COMMUNITY CLASSIFICATION AND MAPPING CRITERIA FOR CATEGORY I INTERDUNAL SWALES AND COASTAL PLAIN POND WETLANDS IN DELAWARE

Final Report

Submitted to:

Division of Water Resources
Wetlands and Aquatic Protection Branch
Department of Natural Resources and Environmental Control

By:

Delaware Natural Heritage Inventory
Division of Parks and Recreation
Department of Natural Resources and Environmental Control

Principle Investigators:

William McAvoy
Keith Clancy

May 1994

COMMUNITY CLASSIFICATION AND MAPPING CRITERIA FOR CATEGORY I INTERDUNAL SWALES AND COASTAL PLAIN POND WETLANDS IN DELAWARE

Final Report

Submitted to:

Division of Water Resources
Wetlands and Aquatic Protection Branch
Department of Natural Resources and Environmental Control

By:

Delaware Natural Heritage Inventory
Division of Parks and Recreation
Department of Natural Resources and Environmental Control

Principle Investigators:

William McAvoy
Keith Clancy

May 1994

ACKNOWLEDGEMENTS

Over the last two years of this grant, many people have provided technical advice and support, and contributed valuable field time and data towards helping to complete this project and final report. We would like to thank the following individuals for their contributions: Janet Ebert, Peggy Emslie, Christopher Heckscher, Frank Hirst, Jack Holt, Susan Laporte, Mick McLaughlin, Larry Pommato, Jim White and Ron Wilson. We would especially like to thank Dave Saveikis of the Wetlands and Aquatic Protection Branch (DNREC) for obtaining financial support for this project and also for his technical advice and encouragement.

TABLE OF CONTENTS

INTRODUCTION

Human threats to unique and significant wetland habitats in the state of Delaware (e.g. draining and filling) have prompted the Wetlands and Aquatic Protection Branch (WAPB) of the Division of Water Resources and the Delaware Natural Heritage Inventory (DNHI) of the Division of Parks and Recreation, Department of Natural Resources and Environmental Control (DNREC), Dover, Delaware, to locate, identify and map these sites for purposes of regulation and protection. Unique and significant wetland types, such as bald cypress and Atlantic white cedar swamps, interdunal wetlands and coastal plain ponds (i.e. Carolina/Delmarva Bays) have been classified as Category I wetlands. This classification is assigned based on their limited extent in the state, the assemblage of rare plant species that they often contain, their unique geological origins, and their distinctive physiognomic characteristics. Category I wetlands will receive the highest priority for protection.

Mapping of Category I wetlands is critical to the process of protection and regulation, and will be accomplished through interpretation of aerial photography. The procedure begins with ground reconnaissance: characterizing specific wetland communities through detailed, and intense biological surveys during the growing season. Classification of natural communities entails complex field studies which ultimately give a complete, over-all description of a community. Data collected will aid interpreters in locating Category I wetlands on aerial photographs so that boundaries can be drawn and maps produced.

The WAPB has contracted a two year study with the Delaware Natural Heritage Inventory to locate Category I wetlands, to develop community classifications of Category I wetlands, and to recommend criteria to be used for mapping of Category I wetlands. The first year of the study began in January of 1992 and its focus was on bald cypress and Atlantic white cedar wetlands. The second year of study (1993), concentrated on interdunal wetlands and coastal plain ponds. Base-line data for Piedmont stream valley wetlands and sea-level fen wetlands were also collected to determine their Category I potential (a separate report summarizing preliminary studies for these wetlands types has been completed).

This study will also provide the Delaware Natural Heritage Inventory with important information to be used in the development of a state-wide natural community classification. This work will contribute to protection and management efforts of Delaware's most significant and unique wetland communities.

MATERIALS AND METHODS

In-depth surveys of interdunal wetlands and coastal plain pond wetlands in Delaware were undertaken during the 1993 season. Preliminary work involved gathering known information on the occurrence of these habitat types in Delaware: from published reports, unpublished data (primarily from the DNHI database), and conversations with knowledgeable individuals. This step was critical to subsequent field investigations of these wetlands.

A study of aerial photography (1988 CIR at 1:24000 and 1992 CIR at 1:40,000) was undertaken. First, photographs of known interdunal wetlands and coastal plain pond sites were studied to determine a characteristic "signature" for each of the two habitat types. This information was then used to identify additional sites. Photographs from all areas in the state that were suspected to contain interdunal wetlands and coastal plain ponds were studied.

Once areas of known or suspected occurrence of the two habitat types were identified, field surveys were undertaken to verify the presence of the two communities and to assess their structure and species' compositions. At most sites, cover values were estimated, information on soils were recorded, habitat disturbances were noted, and a list of associated species for each site was made. Several "reference" interdunal wetland and coastal plain pond sites were selected, in which detailed surveys were undertaken for comparative purposes to other sites.

For each interdunal wetland and coastal plain site visited, a detailed description of the site was made (see discussions for each habitat type below), its location in the state noted on a U.S.G.S. topographic map, site boundaries were indicated, size of the natural community estimated, and any other pertinent information about the site (e.g. presence of rare species, adjacent land use, threats, etc.) discussed.

PART I

INTERDUNAL WETLANDS IN DELAWARE

INTRODUCTION - INTERDUNAL WETLANDS

The focus of this study was descriptive in nature and botanically and ecologically based. Data collected are presented in a systematic, narrative way and a review of the literature is summarized within each discussion. Criteria and justification for Category I wetland mapping are based on field observations and data collected.

Interdunal wetland sites chosen to be sampled were selected by review of the DNHI database files, two aerial surveys done by plane, and by review of aerial photographs (1988 CIR at 1:24000 and 1992 CIR at 1:40,000).

Forty sites were sampled. For each site visited, all vegetation present were identified, hydrology was noted (surface water and groundwater measurements), soil characteristics were indicated, size and shape of a site was approximated, casual observations were transcribed, physical position on the landscape was noted and the approximate location was recorded onto a U.S.G.S. topographic map (1:24,000). Sampling was done randomly from May to December, 1993.

GENERAL DESCRIPTION OF AN INTERDUNAL WETLAND IN DELAWARE

Interdunal wetlands in Delaware, occur exclusively along the Atlantic coastal strand and barrier islands from Cape Henlopen south to the Delaware-Maryland state line (all within Sussex County). They are found as low, shallow depressions behind primary dune ridges of the shoreline. They are variable in size (none greater than 1 acre in area covered) and irregular in shape (see Fig. 1, Appendix B for a profile of an interdunal wetland). They are non-tidal, freshwater systems that are primarily groundwater driven. Water levels fluctuate seasonally and annually reflecting changes in groundwater levels. Soils are coarse textured sands and a very thin layer of organic matter, or peat is typically found at the soil surface. Interdunal wetlands are floristically diverse systems and the major vegetative groups represented are sedges (Cyperaceae), grasses (Poaceae), asters (Asteraceae) and rushes (Juncaceae). A suite of characteristic "signature" plant species (i.e. an assemblage of species that are frequently found) have been determined for Delaware interdunal wetlands, and a number of rare plant species have also been identified. Interdunal wetlands as ecological communities are also quite diverse, and five community variants have been identified for Delaware. Interdunal wetlands provide habitat for wildlife and also serve as a source for freshwater for animals utilizing coastal dune systems.

