drainage of approximately 146 mi^2 within Burlington, Mercer, Monmouth and Ocean Counties and flows into the Delaware River at Bordentown. The mainstem and its tributaries drain the northwestern portions of the Pinelands area. Agricultural and forested land comprise about 80% of the basin; however, significant development exists in the vicinity of McGuire Air Force Base which contains the headwaters of several tributaries (U.S.F.W.S., 1978).

Only one report is available for the Pinelands portion of this system. Brindle Lake was investigated during the State Lakes and Ponds Survey and found to have a typical Pinelands fish fauna (N.J. Div. of Fish and Game, 1951), with species such as chain pickerel, yellow bullhead, pirate perch (Aphredoderus sayanus) and blackbanded sunfish. Lahaway Creek to the north and downstream portions of Crosswicks Creek yield non-Pinelands fishes.

Additional data available for Crosswicks Creek consist of fish and macroinvertebrate information from the tidal portions near Delaware River.

Maurice River (Mau. R)

The Maurice River drains approximately 388 mi^2 in Gloucester, Cumberland and Salem Counties. The river flows southeast to its confluence with Delaware Bay just south of Port Norris. Approximately 58% of the land is forested and 30% supports agriculture. Suburban development is most prevalent in Gloucester County (U.S.F.W.S., 1978).

The chief tributaries within the Pinelands include Manantico Creek, Manumuskin Creek (Man. C) and Scotland Run. Manumuskin Creek reportedly has a pH of 4.9, which is indicative of Pinelands waters. However, the pH of the Maurice River in Vineland Township just above Union Lake is 7.4, a value significantly higher than the pH range considered to be typical of Pinelands streams (B.C.M., 1980).

Biological data are limited for most sections of the Maurice River system; however, it appears that the upper Manantico and Manumuskin watercourses, as well as some mainstem headwater areas may be relatively pristine Pinelands waters.

The only reports of algal species from the Maurice River basin are a few desmid records from ponds in the vicinity of Malaga and Newfield.

The major tributaries support typical Pinelands species of aquatic macrophytes on their upper portions. Such species include rush-like bladderwort (Utricularia juncea) and pipewort (Eriocaulon compressum) on Manantico Creek and several bladderworts and mermaid-weed (Proserpinaca intermedia) on the Manumuskin River. Upper Maurice River (UMau. R) tributaries with Pinelands species are Scotland Run (fragrant water-lily), Little Ease Run (floating-heart: Nymphoides cordata), and Blackwater Branch (duckweed: Potamogeton Oakesianus, and bladderwort: Utricularia gemiscapa).

Macroinvertebrate information is very sparse; however, estuarine macroinvertebrates such as polychaete worms, mud crabs and blue crabs extend up the Maurice River at least as far as the mouth of the Manantico River where midge larve also are present (Walton and Patrick, 1973).

Fish in the lower Maurice River (LMau. R) have been rather well-surveyed. The fish fauna of the lower river is non-Pinelands in nature, with only three characteristic Pinelands species recorded (and no "restricted" Pinelands species) out of a total of 44 species. In view of the tidal nature of this system, it is not surprising that almost half (20) of the recorded species are marine. Only limited data are available for the Manumuskin River, but that which is present indicates that the upper portion is a pristine Pinelands stream with characteristic Pinelands fishes such as yellow bullhead, pirate perch and blackbanded sunfish. In contrast the lower, and apparently tidal, portion near its junction with the Maurice is characterized by peripheral Pinelands species typified by white perch (Morone americana), golden shiner (Notemigonus crysoleucas) and white catfish (Ictalurus catus).

Dennis Creek (Den. C)

The Dennis Creek watershed drains a relatively small area in southwestern Cape May County. West and East Creeks drain Belleplain State Forest, and Dennis Creek flows through forest, farmland and salt marsh. Land is predominantly forested or utilizedfor agriculture, and development is relatively sparse.

Although pH records are unavailable, pH is expected to be quite low in the upper reaches of West and East Creeks due to a low level of human impact, and much more alkaline downstream in the tidal zone.

Dennis Creek algal data are restricted to a few isolated algal records by Britton (1889) and Woole (in Moul and Buell, 1979).

Aquatic macrophyte species constituting a typical Pinelands community were found on upper Dennis Creek. Water-willow (Decodon verticillatus), which is common in Pinelands waters, has been recorded on both East and West Creeks.

Lower Dennis Creek supports characteristic estuarine macroinvertebrates (Walton and Patrick, 1973). No data were found for fresh water portions of the watershed.

This watershed has been well surveyed for fish, apparently because it drains Belleplain State Forest and has been the site of neutralization experiments by the State Division of Fish and Game (Lakes and Ponds Survey, Report No. 3 - Nummy Lake). The fish fauna is generally that of a pristine Pinelands environment, with the addition of several game and panfish (Centrarchidae) which have been stocked by the State, including pumpkinseed and bluegill sunfishes (Lepomis gibbosus and L. macrochirus respectively). Dennisville Lake is the site of annual rainbow trout (Salmo gairdneri) stocking for "put-and-take" angling.

B. Major Atlantic Coastal Drainage

Great Egg Harbor River (GEH. R)

The headwaters of the Great Egg Harbor River are in Camden County, from which the river flows southeast through Gloucester and Atlantic Counties to the Atlantic Ocean in the vicinity of Somers Point. The watershed drains approximately 338 mi^2, nearly all of which are within the Pinelands area. About 67% of the land is forested and 22% agricultural. Suburban development occupies approximately 11% of the watershed and is concentrated in eastern Camden and Gloucester Counties. Major tributaries include Four Mile Branch, Squankum Branch and Hospitality Branch (U.S.F.W.S., 1978). Acidity in the basin is variable and undoubtably reflects the degree of degradation from sewage and agricultural pollutants. However, the pH in the Four Mile Branch, Hospitality Branch, sections of the lower Egg Harbor River and the Tuckahoe River is 6.5 or less and indicates relatively unmodified Pinelands waters. The upper mainstem as well as Squankum Branch are more alkaline (B.C.M., 1980).

Except for algae, the Great Egg Harbor River basin has been moderately well-collected. The only information for algae in the Great Egg Harbor River basin consists of a few records of diatom species and one record of the green alga Cladophora sp. The diatom records were from the Mays Landing area and upstream from Mays Landing. The species recorded are indicative of acid-water streams (Patrick et al., 1979).

Many sites have been sampled on the upper Egg Harbor River (UGEH. R) for rooted aquatics and numerous species have been recorded. Pineland species such as American burreed (Sparganium americana) and water-willow are reported from Albion at the headwaters. Water-willow is also reported from Sicklerville, New Brooklyn Lake and Huber's Lake. The Hospitality Branch supports water-chickweed (Callitriche heterophylla) at its headwaters, and floating-heart as well as bladderwort from Penny Pot area. Arrowhead (Saggitaria graminea) and pipewort, two species characteristic of the Pinelands, were reported from an impoundment near Vineland. The lower Great Egg Harbor River (LGEH. R) and Tuckahoe River have not been thoroughly investigated for rooted aquatics. Still, several typical Pinelands species have been found including arrowhead (Saggitaria teres) from Miry Run below Mays Landing, and pondweed (Potamogeton Oakesianus) from the Stephen Lake vicinity. Bladderwort (Utricularia intermedia) and blue flag (Iris prismatica) have been reported on the Tuckahoe River west of Tuckahoe.

In 1976, invertebrates in the Great Egg Harbor River were sampled by the N.J. Div. of Water Resources at five locations extending from the headwaters down to Mays Landing and beginning in 1977, the river has been sampled annually at Folsom (Route 54). Altogether, 77 genera included in 6 phyla have been reported (N.J. Div. of Water Resources, 1976; Brzozowski, 1978). Nematodes, flatworms, oligochaetes, isopods, amphipods, aquatic insects and mollusks have been reported to occur. Aquatic insects, the predominant group, were represented by 10 orders and 59 genera. The most important order was Diptera (flies and midges) with 22 genera; Trichoptera (caddisflies) was second in importance with 13 genera. Additionally, while not common, mollusks occurred at most stations and included both snails and fresh water clams.

Most of the mayflies, stoneflies and caddisflies reported for the river were found in the lower river at Pennypot (U.S. Route 322). Species diversity was lowest in the headwater region of the river near Sicklerville. Here, aquatic worms, midge larvae and isopods, all pollution-tolerant groups, were reported as being dominant. No macroinvertebrate data are available for tributaries of the Great Egg Harbor River.

The upper Great Egg Harbor system includes mostly characteristic Pinelands fishes with the addition of several peripheral species, namely pumpkinseed and bluegill sunfishes. Also, a relatively large number of introduced species (seven out of a total of 25) are present, including black crappie (Pomoxis nigromaculatus), largemouth bass (Micropterus salmoides) and goldfish (Carassius auratus). Thus, it represents a typical Pinelands drainage which has been somewhat modified by human influences. Of particular note is the reported occurrence of the ironcolor shiner in Lenape Lake (N. J. Div. of Fish and Game, 1951). The neutralization studies (Stewart, 1972) conducted at Winslow

Ponds (Winslow Wildlife Management Area) report eight species in these artificial ponds, five of which are introduced fishes. These include redear sunfish (Lepomis microlophus) and fathead minnow (Pimephales promelas).

The lower portion of the Great Egg Harbor River is well-studied (McClain, 1972) and is similar to the lower Maurice River in that it includes a large number of peripheral and marine species and relatively few characteristic Pinelands species. However, few of the smaller tributaries which might be expected to have typical Pinelands fishes have been surveyed. One for which data are available, the South River, has a pristine Pinelands stream fish fauna typified by swamp darter (Etheostoma fusiforme), pirate perch and chain pickerel.

The lower Tuckahoe River was also included in McClain's (1972) study, and is virtually identical to the lower Great Egg Harbor in the species of fishes present, with most species marine or peripheral Pinelands forms. The upper mainstem of the Tuckahoe appears to have a more typical Pinelands fish fauna with species such as blackbanded sunfish, banded sunfish and pirate perch; however, it is possibly more comparable to the upper Great Egg Harbor River or its other tributaries.

In summary, the collections indicate that Four Mile Branch, Hospitality Branch and Tuckahoe River are relatively undisturbed Pinelands watercourses; however, water chemistry (B.C.M., 1980) and macroinvertebrate data indicate that the upper mainstem has been impacted, although many of its tributaries may still be relatively unmodified. This is evidenced by the undeveloped red maple-gum-cedar swamps that exist in these areas. The lower Great Egg Harbor River appears to be less impacted than the upper mainstem.

Mullica River (Mul. R)

The Mullica River watershed is the largest in the Pinelands area, draining approximately 568 mi^2 within Atlantic, Burlington, Camden and Ocean Counties. It is, in general, the least disturbed system in terms of human impact. The river flows through several State and Federally-designated natural areas, including Wharton State Forest, Penn State Forest, Bass River State Forest and Brigantine National Wildlife Refuge.

About 83% of the basin is forested, 12% is agricultural and 5% suburban. Development pressure is increasing in the western headwater regions as well as in Atlantic County (U.S.F.W.S., 1978).

Because of the size and complexity of the Mullica River system, the ecological inventory is discussed by six major sub-basins which comprise the watershed: the Atsion (Ats. R), the Batsto (Bat. R), the Sleeper (Mechesactauxin) (Sle. R), the Nescochague (Nes. R), the Wading (Wad. R) and the lower Mullica (LMul. R). Measurements of pH indicate that the Wading River is most acidic (pH 4.8-5.2); the Bass, Batsto, and Atsion Rivers moderately acidic (5.1-6.6), and a large portion of Nescochague system is the least acidic (6.5-7.4) (B.C.M., 1980). Similarly, the aquatic ecological data indicate that the Wading and Bass Rivers are pristine, the Atsion, Batsto and Sleeper are modified at some locations and the Nescochague is the most modified.

Atsion River (Ats. R)

The Atsion (upper Mullica) River flows for about 13 miles and drains 43 mi^2 of Atlantic, Burlington and Camden counties. Much of it flows through Wharton State Forest, but suburban development is increasing in the headwaters (U.S.F.W.S., 1978).

Algal records from the Atsion area include desmids, filamentous green algae such as species of Microspora and Mougeotia and several species of typical acid water diatoms. Blue-green algae and the red alga Batrachospermum are also recorded.

Numerous collections of macrophytes have been made on the Atsion River and these reflect a diversity of characteristic Pinelands species present here. These include golden club, pipewort, pickerelweed (Pontederia cordata), fragrant water-lily, bladderworts, broad-fruited bur-reed (Sparganium eurycarpum), rushes (Juncus pelocarpus and J. militaris) and floating-heart collected at Atsion Lake. Some of these species as well as broad-fruited bur-reed have been reported in several headwater areas.

Aquatic macroinvertebrates were sampled in 1976 and 1977 by the N.J. Div. of Water Resources at five locations on the mainstem, three of which were on the Atsion River. These stations were located on the upper Atsion River at Medford Road near Atco, at the Rte. 534 bridge and at the Atsion Lake outfall on Rte. 206 (Brzozowski, 1978). The collections included flatworms, aquatic earthworms, nemotodes, aquatic insects and freshwater clams. Aquatic insects, the largest group, were represented by eight orders and approximately 50 genera. The most common genera included Pentaneura and Eukieffierella (midges), Stenonema (mayfly) and Hydropsyche (caddisfly).

Altogether, seven macroinvertebrate phyla were reported for the entire mainstem of the Mullica River. Included were flatworms, annelids, crustaceans, aquatic insects and mollusks. Aquatic earthworms were represented by 6 genera, insects by 54 genera and mollusks by 3. Dipterans were most important in terms of the number of genera with 21; however, the river evidently also supports a relatively diverse assemblage of mayflies (7 genera), caddisflies (9 genera) and odonates (5 genera).

The main portion of the upper Mullica River supports a characteristic fish fauna; only a few peripheral or introduced species occur here. Thirteen out of the 20 species recorded are characteristic Pinelands species (see page 32); 3 are peripheral and 3 are introduced (plus 1 anadromous species in the lower portion). Four of the peripheral and introduced species were recorded in the extreme upper end of the system (near Bishops), an area of significant agricultural and residential development. These included bluegill and pumpkinseed sunfishes and largemouth bass. Wesickaman Creek may also be somewhat modified, as exemplified by the presence of golden shiner (Notemigonus crysoleucas). Also, redfin pickerel (Esox americanus) are more numerous than in most other streams of the Pinelands, another indication of modification. Atsion Lake is mostly pristine but with the addition of bluegill and pumpkinseed sunfishes, which have apparently been stocked there in the past.

Batsto River (Bat. R)

The Batsto River is approximately 16 miles long and drains 67 mi^2 of southern Burlington County (U.S.F.W.S., 1978). The main portion of the River appears to be an unmodified Pinelands stream in terms of aquatic ecology, draining the northern portion of the Wharton Tract and an area to the north along State Route 532 which includes little development except for cranberry bogs.

Algal records from the Batsto River are very sparse but indicative of natural acid water conditions. Genera include the green alga Pleurotaenium and the red alga Batrachospermum.

The occurrence and distribution of aquatic macrophytes in the Batsto River indicate that it is the least disturbed of the upper Mullica tributaries in these terms. Pondweed (Potamogeton confervoides), pipewort, rush (Juncus pelocarpus) and mermaid-weed have been collected at Hampton. In addition, bur-reed (Sparganium androcladum), wapato (Saggitaria latifolia), pickerelweed and pipeworts are reported from Quaker Bridge; and characteristic species including swaying bulrush (Scirpus subterminalis), floating-heart and bullhead-lily are reported in the vicinity of Batsto Lake.

No macroinvertebrate data have been found for the Batsto River.

Most of the Batsto River supports a natural fish fauna typical of undisturbed Pinelands streams. In contrast, Springers Brook to the west (including Indian Mills and Muskingum Brooks) is somewhat modified by agricultural and residential influences, and include several peripheral and introduced species such as golden shiner, pumpkinseed and bluegill sunfishes and largemouth bass. Aquatic macrophyte data also indicated disturbances in Springers Brook. The ironcolor shiner has been reported recently from the lower Batsto River (Warren E. Fox, 1980). Thus the Batsto may support one of the few remaining populations of this minnow in New Jersey.

Sleeper Branch (Mechesactauxin River) (Sle. R)

The Sleeper Branch flows for about 10 miles and encompasses about 46 mi^2 of Camden and Atlantic Counties (U.S.F. W.S., 1978). Although some headwater areas are affected by agriculture and suburban development, most of the watercourse flows through Wharton State Forest and is undisturbed.

Algal data are sparse but indicate typical Pinelands conditions. Also, characteristic Pinelands rooted aquatics have been collected including spike-rush (Eleocharis Robbinsii), pipewort, water-willow, water-milfoil (Myriophyllum humile) and bladderwort (Utricularia fibrosa) from Hayes Mill Creek, a tributary to the Sleeper Branch. Additional species reported in the Sleeper Branch are slender arrowhead (Saggitaria Englemanniana), manna-grass (Glyceria obtusa), arrow-arum (Peltandra virginica), pickerelweed, rush (Juncus pelocarpus) and mermaid-weed.

No macroinvertebrate data have been found from the Sleeper Branch.

One of the most typical Pinelands fish fauna of any upper Mullica tributary, except for possibly the Batsto, occurs in the Sleeper Branch. Characteristic species recorded here include swamp darter, yellow bullhead, mud sunfish, blackbanded sunfish, bluespotted sunfish (Enneacanthus gloriosus) and pirate perch. All of the peripheral and introduced species, except for the golden shiner, are apparently confined to Atco Lake in the extreme upper end of this system and to a nearby area of agricultural and residential development. The golden shiner was also recorded in Clark Branch, which drains agricultural land.

Nescochague River (Nes. R)

The Nescochague River watershed is located south of the Sleeper Branch and drains 76 mi^2. The river is about 10 miles long (U.S.F.W.S., 1978). Agricultural, residential and commercial development are widespread in this watershed and it is the most impacted of any of the Mullica River sub-basins. The Hammonton Creek portion is severely degraded by sanitary sewage and storm water runoff from Hammonton.

Algal data for the Mullica River Basin are primarily from the Hammonton area, much of it from ponds and bogs in this region. Diatoms, the most prevalent algae, were represented by the typical acid water species of Eunotia and Pinnularia as well as Actinella punctata, Semiorbis hemiculus and Frustulia rhomboides. Desmids made up the second largest algal group and a few other species of green algae were also reported, primarily species of Microspora and Mougeotia. Some blue-green algae were also reported in this area, but no specifics as to habitat were recorded. Species of the diatoms Pinnularia and Eunotia as well as the red alga, Batrachospermum were reported from the stream areas. Since many of these records are relatively old, some probably are not representative of the Hammonton Creek today.

Aquatic macrophytes commonly found in Pinelands streams were collected in two tributaries which form the headwaters of the Nescochague River: wapato and pipewort occur in Albertson Brook while water-chickweed (Callitriche heterophylla and C. palustris) and mermaid-weed occur in Great Swamp Branch. American bur-reed (Sparganium americanum), manna-grass, swaying bulrush and rush (Juncus pelocarpus) were reported in Hammonton Creek in the 1930's; and they may not be representative of conditions today.