Through review of the literature, a number of synonyms were found for interdunal wetlands: dune meadow, dune slack, mesic meadow, dune marsh, dune swale, maritime wet grassland, and dune sedge. The terminology of interdunal wetland is suggested, to cover the broad

range of variation within the community type.

OVERALL DISTRIBUTION

Interdunal wetlands have been identified in the Atlantic coastal states of Massachusetts, Long Island, New York, New Jersey, Delaware (from Cape Henlopen south to the DE-MD state line), Maryland, Virginia, North Carolina, Georgia, and Florida (Odum and Harvey 1988, Jones 1992).

FORMATION/GEOLOGY

It has been theorized that interdunal wetlands are formed by "blowouts," in the loose, unvegetated sand of the inner dunes. These blowouts, resulting in the formation of depressions, lower the soil surface to groundwater levels and are therefore considered to be "windows" of the groundwater table (Ranwell 1959, Jones 1992). Many of the interdunal wetlands that have been identified are found on coastal barrier islands. These islands have developed what is called a ridge and swale topography (Odum and Harvey 1988), which consists of a high foredune or ridge, and low depressional areas or swales within the inner dunes. This accurately describes the geologic setting of Delaware's interdunal wetlands. The question has been asked, does this wetland type occur on the Delaware Bay coastline? Efforts to locate examples of this wetland community type through aerial surveys and review of aerial photographs, have been unsuccessful. Physical characteristics and natural processes of the Delaware Bay region do not appear to be favorable for interdunal wetland formation. For more detailed discussions of the geology of coastal interdunal wetlands, see Ranwell (1959, 1960) and Odum and Harvey (1988).

DYNAMICS/SUCCESSION

Interdunal wetlands occur within a dynamic environment, and may be subject to disturbance or modification by natural processes, such as shifting sand dunes, salt spray, oceanic overwash and storm erosion. Such disturbances appear to be important in preventing succession of interdunal wetlands to palustrine shrub, or dry dune shrub communities (Schafale and Weakley 1990). Field observations indicate that areas that are more sheltered than others (e.g. high, intact primary dunes with vegetative cover) are not subjected to the degree of disturbance that more open, unvegetated areas are. Sheltered areas are likely to succeed, while open, unvegetated areas are more conducive to wetland formation.

From studies of interdunal wetlands in Great Britain, Ranwell (1960) offers this possible cycle of succession: bare, moist sand of inner dune depressions are first colonized by germinating seeds,

carried by birds or wind from surrounding areas; perennial plants later become established; as sand deposition and dune movement takes place, interdunal wetlands become drier and dunes are eventually formed; over time, the process of shifting dunes and storm erosion continues to occur, and new depressions are formed, once again bare moist sand is suitable for colonization by seedlings. Ranwell predicts approximately 80 years for this cycle to take place. A review of early aerial photographs to the present, may reveal indications of this phenomenon occurring along Delaware's Atlantic coast.

Over the short term, water level fluctuations drive community dynamics. During periods of drought, shrubs and trees may become established and shade and out-compete the characteristic herbaceous plants, but most woody plants will likely be eliminated by later periods of prolonged flooding (Schafale and Weakley 1990). Dead, standing stems of *Acer rubrum* (red maple) and *Myrica cerifera* (bayberry) were often observed within many of the wetlands sampled during this study.

HYDROLOGY

Survey work completed for the Category I wetland project during 1993, as well as field observations made in previous years, indicate that interdunal wetlands are a reflection of the groundwater table. Ecological studies of interdunal wetlands done by other researchers also suggest this (Snow 1902, Ranwell 1959, 1960, Odum and Harvey 1988, Seliskar 1986, Jones 1992, Whittecar and Emery 1992). It has been found through Category I wetland surveys, that surface water levels of interdunal wetlands in Delaware will fluctuate through the seasons. A typical water regime may be as follows: maximum surface water depths occurring in the winter and spring, and minimum depths in mid to late summer, with occasional periods of random flooding after intense storm events. Observations made during this study show that interdunal wetlands will flood and remain flooded long after a severe storm. Although standing water was not typically found in interdunal wetlands in mid and late summer, and also between storm events, soils were always moist or saturated. During ecological surveys of Delaware's Atlantic coastal habitats from Cape Henlopen to Rehoboth Beach, Snow noted the same hydro regime as above; she described "swampy, dune-meadows" that flooded in winter and were dry in summer. Water table fluctuations in interdunal wetlands appear to be primarily associated with precipitation. Direct correlations have been found between the rise and fall of coastal groundwater tables and regional and local climatic cycles (Odum and Harvey 1988). The range of water table fluctuation throughout the year is dependent on rainfall, rate of sub-surface drainage and soil permeability, evapotranspiration, and infiltration by rainfall (Ranwell 1959).

The National Wetlands Inventory (NWI) program of the U.S. Fish and Wildlife Service were able to locate and map many of the larger interdunal wetlands along Delaware's Atlantic coast.

A range of water regimes were mapped during the National Wetlands Inventory (1977, 1981):

temporarily flooded	(A regime)
saturated	(B regime)
seasonally flooded	(C regime)
seasonally flooded/saturated	(D regime)

Past and present studies have shown that coastal interdunal wetlands are truly non-tidal, freshwater systems (Kearney 1904, Kelly 1925, Martin 1958, Ranwell 1959, Odum and Harvey 1988, Priestley pers. comm. 1994,). Ranwell has found that groundwater levels of interdunal wetlands in Great Britain are not affected by spring high tides, and no penetration of seawater beneath dunes has been measured or correlated with tide cycles. Kelly, during studies of soil water of the New Jersey coast, found that sub-surface lateral movement of groundwater is towards the sea, and there is no measurable passage of salt landward. Kearney, while studying sea beach vegetation, also determined that soil water of the inner dunes contains no appreciable amounts of soluble salts. Martin, during studies of the vegetation of Island Beach State Park, New Jersey, found that salinity measurements indicate no more than a negligible amount of salt in the groundwater. Salinity measurements taken of surface water in eight separate interdunal wetlands in Delaware (January 1994), revealed zero levels of salinity. However, interdunal wetlands may be found at times to be somewhat brackish, which is likely a result of salt spray (Kelly 1925), or maritime overwash during storm events (Odum and Harvey 1988). The eight interdunal wetlands mentioned above that were sampled for salinity levels in January of 1994, were also sampled in March of 1994, following an intense storm event where the primary dune ridge was breached by oceanic overwash, salinity levels were measured as high as 15 parts/thousand. A few sites sampled during this survey contained plant species tolerant of high levels of salinity (e.g. *Spartina patens*, salt hay; *Distichlis spicata*, spike grass; *Eleocharis parvula*, saltmarsh spike-rush; and *Baccharis halimifolia*, high-tide bush). Salt tolerant plant species were also found in interdunal wetlands in Virginia (Jones 1992). These sites should eventually be flushed by fresh groundwater and rainfall, and salt tolerant species will either become much less important, or be altogether eliminated (Odum and Harvey 1988). Odum and Harvey suggest that rainfall, infiltrating directly into the groundwater aquifer, displaces saline water and forms a lens of freshwater which may float on top of a layer of brackish water beneath.