The only macroinvertebrate data for the Nescochague Branch are from Hammonton Creek. This fauna was limited chiefly to a few pollution-tolerant groups such as midge larvae, leeches and oligochaete worms (Regensberg, 1980). Proceeding downstream, additional taxa were recorded including several mayfly genera, indicating improved water quality.

The Nescochague system is the most modified of the Mullica River tributaries in terms of fish. Almost half (12) of the 26 species recorded in this system are peripheral and introduced. The Hammonton Creek portion is extremely modified, as a result of management practices in Hammonton Lake and the addition of pollutants from the Hammonton area. The upper portion of the Nescochague branch is also significantly modified as it drains the Blue Anchor-Ancora area and the large expanse of agricultural land to the north of Hammonton. Fish fauna in these disturbed reaches include pumpkinseed and bluegill sunfishes, largemouth bass, black crappie, brown bullhead (Ictalurus nebulosus) and carp (Cyprinus carpio). The lower portions of these streams (especially Albertson Brook and Great Swamp Branch) may be more typical Pinelands waters as a result of passing through areas of typical Pinelands vegetation.

Lower Mullica River (LMul. R)

The lower Mullica River is designated as that portion which is tidal, roughly downstream of the Route 542 bridge. This 16-mile long segment forms the Atlantic County-Burlington County border and drains 191 mi^2 of these two counties. Tributaries flowing into this system include the Wading and Bass Rivers and lesser watercourses such as Landing and Nacote Creeks.

N.J. DEP has collected algae and aquatic macroinvertebrates at Green Bank in 1977 and 1979 (Brzozowski, 1978 and 1980). Dominant algal genera were Cocconeis, Spirogyra and Phycopeltis.

Tidal influence is minimal on rooted aquatic communities upstream of Route 542. Here characteristic freshwater Pinelands species such as pondweed (Potamogeton epihydrus), arrowhead (Saggitaria latifolia, S. Englemanniana and S. montevidensis), manna-grass, swaying bulrush, pipewort, bullhead lily and fragrant water- lily have been reported. Landing Creek is similar, with additional species such as mermaid-weed and bladderworts (Utricularia vulgaris and U. juncea). Downstream from Lower Bank species such as horned-pondweed (Zannichellia palustris), water-celery (Vallisneria americana), three-square bulrush (Scirpus pungens) and eastern lilaeopsis (Lilaeopis chinensis) indicate brackish conditions. Additionally, several other pondweeds (Potamogeton pusillus and P. perfoliatus), widgeongrass (Ruppia maritima) and naiad (Najad flexilis) have been recently recorded in saline-influenced Nacote Creek.

Macroinvertebrate collections by N.J. Div. of Water Resources at Green Bank (Brzozowski, 1978 and 1980) were dominated by amphipods (Gammarus), with mollusks and six orders of aquatic insects also present. The most prevalent insects were dipterans. Most were from the family Chironomidae.

Since most of the lower Mullica is tidal, its fish fauna is similar to the lower Maurice, Tuckahoe, and Great Egg Harbor rivers. It includes a mixture of characteristic Pinelands, peripheral, anadromous, introduced and marine species. Most of the characteristic Pinelands species which are generally restricted to the Pinelands area in New

Jersey were recorded only in the Bass River, a relatively unmodified tributary of the lower Mullica. These include swamp darter, pirate perch, eastern mudminnow (*Umbra pygmaea*) and banded sunfish. Of 50 species recorded in the lower Mullica most (21) are marine. Of the freshwater forms, 13 are characteristic Pinelands species and 11 are peripheral species.

Wading River (Wad. R)

The Wading River flows for approximately 12 miles and drains 145 mi^2 of Burlington and Ocean Counties. There are two main branches: the Oswego originates in Ocean County near Howardsville and flows southwest through Penn State Forest; the West Branch originates in Woodland Township, Burlington County and flows south to its junction with the Oswego River in Wharton State Forest. Most of this sub-basin is forested and supports little development(USFWS, 1978).

Algal data for the Wading River sub-watershed are sparse but characterized it as a natural acid water system. Such species include the green algae *Ulothrix* spp., *Eremosphaera irridis*, *Tabellaria fenestrata*, *Actinella punctata* and the red alga *Batrachospermum* spp.

Rooted aquatics information likewise indicate the river is relatively undisturbed. Three species each of arrow-heads, pipeworts and bladderworts have been found. Additional characteristics such as fragrant water-lily, manna-grass, blue flag and golden club have been reported. The communities in the Oswego River are very similar; additional species include water-milfoil and pickerelweed.

The Oswego River has been investigated by Fikslin and Montgomery (1971) and by Stevenson (1973). Additionally, Epstein (1980) collected macroinvertebrates here during several recent summers. Low pH and relatively diverse invertebrate faunas recorded by these studies indicate undisturbed conditions. All of the major groups were found including various genera of mayflies and stoneflies. Caddisflies and midge larvae were important groups, especially as recorded by Stevenson.

There have been no peripheral or introduced fish species recorded on the Wading and Oswego Rivers; this deems the system as the most natural watercourse in the Pinelands in terms of fish fauna. All seven characteristic-restricted species and five of the eight characteristic-widespread species have been collected here.

C. Lesser Atlantic Coastal Drainage

Patcong Creek (Pat. C)

Patcong Creek originates in Egg Harbor Township, Atlantic County near Cardiff and flows southeast to its mouth at Great Egg Harbor Bay just west of the Garden State Parkway. It is an acid water Pinelands stream in its upper reaches west of the Parkway. This is reflected in pH readings near 5.0 in the vicinity of the Patcong Lake bed (T. Lloyd Associates, 1979). Headwater regions are generally wooded and undeveloped.

The only algal record for Patcong Creek is the red alga *Batrachospermum* which occurred in the Patcong Lake vicinity.

In 1979, American bur-reed, Pondweed (*Potamogeton Oakesianus*), pickerelweed and rush-like bladderwort were. observed in the vicinity of the Patcong Lake bed (the lake was drained approximately five years ago).

The creek was sampled at two locations for macroinvertebrates (T. Lloyd Associates, 1979). Besides aquatic insects, which were dominant, the stream supports flatworms, oligochaetes, leeches and amphipods. At the upstream sampling area, where currents are relatively fast and cedar logs and stumps litter the bottom, caddisflies were dominant. Both blackflies and isopods were common while mayflies and midge larvae were less so. Dragonflies and damselflies were present at both stations but more numerous downstream where the current was sluggish.

This stream is characterized by a typical Pinelands fish fauna, with only one peripheral and one introduced species recorded. All characteristic-restricted species have been collected except blackbanded sunfish; additionally, five characteristic-widespread species have also been recorded.

Absecon Creek (Abs. C)

Absecon Creek originates in the vicinity of NAFEC (National Aviation Facilities Experimental Center), Atlantic County and drains northeastern Egg Harbor Township. The creek has two branches, both of which have been impounded for Atlantic City's water supply. The impoundments are located on either side of the Garden State Parkway.

West of the Parkway, the water in Absecon Creek is acid: pH measurements on both the north and the south branches ranged between 4.4 and 5.6 (Betz Environmental Engineers, 1975). The upper reaches of both tributaries are generally undeveloped.

Algal and macroinvertebrate data were found, but none for either aquatic macrophytes or fish. Algal data consisted almost entirely of diatom species characteristic of acid-water conditions, such as Fragilaria binodis, Eunotia spp., and Surirella spp.

Relatively high diversity amongst macroinvertebrates suggests that neither branch of Absecon Creek is impacted. Macroinvertebrate samples from six stream and two lake stations yielded 139 species (B.E.E., 1975). This is one of the few studies reviewed in which an attempt was made to collect all macroinvertebrates; most other studies were quantitive and indicative only of a given area (i.e. square foot samples) or type of substrate (i.e. Hester-Dende substrates). Important macroinvertebrate groups included sponge, moss animals (bryozoans), flatworms, crustaceans, aquatic insects and mollusks. Aquatic worms (Lumbriculidae) several leeches, especially Mooreobdella tetragon, the isopod Asellus, odonates (dragonflies and damselflies), hemipterans (Gerridae and Corixidiae), the caddisfly (Molanna) and four dipteran genera (Thienemanniella, Cricotopus, Psectrocladius and Bezzia) were common to most stations. Other insects which were numerous at one or more stations include the mayflies Siphonoplecton and Paraleptophlebia, the damselfly Enallagma and the stonefly Taeniopteryx. Isopods (Asellus) and amphipods (Hyalella azteca and Gammarus fasciatus), all crustaceans, occurred at west stations. Mollusks were not abundant at any station but it is interesting to note that fingernail clams (Pisidium sp.) were found at four of the six stream stations.

Westecunk Creek (Wes. C)

Westecunk Creek originates in eastern Little Egg Harbor Township, Ocean County and flows southeast through the eastern Plains region to enter Little Egg Harbor Bay north of Tuckerton. It has been impounded several times at Stafford Forge Fish and Wildlife Management Area. The pH has been recorded at 5.3-5.6, well within the range of acidic Pine Barrens streams (B.C.M., 1980). The entire drainage is relatively undeveloped.

Only one algal species record is available from Westecunk Creek. The diatom, Tabellaria flocculosa, an acid water form, was collected here.

Pipewort and rush (Juncus pelocarpus) have been recently collected from the Stafford Forge bogs. Additionally, swaying bulrush is reported in Westecunk Creek upstream from West Creek.

No macroinvertebrate records were found for Westecunk Creek.

Two fish collections on this stream, both at Stafford Forge, indicate that this is an unmodified Pinelands stream. The seven species recorded are all characteristic Pinelands species: four are restricted and three are widespread.

Mill Creek (Mil. C)

The Mill Creek headwaters are located in Barnegat and Stafford Townships, from which the watercourse flows southeast to enter Little Egg Harbor Bay just south of Beach Haven West. The creek is moderately acidic, with pH measurements ranging from 5.8 to 6.2 (B.C.M., 1980). Except for the headwaters region, Mill Creek is modified by suburban development.

Algal and macroinvertebrate information were not available from Mill Creek.

Data on aquatic macrophytes is sparse; however, mannagrass was reported west of Manahawkin in the 1950's.

Two collections of fishes were comprised of a mixed assemblage, indicating a modified Pinelands stream.

Forked River and Oyster Creek (For. R-Oys. C)

Forked River and Oyster Creek are two separate, but adjacent systems; however, they are discussed jointly, as much of the data is from the vicinity of the Oyster Creek Nuclear Generating Station which utilizes both streams.

Oyster Creek originates in Ocean Township and Forked River originates in Lacey Township, both in Ocean County; both headwater areas are relatively undeveloped Pinelands forest. Both creeks exhibit typical acid water conditions upstream of tidal influence with pH readings of 4.4 to 4.9.

Algal records include the diatom *Tabellaria fenestrata*, species of the red alga *Batrachospermum*, and the green alga *Microspora*, all characteristic of natural Pinelands streams and collected from Oyster Creek.

Characteristic Pinelands rooted aquatics have been found on Forked River near Forked River City such as bulrushes (*Scirpus subterminalis* and *S. americanus*) and spike-rush. Recently pipewort, rush (Juncus militaris) and fragrant water-lily were reported on Forked River near the generating station. In Oyster Creek in the vicinity of the generating station, pondweed (Potamogeton confervoides), manna-grass, spike-rush, bulrush (Scirpus subterminalis) and fragrant water-lily, all typical Pinelands species, were recently collected.

Macroinvertebrates are monitored on Oyster Creek in an area downstream from the Garden State Parkway (Ichthyological Associates, 1979). Three phyla and 71 genera have been recorded from three sampling stations situated between Route 9 and the Parkway. Caddisflies, numerically most important, included Chimarra, Hydropsyche, Molanna, Banksiola and Oecetis. Five mayflies genera and two stoneflies genera (Taeniopteryx and Isoperla) occur here besides numerous coleopterans.

Macroinvertebrates in the South Branch of Forked River are being monitored just as at Oyster Creek, further downstream. Fifty-seven genera and families were reported as opposed to 71 in Oyster Creek. Coleopteran diversity was lower in Forked River but there were also fewer mayfly, dragonfly and caddisfly genera. Only six coleopterans were reported for Forked River, fifteen for Oyster Creek. Nevertheless, Stenonema, Siphloplecton, Leptophlebia, Agrion, Polycentropus, Hydropsyche, Molanna and many other genera found elsewhere in Pinelands streams occurred in Forked River.

These two systems are relatively well-surveyed for fish (Ichthyological Associates, 1979). In addition, the State Lakes and Ponds Survey, Report No. 2 includes accounts for Barnegat Pines and Deerhead Lakes on Forked River. These two systems apparently represent typical Pinelands streams. Of 12 species recorded, 10 are characteristic Pinelands species. The other two (pumkinseed sunfish and golden shiner) are widespread peripheral species.

Cedar Creek (Ced. C)

Cedar Creek originates in western Lacey Township, Ocean County and drains about half of the municipality. Most of its upper tributaries flow through relatively undeveloped Pineland forest; also, the mainstem flows through Double Trouble State Park to the west of the Parkway. Cedar Creek is an acid stream (pH 4.9-5.4) and supports many characteristic Pinelands species west of the Garden State Parkway. Three species of bladderwort (Utricularia purpurea, U. cornuta and U. intermedia) and pipewort have been reported recently from Webbs Mill and U. cornuta for Chamberland

Branch. The mainstem supports a high diversity of aquatic insects especially amongst mayflies, stoneflies and caddisflies (Appendix C). Studies by the N.J. Division of Water Resources (1976) indicate that at least 6 genera each of mayflies and stoneflies and 19 genera of caddisflies occur here.

The fish fauna of Cedar Creek represents that of an undisturbed Pinelands stream, except for the record of white catfish (Ictalurus catus) at one site. The presence of this fish is somewhat puzzling but it may occur there as a result of stocking in Bamber Lake. Nine of the eleven species recorded in this system are characteristic Pinelands species: restricted fishes include pirate perch, banded and mud sunfishes; the other fishes are widespread. The anadromous alewife has been recorded near the mouth of the creek.

Toms River (Tom. R)

Toms River is the largest of the lesser Atlantic drainage systems. It originates in northern and western Ocean County and drains much of these regions. Most of the headwater portion flows through relatively undeveloped forest and agricultural land; however, suburban development becomes significant as the watercourse approaches the Parkway and it is steadily spreading westward.

Most of the tributaries are quite acidic, with pH readings less than 5.0. The mainstem pH is somewhat higher, with most measurements usually between 5.0 and 6.0 (B.C.M., 1980). It appears that some upper tributaries may be relatively undisturbed Pinelands streams; however, many are modified by suburban development.

Very little algal data were available from the Toms River basin and these consisted primarily of a few diatom species, one species of green algae, one desmid and two species of blue-green algae. In general, the species were indicative of acid water conditions, although some species reported tolerate a wide pH range.

Aquatic macrophytes found in headwater areas are indicative of Pinelands streams and include manna-grass near Cassville, fragrant water-lily and water-willow at Archers Corners, fanwort and bladderworts (Utricularia gibba and U. subulata) in Old Hurricane Brook, and pondweed (Potamogeton epihydrus) and golden club in the headwaters of Old Hurricane Brook. The records for downstream from Route 9 are old and probably do not reflect any influences of the recent suburban development here: Pinelands- characterizing species included American bur-reed, manna-grass, swaying bulrush, mermaid-weed and bladderworts (Utricularia subulata and _U. intermedia_).

No invertebrate data were located for this watershed.

The Toms River system has a relatively high diversity of fish species present. Of the 27 species recorded, 14 are characteristic Pinelands species, 9 are peripheral, 1 is anadromous, and 3 are introduced. Thus, it has the greatest number of freshwater species of any of the watersheds considered in this report, except for the lower Mullica. This large number of species, including many peripheral species, indicates the modified nature of this system. Some branches, such as those coming out of the Colliers Mills area, support mostly characteristic Pinelands fishes (including all six restricted species), but also include several peripheral forms. Other portions of the system are significantly modified and contain species such as largemouth bass, brown trout and bluegill sunfish.

Metedeconk River (Met. R)

The Metedeconk River originates in southern Monmouth and northern Ocean Counties, and delineates the boundary of these two counties for some of its course. Its estuary forms the northernmost portion of Barnegat Bay. Although most of this watercourse flows through Pinelands, much of it is modified by suburban development.

There were no significant data located for this watershed within the Pinelands area; however, characteristic Pinelands fish species including chain and redfin pickerel, and blackbanded, mud and banded sunfishes have been collected from the system at other locations.

Manasquan River (Man. R)

Although the Manasquan River is located outside of the State-designated Pinelands National Reserve/Pinelands area, biological data are nevertheless included, because the data are illustrative of impacted conditions. The river was sampled for macroinvertebrates at Squankum, Howell Township (N.J. Div. of Water Resources, 1979; Wichser, 1977). Here, midge larvae (_Polypedilum_) and various aquatic earthworms (_Tubificidae_, _Lumbriculidae_) were dominant. Low species diversity also was found by the New Jersey Division of Water Resources (1979) who reported only four species besides _Polypedilum_. These were: _Endochiromus_, _Chironomus_, _Hydropsyche simulans_ and _Rhyacophila_ sp. A tributary, Mingamahone Brook, which Wichser sampled apparently is in better biological condition because three species of mayflies (_Ephemerella_ spp. and _Cinygula_), stoneflies (_Isoperla_) and other aquatic insects were found in addition to smaller populations of tubificids as compared to the river.

IV DISCUSSION OF RESULTS

A. Pinelands Habitats and Characteristic Species

Pinelands aquatic habitats are rather unique when compared to most North American fresh waters, but quite similar to other lowland streams of the southeastern Coastal Plain. Three major aquatic habitat types can be recognized in the Pinelands: streams and rivers, lakes and ponds, and bogs. The typical aquatic habitat in the Pinelands is a shallow slow-moving stream originating in an Atlantic white-cedar swamp with abundant sphagnum and terminating in a broad, tidal estuarine portion which enters the Atlantic Ocean or Delaware Bay. Natural lakes and ponds are few, but in places the streams expand to form shallow marshy habitats and back-water eddies or quiet, pond type habitats behind obstructions such as beaver dams. Atlantic white-cedar and cranberry bogs are found throughout the Pinelands area.

As a result of various geological, biological and chemical factors, the water in Pineland streams is generally quite acid (pH 4.0-6.0) and clear but dark-stained by humic acids. Substrates tend to be sandy, but in places there are extensive gravel beds and also scattered deposits of debris. Organic material accumulates in beds of vegetation, in sheltered areas along stream banks and in back-water eddies. In most streams, hard substrates are provided by logs, stumps, or roots; and in places, undercut banks provide sheltered habitat. Soft organic muck substrates are often present in lakes and ponds.

Certain species of aquatic plants and animals are better adapted to physical and chemical conditions in the Pinelands than others. Most occur repeatedly in collections from the area and thus are considered to be characteristic of Pinelands waters. One can expect characteristic species to occur in undisturbed (pristine) aquatic environments but few if any are restricted to the New Jersey Pinelands, and most occur in other Atlantic

Coastal Plain drainage systems where habitats are similar. Since many species also occur in alkaline waters of the Piedmont and other physiographic provinces, the definition of such pristine aquatic environments is not absolute, and may be dependent upon the recognition of a complex assemblage of characteristics.