SOILS

Soils of the interdunal wetlands sampled during this study were found to be predominately composed of coarse textured sand, with a thin layer (1-5mm) of humus at the surface. No true soil horizons were noted, indicating a lack of soil development. Similar observations have been made by other researchers studying the ecology of coastal interdunal wetlands (Kearney 1904, Oosting and Billings 1942, Martin 1958, Odum and Harvey 1988, Tyndall and Levy 1978, Jones 1992). Tyndall, in sampling interdunal wetlands of the Virginia coast, found the texture of all soil samples to be 98% sand. Odum and Harvey speculated that the periodic drying of interdunal wetlands and subsequent oxidation of their accumulated bottom sediments, may be a reason for low amounts of organic matter build-up and lack of soil development. The Sussex County Soil Survey (1974) maps the interdunal region of Delaware's Atlantic coast as either coastal sand (co), or tidal marsh (Tm).

Odum and Harvey (1985) suggest that interdunal depressional wetlands are underlain by confining mixed layers of sand, silt, clay and organic matter. In this case, groundwater exchange would then likely be most important around the edge of the wetland, with lesser amounts moving through the wetland bottom. In studies along the New Jersey coast, it was found that shallow layers of peat occurred under interdunal "cranberry bog" wetlands (Martin 1959).

The literature, as well as the species composition of interdunal wetlands sampled, suggests that the soil of coastal interdunal wetlands tends to vary from nutrient poor to nutrient rich (Oosting and Billings 1942, Ranwell 1959, Tyndall and Levy 1978, Jones 1992). A few sites sampled during this study contained plant species that are often found growing in eutrophic wetlands, such as *Echinochloa walterii* (Walter's millet), *Hibiscus moscheutos* (marsh mallow), *Ludwigia palustris* (water purslane), *Pluchea odorata* (flea-bane), *Polygonum* spp. (smartweeds), and *Proserpinaca palustris* (mermaid weed). The frequent occurrence of the carnivorous plant *Drosera intermedia* (sundew) in the majority of the interdunal wetlands sampled however, may indicate nutrient poor conditions in those wetlands where it was found. Due to the extreme sandy texture of the soils and the lack of organic material, primary sources of nutrients are from precipitation, salt spray, and groundwater (Oosting and Billings 1942, Jones 1992).

Although soil pH was not measured during this study, the vegetative composition of the majority of interdunal wetlands sampled (e.g. *Drosera intermedia; Sphagnum* sp., sphagnum moss; *Utricularia subulata,* zig-zag bladderwort; *Viola lanceolata,* lanceleaf violet; *Vaccinium macrocarpon,* cranberry; and *Xyris* spp., yellow-eyed grasses), indicate low levels of soil pH. Tyndall (1978) found a range of pH measurements from 5.0 to 5.7. Odum and Harvey have measured soil pH as low as 4.5.

Salt content of interdunal wetland soils is barely measurable (Oosting and Billings 1942). Kearney (1904) found only .003% salt in samples taken, and concludes that any salt measured is likely from salt spray or oceanic overwash. Such low levels of soil salinity are not enough to affect freshwater vegetation (Oosting and Billings 1942).

VEGETATION

Interdunal wetlands in Delaware are highly diverse plant communities, that typically contain herbaceous vegetation with varying degrees of emergent and prostrate growth forms. A mixture of wetland and mesic species are found, which are primarily perennial, and includes grasses, sedges, rushes, forbs, ferns, fern allies and mosses. The major plant families represented are: Cyperaceae (sedge family), 23 species; Poaceae (grass family), 14 species; Asteraceae (aster family), 13 species; Juncaceae (rush family), 7 species. The orchid family (Orchidaceae) is also fairly well represented with 5 species. Arborescent and frutescent vegetation are also encountered, but usually on the edges of moist perimeters, or in stunted forms if found in standing water. Many of the species found are persistent, allowing for identification throughout the year.

In Appendix A, a list of plant species associated with interdunal wetlands in Delaware can be found. Scientific and common names are given, as well as state ranks (ranks are a measure of a species rarity in the state), frequency class (based on the number of occurrences out of 40 survey sites), and wetland indicator status (Reed 1988).

Fourteen characteristic signature plant species have been determined for interdunal wetlands in Delaware (listed below). This determination is based on frequency classes of 3 and 4 (frequency class 3 = 14-26 occurrences, frequent; frequency class 4 = 27-40 occurrences, common). Frequency classes are calculated from 40 survey sites.

This suite of taxa represents the typical community assemblage of interdunal wetland plants to be found in Delaware (wetland indicator status is also given):

Andropogon virginicus	broom-sedge grass	FACU
Cladium mariscoides	twig-rush	OBL
Drosera intermedia	sundew	OBL
Eupatorium leucolepis	white-bract thorough-wort	FACW+
Euthamia tenuifolia	slender fragrant goldenrod	NOT LISTED
Juncus biflorus	grass-leaf rush	FACW
Juncus canadensis	Canada rush	OBL
Juncus dichotomus	forked rush	FACW
Juncus scirpoides	sedge rush	FACW
Lycopodium appressum	southern bog-clubmoss	FACW+

Scirpus pungens	three square sedge	OBL
Sphagnum sp.	sphagnum moss	NOT LISTED
Xyris difformis var. *difformis*	yellow-eyed grass	OBL
Vaccinium macrocarpon	cranberry	OBL

Several of the above listed signature species were also noted during Snow's survey of Delaware Atlantic coastal habitats in 1902: *Andropogon virginicus, Juncus scirpoides, Lycopodium appressum, Vaccinium macrocarpon,* and *Xyris flexuosa* (syn = *X. caroliniana, flexuosa* was likely misapplied and is treated here as *X. difformis* var. *difformis*).

Although a consistent assemblage of interdunal wetland plants are usually found, vegetational differences, or floristic variations between sites are often encountered. This is likely due to such factors as hydrology, soils, natural and unnatural disturbances, and randomness of plant dispersal events.

There is a wide variety of arenaceous species (plants growing in sand) of the surrounding dry dunes, that grade towards the wetter soils of the interdunal wetlands. Xeric vegetation, such as *Hudsonia tomentosa* (sand heather), *Solidago sempervirens* (seaside goldenrod), *Cyperus grayi* (Gray's nut-sedge), *Ammophila breviligulata* (American beach grass), *Panicum amarum* (a panic grass), *Prunus maritima* (beach plum), *Pinus thunbergii* (Japanese black pine), and *Juniperus virginiana* (red cedar) grade into a typical assemblage of mesic, wetland edge species that includes: *Rhus copallina* (winged sumac), *Toxicodendron radicans* (poison ivy), *Myrica cerifera, Ilex glabra* (inkberry), *Vaccinium corymbosum* (highbush blueberry), *Aronia arbutifolia* (chokecherry), *Acer rubrum, Prunus serotina* (black cherry), and *Liquidambar styraciflua* (sweetgum).

The following 23 plant species identified during this study are considered to be rare in the state of Delaware by the Delaware Natural Heritage Inventory (five ranked as S1, extremely rare; eleven ranked as S2, very rare; six ranked as S3, rare to uncommon; and one ranked as SU, status uncertain; (see Appendix A for further ranking criteria):

Calopogon tuberosus	grass-pink orchid	S1
Carex longii	Long's sedge	S1
Hypericum boreale	northern St. Johnswort	S1
Platanthera blephariglottis	white-fringe orchis	S1
Sabatia campanulata	slender marsh pink	S1
Bidens coronata	tickseed sunflower	S2
Centella erecta	erect coinleaf	S2
Eryngium aquaticum	button snakeroot	S2
Fuirena pumila	small umbrella sedge	S2
Panicum roanokense	a panic grass	S2
Pogonia ophioglossoides	rose-pogonia	S2

Rhynchospora gracilenta	slender beak-rush	S2
Spiranthes vernalis	spring ladies tresses	S2
Utricularia geminiscapa	hidden-fruit bladderwort	S2
Utricularia subulata	zig-zag bladderwort	S2
Xyris torta	slender yellow-eyed grass	S2
Vaccinium macrocarpon	cranberry	S3
Eleocharis quadrangulata	four-square sedge	S3
Eleocharis robbinsii	Robbin's spike-rush	S3
Fuirena squarrosa	umbrella sedge	S3
Juncus pelocarpus	brown-fruited rush	S3
Rhynchospora alba	white-bract sedge	S3
Pluchea foetida	marsh flea-bane	SU

To date, there does not appear to be any plant species that are endemic to interdunal wetlands in Delaware, however 19 of the 21 known Delaware populations for *Vaccinium macrocarpon* (cranberry) occur within interdunal wetlands along the Atlantic coast. Cranberry occurs in northern boreal bogs, Atlantic white cedar swamps, and mountain bogs of the southern Appalachians (Gleason and Cronquist 1991). Its natural range is from Newfoundland to Virginia, and in the mountains of North Carolina and Tennessee (Gleason and Cronquist 1991).

The assembly of signature plant species listed above, is actually a rather unique collection of plants for Delaware. I know of no other habitat in Delaware that consistently contains all of the species listed. A consideration of endemism to interdunal wetlands in Delaware could be given to this assemblage.

There is a high prevalence of *Juncus* species found in intedunal wetlands in Delaware, the most frequently occurring species are: *Juncus biflorus, Juncus canadensis, J. dichotomus,* and *J. scirpoides*. *J. acuminatus* (sharp-fruited rush), *J. effusus* (smooth rush), and *J. pelocarpus* (brown fruited rush) have also been recorded, but only rarely. A similar assemblage of rushes is also found in interdunal wetlands in Virginia (Jones 1992).

Interdunal wetlands in Delaware are closely related floristically to interdunal wetlands found in Virginia. Twelve characteristic signature species have been determined for Virginia (Jones 1992), of that twelve, five are also on the Delaware list shown above: *Andropogon virginicus, Drosera intermedia, Juncus biflorus, J. scirpoides,* and *Scirpus pungens*. In addition, of the 47 associated interdunal wetland species listed for Virginia (Jones 1992), 29 also occur in interdunal wetlands in Delaware. Further south of Virginia, plant species composition of interdunal wetlands change considerably, to the point where floristic relationships with Delaware are insignificant (Schafale and Weakley 1990). Plant species of interdunal wetlands of Long Island, New York, are also closely allied with Delaware. Many of the characteristic species described from Long Island (Reschke 1990) also occur in Delaware interdunal wetlands: *Cladium mariscoides, Cyperus* spp. (nut-

sedges), *Rhynchospora capitellata* (small headed beak-rush), *Juncus canadensis*, *Drosera* spp., *Vaccinium macrocarpon*, *Vaccinium corymbosum*, *Utricularia subulata*, and *Xyris torta*. North of Long Island, other than Cape Cod, Mass., dune activity is limited, and coastal wetlands are of different forms than what are usually found further south (Jones 1992).

NATURAL COMMUNITY DESCRIPTIONS

Interdunal wetlands are a broad community category with a great deal of diversity, diversity expressed in floristic associations. Diversity within the community type is primarily a result of hydroperiod. It is considered by many that depth to ground water table is the major selection factor influencing the interdunal wetland environment. Ranwell (1959), after recognizing distinct differences in the vegetation which accompanied changes in the water table depth, separated sites into "wet-vegetation" associations and "dry-vegetation" associations. Wet-vegetation associations are those in which the water table never falls below one meter from the surface throughout the season; dry-vegetation associations are those where the water table in summer, lies between one and two meters below the surface. Similar observations were made during this study; overall plant species richness and % cover were quite low when the groundwater table was measured below 15" from the surface. When the groundwater table was measured at 6-12," overall species richness and % cover increased.

To date, based on dominant vegetation present, five interdunal wetland variants are recognized in Delaware (future inventory work may identify additional community variants):

1) *Juncus scirpoides-Scirpus pungens* interdunal wetland association.

This association is the most common community variant to be found along Delaware's Atlantic coast. This type is distributed from Cape Henlopen, south to the DE-MD State line (Fig. 3, 4, 6, 7, Appendix B). Some of the best examples of this community type can be found on the Assawoman Bay quadrangle north of Fenwick Island, and on the Cape Henlopen quadrangle within Cape Henlopen State Park. The assemblage of characteristic signature plant species listed above are typically found, as well as rare plants such as *Panicum roanokense* (S2), *Spiranthes vernalis* (S2), *Utricularia subulata* (S2), *Vaccinium macrocarpon* (S3), and *Xyris torta* (S2). Where identified, NWI maps this wetland type as either: scrub/shrub, broad-leaved evergreen or narrow-leaved evergreen, or emergent, narrow-leaved persistent. Water regimes vary: saturated, temporarily flooded, seasonally flooded, and seasonally flooded/saturated.