Rivers and Streams

Some 350 taxa of algae have been reported from Pinelands waters (Appendix A). The characteristic algal flora in streams includes several species of the red alga Batrachospermum and numerous species of diatoms and desmids. Diatom species from the genera Frustulia, Fragilaria, Eunotia, and Pinnularia are usually present as well as Actinella punctata, a diatom highly characteristic of the Pinelands and found only in acid waters (Patrick and Reimer, 1966). Genera of green algae generally present are Mougeotia, Zygogonium, Zygnema, Spirogyra and Microspora. Desmids from almost all known genera are usually present in the streams (Moul and Buell, 1979).

Typical stream species of aquatic macrophytes include bur-reed (Sparganium spp.), water celery (Vallisneria americana), rushes (Eleocharis spp. and Scirpus spp.), golden club (Orontium aquatica) and waterwort (Elatine minima).

Larger streams with increased light may have the following species as members of the flora: bur-reeds, pondweeds (Potamogeton spp.), arrowheads, water celery, manna grass (Glyceria obtusa), spike-rush (Eleocharis Robbinsii), swaying bulrush (Scirpus subterminalis), golden club, pipeworts (Eriocaulon spp.), pickerelweed (Pontederia cordata), rushes (Juncus spp.), Iris (Iris prismatica), bullhead-lily (Nuphar variegatum), fragrant water-lily, and bladderworts.

Fresh water tidal regions have swaying bulrush, bullhead-lily, golden club, Parkers pipewort (E. parkeri), arrow-arum, pickerelweed (Pontederia cordata), arrowheads (S. Englemanniana, S. montevidensis) and a decumbent form of wild rice (Zizania aquatica) as floral components. Areas of saline influence are represented by arrow-arum, cattails (Typha spp.), threesquare bulrushes (Scirpus pungens, S. americanus), pondweeds (Potamogeton perfoliatus, P. pusillus) and water celery in addition to the already stated species of Ruppia and Zannichellia.

Macroinvertebrate communities in uncontaminated streams are typically small but often diverse. Aquatic insects almost always are dominant and as elsewhere, aquatic earthworms, leeches, crustaceans and mollusks are invariably present. Amongst more than 275 genera of aquatic macroinvertebrates reported in Pinelands waters so far, 260 are aquatic insects (see Appendix C). The three most important orders are dipterans (53 genera), odonates (41 genera) and trichopterans (39 genera).

Local environmental conditions dictate species distribution, and therefore it is not possible to fully describe a typical Pinelands macroinvertebrate community. Nevertheless, certain genera were recorded in almost every watershed and thirteen of these genera are listed in Table 1.

Table 1 Macroinvertebrate genera with widespread distribution in Pinelands waters

Crustaceans
- *Asellus* (Isopoda)

Aquatic Insects
- Mayflies (Ephemeroptera)
  - *Stenonema*
  - *Ephemerella*
- Dragonflies and Damselflies (Odonata)
  - *Gomphus*
  - *Agrion*
  - *Enallagma*
- Fishflies and Alderflies (Megaloptera)
  - *Sialis*
- Caddisflies (Trichoptera)
  - *Cheumatopsyche*
  - *Hydropsyche*
- Flies and Midges (Diptera)
  - *Pentaneura*
  - *Psectrocladius*
  - *Polypedilum*
  - *Tanytarsus*

It is important to emphasize that most of the genera listed in Table 1 also occur in streams and lakes outside of the Pinelands area. Therefore, while one can expect to find these genera in Pinelands waters, they are not indicators of them. In general, species and not genera are useful as indicators; thus, fish are much more useful for this purpose than macroinvertebrates owing to taxonomic difficulties with the latter group.

Pinelands streams including both interior and estuarine segments support at least 91 species of fish. The 15 species listed in Table 2 are thought to be characteristic of acid-water Pinelands streams.

Table 2 List of characteristic Pinelands fishes

A. Restricted Distribution

Ironcolor Shiner - *Notropis chalybaeus*
Yellow Bullhead - *Ictalurus natalis*
Pirate Perch - *Aphredoderus sayanus*
Mud Sunfish - *Acantharchus pomotis*
Blackbanded Sunfish - *Enneacanthus chaetodon*
Swamp Darter - *Etheostoma fusiforme*

B. Widespread Distribution

American Eel - *Anguilla rostrata*
Eastern Mudminnow - *Umbra pygmaea*
Redfin Pickerel - *Esox americanus*
Chain Pickerel - *Esox niger*
Creek Chubsucker - *Erimyzon oblongus*
Tadpole Madtom - *Noturus gyrinus*
Bluespotted Sunfish - *Enneacanthus gloriosus*
Tessellated Darter - *Etheostoma olmstedi*

In general, fishes in Pinelands streams tend to be rare except in areas of abundant vegetation. The open sandy bottom streams give the impression of being devoid of life but several species are quite common, especially darters. The swamp darter occupies areas of moderate current while the tessellated darter is common in some of the faster flowing streams of the Pinelands. Tree roots and indentations along the stream margin are favored by the eastern mudminnow (*Umbra pygmaea*). The creek chubsucker is the dominant open water fish characteristic of the Pinelands, usually found in quiet back-water areas. The ironcolor shiner, which was apparently more abundant in the past than it is now, was commonly observed in small channels in Atlantic white-cedar bogs (Fowler, 1906).

Vegetation beds and quiet backwater areas provide habitat for the majority of Pinelands species. Included in this group are American eel, redfin and chain pickerel and yellow bullhead. The brown bullhead (*Ictalurus nebulosus*) is also present in streams but it is much less numerous than the yellow bullhead and seems to be more characteristic of modified streams.

Several species are secretive by nature and remain hidden in vegetation. Examples include the tadpole madtom and pirate perch; both species are common in many Pinelands streams.

Sunfishes characteristic of the Pinelands are the mud sunfish, blackbanded sunfish and banded sunfish. Of these the blackbanded and banded sunfishes are virtually restricted to the Pinelands in New Jersey where they are quite common and represent two of the most characteristic species of the area. Another species, the bluespotted sunfish is common in the Pinelands but is found in quiet, densely vegetated waters throughout the state.

In the lower reaches of Pinelands rivers and streams, as they leave the Pinelands area or expand as tidal, estuarine rivers, a quite different assemblage of fishes may occur. Those flowing west into the Delaware River (Rancocas Creek and Crosswicks Creek) pass out of the Pinelands and are soon exposed to conditions which neutralize acidity (and modify water quality in other ways), and thus modify the environment sufficiently to change the fish fauna. This situation is illustrated dramatically by unpublished data taken by the State Division of Fish, Game and Shellfisheries on North Branch Rancocas Creek (Burlington County) in July and August, 1975. Creek pH values were 4.8 at New Lisbon, 6.5 at Smithville, and 7.0 at Mt. Holly. Similar modifications apparently occur as other systems move south or east into Delaware Bay or the Atlantic Ocean and become tidal. In the lower reaches of these streams, many peripheral Pinelands species are common, as well as marine species which stray into coastal streams and several anadromous forms which move upstream to spawn.

Common peripheral species in the lower reaches of streams such as the Mullica, Great Egg Harbor, Tuckahoe, and Maurice Rivers are golden shiner (Notemigonus crysoleucas), spottail shiner (Notropis hudsonius), white sucker (Catostomus commersoni), white catfish (Ictalurus catus), banded killifish (Fundulus diaphanus), mummichog (Fundulus heteroclitus), fourspine stickleback (Apeltes quadracus), threespine stickleback (Gasterosteus aculeatus), white perch (Morone americana), pumpkinseed (Lepomis gibbosus), and yellow perch (Perca flavescens).

Some of these, such as golden shiner, pumpkinseed, and yellow perch are well-established in some waters strictly within the Pinelands. Their presence usually indicates some type of disturbance, and they do not normally occur in the most acid and natural Pinelands waters. They are most characteristic of artificial impoundments where they often are present as a result of stocking programs. The pumpkinseed and yellow perch are sometimes stocked as small game fish and the golden shiner is stocked as forage for larger predatory fish.

Anadromous fishes which spawn in streams of the Pinelands are blueback herring (Alosa aestivalis), alewife (Alosa pseudoharengus), Atlantic shad (Alosa sapidissima) and striped bass (Morone saxatilis). These fishes are generally restricted to the lower reaches of Pinelands streams because their upstream migrations are blocked in most cases by dams. However, alewife spawning has been reported as far upstream as Nescochague Creek and Mullica (Atsion) River at Constable Bridge (N.J. Div. of Fish, Game and Shellfisheries, 1976).

The occurrence of marine fishes in the lower reaches of Pinelands streams is typical of that occurring in most estuarine systems. Thirty-nine marine species are included in the table for this report and additional species could be expected to occur occasionally.

Lakes and Ponds

Impoundments such as man-made lakes, ponds and flooded cranberry bogs support different plant and animal communities then streams, but there is considerable overlap amongst individual species especially amongst algae.

Lakes and ponds of the Pinelands support algal communities similar to other aquatic habitats in the area with some additional species. Attached algae are abundant along the shoreline with planktonic species frequently entangled in the filamentous forms. Desmids tend to be less abundant than in other habitats. Species of *Oedogonium* are frequent on submerged stems of vascular plants and often present with *Aphanochaete repens* which is characteristically found on other filamentous algae. *Ulothrix zonata* was also recorded in the spring (Moul and Buell, 1979).

Other types present in lakes and ponds are the flagellated forms *Phacus* and *Trachelomonas* as well as *Gonyostomum semen*, a green flagellate often appearing as green patches on the water surface in protected areas. *Cyclonexis annularis* occurs in the plankton, most often over beds of submerged sphagnum (Moul and Buell, 1979).

Common aquatic macrophytes in impoundments include species such as fragrant white water-lily, spike-rush, swaying bulrush, floating-heart (*Nymphoides cordata*) as well as others previously mentioned for streams.

Specific macroinvertebrate data for lakes and ponds are generally lacking. However, in a study performed in the watershed of Absecon Creek (B.E.E., 1975), the number of species found at stations located in the Atlantic City Reservoir was somewhat lower than the number of species found in tributaries flowing into the impoundment. The difference probably is due to more varied habitats in the streams. The reservoir supported more species of hemipterans than the streams, but mayflies, stoneflies and caddisflies, groups associated with flowing water, were much reduced in the reservoir.

Since natural lake or pond habitat is rare in the Pinelands, one might expect characteristic Pinelands fishes to be absent from artificial lakes, cranberry bogs, and mill ponds which have been created thoughout the area. However, the predisposition of most Pinelands fishes to quiet vegetated back-water areas of streams makes them well adapted to the artificial habitat of an impoundment. Thus, virtually all of the characteristic Pinelands stream fishes are also quite numerous in lake and pond habitats in the area, especially in those where dense aquatic vegetation has developed. Even the typically stream-dwelling swamp darter often occurs in non-flowing habitats in lakes or ponds. In fact, Collette (1962) suggested that artificial mill ponds and cranberry bogs provide ideal habitat for the swamp darter.

In addition to these characteristic Pinelands species, a number of other species are generally common in lake and pond habitats in the Pinelands. Important among these are golden shiner, pumpkinseed and yellow perch. Another peripheral Pinelands species which may occur in lake and pond habitats is the redbreast sunfish (Lepomis auritus). It is most characteristic of the Rancocas Creek basin (South Branch) especially among the Pinelands drainages, but also occurs in Hammonton Lake (in the Nescochague Basin) where it was undoubtedly stocked.

The fish fauna of all but the most acid-water lakes and ponds of the Pinelands includes several non-native introduced species which have been stocked for angling purposes. Important among these are bluegill (Lepomis macrochirus), largemouth bass (Micropterus salmoides), and black crappie (Pomoxis nigromaculatus). These three species are well established in New Jersey waters and exhibit distribution patterns of peripheral Pinelands species, such as pumpkinseed. They also occur in some stream habitats within the Pinelands which have modified water conditions and in the lower tidal reaches of Pinelands streams.

The trouts (rainbow trout-Salmo gairdneri, brown trout-Salmo trutta, and brook trout-Salvelinus fontinalis) have been extensively stocked for "put-and-take" fishing in New Jersey; however none of these have become established in Pinelands waters. The native brook trout may have occurred naturally but apparently does not now survive as a naturally reproducing species.

The redear sunfish (Lepomis microlophus) and fathead minnow (Pimephales promelas) have also been stocked in Pinelands waters (Winslow Ponds,-Stewart, 1972) but the present status of these populations is unknown. In addition, the introduced black bullhead (Ictalurus melas) and channel catfish (Ictalurus punctatus) may be established in the lower Maurice River. Two other introduced species which may occur in Pinelands waters are the goldfish (Carassius auratus) and carp (Cyprinus carpio). These species generally only occur in waters with high biological productivity and thus are excluded from most Pinelands waters. Where they do occur, they are good indicators of excessively disturbed, or even polluted, conditions.

Bogs

Bogs, including both Atlantic white-cedar and cranberry habitats support many of the same species as the other habitats.

Moul and Buell (1979) reported little variation in the composition of the algae among white-cedar swamps and bogs including cranberry bogs. Many of the species found in the streams are also found in these areas. Differences include somewhat more blue-green algae with desmids as the dominant algae type in swamps and bogs, and the filamentous species Desmidium grevillii and Hyalotheca dissiliens.

Blue-green algae species frequently collected in Pinelands bogs were: Chroococcus turgidus from shallow ponds with Sphagnum, Scytonema tolypothrichoides and Merismopedia punctata from the black organic ooze in white-cedar swamps. Species of Oscillatoria were sometimes common.

Amongst diatoms, Tabellaria fenestrata and Actinella punctata are the most common species. Other diatom genera common in bogs are Stauroneis, Pinnularia, Fragilaria, Surerilla, Frustulia and Eunotia. The flagellated algae Euglena mutabilis and Trachelomonas volvocina are widespread but not found in great numbers. Another yellow-green alga that was quite common is Synura ulvella. Other algae characteristic of Pinelands bogs are Gymnodinium spp., Cystodinium bataviense, Cryptomonas spp. and, in areas with some current, Batrachospermum. In addition the green alga Eremosphaera viridis which is characteristic of acid waters was found frequently in white-cedar swamps in Lebanon Forest (Moul and Buell, 1979).

Typical aquatic macrophytes found in open bogs include pipeworts, water-willow (Decodon verticulatus) water-milfoil (Myriophyllum spp.) mermaid-weed (Proserpinaca sp.) and bladderworts (Utricularia spp.).

No data were found which would suggest the typical bog macroinvertebrate community, but the species present probably would be very much a function of currents and substrates.

Any of the characteristic Pinelands species of fish could occur in bog environments but fish usually are not present in large numbers. Limited personal observations (R.W. Hastings) indicate that only the eastern mudminnow should be expected in such habitats in significant numbers.

B. Natural Factors Influencing Pinelands Aquatic Communities

Interacting physical, chemical and biological factors are responsible for the unique character of Pinelands aquatic communities. Together, these factors limit the distribution of many species and enable a relative few to survive successfully. Those able to do so are adapted to the chemical quality of the water (high acidity, low nutrients, etc.) and to the distinctive physical features of the aquatic habitat (i.e. currents, substrate, light availability and temperature). Besides physical and chemical factors which influence the composition of Pinelands communities, there are biological factors (such as competition amongst species) which are difficult to define on the basis of available data but which are probably very important.

Water Quality

The low pH (4.0 to 6.0) is perhaps the most characteristic feature of Pinelands waters. It is caused by the leaching of humic acids from peat and other organic materials into surface waters. Acidity restricts the distribution of not only individual species but even much broader taxonomic groups. For example, amongst algae, the combination of high acidity and low nutrients (including calcium) seems to favor diatoms and desmids and restricts blue-green and some green algae (Moul and Buell, 1979).

Amongst aquatic macrophytes there are some species associated with acid water but many others tolerate a wide range of pH. The former group includes bur-reed (*Sparganium* spp.), various pondweeds (*Potamogeton Oakesianus*, *P. epihydrus*, *P. confervoides*), arrowheads (*Sagittaria Englemanniana*, *S. teres*), rushes (*Eleocharis Robbinisii*, *Scirpus subterminalis*), golden club (*Orontium aquaticum*), pipeworts (*Eriocaulon* spp.), iris (*Iris prismatica*), fragrant white water-lily (*Nymphaea odorata*), watermilfoils (*Myriophyllum* spp., *Proserpinaca* spp.), floating-heart (*Nymphoides cordata*) and bladderworts (*Utricularia* spp.).

In general, pH severely restricts the distribution of mollusks, since calcium, the primary shell ingredient, tends to remain dissolved in the water. Snails usually are not numerous. Other mollusks evidently also are affected. For example, *Elliptio*, a freshwater mussel with widespread distribution throughout the eastern United States (Pennak, 1978), is rare in the Pinelands; however, two genera of freshwater clams (*Pisidium* and *Musculium*) have been reported from many watersheds (see Appendix C) and are therefore probably not much affected by acid water. The same can be said for some crustaceans such as the isopod *Asellus* which is found almost anywhere in the Pinelands where there is decaying vegetation and two amphipods, *Hyalella azteca* and *Gammarus fasciatus*, which are locally abundant in acid streams where other habitat conditions are favorable.

Our data indicate that at many locations in the Pinelands, pH is not low enough to directly affect aquatic insect abundance or species diversity; bioassay studies for Bell (1971) and others have shown that above 4.5, pH is not toxic to many invertebrates. Relatively few streams in the Pinelands are this acid over a long period of time (B.C.M., 1980). Quite possibly, other factors such as substrate and food availability have a greater effect on most invertebrates than pH. However, nearly all of the 13 genera which commonly occur in the Pinelands also occur in streams polluted by acid mine drainage (Tomkiewicz and Dunson, 1977; Warner, 1971; Roback and Richardson, 1969).

Most fresh water fishes require waters close to neutral. Characteristic Pinelands fish species are amongst a relatively small group of fishes that tolerate acidity ranges down to about 4.0. Low pH has detrimental physiological effects by interfering with respiration in some species or by interfering with reproduction in others. Using goldfish, Westfall (1954) found that acid water caused a change in the permeability of the gills and that the fish died from an oxygen deficiency. Acid water is lethal to largemouth bass at about pH 4.0 (Calabrese, 1969) and to goldfish and channel catfish (*Ictalurus punctatus*) between 4.0 and 4.5 (Ultsch, 1978).

Other studies have shown that acid water is lethal to eggs and larvae, often more so than for the adults. A good example is the adult bluegill sunfish which can withstand a pH of about 4.0 (Calabrese, 1969), but spawns sparingly at pH 5.0-5.5 (Swingle, 1956). Thus, bluegill may not be able to reproduce in Pinelands waters.

Water pH probably has been somewhat over-emphasized as a determining factor in the distribution of fishes, but there is no doubt that it is an important factor. None of the Pinelands species require acid water, although this has been suggested for some such as the blackbanded sunfish.