2) *Scrub-shrub/mixed herbaceous* interdunal wetland association.

This interdunal wetland variant has been identified from three separate sites, all on the Bethany Beach quadrangle (Fig. 5, Appendix B). All three are of fairly large size (up to one acre) and are floristically diverse in regards to variations in life forms (i.e. woody and herbaceous growth). This wetland type contains scrub-shrub vegetation (woody shrubs and stunted trees) on its perimeter, which will often grade into herbaceous openings. Scrub-shrub vegetation includes the following: *Pinus rigida* (pitch pine), *Acer rubrum, Liquidambar styraciflua* (sweetgum), *Ilex glabra, Vaccinium corymbosum, Myrica cerifera, Rosa palustris* (swamp rose) and *Aronia arbutifolia*. Some of the more prevalent herbaceous vegetation that were common to all three sites includes: *Cladium mariscoides, Scirpus pungens, Euthamia tenuifolia, Juncus scirpoides, J. canadensis, Andropogon glomeratus* (bushy broomsedge), *Panicum scoparium* (velvet panic grass), *P. virgatum* (switch grass), *Prosperpinaca palustris, Lycopus virginicus* (Virginia bugleweed), *Hypericum mutilum* (dwarf St. Johns-wort), *Viola lanceolata* (lanceleaf violet), *Osmunda regalis* (royal fern), *Triadenum virginicum* (marsh St. Johns-wort), *Spartina patens,* and *Rhynchospora capitellata* (small headed beak-rush). Rare plant species identified from this community type were: *Bidens coronata* (S2), *Centella erecta* (S2), *Fuirena squarrosa* (S3), *Panicum roanokense* (S2), *Rhynchospora gracilenta* (S2) and *Vaccinium macrocarpon* (S3). These three sites have been identified by NWI, and have been mapped as scrub-shrub, broad-leaved evergreen/needle-leaved evergreen, temporarily flooded (PSS3/4A).

3) *Cladium mariscoides-Eryngium aquaticum* interdunal wetland association.

Only one site was identified for this community type; located on the Bethany Beach quadrangle, west of Rt. 1 (Fig 6, Appendix B). This site, which still lies within the ridge and swale topography of the Atlantic coast and is only interrupted by highway Rt. 1, is situated within a sandy, pitch pine (*Pinus rigida*) woodland of high quality. This wetland is an open depression, that is more concave than the typical *Juncus scirpoides-Scirpus pungens* variant. In addition to the dominant species of *Cladium mariscoides* and *Eryngium aquaticum*, the following associates are also found: *Juncus canadensis, Rhynchospora chalarocephala* (a beak-rush), *Drosera intermedia, Lycopus* sp., *Hypericum* sp., *Thelypteris palustris* (marsh fern), *Hibiscus moscheutos, Viola lanceolata, Myrica cerifera, Toxicodendron radicans* and *Rosa palustris*. Rare plant species identified included: *Eryngium aquaticum* (S2), *Sabatia campanulata* (S1), *Rhynchospora gracilenta* (S2), *Panicum roanokense* (S2) and *Pluchea foetida* (SU). This site has not been identified or mapped by NWI.

4) *Vaccinium macrocarpon-Mixed Orchid/Sphagnum* interdunal wetland association.

This interdunal wetland variant, the only one identified of its kind during this survey, is a rather small (ca 10x12 meters) site, and is located on the Cape Henlopen quadrangle within Cape Henlopen State Park (Fig. 3, Appendix B). A dense carpet of sphagnum moss and a variety of rare orchids are found; cranberry is also a common associate at this site. The rare orchids found here are: *Platanthera blephariglottis* (S1), *Calopogon tuberosus* (S1), and *Pogonia ophioglossoides* (S2). This site may have been much larger in the past; sand movement and woody plant establishment appear to have constricted the size of this wetland. A review of early aerial photographs may confirm this. This site has been mapped by NWI as emergent, narrow-leaved persistent, seasonally flooded (PEM5C).

5) *Emergent, mixed sedge/mixed scrub-shrub-mixed herbaceous peatmats* interdunal wetland association.

This site, located on the Cape Henlopen quadrangle, within Cape Henlopen State Park (Fig. 3, Appendix B), is one of the more unique wetland variants identified. The site is relatively large in area (up to one acre), is bordered by palustrine forest and dry dunes, appears to have a permanently flooded to semi-permanently flooded water regime, and has an unusual occurrence of floating peatmats on its perimeter. Data from previous field seasons (1991-92), as well as multiple visits in 1993, indicate flooded conditions year round, although surface water levels do appear to drop through the dry summer. Growing from the wetlands bottom substrate, and in standing water, are found such plants as *Cladium mariscoides, Juncus canadensis,* and *Nymphaea odorata* (fragrant waterlily). Rare plants of standing water include *Rhynchospora scirpoides* (S2), *Eleocharis quadrangulata* (S3), and *E. robbinsii* (S3). Floating mats of organic matter, or peat are found on the wetlands perimeter, which contain a mixture of scrub-shrub and herbaceous vegetation. Scrub-shrub vegetation includes *Acer rubrum, Cephalanthus occidentalis* (buttonbush), and *Decodon verticillatus* (water willow). Herbaceous plants found are *Eleocharis olivacea* (spike-rush), *Rhynchospora macrostachya* (horned rush), *R. chalarocephala* (a beak-rush), *Drosera intermedia, Sphagnum* sp., *Xyris difformis* var. *difformis,* and *Hydrocotyle umbellata* (pennywort). Rare plant species found growing on the floating peatmats include *Fuirena pumila* (S2), *Juncus pelocarpus* (S3), *Rhynchospora alba* (S3), *Hypericum boreale* (S1), *Vaccinium macrocarpon* (S3), and *Panicum roanokense* (S1). On the wetlands northern edge, an advancing sand dune is creeping into the site. A small stand of *Phragmites australis* has become established on this dune and control will be needed. NWI maps this wetland as a palustrine forested, broad-leaved deciduous wetland (PFO1C). This wetland, as delineated by Greenhorne and O'Mara Inc. (1991), is mapped as an interdunal wetland with a water regime of

intermittently exposed (HASG). Review of the DNHI database files, revealed that there are 3 similar sites immediately east of the above referenced site. Site survey summaries describe ditches leading from all three sites, and woody vegetation and *Phragmites australis* are established in all. Due to lack of time, these sites were not field checked.