Schwartz (1961) reported blackbanded sunfish in basic waters. However, in addition to its potential toxicity, acid water may also affect the distribution of fishes indirectly by limiting important food sources. Therefore, the absence of some fishes from acid waters may be more a factor of their food sources being rare than of their sensitivity to acid conditions.

The acidity of Pinelands waters also may limit decomposers (bacteria and fungi) and thereby affect nutrient cycling. Slow decomposition rates could be one reason why undisturbed Pinelands waters are characterized by low concentrations of most nutrients (Zimmer, 1979). Low concentrations of nitrogen, phosphorus and other essential nutrients limits biological production.

Substrate and Current

Topographic and geologic features of the Pinelands area are such that water currents tend to be slow and quite consistent; stream beds, therefore, tend to be composed of well sorted sands and gravels with accumulations of organic materials in backwater areas and on the bottom of lakes and ponds. In the absence of rocks the only firm substrates that benthic (bottom dwelling) algae and macroinvertebrates can attach to are roots, fallen logs, aquatic vegetation and debris. Substrate availability is, therefore, an important factor affecting biological productivity in Pinelands waters. Where hard substrates are scarce and the bottom is composed largely of shifting sand and gravel or silt, benthic communities tend to be small and low in diversity, regardless of water quality. Patcong Creek provides a good example of this: west of the Garden State Parkway, cedar logs and stumps which litter the bottom support large and diverse caddisfly populations, but relatively few occur east of the Parkway in a channelized reach of the stream.

Caddisflies and filter feeding animals are often abundant downstream from lakes; evidently they avail themselves of the plankton produced in quiet waters. In general, however, macroinvertebrate productivity is low. This is attributed both to low primary productivity and the absence of hard substrates.

Amongst aquatic macrophytes, particle size and organic content of bottom sediments evidently are important, but the relationship between species distribution and substrates has not been investigated in the Pinelands area. Elsewhere, Moore and Clarkson (1967) found that in acid West Virginia streams, substrate composition was the most significant factor affecting species distribution and Mirsa (1935) reported a close correlation between physical and chemical factors of lake sediments.

The absence of strong currents may favor some fish species and limit the distribution of others that might otherwise be able to tolerate the acid water. For example, the sluggish, swampy nature of Pinelands streams is of prime importance to most of the 15 characteristic species (see Table 2, page 32) of fish; in streams where currents are strong, most Pinelands species confine themselves to the backwater areas and undercut banks away from currents. The 8 species listed as "characteristic widespread" almost always occur in quiet waters, even outside the Pinelands area; thus, these fishes may be primarily adapted to sluggish conditions and may have secondarily developed the adaptation to acid water in order to live in coastal streams.

Light and Temperature

Light is an important factor in Pinelands aquatic communities, and probably is limiting where surface water is shaded by a closed canopy such as in an Atlantic white-cedar bog. Dense growths of aquatic macrophytes and algae seldom occur in cedar bogs. In contrast, aquatic vegetation often grows profusely just outside the bogs in full sunlight. These areas also may support relatively large animal populations because macroinvertebrates and fish use the vegetation for food and cover. Thus, light has both direct and indirect effects on Pinelands communities.

The effects of temperature on Pinelands communities has not been thoroughly investigated, but there is little doubt that it is of significance for at least some groups. The seasonality of some algal species indicates water temperature plays a significant role in their growth. Some algae are present throughout the year, even under ice cover while others occur primarily in the warmer months.

Daily temperature fluctuations are also believed to play a role in algal distribution. Moul and Buell (1979) reported temperatures measured on June 8, 1965, for the following sites: upwelling 18°C; stream 20°C; shady pool 25°C; sunny pool 29°C; and gelatinous film on the surface of muck layers in full sun, 38.5°C. Undoubtedly such wide variation has an influence on species distributions; however, it is difficult to separate the effect of light and temperature in the field since areas with cooler temperature also may receive less light.

Biological Factors

The association between aquatic plants and animals has already been discussed. In addition, competition between species may be an important factor. Smith (1953) suggested that the acid nature of Pinelands waters excludes some fishes from the area. He theorized that the more "retiring" species, such as the blackbanded sunfish, might be out-competed by other species such as the pumpkinseed where they occur together. Smith's theory is still not proven conclusively, but when pH is elevated, there is evidence that suggests peripheral species (including the pumpkinseed) tend to become established and that acid water species tend to be reduced in numbers or eliminated.

C. Human Influences on Pinelands Communities

Human influences have had a profound effect upon the Pinelands flora and fauna. Some changes appear to have had a beneficial effect while most others have had just the opposite. Impoundments (cranberry bogs and mill ponds) create quiet water habitat with dense vegetation, the ideal habitat for many characteristic Pinelands species. However, in general, human influences probably have been mostly negative: reduced beaver populations in the Pinelands possibly eliminated an important natural source of quiet water habitat; channelization of some streams eliminated backwater eddies and vegetation beds. Siltation has destroyed fish habitats and eliminated fish food organisms. The application of lime or limestone (either from agricultural practices or as a direct application to water) has resulted in neutralized acidity in some streams. The introduction of nutrients has enhanced the growth of aquatic plants. Such changes in Pinelands streams generally result in modifications of the typical Pinelands aquatic communities. The most significant changes are those which buffer the natural acidity of the Pinelands water. However, elevated pH is usually correlated with other changes in water quality, such as increased nutrient levels, turbidity, or reduced dissolved oxygen. These modifications usually lead to changes in the flora and fauna, either through natural colonization of peripheral species or in this case of fish through introductions of exotic and/or native species.

Elevation in pH occurs as a result of liming, wastewater discharges and when aquatic plant growth is stimulated so as to affect the carbonate-bicarbonate buffering system in Pinelands waters. Any change in water chemistry that raises the pH above about 6.0 usually results in the replacement of acid water species; however, species which tolerate a wide range in pH usually remain. For example, amongst algae, *Tabellaria fenestrata* would probably remain (Moul and Buell, 1979). Likewise, certain macrophytes which require acid water may be eliminated, such as golden club (*Orontium aquaticum*). Arrowhead (*Saggitaria Englemanniana*) and swaying bulrush (*Scirpus subterminalis*) may be eliminated, but other species such as arrow arum or yellow water-lily would remain. Water-chickweed (*Callitriche palustris*) would likely be present in such a situation, as it is generally indicative of disturbed conditions where nutrient levels are higher and acidity neutralized.

In general, increased nutrient concentrations often result in dense growths of aquatic vegetation. For example, data from the Great Egg Harbor River downstream from the entrance of sanitary wastes revealed huge populations of the diatoms *Eunotia pectinalis* and *E. pectinalis* var. *ventricosa* (Patrick, 1979). Water quality data indicate fairly high levels of nitrates and phosphates. Large masses of the red alga *Batrachospermum* also have been reported under similar conditions. Several species of *Batrachospermum* are typically found in the Pinelands but are not abundant under normal conditions. Aquatic macrophytes also respond to nutrients; dense growths of *Cabomba* became a nuisance in the Birchwood Lakes (ANSP, 1973).

The abundance and sometimes diversity of macroinvertebrates may increase with mild pollution, especially if there is a concurrent increase of aquatic plants. However, silt, pesticides, high concentrations of ammonia and other toxic substances contained in sewage and storm-water runoff are tolerated by a relatively small proportion of the macroinvertebrates typically found in pristine waters. Therefore, pollution, with the possible exception of very mild organic enrichment, tends to reduce species diversity. Stoneflies, mayflies and certain caddisflies are reduced in numbers or eliminated. This has occurred in a few Pinelands streams including the upper Manasquan River (Wichser, 1977), the upper Egg Harbor River (N.J. Div. Water Resources, 1976 unpublished data) and the Southwest Branch Rancocas Creek at several locations (ANSP, 1973). When pollution has been very severe, such as in the Manasquan River, oligochaete worms and midge larvae may be the only groups present.

Fishes can be used to indicate various levels of disturbance. We should emphasize, however, that such distinctions are not clear-cut and absolute, and much variation will be evident as correlated with the type of disturbance or other factors in the environment. As noted previously, a completely "pristine" Pinelands environment can be reconized by the presence of the 15 species listed in Table 2 and no others. The most significant are those more or less restricted to Pinelands habitats (such as yellow bullhead, pirate perch, mud sunfish, blackbanded sunfish, banded sunfish, and swamp darter). The ironcolor shiner is so rare in the state today that its importance as an indicator species is not known but its scarcity at some sites where it was once common may indicate its sensitivity to disturbance.

Characteristic species with "Widespread Distribution" (eastern mudminnow, redfin and chain pickerel, tadpole madtom,etc.) do not appear to be directly affected by moderate changes in water quality and therefore areas where only slight increases in nutrients and/or pH occur often continue to support these species. In fact, in some situations their numbers may increase as a result of increased food sources and vegetative cover.

Although characteristic Pinelands species are generally not excluded by moderate changes in water quality, such modifications may be sufficient to allow the invasion of other species not characteristic of the extremely acid, low nutrient Pinelands water. Sewage or agricultural runoff can sufficiently reduce the acidity such that acid sensitive fish can survive and reproduce. As noted previously, the pH tolerance of various fish species varies considerably, and thus there is no single value which can be designated as the maximum pH for typical Pinelands waters. Of importance are extreme ranges as well as mean values. Also, levels occurring during spawning are important, since eggs and larvae are generally more sensitive than adults. In general, however, we can say that waters below pH 5.0 rarely support peripheral and introduced species. Fishes like golden shiner, brown bullhead, pumpkinseed, and yellow perch are the most widely distributed in modified Pinelands waters and thus must tolerate a relatively wide range in pH. Pinelands streams supporting a predominance of characteristic Pinelands species plus these four peripheral species might be regarded as supporting slightly modified Pinelands communities. Other species which might be added to this community (but are somewhat less tolerant of acid water) are the bluegill and largemouth bass which occur in many places because of their long history of stocking.

With further increases in disturbance of Pinelands streams resulting from higher levels of sewage discharge, agricultural runoff, and concomitant algal blooms and turbidity, many of the characteristic Pinelands species will not be present. The major factors contributing to their decline and disappearance are not known, but a combination of factors is most likely involved, including pH, dissolved oxygen, substrate type, turbidity, food availability, and competition amongst species. Such modified Pinelands aquatic communities can thus be recognized by the reduced abundance of characteristic Pinelands species, especially those with restricted distribution, the increased abundance of peripheral species, as well as the addition of various introduced species. Among the latter group, the goldfish and carp are indicative of the greatest degree of disturbance in the form of increased nutrient levels. However, a further level of disturbance is possible, as exemplified by portions of Hammonton Creek, where virtually no fish are present.

D. Protection Measures

Pinelands Species Warranting Protection

With the exception of American shad (Alosa sapidissima) and brook trout (Salvelinus fontinalis), none of the plant and animal species encountered in this inventory are listed as "threatened" or "endangered" by the State of New Jersey (NJDEP, 1979). American shad has been reported in the Lower Maurice River and may occur occasionally in other estuaries such as the Mullica. Brook trout is reported only for Toms River where it has been stocked.

Although not included on a State list, the status of five species of aquatic macrophytes and two species of fish is of concern. All seven are characteristic Pinelands species. Fairbrothers and Hough (1973) considered purple bladderwort (Utricularia purpurea) "rare" and another species, Utricularia resupinata "endangered". Fairbrothers (1979) considered humped bladderwort (Utricularia gibba) "rare" and two pondweeds, Potamogeton confervoides and P. Oakesianus, respectively, "rare" and "status undetermined." In the 1930's, several of these species were reported in the Upper Maurice River and Dennis Creek watersheds but it is not known whether they are still present. Three species, however, have been reported recently: Potamogeton Oakesianus in Oyster Creek and Patcong Creek, Potamogeton confervoides in the Batsto River and Utricularia gibba in a small tributary to the Upper Mullica.

Two species of fish, the blackbanded sunfish (Enneacanthus chaetodon) and the ironcolor shiner (Notropis chalybaeus) are worthy of special consideration. The blackbanded sunfish is probably the most characteristic Pinelands fish, both for its uniqueness to the area and for its striking color pattern. Throughout its range, it is largely restricted to waters typical of those in the Pinelands, i.e. quiet, shallow, heavily vegetated, non-turbid, darkly stained, acidic waters (Jenkins et al., 1975). It was once found in several streams or lakes in central New Jersey, but is now more-or-less confined to the pristine "cedar" waters of the Pinelands in the state. It has been eliminated from such non-Pinelands areas either by reductions in water quality or through competition from related species.

The distribution of this fish south of New Jersey is discontinuous, and remarkably similar to that of the Pine Barrens Treefrog (Hyla andersonii), a species characteristic of the New Jersey Pinelands and now considered "endangered" (Means and Longden, 1976). There are a few scattered localities of blackbanded sunfish in the Delmarva Peninsula, one in Virginia, numerous sites in North and South Carolina, and a few scattered localities in Georgia and Florida.

The ironcolor shiner (Notropis chalybaeus) is also worthy of special consideration, because this fish was once numerous at various sites in southern New Jersey but is now quite rare. It may have been extirpated in some streams where it was once common. This species is listed as status "undetermined" by the State (NJDEP, 1979).

Areas Warranting Protection

Although major portions of the upper mainstem Great Egg Harbor and lower mainstem Rancocas watersheds are already degraded and no longer support characteristic Pinelands communities, it is encouraging to note that disturbance has been relatively minor throughout most of the Mullica and a few other systems. Those relatively pristine areas that remain, however, are jeopardized by expanding suburban development. Strong pressures for development extend southeast from Camden along major transportation corridors into the headwater region of the Great Egg Harbor and Mullica Rivers.

The headwaters of any stream system are important to protect for biological and other reasons. The first, second and third order streams (see Strahler, 1957 for definitions) make the headwater region of a river system particularly vulnerable to pollution because these streams tend to be small, and in the Pinelands the water in them is poorly buffered. From a biological standpoint, these headwater streams are important because much of the reproduction in a river system occurs in them. Populations of some species of fish and many species of fish food organisms in the mainstem are maintained largely by downstream drift from the tributaries. Furthermore, in the event that some catastrophe destroys aquatic life in the mainstem, tributaries are the principal source of organisms to recolonize stressed areas. The tributaries, therefore, make a significant contribution to the recovery process (Herricks, 1977). Additionally, first, second and third order streams in the Pinelands may have a special significance, because many of them drain acid water swamps and thus they help to maintain low pH in the mainstem.

Besides headwater areas, there are specific watersheds that warrant protection, because they support pristine (unmodified) communities (see page 47). Whole watersheds are recommended for protection rather than areas delineated by political boundaries because a river must be thought of as having interdependent components in that most species utilize both tributaries and the mainstem during their life cycle.

Most of the recommendations suggested in the following section of this report are for land and water management techniques aimed at protecting water quality. There are numerous potential pollutants including nutrients from sewage and fertilizers, sediment, herbicides, pesticides and other toxic substances such as heavy metals and oil. Stormwater runoff from urban, suburban and agricultural areas are the principal source of many of these substances. Pollution from stormwater runoff could be reduced if development (including cultivation) were kept away from surface water and if natural shoreline vegetation was preserved. A buffer system along the banks of streams, lakes and bogs would do much to filter out contaminants in stormwater runoff. In addition, the roots along the waters edge help to stabilize the banks and prevent erosion. The width of the buffer zone will vary depending on factors such as slope, vegetation density and type, volume of stormwater, soil type, etc. and thus cannot be specified. However, the width should not be arbitrary and should be defined by some natural feature such as a flood frequency interval or perhaps by soil or vegetation.

Water quality standards should be based on <u>ambient</u> water quality conditions because water quality in the Pinelands area is very variable. For example, conditions in lower Rancocas Creek, are very different from conditions in the Oswego River and other pristine streams. Also, portions of some rivers such as the Maurice are tidal and strongly influenced by brackish water. State water quality criteria do differentiate between tidal and freshwater areas, but it may be necessary to make some criteria more stringent, if characteristic Pinelands aquatic communities are to be preserved.

A list of recommendations aimed at protecting and enhancing Pinelands communities is presented in the following section.

V RECOMMENDATIONS

A. Pinelands Species Warranting Protection

Steps should be taken to insure the survival of rare and endangered species of both plants and animals. To begin with, their present distribution and biology should be investigated thoroughly in order to determine their environmental requirements. In view of their restricted occurrence, protection of pristine areas in the Pinelands may be critical for their survival.

B. Areas Warranting Protection

The results of this inventory indicate some watersheds are still pristine. We wish to emphasize, however, that since little or no data are available for many streams, additional candidate areas are very probable. Figure 1 portrays areas considered to be environmentally sensitive on the basis of biological data alone. Water quality data should help to reinforce our information. Altogether, we identified 16 areas - 4 are known to support a characteristic flora andfauna and 12 others for which there is incomplete biological evidence. Areas known to be pristine include:

1. entire Wading River watershed
2. entire Batsto River watershed
3. upper Cedar Creek west of Garden State Parkway
4. upper Westecunk Creek west of Garden State Parkway

Potentially pristine areas include:

1) North Branch Rancocas Creek east of Browns Mills
2) Burrs Mill Brook upstream from its confluence with Gum Spring
3) Manumuskin River upstream from Route 49
4) Dennis Creek upstream from Route 47
5) entire Atsion River
6) entire Sleeper Branch
7) Landing Creek upstream from Route 30
8) entire Make Peace Stream
9) Absecon Creek west of Garden State Parkway
10) Patcong Creek west of Garden State Parkway
11) Oyster Creek west of Garden State Parkway
12) Forked River west of Garden State Parkway

To maintain the most pristine aquatic communities such as those in the Wading River system, it may be necessary to prohibit additional growth of any significance. Elsewhere it will be necessary to apply stringent land and water management techniques aimed at preventing contaminants from entering surface waters.

C. Land and Water Management Techniques

Silt and nutrients from both urbanized and agricultural areas are the principal contaminants of Pinelands waters. Sources of these substances are so numerous that it is beyond the scope of this report to be specific; in general, however, they include municipal and industrial wastewater discharges, stormwater runoff, seepage from on-lot septic systems, fertilizers, and silt from unprotected building sites and cultivated fields. In order to maintain ecological balance in the Pinelands, stringent land and water management policies and practices must be applied to the area. These include the following:

General Recommendations

- enforce stringent land management practices in first, second and third order streams; similarly protect larger streams which support pristine communities (see lists in previous section)

- discourage drainage and channelization projects, especially in pristine areas in order to protect physical habitats; protect Atlantic white-cedar bogs and similar sources of acid water

- limit the liming of acid waters and the introduction of exotic species into pristine watersheds; concentrate fishery management practices in disturbed areas

- expand the water quality monitoring network in the Pinelands National Reserve/Pinelands area; monitor pH, nutrients and potentially toxic substances as well as algae, macroinvertebrates and fish.