WILDLIFE

Interdunal wetlands provide habitat and serve as a source of freshwater for animal species associated with coastal dune ecosystems. Brief zoological inventories have recorded frequent occurrences of the southern leopard frog (*Rana utricularia*) and the Fowler's toad (*Bufo woodhousii* var. *fowleri*) utilizing interdunal wetlands. A suite of damselfly and dragonfly species have also been collected: forktail damselfly (*Ischnura ramburi*), saltmarsh dragonfly (*Erthrodiplax berenice*), common green darner dragonfly (*Anax junius*), and the red saddlebag dragonfly (*Tramea carolina*). A variety of birds, which utilize coastal dune systems to feed and nest, were observed drinking from interdunal wetlands (terns, swallows, common night hawks, oyster catchers and shore birds). Interdunal wetlands may also be used by migrating waterfowl. Small depressions, void of vegetation, found within interdunal wetlands were noted in a few sites sampled. This observation suggests rooting by waterfowl for underground plant rhizomes and tubers. Deer and rabbit tracks have also been noted in the moist sand of interdunal wetlands, an indication that these species are using the wetlands as a source for freshwater. More zoological inventory work is certainly needed in interdunal wetlands to assess the full extent of wildlife use.

THREATS

Threats to fragile dune ecosystems are many, but one that has caused the greatest amount of habitat loss is development. Delaware's Atlantic coast is a popular and attractive area to live, and the leveling of dunes for homes has been, and continues to be, the major threat to intact natural dune systems.

Hydrologic studies have shown that excessive ground water pumping can result in serious negative impacts to interdunal wetlands (Whittecar and Emery 1992). Large groundwater withdrawal from aquifers connected to interdunal wetland systems will cause these wetlands to gradually dry-out, or become saline if brackish water intrudes into the freshwater lens (Odum and Harvey 1988, Whittecar and Emery 1992).

Ditching, and attempts at draining interdunal wetlands is another serious threat to their ecological integrity. Parallel ditches were found at each of the three *scrub-shrub/mixed herbaceous* community

variants on the Bethany Beach quadrangle. It is difficult to determine from only one year of study what impacts may have resulted from ditching, but negative impacts to hydrology have likely occurred.

The construction of dune crossings, from parking areas to the beach, have been documented as a real threat to interdunal wetlands. A pedestrian crossing at Cape Henlopen State Park was discovered to be bisecting through the center of an interdunal wetland. Fortunately, with the help of park personnel, the crossing was rerouted to eliminate impacts. Mapping of Delaware's Category I coastal dune wetlands is critical, so that agencies involved in beach and dune activities can be made aware of their locations.

Dune restoration is also a potential threat to interdunal wetlands. Depending on the location, dune ridges breached or destroyed during severe storms are often rebuilt. If bulldozers are used in restoration efforts, there is high potential for severe disturbance to interdunal wetlands. Again, this is clearly another example of why the mapping of interdunal Category I wetlands is important.

A series of interdunal wetlands found on the Rehoboth Beach quadrangle, were modified by the Delaware Division of Fish and Wildlife, Mosquito Control during the years of 1980 and 1981 (Saveikis pers. comm. 1994). As part of Mosquito Controls Open Marsh Water Management (OMWM), existing interdunal wetlands were dredged deeper (ca 2-2.5ft.) to create perennial "ponds" for mosquito eating fish to reside in. Shallow, blind ditches leading from these wetlands were also constructed, to allow fish to swim up them and devour mosquitos; these activities have changed the ecology and community structure of the wetlands involved. Some levels of standing water are usually found year round now, and weedy taxa have become established. Overall plant diversity is lower within these wetlands and *Phragmites australis* has invaded several of them. The salt tolerant plant species *Spartina patens, Eleocharis parvula* and *Distichlis spicata* have also been found in a few sites sampled. This may indicate possible brackish water intrusion into the freshwater lens due to dredging. Although modification and disturbance has taken place within these wetlands, they should still be considered and mapped as Category I wetlands, although OMWM practices within interdunal wetlands should be discontinued. Category I consideration is still given, because of their physiographic position on the landscape (i.e. Atlantic coastal ridge and swale topography), they continue to function as interdunal wetlands (i.e. groundwater recharge, habitat for wildlife), many still contain some of the characteristic signature plant species, as well as state rare species, which include *Fuirena pumila* (S2) and *Utricularia subulata* (S2). The possibility also remains that natural, dynamic processes involved in the formation and serial stages of succession of interdunal wetlands will "naturally restore" these sites. Wetlands that have been disturbed by OMWM practices are lumped into the *Juncus scirpoides-Scirpus*

pungens community variant. Undisturbed examples of this community type are still found within the area, and OMWM sites were likely of this wetland type before modification. These wetlands can be identified and located on aerial photographs by their relatively regular shape, and by the straight, blind ditches which radiate from them.

The invasion and establishment of the aggressive plant species *Phragmites australis* is also a serious threat to interdunal wetlands. Several wetlands sampled either contained some degree of infestation, or were completely dominated by *P. australis*. Invasion of *P. australis* usually follows a disturbance, such as dredging and filling, or artificial changes to the groundwater table, usually from withdrawal from the aquifer. *P. australis* will also find favorable conditions for establishment if an increase in salinity levels of a wetland occurs. As mentioned above, excessive groundwater pumping can lead to brackish water intrusion. Control measures such as chemical treatment or burning should be applied to any interdunal wetland found to be infested with *P. australis*.

JUSTIFICATION FOR CATEGORY I RANKING

As presented here, there are many reasons to justify the designation of interdunal wetlands in Delaware as Category I.

Interdunal wetlands may be relatively common when considering their overall, regional distribution (Massachusetts to Florida), but like all coastal and barrier island natural communities, they are limited in their local extent (Shafale and Weakley 1990). In Delaware, interdunal wetlands have a very narrow and local county distribution (limited to the Atlantic coastal strand and barrier islands of Sussex County, Cape Henlopen south to the DE-MD state line).

Interdunal wetlands are situated within the geologically unique ridge and swale topography of the fragile Atlantic coast.

Complex, dynamic natural processes work to form and create interdunal wetlands, and are an integral part of coastal dune ecosystems.

Interdunal wetlands are significant, in that they are primarily groundwater driven, and community structure is a function of groundwater level fluctuations.

Interdunal wetlands are unique, in that they are freshwater, non-tidal wetland systems, that are geographically bordered by tidal, saline wetland systems.

Interdunal wetlands in Delaware harbor numerous state rare plant species; 23 plant species considered to be rare by DNHI have been

identified: five ranked as S1, extremely rare; eleven ranked as S2, very rare; six ranked as S3, rare to uncommon; and one ranked as SU, status uncertain.

Interdunal wetlands in Delaware contain a unique assemblage of characteristic "signature" plant species. An assemblage that may be restricted to interdunal wetlands in the State.

Interdunal wetlands at the community level are variable, but their variation is distinct. Five community variants have been recognized and two could be considered rare in the state, with only a single occurrence for both.

Interdunal wetlands provide habitat and serve as a source of freshwater for animal species associated with coastal dune systems.

Interdunal wetlands in Delaware are vulnerable to a number of defined threats, which are listed in detail above.

CATEGORY I MAPPING CRITERIA

Maps provided in Appendix B will direct aerial interpreters to known, field documented interdunal wetlands, so that a "signature" can be developed for identification. Symbols designating interdunal wetlands found on site maps are only an approximation of their location and are not meant to be their exact location.

When a signature for interdunal wetlands has been determined, any area identified with such a signature, that is found within the Atlantic interdunal ecosystem from Cape Henlopen, south to the DE-MD state line, should be mapped as Category I.

The Atlantic coastal interdunal ecosystem in Delaware, is here defined as: an area approximately 0.5 mile inland, behind primary dune ridges of the Atlantic coastal region, from Cape Henlopen south to the DE-MD state line. However, there are active dune areas (vegetated and unvegetated) beyond the ca 0.5 mile boundary on the Cape Henlopen quadrangle, where interdunal wetlands have been identified (Fig. 3, Appendix B). This area is also considered to be within the Atlantic coastal interdunal ecosystem.

The Delaware highway Rt. 1 only artificially interrupts the interdunal system and does not delineate a boundary; interdunal wetlands have been identified west of Rt. 1.

Interdunal wetlands appear as dark, glossy spots on aerial photographs that can sometimes be difficult to distinguish from island clumps of scrub-shrub vegetation. Interdunal wetlands that are surrounded by woody vegetation may also be difficult to identify.

Aerial interpreters must be aware that some interdunal wetlands may be dominated by *Phragmites australis,* which may present problems in identification.

Wetlands that have been modified by OMWM practices (see above discussion under Threats) can be identified and located on aerial photographs by their relatively regular shape, and by the straight, blind ditches which radiate from them.

The mapping of interdunal wetlands should be a dynamic process of updating (i.e. adding and deleting), just as the interdunal wetland is a dynamic system in itself. The discussion found above dealing with the dynamics and succession of interdunal wetlands should be seriously considered. Unvegetated, or sparsely vegetated moist areas, may be missed by aerial interpreters (as well as by field investigators), but they may be interdunal wetlands in very early stages of formation. Conversely, interdunal wetlands initially mapped as Category I, may disappear due to natural disturbance processes.

It is recommended that field verification of interdunal wetlands be done before the mapping process is completed. As implied above, potential exists for misidentification during aerial interpretation. The community classifications, descriptions, and list of characteristic signature plant species described within, should be used as guidelines for field determinations.

It has been found, in the field, that specific areas possessing an interdunal wetland photographic signature (i.e. flooded conditions), may lack or even be completely devoid of characteristic interdunal wetland vegetation. These areas would likely not meet jurisdictional criteria as a wetland (since wetland vegetation is not present) and should not be mapped as a Category I wetland at this time. However, as recommended above, aerial interpretation and future ground verification, may find that sites such as these have succeeded to mature interdunal wetlands and should then be mapped accordingly.

It is also recommended that before wetland maps are made public, the DNHI should be given the opportunity to refine Category I boundaries, or to include known sites that may have been missed through aerial interpretation.

A freshwater wetlands map of an area of the Cape Henlopen quadrangle (produced by Greenhorne and O'Mara Inc., 1991), identifies many of the interdunal wetlands located in this area during this survey, as well as from previous surveys. However, many were misidentified, or were missed entirely. This is likely due to the fact that a community description for interdunal wetlands was not yet developed, and mapping criteria had also not been determined.

LITERATURE CITED AND RELATED SCIENTIFIC REFERENCES

Breden, T.F. 1989 A preliminary natural community classification for New Jersey. New Jersey's rare and Endangered Plants and Animals. E.F. Karlin, editor. Institute for Environmental Studies, Ramapo College, Mahwah, NJ. 280 pp.

Brown M.L. and R.G. Brown. 1984. Herbaceous plants of Maryland. University of Maryland, College Park, Maryland.

Clemants, S.E. 1990. Juncaceae (Rush Family) of New York State. Contributions to a Flora of New York State VII, R. Mitchell, Editor. Bulletin No. 475. New York State Museum, Albany, New York.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Biological Services Program. FWS/OBS-79/31, 103 pp.

Delaware Natural Heritage Inventory database. 1988-1992.

Gleason, H.A. 1952. The new Britton and Brown illustrated flora of the northeastern United States and adjacent Canada. Vol. I-III. Hafner Press, New York.

Gleason, H.A. and A. Cronquist. 1991. Manual of vascular plants of the Northeast and adjacent Canada, second edition. The New York Botanical Garden, New York.

Greenhorne and O'Mara. 1991. State of Delaware Freshwater Wetlands Inventory Pilot Project. Prepared for Delaware Department of Natural Resources and Environmental Control, Dover, DE.

Godfrey, R.K. and J.W. Wooten. 1979. Aquatic and wetland plants of the Southeastern United States, monocotyledons. The University of Georgia Press, Athens, Georgia.

Jones, H.A. 1992. A vegetational analysis of interdunal swale communities of False Cape State Park, Currituck Spit, Virginia. Masters Thesis. The College of William and Mary, Virginia.

Kelly, A.P. 1925. Soil water of the New Jersey coast. Ecology 6(2):143-149.

Kearney, T.H. 1904. Are plants of sea beaches and dunes true halophytes?. Botanical Gazette June:424-436.

Martin, W.E. 1958. The vegetation of Island Beach State Park, New Jersey. Ecological Monographs 29(1):1-46.

National Wetland Inventory Maps. 1977, 1981. 1:24,000. U.S. Fish and Wildlife Service, Washington, D.C.

Odum, W.E. and J.W. Harvey. 1988. Barrier island interdunal freshwater wetlands. ASB Bulletin 35(4):149-155.

Oosting, H.J., and W.D. Billings. 1942. Factors affecting vegetational zonation on coastal dunes. Ecology 23:131-142.

Ranwell, D. 1959. Newborough Warren, Anglesey. I. The dune system and dune slack habitat. Ecology 47:571-601.

Ranwell, D. 1960. Newborough Warren, Anglesey. II. Plant associes and succession cycles of the sand dune and dune slack vegetation. Ecology 48:117-141.

Reed, P.B. 1988. National list of plant species that occur in wetlands: Northeast (Region 1). U.S. Fish and Wildlife Service, Washington, D.C.

Reschke, C. 1990. Ecological communities of New York State. New York Natural Heritage Inventory Program. New York State Department of Environmental Conservation. Latham, New York.