Recommendation For Residential and Commercial Development

- concentrate and cluster development

- locate development where soils, geology and topography are such that water quality will be least impaired

- establish standards for storm water and sanitary wastes based on ambient physical, chemical and biological conditions throughout the region; existing State Water Quality Standards should be complied with but correlations between water quality and aquatic life may reveal that some standards should be more stringent

- require baseline and monitoring studies during and after construction and establish a mechanism for review and remedial action; such studies would help to establish ambient conditions throughout the region and would provide a basis for "performance standards"

- prohibit wastewater discharges into surface waters of environmentally critical areas; encourage innovative techniques in wastewater management such as spray irrigation

- prohibit sanitary sewage discharges into all lakes, even those located in areas not designated as environmentally sensitive

- discourage the use of fertilizer, pesticides and herbicides on lawns bordering surface waters

- preserve natural shoreline and riparian vegetation in order to protect the banks from erosion and to filter stormwater runoff

- provide a buffer zone along the banks of streams; and the width should conform to some natural feature such as alluvial soils or a particular flood plain

Recommendation For Roads and Public Utilities

- limit the construction of new roads so as to discourage access to pristine areas

- discourage excessive use of road salt and other alkaline substances

- minimize stream crossings of sanitary sewer lines

- when sewer lines are located in flood plains, stringent sediment and erosion control measures should be employed; distrubed areas should be replanted

Recommendation For Agriculture and Forestry

- promote and encourage soil conservation practices recommended by the U.S. Department of Agriculture

- monitor the concentrations of pesticides and herbicides in surface waters

- preserve natural vegetation around surface water in order to filter storm water runoff

- promote those silvicultural practices which help to protect water quality

D. Data Gaps and Recommendations for Additional Studies

Future studies should be directed in three general areas: filling in data gaps identified in the inventory (see Table 3, following page); investigating the biology and distribution of rare and potentially endangered species and investigating the relationship between land use, water quality and aquatic life. Regarding the third area, there are data to show the effects of severe pollution on aquatic life, but the effects of minor degradation are not well understood. It may be possible to resolve some of the unanswered questions using the results of water quality and other studies being performed for the Commission by other consultants.

Table 3 - Summary of Data Availability by Watershed

	Fish	Invertebrates	Macrophytes	Algae
NBRan. C.	*	-	*	O
SB Ran. C	*	-	*	+
Cro. C	-	O	O	O
UMau. R	*	O	*	-
LMau. R	+	-	-	O
Man. C	-	O	-	O
Den. C	*	-	-	-
UGEH. R	*	*	*	-
LGEH. R	-	-	*	-
Tuc. R	-	O	-	O
Mul. R	*	*	-	*
Mec. R (Sle. R)	+	O	-	O
Ats. R (UMul. R)	+	-	*	*
Bat. R	+	O	-	-
Nes. R (inc. Ham. R)	*	-	-	*
Wad. R	-	O	-	O
Osw. R	-	*	-	-
LMul. R	+	*	*	O
Bas. R	-	O	-	-
Pat. C	-	-	-	O
Abs. C	O	*	-	*
Wes. C	-	O	-	-
Mil. C	*	O	O	O
Oys. C-For. R	-	*	-	*
Ced. C	+	*	-	-
Tom. R	-	O	-	-
Met. R	*	O	O	O
Man. R	*	*	*	O

+ = good
* = moderate
\- = poor
O = none

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APPENDIX A

ALGA SPECIES LIST

KEY TO ALGAE APPENDIX

Collection Sites

The numbered heading is the collection site that was listed for the species records. This site is not specific and is for the general area where collections were made.

Habitats

The following abbreviations were used in designating habitat types:

att, attached
bog, Sphagnum bog
ced, cedar swamp
cran, cranberry bog
dit, ditch
ent, entangled with other plants
epi, epiphyte
imp, impoundment
ooze, fine organic muck with no measurable water over it
plank, plankton
squez, squeezings of Sphagnum and mosses
str, stream
pond and pool are not abbreviated

Abundance

R, rare; Oc, occasional; C, common; A, abundant

Authors and Collections

The capital letter following the species indicates the source of the record.

B (Boyer, 1916 from Moul and Buell, 1979); F (Fikslin and Montgomery, 1971 from Moul and Buell, 1979); P (Patrick, 1958, 1964, 1979); S (Stokes, 1885, 1886a,b, from Moul and Buell, 1979); W (Wolle, 1880, 1881a,b, 1881, 1883, 1884, 1885, from Moul and Buell, 1979); M (Moul and Buell, 1979); Br (Britton, 1889); D (Drouet and Daily, 1956; Drouet, 1968, 1973, 1978, In Press); ANSP (Academy of Natural Sciences of Philadelphia, 1973); ANSP-H (Academy of Natural Sciences of Philadelphia Algae Herbaria).

Species authorities are listed when listed by the original author or collector.

A slash (/) followed by an author designation indicates a second author reported the species for that locality.

An asterisk (*) indicates a type collection (for species named new to science from the Pine Barrens).

Seasonality

Numbers following the habitat designation are months of the year species was collected. Numbers in parenthesis are the month of peak abundance, when observed, and (c) indicates the peak abundance is in the cooler months.

Example:

2. South Branch

Tetmemorus spp.; M; bog, ced, str; 6, 9

Several species of Tetmemorus were reported by Moul and Buell (1979) from bogs, cedar swamps, and stream locations in the months of June and September

RANCOCAS CREEK BASIN

1. Rancocas Creek

Division: Chlorophyta (Green Algae)
Order: Ulotrichaceae
Microspora spp.; M; bog, ced, dit, imp, pond, str; all

2. South Branch

Division: Chlorophyta (Green Algae)
Order: Ulotrichaceae
Ulothrix spp.; F; ced, cran, str; 2,4,6
Order: Zygnematales
Family: Zygnemataceae
Mougeotia spp.; M; bog, ced, cran, dit, imp, pond, str; all
Family: Mesotaeniaceae
Netrium spp.; M; ced; R
Family: Desmidiaceae
Pleurotaenium sp.; M; ced, pool; 6
Tetmemorus spp.; M; bog, ced, str; 6,9
Xanthidium spp.; M; ced, pond, squez
Hyalotheca dissiliens (Smith) Breb; M; bog, ced, cran, ooze, pool, squez, str; A (3-6). zygotes A (4)
Bambusina brebissonii Kütz. (Gymnozygon); M; bog, ced, cran, pool, squez, str; 1-6,8,9; Oc

Division: Chrysophyta (Yellow-Green Algae)
Class: Chrysophyceae
Order: Rhizochrysidales
Chrysophyxis bipes Stein; M; ced, epi, str; 3,6
Class: Bacillariophyceae
Order: Pennales
Asterionella formosa Hass.; M; bog, ced, cran, pond, str; (c)
Eunotia spp.; M; bog, ced, cran, pond, squez, str; (c)
Pinnularia spp.; M; bog, ced, cran, dit, pond, squez; all

Division: Cyanophyta
Order: Chroococcales
Merismopedia punctata Meyer; M; bog, ced, pond; 1,6,11

3. Medford Lakes

Division: Chlorophyta (Green Algae)
Order: Zygnematales
Family: Desmidiaceae
Penium spp.
Triploceras gracile Bail; M; pond; 6; R
Order: Euglenales
Entosiphon sulcatum (Duj.) Stein; M; str; 10

Division: Chrysophyta (Yellow-Green Algae)
Class: Chrysophyceae
Order: Chrysomonadales
Dinobryon sertularia Ehr.; M; bog, ced, cran, pond, str;(c)
Class: Bacillariophyceae
Order: Centrales
Melosira ambigua (Grun.) O. Muller; ANSP
M. granulata (Ehr.) Ralfs.; ANSP
M. granulata v. *angutissima* Müll.; ANSP
M. varians C.A. Ag.; ANSP
Thalassiosira nitzschoides Grun.; ANSP
Coscinodiscus marginatus Ehr.; ANSP
C. lineatus Ehr.; ANSP
Cyclotella atomus Hust.; ANSP
C. caspia Grun.; ANSP
C. comta (Ehr.) Kütz.; ANSP
C. kutzingiana Thw.; ANSP
C. meneghiniana Kütz.; ANSP
C. pseudostelligera Hust.; ANSP
C. stelligera Cl. u. Grun.; ANSP
Order: Pennales
Tabellaria fenestrata (Lyngb.) Kütz.; ANSP
T. flocculosa (Roth) Kütz.; ANSP
Asterionella formosa Hass.; ANSP
A. ralfsii W. Sm.; ANSP
Fragilaria constricta Ehr.; ANSP
F. construens (Ehr.) Grun.; ANSP
F. virescens Ralfs.; ANSP
Synedra fasciculata (Ag.) Kütz.; ANSP
S. fasciculata v. *parva* Grun.; ANSP
S. fasciculata v. *truncata* (Grev.) Patr.; ANSP
S. radians Kütz.; ANSP
S. rumpens v. *meneghiniana* Grun.; ANSP
S. ulva (Kütz.) Ehr.; ANSP
Actinella punctata Lewis; ANSP
Eunotia arcus Ehr.; ANSP
E. curvata (Kütz.) Lagirst.; ANSP
E. elegans Østr.; ANSP
E. flexuosa Breb. ex. Kütz.; ANSP
E. gibbosa Grun.; ANSP
E. incisa W. Sm. ex. Greg.; ANSP
E. naeglii Migula; ANSP
E. obesa v. *wardii* Patr.; ANSP
E. pectinales Hust.; ANSP
E. pectinales v. *minor* (Kütz.) Rabh.; ANSP
E. pectinales v. *ventricosa* Grun.; ANSP
E. serra Ehr.; ANSP
E. sudetica O. Mull.; ANSP
E. tanella (Grun.) Cl.; ANSP
E. vanheurckii v. *intermedia* (Krasske ex Hust.); Patr.; ANSP
Cocconeis pedecueus Ehr.; ANSP
C. placentula v. *euglypta* (Ehr.) Cl.; ANSP

C. placentula v. lineata (Ehr.) Cl.; ANSP
Achnanthes clevei v. rostrata Hust.; ANSP
A. exigua heterovalvata Krasske; ANSP
A. flexella (Kütz.) Burn.; ANSP
A. hauckiana Grun.; ANSP
A. lanceolata (Breb.) Grun.; ANSP
A. minutissima Kütz.; ANSP
A. sp. 4 Dil.; ANSP
Rhoicosphenia curvata (Kütz.) Grun. ex Rabh.; ANSP
Amphipleura rutilans v. 1CB; ANSP
Anomoeoneis vitrea (Grun.) Ross; ANSP
Caloneis hyalina Hust.; ANSP
Frustulia rhomboides (Ehr.) DeT.; ANSP
Navicula aikienensis Patr.; ANSP
N. biconica Patr.; ANSP
N. capitata Ehr.; ANSP
N. confervacea (Kütz.) Grun.; ANSP
N. contenta fo. biceps Arn.; ANSP
N. decussis Østr.; ANSP
N. exigua Greg. ex Grun.; ANSP
N. luzonensis Hust.; ANSP
N. minima Grun.; ANSP
N. mutica Kütz.; ANSP
N. pupula Kütz.; ANSP
N. pupula v. rectangularis (Greg.) Grun.; ANSP
N. pygmaea Kütz.; ANSP
N. radiosa Kütz.; ANSP
N. radiosa v. tenella (Breb. ex Kütz.) Grun.; ANSP
N. salinicola Hust.; ANSP
N. secreta v. apiculata Patr.; ANSP
N. seminulum Grun.; ANSP
N. tenelloides Hust.; ANSP
N. tripunctata v. schizonemoides (V.H.) Patr.; ANSP
N. sp.
Navicula spp.; M; bog, pond, str.; 1,6,9-11
Neidium affine (Ehr.) Pfitz.; ANSP
N. apiculatum Reim.; ANSP
Pinnularia biceps Greg.; ANSP
P. gibba Hust.; ANSP
P. interrupta Rabh. Sussw.; ANSP
P. microstauron (Ehr.) Cl.; ANSP
P. nodosa (Ehr.) W. Sm.; ANSP
P. subcapitata Greg.; ANSP
Stauroneis anceps Ehr.; ANSP
Amphiprora alata Kütz.; ANSP
Gomphonema gracile Ehr.; ANSP
G. parvulum (Kütz.) Kütz.; ANSP
Amphora coffeaeformis Agardh.; ANSP
A. delicatula Bljumina.; ANSP
A. tenuissima Hust.; ANSP
A. tumida Hust.; ANSP
Cymbella gracilis (Rabh.) Cl.; ANSP
C. naviculiformis Auersw.; ANSP

C. sinuata Greg.; ANSP
C. tumida Greg.; ANSP
C. ventricosa Kütz.; ANSP
C. sp.; ANSP
Bacillaria paradoxa Gmel. Linn.
Nitzschia acicularis W. Sm.
N. amphibia Grun.
N. filiformis (W. Sm.) Hust.
N. fonticola Grun.
N. frustulum (Kütz.) Grun.
N. kuetzingiana Hilse.
N. linearis W. Sm.
N. palea (Kütz.) W. Sm.
Surirella delicatissima Lewis.
S. ovata Kütz.
S. tenera Greg.

Division: Cyanophyta
Order: Oscillatoriales
Oscillatoria spp.; M, ced, dit, imp, pond; 6,9

4. McDonalds Branch

Division: Chlorophyta (Green Algae)
Order: Volvocales
Chlamydomonas spp.; M; bog, ced, cran, pond, squez. (c)
Order: Tetrasporales
Tetraspora spp.; M; cran, str.; 2,3,6
Order: Ulotricaceae
Ulothrix zonata (Weber and Mohr) Kütz.; M; pond, stream; spring
Microspora quadrata Hazen; M; str; 4
Microspora tumidula Hazen; M; ced, str; 1,3
Microspora spp.; M; bog, ced, dit, imp, pond, str; all
Order: Oedogoniales
Oedogonium spp.; M; ced, imp, pond; 5,6,7
Order: Chlorococcales
Eremosphaera viridis DeBary; M; ced, str.; 1,4-7, 9-11
Order: Zygnematales
Family: Zygnemataceae
Mougeotia spp.; M; bog, ced, cran, dit, imp, pond,str;all
Zygnema spp.; M; ced, pond, str; all
Zygogonium ericetorum Kütz.; M; bog, ent, ooze, pond; 5,9,10,12
Pleurodiscus purpureus (Wolle) Lag.; M; bog, ooze, pond, str; (c)
Spirogyra spp.; M; bog, ced, imp, pond, str; all
Family: Mesotaeniaceae
Mesotaenium mirificum Arch.; M; squez; 4; R
Cylindrocystis brebissonii Men.; M; ced, ent,squez;all;C
Cylindrocystis spp.; M; ent, squez; all; C

Family: Desmidiaceae

Penium spirostriolatum Bark.; M; dit, ooze, pool, squez; all; Oc

Tetmemorus brebissonii (Men.) Ralfs; M; dit, pond, squez; 2-5,9,12; Oc

T. laevis (Kütz) Ralfs; M; ced, pond, pool, squez, str; 4-6,9,10; Oc

Euastrum allenii Cushm; M; pool; 5; R

E. crassum var. *scrobiculatum* Lund; M; pond, pool; 2,9, R

E. giganteum (Wood) Nordst.; M; 1,4-11; Oc

E. validum West and West; M; pool, squez, str; 4,5; R

E. wollei var. *pearlingtonense* Presc. and Scott; M; pool; 11; R

Micrasterias expansa Bail.; M; str; 6; R

M. mahabuleshwarensis var. *ringens* (Bail.) Krieg.; M; ced; 10; R

M. radiosa Ralfs; M; bog, ced, ooze, pond, pool; 4-6,8,10-12; R

Bambusina brebissonii Kütz (Gymnozygon); M; bog, ced, cran, pool, squez, str; 1-6.8.9; Oc

Division: Chrysophyta (Yellow-Green Algae)
Class: Xanthophyceae
Order: Heterococcales

Harpochytrium sp.; M; bog, ced, epi, pond, str; 3

Class: Chrysophyceae
Order: Rhyizochrysidales

Chrysophyxis bipes Stein; M; ced, epi, str; 3,6

Lagynion triangulare (Stokes) Pasch.; M; epi, str; 3,12; (*) central New Jersey

Class: Bacillariophyceae
Order: Pennales

Tabellaria fenestrata (Lyngb) Kütz.; M; bog, ced, cran, pond, str; all

Synedra spp.; M; ced, imp, str; (c)

Asterionella formosa Hass; M; bog, ced, cran, pond, str; (c)

Eunotia currata (Kütz.) Lagerst.; M; bog, ced, imp, pond, squez, str; (c)

Eunotia spp. M; bog, ced, cran, pond, squez, str; (c)

Actinella punctata Lewis; M; bog, ced, cran, ent, epi, str; all

Navicula spp.; M; bog, ced, pond, str; 1,6,9-11

Pinnularia spp.; M; bog, ced, cran, dit, pond, squez; all

Stauroneis spp.; M; ced; (c)

Frustulia rhomboides (Ehr.) Det.; M; squez, str; 3,4,8,12

Frustulia spp.; M; bog, ced, pond, squez, str; (c)

Division: Cyanophyta
Order: Oscillatoriales

Symploca muralis Kütz.; M; mud; 9

Scytonema tolypothrichoides Borr. and Flah.; M; ced, ooze; 9

Schizothrix rubella Gom.; D; mud

Division: Rhodophyta
Order: Nemalionales
Batrachospermum brugiense Sirod; M; str; 3,4,10
Batrachospermum spp.; M; ced, pond, str; all
Audouinella violacea (Kütz.) Hamel; M; str; 12

Order: Cryptomonadales
Chryptomonas spp.; M; bog, ced, imp, pond, squez; (c)

5. Mount Misery

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae
Order: Pennales
Tabellaria fenestrata (Lyngb.) Kütz.; M; bog, ced, cran, pond, str; all
Eunotia serra var. serra Patr.; M; bog, ced, pond, squez; all

6. Browns Mills

Order: Oedogoniales
Oedogonium polymorphus Wittr. and Lund.; W
Order: Zygnematales
Family: Desmidiaceae
Penium clevrei Lund; W
Docidium dilatatum Cleve; W
*D. tridentulum Wolle; W
D. sinuosum Wolle; Br
D. sinuosum var. breve Wolle; Br
Euastrum purum Wolle; W
Calocylindrus clevei (Lund.) Wolle; Br
*Cosmarium pseudotoxichondron Nordst.; W
Cosmarium lunatum Wolle; Br
C. pseudotaxichondrum Nordst; Br.
Staurastrum brachiatum Ralfs; Br
*Staurastrum aspinosum Wolle; W
S. elongatum var. tetragonum Wolle; W; pond
S. forficatulatum Lund; W
S. inconspicuum Nordst.; W; pond
*S. pulchrum Wolle; W; pond
*Phymatodocis nordstedtiana Wolle; W; pond
*Desmidium elongatum Wolle; W
D. guadratum Nordst; W
*Bambusina delicatissiman Wolle; W; pond
Sphaerozosma wallachii Jacobsen; Br
S. rectangulare Wolle; Br

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae

Order: Pennales
Pinnularia major ANSP-H

Division: Cyanophyta (Blue-green Algae)
Order: Oscillatoriales
Scytonema Hofmannii Ag; D

7. Pakim Pond

Division: Euglenophyta (Euglenoids)
Order: Euglenales
Trachelomonas volvocina Ehr.; M; bog, ced, pond, squez, str; (c)

MAURICE RIVER BASIN

8. Malaga

Division: Chlorophyta (Green Algae)
Order: Zygnematales
Family: Desmidiaceae
Euastrum crassum var. *scrobiculatum* Lund; W; pond, pool; 2,9; R
**E. inerme* Lund. var. depressum Wolle; W; pond
**E. magnificum* Wolle; W
**Cosmarium sejunctum* Wolle; W; pond
**Micrasterias dichotoma* Wolle; W; pond
**Staurastrum ankyroides* Wolle; W; pond
**S. leptacanthum* var. *tetrocterum* Wolle; W; pond

9. Newfield

Division: Chlorophyta (Green Algae)
Order: Zygnematales
Family: Desmidaceae
**A. rauii* Wolle; M; pond

DENNIS CREEK

10. Dennisville

Division: Chlorophyta (Green Algae)
Order: Zygnematales
Family: Desmidiaceae
**Docidium spinulosum* Wolle; W
Euastrum intermedium Cleve; W
Micrasterias foliaceae Bail.; W; pond

M. jenneri Ralfs; W; pond
M. laticeps Nordst; W; pond
M. muricata (Bail.) Ralfs; W; pond
M. crux-militensis Ehr.; Br
M. americana var. *recta* Wolle; Br
M. kitchellii Wolle; Br
**Staurastrum coronatum* Wolle; W; pond
Cosmarium dentatum Wolle; Br
C. margaritum Wolle; Br

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae
Order: Pennales
Asterionella formosa Hass; Br; pond, swamp; C
Navicula rhomboides Ehr.; Br; bog, ced, str; A
N. rhomboides var. *crassinervis* Breb; Br; same as non. var.

11. Dennis Creek

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae
Order: Pennales
Tryblionella constricta Greg.; Br
T. hantzschiana Grun; Br
T. marginata W. Sm.; Br
T. punctata W. Sm.; Br

GREAT EGG HARBOR RIVER BASIN

12. Mays Landing

Division: Chrysophyta
Class: Bacillariophyceae
Order: Pennales
Eunotia bidentula Wm. Sm.; B
E. incisa W. Sm. ex Greg. var. incisa Patr.; B
E. pectinalis var. *undulata* Ralfs; Br; brook, ced, pond, str
Navicula rhomboides Ehr.; Br; pond, ced, bog, str, epi; A
N. rhomboides var. *crassinervis*; Br; same as non. var.
Asterionella formosa Hass; Br; pond, swamp; C
Actinella punctata Lewis: M; bog, ced, cran, ent, epi, str; all; B
Pinnularia legumen Ehr.; B
Anomoeoneis serians (Breb) Cl.; B
Nitzschia sigmatella Greg.; B
Surirella anceps Lewis; B
S. arctissima A.S.; B

13. Egg Harbor River

Division: Chlorophyta (Green Algae)
Order: Cladophorales
Cladophora sp.; ANSP-H

Division: Chrysophyta
Class: Bacillariophyceae
Order: Pennales
Asterionella bleakeleyi P
A. inflata P
Actinella punctata P
Fragilaria virescens var. capitata Østr.; P
Eunotia pectinalis var. minor (Kütz.) Rab.; P
E. pectinalis var. ventralis (Ehr.) Hust.; P
E. sudetica O. Müll.; P
E. tenella (Grun.) Hust. in Pascher; P
E. biceps; P
E. bidentula; P
Navicula cuspidata, P
N. erythraea; P
N. schultgei; P

MULLICA RIVER BASIN

14. Hammonton

Division: Chlorophyta (Green Algae)
Order: Volvocales
Chlamydomonas spp; M; bog, ced, cran, pond, squez. (c)
Order: Tetrasporales
Tetraspora spp.; M; cran, str.; 2,3,6
Order: Ulotrichaceae
Ulothrix spp.; F; ced, cran, str.; 2,4,6
Microspora spp.; M; bog, ced, dit, imp, pond, str. all
Aphanochaete globosa (Nordst.) Wolle; Br; pond
Order: Oedogoniales
Bulbochaete brebissonii Kütz.; W; pond
Order: Zygnematales
Family: Zygnemataceae
Mougeotia spp.; M; bog, ced, cran, dit, imp, pond, st.; all
Family: Desmidaceae
*Cosmarium kitchellii Wolle; W; pond
C. amoenum Breb; Br
Staurastrum tricornutum Wolle; Br; pond
S. novae-caesareae Br; pond
S. divaricatum Wolle; W
S. regulosum Breb; M; bog, cran, imp, pond, squez, str.; 3,4,9,11; Oc
Arthrodesmus fragilis Wolle; W; pond
A. incus (Ehr.) Hass; Br

A. octocornis Ehr.; Br
Xanthidium armatum (Breb.) Ralfs; Br; pond
X. eristatum (Breb.) Ralfs; Br
Hyalotheca dissiliens (Smith) Breb; M; bog, ced, cran, ooze, pool, squez, str.; A (3-6), zygotes A (4)
Bambusina brebissonii Kütz. (Gymnozygon); M; bog, ced, cran, pool, squez, str; 1-6,8,9; Oc
Closterium sp.; ANSP-H

Division: Chrysophyta (Yellow-Green Algae)
Class: Chrysophyceae
Order: Chrysomonadales
Synura uvella Ehr.; M; bog, ced, cran, pond, str.; (c)
Dynobryon sertularia Ehr.; M; bog, ced, cran, pond, str; (c)
Class: Bacillariophyceae
Order: Pennales
Tabellaria fenestrata (Lyngb.) Kütz.; M; bog, ced, cran, pond, str.; all/ANSP-H
Fragilaria virescens Ralfs; M; cran, pond, str; 2-5,12
Fragilaria spp.; M; bog, ced, cran, dit, str.; (c)
Asterionella formosa Hass.; M; bog, ced, cran, pond, str.; (c)/Br; pond, sqamp; C
Semiorbis hemicyclus (Ehr.) Patr.; B; pond/P
Eunotia arcus Ehr.; Br
E. denticula (Breb.) Rab; Br, pond; Oc
E. exigua (Breb.) Grun; Br; brook, pond; F
E. flexuosa; Br; pond; Oc
E. gracilia (Ehr.) Rab.; Br; pond, spr; C
E. pectinalis forma curta V.H.; Br; pond; Oc
E. pectinalis forma elongata V.H.; Br; pond; Oc
E. pectinalis var. undulata Ralfs; Br; brook, ced, pond, str; A
E. praerupta Ehr.; Br
E. tridon Ehr.; Br; brook, pond; F
E. serra var. serra Patr.; M; bog, ced, pond, squez; all
Eunotia spp.; M; bog, ced, cran, pond, squez, str; (c)
Navicula firma var. subampliata Grun; Br; pond; F
N. follis Ehr.; Br; pond; F
N. macilenta Ehr.; Br
N. oblonga Kütz.; Br; dit, pond; C
N. rhomboides Ehr.; Br; pond, epi; A/ANSP-H
N. rhomboides var. crassinervis Breb; Br; same as nom. var.
N. serians (Breb.) Kütz.; Br; ponds; C
Neidium dilatatum (Ehr.) Cl/ANSP=H
Actinella punctata Lewis; M; bog, ced, cran, ent, epi, str; all
Pinnularia maior var. pulchella Boyer; B; pond/ANSP
Pinnularia spp.; M; bog, ced, cran, dit, pond, squez; all
Cymbella gracilis (Rab.) Cl.; B; pond
Nitzschia sigmatella Greg.; M; pond
N. curvula W. Sm.; Br; pond; Oc
Surirella anceps Lewis; M; pond

S. bifrons Ehr.; Br
S. intermedia Lewis; ANSP-H swamp/ANSP-H

Division: Cyanophyta (Blue-green algae)
Order: Oscillatoriales
Scytonema natans Breb; Br; pond
S. hofmannii Ag.; D
Hapalosiphon braunii Kütz.; Br; epi, pond
Stigonema muscicola; D

ATLANTIC COASTAL DRAINAGE

15. Mullica River

Division: Chlorophyta (Breen Algae)
Order: Oedogoniales
Oedogonium ciliatum; P; pond, str.
O. flavescens P; str.
Bulbochaete brebissonii P; pond
B. setigera P; pond, str.
Order: Zygnematales
Spirogyra punctata; P; pond
Zygogonium sp.; ANSP-H
Family: Desmidaceae
Arthrodesmus fragilis P; str.
Bambusina delicatissima P; pond
Closterium decorum P; pond
C. ralfsii P; pond
Cosmarium kitchelli P; pond
Docidium dilatum P; pond
D. tridentulum P; pond
Micrasterias fimbriata var. apiculata P; str
M. papillifera P; pond
Staurastrum divarticum P; pond
S. inconspicuum P; pond

Division: Chrysophyta (Yellow-Green Algae)
Class: Bacillariophyceae
Order: Pennales
Asterionella ralfsii P; pond
Actinella punctata P; pond
Eunotia diodon P; pond
E. glacialis P; pond
E. naegellii P; pond
E. pectinalis P; str
E. pectinalis var. undulata P; str
E. robusta P; pond
Frustulia rhomboides (formerly Navicula rhomboides); P; pond
Navicula rhombica P; pond
Neidium dilatatum P; pond
N. iridis var. amphigomphus P; str

Pinnularia gibba P; pond
P. major P; pond
P. parvula P; str
P. stauroptera P; str
P. irridis var. *commutata* P; str
Stauroneis anceps P; pond

Division: Cyanophyta (Blue-green Algae)
Order: Oscillatoriales
Microcoleus anguiformis P; pond
M. lacustris P; pond, str
M. pulvinatus P; str

Division: Rhodophyta (Red Algae)
Order: Nemalionales
Batrachospermum vaguum P; pond
B. sp.; P; str
Chantransia macrospora P; pond

16. Atsion

Division: Chlorophyta (Green Algae)
Order Volvocales
Chlamydomonas spp.; M; bog, ced, cran, pond, squez. (c)
Order: Ulotrichaceae
Ulothrix spp.; F; cedar swamp; cran, str. 2,4,6
Order: Oedogoniales
Oedogonium ciliatum (Hass) Pringsh.; W; pond
Oedogonium platygynum Wittr; Br; pond
Order: Zygnematales
Family: Zygnemataceae
Mougeotia spp.; M; bog, ced, cran, dit, imp, pond, str; all
Spyrogyra spp.; M; bog, ced, imp, pond, str; all
Zygogonium ericetorum Kütz; ANSP-H
Family: Desmidiaceae
Closterium decorum Breb.; W; pond
C. ralfsii Breb.; W; pond
Micrasterias fimbriata var. *apiculata* Men.; W
M. papillifera Breb.; W
Staurastrum rugulosum Breb.; M; bog, cran, imp, pond; squez, str; 3,4,9,11; Oc
Hyalotheca dissiliens (Smith) Berb.; M; bog, ced, cran, ooze, pool, squez; A(3-6) zygotes A(4)
Staurospermum capucinum Kütz.; Br; pond; F
Tetmemorus giganteus Br; pond

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae
Order: Pennales
Tabellaria fenestrata (Lyngb.) Kütz.; M; bog, ced, cran, pond, str; all

Fragilaria virescena Ralfs; M; cran, pond, str; 2-5,12
Asterionella formosa Hass; M; bog, ced, cran, pond, str; (c)
Pinnularis spp.; M; bog, ced, cran, dit, pond, squez; all

Division: Cyanophyta (Blue-green Algae)
Order: Oscillatoriales
Hapalosiphon braunii Kütz; Br; epi, pond

Division: Rhodophyta
Order: Nemalionales
Chantransia macrospora Wood; Br; pond; A

17. Pleasant Mills

Division: Chrysophyta
Order: Zygnematales
Family: Zygnemataceae
Spirogyra punctata Cleve; W
Family: Desmidaceae
Staurospermum capucinum Kütz.; Br; pond; F
Bambusina delicatissima Wolle; Br
Desmidium baileyi (Ralfs) Woole; Br
Xanthidium armatum (Breb.) Ralfs; Br; pond
Micrasterias arcuata Bail; Br
M. expansa Bail; Br

18. Oswego River

Division: Chrysophyta (Green Algae)
Order: Ulotrichaceae
Ulothrix spp.; F; ced, cran, str; 2,4,6
Order: Chlorococcales
Eremosphaera irridis DeBary; ANSP-H; lake
Order: Zygnematales
Family: Zygnemataceae
Debarya sp.; F

Division: Chrysophyta
Class: Bacillariophyceae
Order: Pennales
Tabellaria fenestrata (Lyngb.) Kütz.; M; bog, ced, cran, pond, str; all
Actinella punctata Lewis; ANSP-H; ditch near Lake Oswego

Division: Rhodophyta
Order: Nemalionales
Batrachospermum coerylescens Sirod.; M; str; 10
Batrachospermum spp.; F

19. Bass River

Division: Chrysophyta (Yellow-green Algae)
Class: Chrysophyceae
Order: Chrysomonadales
Uroglena volvox Ehr.; M; pond

20. Batsto River

Division: Chlorophyta (Green Algae)
Order: Zygnemataceae
Family: Desmidaceae
Pleurotaenium sp.; ANSP-H

Division: Rhodophyta (Red Algae)
Order: Nemalionales
Betrachospermum sp.; ANSP-H (1890 & 1965)

21. Absecon

Division: Chlorophyta (Green Algae)
Order: Cladophorales
Cladophora sp.; ANSP-H
Order: Zygnematales
Family: Desmidiaceae
*Euastrum cuspidatum Wolle; W; pond

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae
Order: Centrales
Cyclotella comta (Ehr.) Kütz.; Br; dit, pond; C
C. operculata Kütz.; Br; dit, pond; C
Order: Pennales
Fragilaria binodis Ehr.; Br; pond; R
Asterionella formosa Hass; Br; pond, swamp; C
A. ralfsii W. Sm; Br; pond
Eunotia arcus Ehr.; Br
E. exigua (Breb.) Grun; Br; brook, pond; F
E. falax Grev.; Br; pond; R
E. pectinalis var. undulata Ralfs; Br; brook, ced, pond, str; A
E. praerupta Ehr.; Br
Navicula amphigomphus Ehr.; Br
N. follis Ehr.; Br; F
N. gibba (Kütz.) Ehr.; Br; pond, str; C
N. producta W. Sm.; Br; pond; C
N. rhomboides Ehr.; Br; pond, epi; A/P
N. rhomboides var. crassinervis Breb; same as nom. var.
N. serians (Breb.) Kütz.; Br; pond; C

N. humerosa P; str
N. peregrina P; str
N. punctata P; str
N. tumida P; str
N. vulpina P; str
Pinnularia dactylus var. *dariana* P; str
P. viridis P; str
Nitzschuia curvula W. Sm; Br; pond; Oc
Tryblionella marginata W. Sm; Br
Surirella bifrons Ehr; Br
S. cardinalis Kitton; Br
S. elegans Ehr.; Br; dit, pond; Oc

Division: Cyanophyta (Blue-green Algae)
Order: Oscillatoriales
Stigonema muscicola D

22. Westecunk Creek

Division: Chrysophyta
Class: Bacillariophyceae
Order: Pennales
Tabellaria flocculosa (Roth) Kütz.; M; ced, pond, str; 2,4,9

23. Oyster Creek

Division: Chlorophyta (Green Algae)
Order: Ulotrichaceae
Microspora spp.; M; bog, ced, dit, imp, pond, str; all

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae
Order: Pennales
Tabellaria fenestrata (Lyngb.) Kütz.; M; bog, ced, cran, pond, str; all

Division: Rhodophyta (Red Algae)
Order: Nemalionales
Batrachospermum spp.; M; ced, pond, str; all

24. Webbs Mill Branch

Division: Chlorophyta (Green Algae)
Order: Tetrasporales
Asterococcus limneticus G. M. Smith; M
Order: Ulotrichaceae
Microspora loefgrenii (Nordst.) Lag.; M; str. 10,12

Order: Zygnematales
Family: Zygnemataceae

<u>Mougeotia</u> spp.; M; bog, ced, cran, dit, imp, pond, str; all
<u>Zygnema</u> spp.; M; ced, pond, str; all
<u>Zygogonium ericetorum</u> Kütz; M; bog, ent, ooze, pond; 5,9,10,12
<u>Pleurodiscus purpureus</u> (Wolle) Lag.; M; bog, ooze, pond, str; (c)
<u>Spyrogyra</u> spp.; M; bog, ced, imp, pond, str; all

Division: Chrysophyta (Yellow-green Algae)
Class: Chrysophyceae
Order: Rhizochrysidales

<u>Lagynion triangulare</u> (Stokes) Pasch.; M; epi, str; 3,12

Class: Bacillariophyceae
Order: Pennales

<u>Tabellaria fenestrata</u> (Lyngb.) Kütz.; M; bog, ced, cran, pond, str; all
<u>Fragilaria virescens</u> Ralfs; M; cran, pond, str; 2-5,12
<u>Fragilaria</u> spp.; M; bog, ced, cran, dit, str; (c)
<u>Synedra</u> spp.; M; ced, imp, str; (c)
<u>Asterionella formosa</u> Hass.; M; bog, ced, cran, pond, str; (c)
<u>Eunotia</u> spp.; M; bog, ced, cran, pond, squez, str; (c)
<u>Actinella punctata</u> Lewis; M; bog, ced, cran, ent, epi, str, all
<u>Frustulia rhomboides</u> (Ehr.) Det.; M; squez, str; 3,4,8,12
<u>Frustulia</u> spp.; M; bog, ced, pond, squez, str; (c)

Division: Pyrrophyta (Dinoflagellates)
Order: Gymmodimiales

<u>Gymnodinium</u> spp.; M; ced, imp, pond, str; 2,9,10

Division: Cyanophyta (Blue-green Algae)
Order: Chroococcales

<u>Anacystis dimidiata</u> (Kütz.) Dr. and Dailey; M; bog, ced, str, all
<u>Calothrix</u> sp.; M; ent, str; 12

Division: Rhodophyta (Red Algae)
Order: Nemalionales

<u>Batrachospermum brugiense</u> Sirod.; M; str; 3,4,10
<u>Batrachospermum</u> spp.; M; ced, pond, str; all

25. Bamber

Division: Cyanophyta
Order: Oscillatoriales

<u>Hapalosiphon pumilus</u>; W

26. Toms River

Division: Chlorophyta (Green Algae)
Order: Zygnematales
Family: Zygnemataceae
Pleurodiscus purpureus (Wolle) Lagerh; ANSP-H; swamp
Family: Desmidiaceae
Euastrum formosum Wolle; W; pond

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae
Order: Pennales
Asterionella formosa Hass; Br; pond, swamp; C
Eunotia major; P; str
E. exigua (Breb) Grun.; Br; brook, pond; F
E. robusta Ralfs; Br; bog, pond; C
E. tridon Ehr.; Br; brook, pond; F
E. baetriana Ehr.; B
E. serra var. *serra* Patr.; bog, ced, pond, squez; all
Actinella punctata Lewis; B; bog, ced, cran, ent, epi, str; all/P
Navicula rhomboides Ehr.; Br; ced, bog, str; A
N. rhomboides var. *crassinervis* Breb; same as nom. var.
Nitzschia curvula W. Sm.; Br; pond; Oc

Division: Cyanophyta (Blue-green Algae)
Order: Oscillatoriales
Calothriv parietina (Näg.) Thur.; D
Entophysalis rivularis Drouet; D

27. Forked River

Division: Chlorophyta (Green Algae)
Order: Ulotrichaceae
Microspora spp.; M; bog, ced, dit, imp, pond, str. all

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae
Order: Pennales
Tabellaria fenestrata (Lyngb.) Kütz; M; bog, ced, cran, pond, str; all/ANSP-H
Actinella punctata Lewis; M; bog, ced, cran, ent, epi, str; all

Division: Rhodophyta (Red Algae)
Order: Nemalionales
Bactrachospermum spp.; M; ced, pond, str; all

28. Manahawkin

Division: Chlorophyta (Green Algae)
Order: Ulotrichaceae
  Microspora spp.; M; bog, ced, dit, imp, pond, str, all
  Aphanochaete repens A. Br.; M; epi, imp; 3-10
Order: Oedogoniales
  Oedogonium undulatum A. Br.; M; imp; 5-10
  Oedogonium spp.; M; ced, imp, pond; 5,6,10
Order: Cladophorales
  Cladophora spp.; M; ced, imp.
Order: Zygnematales
Family: Zygnemataceae
  Mougeotia spp.; M; bog, ced, cran, dit, imp, pond, str; all
  Spirogyra buchetii Kütz.; M; dit, 10
  Spirogyra spp.; M; bog, ced, imp, pond, str; all
Family: Desmidiaceae
  Closterium spp.; M; bog, ced, imp, pond, ooze, str.
  Staurastrum rugulosum Breb.; M; bog, cran, imp, pond,
  Desmidium baileyi (Ralfs) Nordst.; M; pondp 10; R
  Phacus pleuronectes (O.F. Müll.) Duj.; M; pond; squez, str; 3,4,11

Division: Euglenophyta
Order: Euglenales
  Phacus pleuronectes (O.F. Müll.) Duj.; M; pond, squez, str; 3,4,11
  Phacus spp.; M; bog, ced, imp, pond; 9
  Trachelomonas spp.; M; bog, ced, imp; (c)

Division: Chrysophyta
Class: Xanthophyceae
Order: Heterococcales
  Ophiocytium parvulum (Perty) A. Br.; M; bog, imp, pond; 5,12
  Botryococcus braunii Kütz.; M; imp, pond, squez; 5
Class: Chrysophyceae
Order: Chrysomonadales
  Lagynion scherffelii Pasch; M; bog, **epi**, imp; 5
Class: Bacillariophyceae
Order: Pennales
  Tabellaria fenestrata (Lyngb.) Kütz.; M; bog, ced, cran, pond, str; all
  T. flocculosa (Roth) Kütz.; M; ced, pond, str; 2,4,9
  Fragilaria crotonensis Kitt.; M; imp; 4
  Synedra spp.; M; ced, imp, str; (c)
  Eunotia curvata (Kütz.) Lagerst.; M; bog, ced, imp, pond, squez, str; (c)
  E. serra var. serra Patr.; M; bog, ced, pond, squez, all
  Pinnularia spp.; M; bog, ced, cran, dit, pond, squez; all

Division: Pyrrophyta (Dinoflagellates)
Order: Gymnodiniales
Gymnodinium spp.; M; ced, imp, pond, str; 2,9,10

Division: Cyanophyta (Blue-green Algae)
Order: Oscillatoriales
Oscillatoria spp.; M; ced, dit, imp, pond; 6,9

Uncertain Position
Order: Crystomonadales
Cryptomonas spp.; M; bog, ced, imp, pond, squez; (c)

29. Vineland

Division: Chlorophyta (Green Algae)
Order: Zygnematales
Family: Zygnemataceae
Spirogyra spp.; M; bog, ced, imp, pond, str; all
Family: Desmidiaceae
Pleurotaenium nodosum var. latum; M; ced, pond, pool; 1,2; R

Division: Chrysophyta (Yellow-green Algae)
Class: Chrysophyceae
Order: Chrysomonadales
Synura ulvella Ehr.; M; bog, ced, cran, pond, str; (c)
Class: Bacillariophyceae
Order: Pennales
Tabellaria flocculosa (Roth) Kütz.; M; ced, pond, str; 2,4,9

30. Berlin

Division: Chlorophyta
Order: Ulotrichaceae
Ulothrix sp.; F; ced, cran, str; 2,4,6
Order: Zygnematales
Family: Zygnemataceae
Mougeotia spp.; M; bog, ced, cran, dit, imp, pond, str; all

Division: Chrysophyta
Class: Bacillariophyceae
Order: Pennales
Tabellaria fenestrata (Lyngb.) Kütz.; M; bog, ced, cran, pond, str; all
Asterionella ralfsii; Br; spr.
Pinnularia spp.; M; bog, ced, cran, dit, pond, squez; all

31. Pinewald Lake

Division: Chlorophyta (Green Algae)
Order: Zygnematales
Pleurodiscus purpureus (Wolle) Lagerh; ANSP-H

32. Horricon Lake

Division: Chlorophyta (Green Algae)
Order: Zygnematales
Family: Desmidiaceae
*Xanthidium columbianum Wolle; W

33. Inskip, Blue Hole - near Winslow

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae
Order: Pennales
Frustulia rhomboides ANSP-H
Neidium tumescens ANSP-H
Navicula cuspidata ANSP-H
Neidium rudimentarum Reim; ANSP-H

GENERAL PINE BARRENS REGION

Division: Chlorophyta (Green Algae)
Order: Oedogoniales
Bulbochaete setigera (Roth) Ag.; Br
Order: Zygnematales
Family: Zygnemataceae
Spirogyra parvispora Wood; W
Family: Desmidaceae
Staurastrum spp.; M
Order: Euglenales
Trachelomonas horrida Palm; M

Division: Chrysophyta
Class: Bacillariophyceae
Order: Pennales
Tabellaria flocculosa (Roth) Kutz.; B
Fragilaria virescens Ralfs; B
T. fenestrata; Br; ced, pond, str; C

Division: Cyanophyta
Order: Chroococcales
Eucapsis alpina Clem. and Shanz.; M
Order: Oscillatoriales
Oscillatoria princeps (Vauch.) Gom.; M
O. tenuis Ag.; M

Available Data from the ANSP Diatom Herbarium.

Locality	Slide Numbers
Birchwood Lake	GC #53730
Brown's Mills	GC #46094-46099 Boyer Collection 1006 GC #43154 GC #47375 a-b
Pakim Pond	GC #53759
Lake Oswego	GC #46351a, GC #50719
Rancocas Creek	GC #44413
Turkey Lake	Teaching Collection 3-C-2, GC #45607a-b GC #50787
Elm	GC #46179
Hammonton	GC #1498, GC #46110, GC #53522, GC #46100-46109, GC #1271, GC #1526 GC #2481, GC #43213, GC #4887, GC #4892, GC #49202a-b, GC #50711, GC #43223, GC #43214
Hammonton Pond	GC #43209 & 43210, GC #42659, Schulze Collection A470, A571, Boyer Coll. #426, GC #1591 & 1592, GC #4897 GC #43222
Inskip; Blue Hole	GC #43216 & 43217, GC #46176-46178, GC #46141
Mays' Landing	GC #1990
Lakewood Pond	GC #43218, GC #42652, GC #42987a-b, GC #49194a-b
Toms River Area	GC #47379a-b-47384a-b, GC #47973a-b
Forked River	GC #47366a-b, BC #47367a-b, GC #47369a-b, GC #47961a-b

Mapping Locations* - Algae

1. Rancocas Creek
2. South Branch
3. Medford Lakes
4. McDonalds Branch
5. Mount Misery
6. Browns Mills
7. Pakim Pond
8. Malaga
9. Newfield
10. Dennisville
11. Dennis Creek
12. Mays Landing
13. Egg Harbor River
14. Hammonton
15. Mullica River
16. Atsion
17. Pleasant Mills
18. Oswego River
19. Bass River
20. Batsto River
21. Absecon
22. Westecunk Creek
23. Oyster Creek
24. Webbs Mill Branch
25. Bamber
26. Toms River
27. Forked River
28. Manahawkin
29. Vineland
30. Berlin
31. Pinewald Lake
32. Horricon Lake
33. Inskip, Blue Hole - near Winslow

*These designations are not specific sampling locations. In many cases the listed locality refers to the nearest municipality or a river system.

APPENDIX B

AQUATIC MACROPHYTE SPECIES LIST

	Growth form	NBRan.C	SBRan.C	Cro.C	UMau.R	LMau.R	Man.C	Dep.C	UGEH.R	LGEH.R	Tuc.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	LMul.R	Pat.C	Abs.C	Wes.C	Mil.C	Oys.C	Ced.C	Tom.R	Met.R	Man.R	Bas.R
Class Angiospermae																											
Subclass Monocotyledoneae																											
Family Typhaceae - Cat-tails																											
Typha latifolia (Common Cat-tail)	E														x		x					x					
Typha angustifolia (Narrow-leaved Cat-tail)	E	x								x						x	x										x
Family Sparganiaceae - Bur-reeds																											
Sparganium eurycarpum (Broad-fruited Bur-reed)	S																										
S. americanum (American Bur-reed)	S														x		x					x		x			
S. androcladum	S													x				x									
S. chlorocarpum (Green-fruited Bur-reed)	S												x														
Family Zosteraceae - Pondweeds																											
Potamogeton Oakesianus (Pondweed)	S					x				x																	
P. epihydrus (Pondweed)	S									x						x	x								x		
P. confervoides (Pondweed)	S							x														x					
P. pusillus (Pondweed)	S																x										
P. perfoliatus (Pondweed)	S																x										x
Ruppia maritima (Ditch-grass)	S																										x
Zannichellia palustris (Horned-Pondweed)	S																x										x
Family Najadaceae - Naiads																											
Najas flexilis (Naiad)	S																x										x
Family Alismataceae - Water-plantains																											
Saggitaria latifolia (Wapato)	E												x	x	x	x	x										
S. graminea (Arrowhead)	E								x																		
*S. subulata (Dwarf Arrowhead)	E																										
S. Englemanniana (Slender Arrowhead)	E							x					x		x	x	x										
S. montevidensis (Arrowhead)	E				x												x										
S. teres (Arrowhead)	E									x																	
S. australis (Arrowhead)	E														x												
Family Hydrocharitaceae - Frog's bits																											
Vallisneria americana (Water-celery)	S								x								x										x
Family Gramineae - Grasses																											
Zizania aquatica (Wild Rice)	E	x													x												
Glyceria obtusa (Manna-grass)	E		x		x			x							x	x	x					x		x			
Family Cyperaceae - Sedges																											
Eleocharis Robbinsii (Spike-rush)	S		x		x			x									x					x					
Scirpus subterminalis (Swaying Bulrush)	S													x			x					x		x			
S. pungens (Three-square Bulrush)	E																x										x
S. americanus (American Bulrush)	E							x								x	x					x					
Family Araceae - Arums																											
Peltandra virginica (Arrow-arum)	E														x		x	x									
Orontium aquaticum (Golden Club)	E	x														x	x							x			
Family Eriocaulaceae - Pipeworts																											
Eriocaulon septangulare (Duckgrass)	E														x	x											
E. Parkeri (Pipewort)	E															x	x										
E. compressum (Pipewort)	E	x												x		x							x				
E. decangulare (Pipewort)	E												x	x		x	x										
Family Pontederiaceae - Pickerelweeds																											
Pontederia cordata (Pickerelweed)	E													x	x	x											
Family Juncaceae - Rushes																											
Juncus militaris (Rush)	E																x					x					
J. pelocarpus (Rush)	E							x					x	x	x	x	x										
Family Iridaceae - Irises																											
Iris prismatica (Blue Flag)	E		x	x							x					x	x										
Subclass Dicotyledoneae																											
Family Nymphaeceae - Water-lilies																											
Nuphar variegatum (Bullhead Lily)	S		x											x		x	x										
Nymphaea odorate (Fragrant Water-Lily)	S		x			x			x							x	x					x		x			
Cabomba caroliniana (Fanwort)	S		x																					x			
Family Callitrichaceae - Water-starworts																											
Callitriche heterophylla (Water-chickweed)	E		x						x						x												
C. palustris	E								x																		
Family Elatinaceae - Waterworts																											
*Elatine minima (Water-wort)	E																							x			
Family Lythraceae - Loosestrifes																											
Decodon verticillatus (Water-willow)	E		x				x		x							x	x							x			
Family Haloragaceae - Water-milfoils																											
Myriophyllum humile (Water-milfoil)	S							x								x											
*Proserpinaca intermedia (Mermaid-weed)	E				x																						
P. palustris	E													x			x							x			
P. pectinata	E						x	x						x	x		x										
Family Umbelliferae - Parsleys																											
Lilaeopsis chinensis	E																x										
Family Gentianaceae - Gentians																											
Nymphoides cordata (Floating-heart)	S				x				x					x			x										
Family Lentibulariaceae - Bladderworts																											
Utricularia purpurea (Bladderwort)	S								x							x						x	x				
U. inflata (Bladderwort)	S																										
U. geminiscapa (Bladderwort)	S					x	x						x		x	x	x										
U. vulgaris (Common Bladderwort)	S						x										x										
U. cornuta (Horned Bladderwort)	S		x													x							x				
U. gibba (Humped Bladderwort)	S/E												x											x			
U. intermedia (Bladderwort)	S/E	x											x				x							x			
U. juncea (Rush-like Bladderwort)	E										x						x	x									
U. resupinata (Bladderwort)	E							x								x											
U. subulata (Awl-like Bladderwort)	E	x											x			x	x						x	x			
*U. fibrosa (Bladderwort)	E											x															

*pre-1940 data

APPENDIX C

MACROINVERTEBRATE SPECIES LIST

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C	Man.R
Phylum Porifera - Sponges													
Class Demospongea													
Order Haplosclerina													
Family Spongilliadae													
Spongilla ingloviformis										x			
Spongilla fragilis													x
Phylum Coelenterata-Coelenterates													
Class Hydrozoa													
Order Hydroida													
Family Hydridae													
Hydra				x									x
Phylum Nematoda - Roundworms		x	x	x									x
Phylum Bryozoa - Bryozoans										x			
Class Phylactolaemata													
Family Laphopodidae													
Lophopodella													x
Pectinatella	x												
Family Plumatellidae													x
Phylum Nemertea-Nemertean worms				x									
Phylum Platyhelminthes-Flatworms													
Class Turbellaria													
Order Tricladidla													
Family Planoriidae			x	x					x				x
Dugesia										x			
Phagocata		x											
Phylum Annelida-Segmented worms													
Class Oligochaeta-Fresh water earthworms													
Order Haplotaxida													
Family Naididae													
Chaetogaster			x										x
Dero										x			
Nais		x	x	x								x	x

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C	Man.R
Ophidonais												x	x
Paranais			x	x								x	x
Pristina		x	x	x								x	x
Slavina				x								x	x
Stylaria		x	x	x									x
Family Lumbricidae													
Lumbricillus				x									
Family Tubificidae													
Limnodrilus	x												x
Peloscolex										x			
Tubifex		x								x			
Order Lumbriculida													
Family Lumbriculidae								x					
Class Polychaeta - Polychaetes							x						
Class Hirudinea - Leeches		x											
Order Rhynchobdellida													
Family Glossiphoniidae											x		
Glossiphonia							x						x
Helobdella			x	x					x	x			
Placobdella							x	x		x			
Batrachobdella												x	x
Family Piscicolidae													
Cystobranchus		x											
Order Gnathobdellida													
Family Hirudinidae													
Macrobdella									x				
Haemopsis							x						
Order Pharyngobdellida													
Family Erpobdellidae													
Mooreobdella										x			
Phylum Arthropoda - Arthropods													
Class Arachnoidea-Spiders & Mites								x					
Order Hydracarina		x		x					x	x			
Family Hydrachnidae													
Hydrachna		x									x		
Family Limnocharidae													
Limnochares		x											
Order Oribatoidea													
Family Oribateidae		x											

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C	Man.R
Class Crustacea-Crustaceans													
Order Isopoda-Isopods													
Family Asellidae													
Asellus		x	x	x				x		x	x	x	x
Lirceus									x	x			x
Family Anthuridae													
Cyathura													x
Order Amphipoda-Amphipods													
Family Talitridae													
Hyalella								x		x	x	x	
Family Gammaridae													
Synurella											x		
Cranganyx										x			
Gammarus			x	x								x	x
Class Insecta-Insects													
Order Ephemeroptera-Mayflies													
Family Ephemeridae													
Hexagenia								x					
Family Caenidae													
Brachycercus								x					
Family Ephemerellidae													
Ephemerella				x			x	x	x	x	x	x	x
Family Leptophlebiidae													
Leptophlebia											x	x	
Paraleptophlebia			x	x								x	
Family Baetidae													
Pseudocleon											x		
Neocleon			x	x									
Baetis				x				x	x	x			x
Callibaetis										x			
Centroptilum										x			
Family Baetiscidae													
Baetisca				x				x				x	
Caenis													
Family Siphlonuridae													
Ameletus										x			
Family Heptageniidae													
Stenonema	x		x				x	x		x	x	x	
Rhithrogena							x						
Cinygmula								x					x
Arthroplea								x					
Family Metretopodidae													
Siphloplecton			x	x					x		x	x	

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C	Man.R
Order Odonata-Dragonflies and Damselflies													
Family Cordulegasteridae													
Cordulegaster			x					x		x			
Family Gomphidae													
Gomphus			x	x				x		x	x	x	
Progomphus				x				x					
Hagenius								x					
Dramogomphus								x				x	
Lanthus								x					
Family Aeschnidae													
Coryphaeschna										x			
Boyeria			x						x	x	x	x	
Aeschna								x		x			
Basiaeachna											x	x	
Epiaeschna								x				x	
Gomphaeschna								x					
Family Libellulidae													
Tetragoneuria								x		x		x	
Leucorrhinia								x		x			
Sympetrum								x		x	x		
Orthemis										x			
Celithemus		x											
Libellula				x				x					
Ladona		x						x					
Pachydiplax		x						x					
Perithemis								x					
Tramea							x						
Family Petaluridae													
Tachopteryx								x		x			
Family Macromidae													
Didymops								x					
Macromia								x					
Family Corduliidae													
Helocordulia								x					
Cordulia								x		x			
Epicordulia								x					
Family Agrionidae													
Agrion			x	x				x	x	x			x
Family Lestidae													
Lestes								x			x		
Archilestes										x			

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C	Man.R
Family Coenagriidae		x											
Argia			x					x		x	x	x	
Amphiagrion								x		x	x		
Anomalagrion								x		x	x		
Family Coenagriidae													
Chromagrion								x		x			
Enallagma			x	x				x	x	x	x		
Hesperagrian								x					
Hyponeura										x			
Ischnura								x	x	x			
Nehallenia								x					
Teleallagma							x						
Order Plecoptera-Stoneflies													
Family Taenioptergidae													
Taeniopteryx			x	x				x			x	x	
Family Leuctridae													
Leuctra									x			x	
Family Perlodidae													
Isoperla			x	x				x			x		x
Family Perlidae													
Acroneuria			x	x									
Perlinella												x	
Perlesta								x					
Family Chloroperlidae													
Hastaperla												x	
Alloperla												x	
Family Capniidae													
Allocapnia								x					
Order Hemiptera-True bugs													
Family Corixidae		x					x	x					
Trichocorixa										x	x		
Callicorixa										x			
Sigara											x		
Corixa									x				
Family Notonectidae								x					
Notonecta								x	x	x	x		x
Bueona		x											
Family Naucoridae													
Pelocoris										x			
Family Belostomidae													
Belostoma							x	x					
Lethocerus										x			

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C	Man.R
Family Nepidae								x					
Ranatra										x			
Family Gerridae								x					
Gerris							x		x	x			
Trepobates				x					x	x		x	
Rheumatobates										x			
Metrobates		x											
Family Veliidae													
Microvelia				x						x			
Rhagovelia							x		x		x		
Family Mesoveliidae													
Mesovelia										x			
Order Megaloptera-Fishflies and Alderflies													
Family Sialidae													
Sialis			x	x				x	x	x	x	x	
Family Corydalidae													
Chauliodes								x	x	x	x		
Nigronia			x	x				x				x	
Corydalus				x			x	x					
Dysmicohermes							x						
Order Coleoptera-Beetles													
Family Halipidae								x					
Halipus								x		x			
Peltodytes			x						x				
Family Dytiscidae								x					
Bidessus										x			
Laccophilus										x	x		
Agabus										x			x
Ilybius										x			
Neoscutopterus										x			
Dytiscus							x			x			
Hygrotus											x		
Hydroporus											x		
Carrhydrus											x		
Agabinus		x											
Celinia											x	x	
Coptotomus											x		
Hydroporus											x		
Family Gyrinidae		x						x					
Dineutus									x	x			x
Gyrinus									x		x		

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C	Man.R
Family Noteridae													
Hydrocanthus										x			
Protonerus										x			
Family Hydrophilidae													
Hydrochus										x			
Tropisternus										x			
Helophorus										x			
Helochares										x			
Sperchopsis										x	x		
Enochrus											x		
Berosus				x				x				x	
Family Elmidae													
Ancyronyx			x							x	x		x
Oulimnius											x	x	
Stenelmis		x	x	x							x	x	
Heterelmis							x						
Optioservus												x	
Cleptelmis				x									
Dubiraphia							x						
Limnius							x						
Macronychus								x					x
Family Chrysomelidae													
Galerucella									x		x		
Order Tricoptera-Caddisflies													
Family Glossomatidae													
Agapetus											x		
Protoptila												x	
Glossosoma												x	
Family Psychomyiidae													
Psychomyia			x				x					x	
Phylocentropus										x			
Psychomyiid										x			
Lype									x				
Family Hydropsychidae													
Cheumatopsyche	x		x	x				x		x		x	
Hydropsyche			x	x				x	x	x	x	x	x
Macronema				x									x
Family Hydroptilidae		x											
Hydroptila											x		
Oxyethira												x	
Agraylea												x	
Leucotrichia	x												

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C	Man.R
Family Phryganeidae													
Oligostomis										x			
Banksiola		x									x	x	
Ptilostomus											x	x	
Phryganeid													x
Family Limnephilidae													
Pycnopsyche			x							x	x	x	
Frenesia										x			
Limnephilus			x							x			
Platycentropus											x	x	
Goera			x										
Neophylax							x						
Family Molannidae		x											
Molanna			x	x						x	x	x	
Family Odotoceridae													
Psilotreta			x								x	x	
Family Leptoceridae													
Leptocella		x		x						x			
Mystacides											x	x	
Oecetis	x		x	x							x	x	
Triaenodes												x	
Family Lepidostomatidae													
Lepidostoma			x									x	
Family Philopotamidae													
Chimarra			x						x		x	x	
Family Polycentropodidae													
Nyctiophylax									x		x		
Polycentropus			x	x							x	x	
Neureclipsis				x					x			x	
Cyrnellus													
Family Brachycentridae													
Brachycentrus									x		x	x	
Micrasema											x		
Family Rhyacophilidae													
Rhyacophia			x	x									x
Order Lepidoptera-Aquatic Caterpillars													
Family Pyralidae													
Nymphula			x							x	x		x
Paraponyx											x		
Pyrausta													x

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C	Man.R
Order Diptera-Flies and Midges													
Family Tipulidae		x						x					
Tipula			x						x	x	x	x	
Limonia			x							x			
Pedicia										x			
Hexatoma			x	x							x	x	
Family Psychodidae													
Psychoda			x										
Family Culicidae													
Culex											x		
Chaoborus		x											
Family Ceratopogonidae											x	x	
Bezzia										x			
Palpomyia		x								x		x	x
Probezzia		x											
Stilobezzia											x		
Family Chironomidae													
Ablabesmyia		x								x			
Conchapelopia										x			
Psectrotanypus										x			
Thienemannimyia										x			
Natarsia										x			
Procladius			x							x			
Clinotanypus										x			
Pentaneura	x	x	x	x			x					x	x
Cricotopus			x	x						x		x	
Psectrocladius			x	x					x	x		x	x
Corynoneura			x	x						x		x	x
Thienemanniella				x					x	x			
Eukiefferiella													x
Brillia			x	x									x
Smittia													x
Metriocnemus			x									x	
Heterotrissocladius				x								x	
Diplocladius			x	x									
Trichocladius			x										
Phaenopsectra(Tribelos)				x					x	x		x	x
Polypedilum	x		x							x		x	x
Cryptocladopelma										x			
Parachironomus										x			
Demicryptochironomus										x			
Stictochironomus										x		x	
Chironomus(Tendipes)		x	x	x									x
Pseudochironomus		x											

DISTRIBUTION OF MACROINVERTEBRATES

	NBRan.C	SBRan.C	GEH.R	Mul.R	Ats.R	Bat.R	Nes.R	Wad.R	Pat.C	Abs.C	Oys.C	Ced.C
Cryptochironomus	x											
Dicrotendipes			x									
Glyptotendipes							x					
Paratendipes			x									
Endochironomus												
Stenochironomus									x			
Paralauterborniella			x									
Rheotanytarsus									x	x		
Cladotanytarsus										x		
Tanytarsus(=Calopsectra)	x	x	x	x					x			x
Family Simuliidae										x		
Simulium			x	x				x	x			x
Family Stratiomyinae												
Chrysops										x	x	x
Family Rhagionidae								x				
Atherix			x	x								
Family Muscidae								x				
Family Anthomyiidae												
Limnophora									x	x		
Family Empididae												
Hemerodromia	x		x	x							x	x
Phylum Mollusca - Mollusks												
Class Gastropoda - Snails												
Order Mesogastropoda												
Family Viviparidae												
Campelama							x					
Family Hydrobiidae												
Gillia			x									
Family Lymnaeidae												
Lymnaea										x		
Family Physidae												
Physa			x	x								
Family Planorbidae												
Gyraulus			x	x			x					
Heliasoma		x	x									
Family Ancylidae												
Ferrissia	x											x
Class Bivalvia-Clams and Mussels												
Family Spaeriidae												
Musculium			x	x								
Pisidium											x	
Sphaerium		x	x									

APPENDIX D

FISH SPECIES LIST

FISH SPECIES LIST

In this appendix, the distribution of all fishes recorded for the Pinelands is presented in tabular form. Tha table also includes our classification according to category (Characteristic-Restricted, Anadromous, etc.) for each species. An explanation of these categories is presented on page 7.

Legend of Categories

- C-R - Characteristic-Restricted
- C-W - Characteristic-Widespread
- P - Peripheral
- A - Anadromous
- I - Introduced
- I-E - Introduced-Established
- M - Marine

Besides the table presented in this appendix, the Pinelands Commission has been provided with additional data on fish distribution. The location of all sampling stations was portrayed on 7½-minute USGS topographic quadrants, and in the same maps the distribution of 4 species was portrayed. The four species, blackbanded sunfish, golden shiner, chain pickerel and largemouth bass are representative respectively of Characteristic-Restricted, Peripheral, Widespread and Introduced species. The Pinelands Commission also has been provided with tables which show the composition of individual collections at all sampling sites.

FISH SPECIES LIST

	Criteria	NBRan.C	SBRan.C	Cro.C	LMau.R	Man.C	Den.C	UGEH.R	LGEH.R	Tuc.R	Ats.R	Sle.R	Bat.R	Nes.R	Wad.R	LMul.R	Pat.C	Abs.C	Wes.C	Oys.C.-For.P	Ced.C	Tom.R	Net.P	Mil.C	Man.R
Class Osteichthyes - Bony Fishes																									
Order Anguilliformes																									
Family Anguillidae - Freshwater Eels																									
Anguilla rostrata American Eel	C-W	x	x	x	x		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		
Order Clupeiformes																									
Family Clupeidae - Herrings																									
Alosa aestivalis Blueback Herring	A				x					x						x			x						
Alosa mediocris Hickory Shad	M				x				x																
Alosa pseudoharengus Alewife	A				x	x	x		x	x	x		x	x	x	x	x	x			x	x			
Alosa sapidissima American Shad	A				x																				
Brevoortia tyrannus Atlantic Menhaden	M				x				x	x						x									
Clupea harengus Atlantic Herring	M									x															
Dorosoma cepedianum Gizzard Shad	P				x																				
Family Engraulidae																									
Anchoa hepsetus Striped Anchovy	M				x				x							x									
Anchoa mitchilli Bay Anchovy	M				x				x	x						x									
Order Salmoniformes																									
Family Salmonidae - Trouts																									
Salmo gairdneri Rainbow trout	I													x											
Salmo trutta Brown trout	I-E													x								x			
Salvelinus fontinalis Brook trout	P																					x			
Family Umbridae - Mudminnows																									
Umbra pygmaea Eastern mudminnow	C-W	x	x				x	x	x		x	x	x	x	x	x	x			x	x	x			
Family Esocidae - Pikes																									
Esox americanus Redfin Pickerel	C-W	x	x					x		x	x	x	x		x	x		x	x		x	x	x		
Esox niger Chain Pickerel	C-W	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x		
Order Myctophiformes																									
Family Synodontidae - Lizard fishes																									
Synodus foetens Inshore Lizard fish	M															x									
Order Cypriniformes																									
Family Cyprinidae - Minnows																									
Carassius auratus Goldfish	I-E	x						x			x														
Cyprinus carpio Carp	I-E	x	x		x			x						x											
Hybognathus nuchalis Silvery minnow					x																				
Notemigonus crysoleucas Golden Shiner	P	x	x		x	x	x	x	x	x	x	x	x	x		x	x	x	x	x		x	x		
Notropis analostanus Satinfin Shiner	F			x	x																				
Notropis chalybaeus Ironcolor Shiner	C-R							x																	
Notropis hudsonius Spottail Shiner	P		x		x	x			x																
Pimephales promelas Fathead Minnow	I-E							x																	
Semotilus corporalis Fallfish	P			x																					
Family Catostomidae - Suckers																									
Catostomus commersoni White Sucker	P	x	x	x	x				x							x						x			
Erimyzon oblongus Creek Chubsucker	C-W	x	x			x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x		
Order Siluriformes																									
Family Ictaluride - Catfishes																									
Ictalurus catus White catfish	P				x	x			x	x				x		x					x	x			
Ictalurus melas Black Bullhead	I				x																				
Ictalurus natalis Yellow Bullhead	C-R	x	x	x			x	x		x	x	x	x	x	x	x	x		x	x		x			
Ictalurus nebulosus Brown Bullhead	P	x	x		x		x	x	x	x	x	x		x		x		x	x			x	x		
Ictalurus punctatus Channel catfish	I				x																				
Noturus gyrinus Tadpole Madtom	C-W	x	x					x				x	x	x								x			
Order Percopsiformes																									
Family Aphredoderidae - Pirate Perches																									
Aphredoderus sayanus Pirate Perch	C-R	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x			
Order Batrachoidiformes																									
Family Batrachoididae - Toadfishes																									
Opsanus tau Oyster Toadfish	M				x				x	x						x									
Order Gadiformes																									
Family Gadidae - Codfishes																									
Pollachius virens Pollock	M								x							x									
Urophycis chuss Red Hake	M								x																
Urophycis regius Spotted Hake	M				x					x															
Family Ophidiidae - Cusk-eels and Brotulas																									
Rissola marginata Striped cusk-eel	M				x																				
Order Atheriniformes																									
Family Belonidae																									
Strongylura marina Atlantic Needlefish	M								x	x															
Family Cyprinodontidae - Killifishes																									
Cyprinodon variegatus Sheepshead Minnow	M									x						x									
Fundulus diaphanus Banded killifish	P	x			x				x	x		x				x		x				x			
Fundulus heteroclitus Mummichog	P		x		x		x		x	x						x		x							
Fundulus majalis Striped Killifish	M				x											x									

FISH SPECIES LIST

Species	Category	NBRan.C	SBRan.C	Cro.C	LMau.R	Man.C	Den.C	UGEH.R	LGEH.R	Tuc.R	Ats.R	Sle.R	Bat.R	Nes.R	Wad.R	LMul.R	Pat.C	Abs.C	Wes.C	Oys.C.-For.R.	Ced.C	Tom.R	Wet.R	Mil.C	Man.R
Family Poeciliidae - Livebearers																									
Gambusia affinis Mosquitofish																									
Family Atherinidae - Silversides																									
Menidia beryllina Tidewater Silverside	M				x				x	x						x									
Menidia menidia Atlantic Silverside	M								x	x						x									
Order Gasterosteiformes																									
Family Gasterosteidae - Sticklebacks																									
Apeltes quadracus Fourspine Stickleback	P								x	x						x									
Gasterosteus aculeatus Threespine Stickleback	P									x						x									
Family Syngnathidae - Pipefishes and Seahorses																									
Syngnathus fuscus Northern Pipefish	M				x				x	x						x									
Order Perciformes																									
Family Percichthyidae - Temperate Basses																									
Morone americana White Perch	P	x			x	x			x	x						x		x				x			
Morone saxatilis Striped Bass	A									x						x									
Family Centrarchidae - Sunfishes																									
Acantharchus pomotis Mud Sunfish	C-R	x	x	x			x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x		
Enneacanthus chaetodon Blackbanded Sunfish	C-R	x	x	x		x	x	x	x	x	x	x	x	x	x	x						x			
Enneacanthus gloriosus Bluespotted Sunfish	C-W	x	x			x	x	x	x		x	x	x	x		x	x	x	x	x		x			
Enneacanthus obesus Banded Sunfish	C-R	x	x	x		x	x	x	x	x	x	x		x	x	x	x		x	x	x	x	x		
Lepomis auritus Redbreast Sunfish	P	x	x		x									x											
Lepomis gibbosus Pumpkinseed	P	x	x		x		x	x	x	x	x	x	x	x		x		x	x	x		x	x		
Lepomis macrochirus Bluegill	I-E	x	x		x		x	x	x		x	x	x	x		x	x	x				x			
Lepomis microlophus Redear Sunfish	I-E							x																	
Micropterus salmoides Largemouth Bass	I-E	x	x		x		x	x		x	x	x	x	x		x						x	x		
Pomoxis nigromaculatus Black Crappie	I-E	x	x					x						x									x		
Family Percidae - Perches																									
Etheostoma fusiforme Swamp Darter	C-R	x	x	x			x	x	x		x	x	x	x	x	x	x			x		x			
Etheostoma olmstedi Tessellated Darter	C-W		x	x	x			x	x	x	x		x	x		x					x	x			
Perca flavescens Yellow Perch	P	x	x		x	x	x		x	x				x		x		x				x	x		
Family Pomatomidae - Bluefish																									
Pomatomus saltatrix Bluefish	M				x				x	x						x									
Family Carangidae - Jacks and Pompanos																									
Caranx crysos Blue Runner	M									x															
Caranx hippos Crevalle Jack	M				x					x						x									
Caranx latus Horse-eye Jack	M								x	x															
Selene vomer Lookdown	M															x									
Trachinotus carolinus Florida Pompano	M									x															
Family Gerreidae - Mojarras																									
Eucinostomus lefroyi Mottled Mojarra	M															x									
Family Sparidae - Porgies																									
Stenotomus chrysops Scup	M								x																
Family Sciaenidae - Drums																									
Bairdiella chrysura Silver Perch	M								x	x						x									
Cynoscion regalis Weakfish	M				x				x	x															
Leiostomus xanthurus Spot	M				x				x	x						x									
Menticirrhus saxatilis Northern Kingfish	M								x																
Micropogon undulatus Atlantic croaker	M				x																				
Family Mugilidae - Mullets																									
Mugil curema White mullet	M															x									
Family Uranoscopidae - Stargazers																									
Astroscopus guttatus Northern Stargazer	M				x																				
Family Gobiidae - Gobies																									
Gobiosoma bosci Naked Goby	M				x				x							x									
Family Stromateidae - Butterfishes																									
Peprilus triacanthus Butterfish	M								x																
Family Triglidae - Searobins																									
Prionotus carolinus Northern Searobin	M								x																
Order Pleuronectiformes																									
Family Bothidae - Lefteye Flounders																									
Etropus microstomus Smallmouth Flounder	M								x																
Paralichthys dentatus Summer Flounder	M				x																				
Scophthalmus aquosus Windowpane	M								x	x															
Family Pleuronectidae - Righteye flounders																									
Pseudopleuronectes americanus Winter flounder	M								x	x						x									
Family Soleidae - Soles																									
Trinectes maculatus Hogchoker	M				x				x	x						x									
Order Tetraodontiformes																									
Family Tetraodontidae - Puffers																									
Sphoeroides maculatus Northern Puffer	M				x				x																
Family Diodontidae - Porcupinefishes																									
Chilomycterus schoepfi Striped burrfish	M									x															

FISH SPECIES LIST

SYNOPSIS

	Total	Characteristic Restricted	Characteristic Widespread	Peripheral	Anadromous	Introduction	Marine	Collectio
NBRan.C	26	6	7	8	0	5	0	11
SBRan.C	26	6	8	8	0	4	0	31
Cro.C	12	6	3	3	0	0	0	2
LMau.R	44	0	3	14	3	5	20	13
Man.C	12	3	3	5	1	0	0	4
Den.C	19	6	5	5	1	2	0	7
UGEH.R	25	7	8	3	0	7	0	17
LGEH.R	50	5	6	11	1	1	26	19
Tuc.R	46	5	5	10	3	1	22	14
Ats.R	20	6	7	3	1	3	0	12
Sle.R	19	6	7	4	0	2	0	8
Bat.R	18	5	8	2	1	2	0	10
Nes.R	26	6	7	6	1	6	0	19
Wad.R	12	6	5	0	1	0	0	7
LMul.R	50	6	7	11	3	2	21	21
Pat.C	13	5	5	1	1	1	0	3
Abs.C	12	0	3	7	1	1	0	1
Wes.C	12	4	4	3	1	0	0	6
Oys.C-For.R	12	5	5	2	0	0	0	10
Ced.C	11	3	6	1	1	0	0	11
Tom.R	27	6	8	9	1	3	0	20
Met.R	12	2	4	4	0	2	0	12
Mil.C	0	0	0	0	0	0	0	0
Man.R	0	0	0	0	1	0	0	1