Schafale, M. P. and A.S. Weakley. 1990. A classification of natural communities of North Carolina, 3rd Approximation. North Carolina Natural Heritage Program, Division of Parks and Recreation. North Carolina Department of Environment, Health, and Natural Resources.

Seliskar, D.M. 1986. Waterlogging and sand deposition in dune slack vegetation: plant morphology and ethylene production. Doctoral Thesis. University of Delaware, College of Marine Studies, Lewes, Delaware.

Snow, L.M. 1902. Some notes on the ecology of the Delaware coast. The Bot. Gaz. 34:284-306.

Stetzar, E.J. and L.A. Gelvin-Innvaer. 1992. Delaware bog turtle project, 1992 progress report. Nongame and Endangered Species Program, Division of Fish and Wildlife, DNREC, Dover, Delaware.

Tiner, R.W. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service, Region 5. Delaware Department of Natural Resources and Environmental Control, Dover, Delaware.

Tyndall, R. W. and G.F. Levy. 1978. Plant distribution and succession within interdunal depressions on a Virginia barrier dune system. J. Elisha Mitchell Scientific Society 49(1):1-15.

APPENDIX A

PLANT SPECIES ASSOCIATED WITH INTERDUNAL WETLANDS OF DELAWARE'S ATLANTIC COAST

USDA Soil Conservation Service, Soil Survey, Sussex County, Delaware. 1974. Washington, D.C.

U.S.G.S. Topographical Maps, 1:24,000. Cape Henlopen (1984), Rehoboth Beach (1984), Bethany Beach (1984), Assawoman Bay (1967, photorevised 1981).

Whittecar, R.G. and J.S. Emery. 1992. Hydrogeology of a regressive barrier island segment, Bodie Island, North Carolina. Barrier Island Ecology of the Mid-Atlantic coast: A Symposium. National Park Service, Southeast Regional Office, Atlanta Georgia.

PLANT SPECIES ASSOCIATED WITH INTERDUNAL WETLANDS OF DELAWARE'S ATLANTIC COAST 1993

This list is not meant to be comprehensive; further inventory work may result in additional species being added. This list is composed of 37 families of vascular plants (including 4 pteridophytes and 1 gymnosperm), 71 genera (including 3 mosses), 108 species (including 3 mosses), and 3 varieties. Herbaceous taxa includes 95 species and 3 varieties, and woody taxa comprise 15 species. Nomenclature generally follows Gleason and Cronquist's (1991) *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. Where this differs from the treatment in Gleason and Cronquist, the name used in that work is indicated in parentheses (see state ranking and frequency class criteria below).

Scientific Name	Common Name	State Rank	Frequency
Herbaceous Taxa:			
Ambrosia artemisifolia	rag-weed	S5	1
Ammophila breviligulata	American beach grass	S5	1
Andropogon glomeratus (*virginicus* var. *abbreviatus*)	bushy broom-sedge grass	S5	1
Andropogon virginicus	broom-sedge grass	S5	3
Bidens coronata	tickseed sunflower	S2	1
Calopogon tuberosus	grass-pink orchid	S1	1
Campylium sp.	a moss	?	1
Carex canescens	a sedge	S4	1
Carex longii	Long's sedge	S1	1
Centella erecta	erect coinleaf	S2	1
Cladium mariscoides	twig-rush	S4	3
Cyperus filicinus	nut-sedge	S4	1
Decodon verticillatus	water willow	S5	1
Diodia virginiana	virginia buttonweed	S4	1
Distichlis spicata	seashore salt-grass	S5	1
Drosera intermedia	sundew	S5	3
Dulichium arundinaceum	a sedge	S5	1
Echinochloa walterii	Walter's millet	S5	1
Eleocharis olivacea (*flavescens* var. *olivacea*)	spike-rush	S5	2
Eleocharis palustris	spike-rush	S5	1
Eleocharis parvula	saltmarsh spike-rush	S5	1
Eleocharis quadrangulata	four square sedge	S3	1
Eleocharis robbinsii	Robbin's spike-rush	S3	1
Eleocharis tuberculosa	tuberculed spike-rush	S4	1
Erianthus giganteus	giant plume-grass	S5	1
Eryngium aquaticum	button snakeroot	S2	1
Eupatorium hyssopifolium	hyssop-leaf thorough-wort	S5	1
Eupatorium leucolepis	white-bract thorough-wort	S4	3
Eupatorium rotundifolium	round-leaf thorough-wort	S5	1
Eupatorium rotundifolium var. *ovatum*	hairy thorough-wort	S5	1
Euthamia tenuifolia	slender fragrant goldenrod	S5	3
Fimbristylis autumnalis	fall fimbry	S5	1
Fimbristylis castanea	salt-marsh fimbry	S5	1
Fuirena pumila	small umbrella grass	S2	1
Fuirena squarrosa	umbrella grass	S3	1
Hibiscus moscheutos	marsh mallow	S5	1
Hydrocotyle umbellata	pennywort	S5	1
Hypericum boreale	northern St. Johnswort	S1	1
Hypericum canadense	Canada St. Johnswort	S5	2
Hypericum mutilum	dwarf St. Johnswort	S5	2
Hypericum stans	St. Peterswort	S4	1
Juncus acuminatus	sharp-fruited rush	S5	1
Juncus biflorus	grass-leaf rush	S4	3
Juncus canadensis	Canada rush	S5	3

Juncus dichotomus (*tenuis* var. *dichotomus*)	forked rush	S5	3
Juncus effusus	smooth rush	S5	1
Juncus pelocarpus	brown fruited rush	S3	1
Juncus scirpoides	sedge rush	S5	4
Leersia oryzoides	rice cut-grass	S5	1
Lindernia dubia var. *anagallidea*	slender false pimpernel	S4	1
Ludwigia alternifolia	common seedbox	S5	1
Ludwigia palustris	water purslane	S5	1
Lycopodium appressum	southern bog-clubmoss	S4	3
Lycopus virginicus	Virginia bugleweed	S5	1
Lysimachia terrestris	swamp candles	S4	1
Mikania scandens	climbing hempweed	S5	1
Nymphaea odorata	fragrant waterlily	S5	1
Osmunda regalis	royal fern	S5	2
Panicum longifolium	panic grass	S4	1
Panicum scoparium	velvet panic grass	S5	2
Panicm verrucosum	panic grass	S5	1
Panicum virgatum	switch grass	S5	2
Panicum roanokense (*dichotomum*)	panic grass	S2	1
Phragmites australis	common reed	S5	3
Platanthera blephariglottis	white-fringe orchis	S1	1
Pluchea foetida	marsh flea-bane	SU	2
Pluchea odorata	saltmarsh flea-bane	S5	2
Pogonia ophioglossoides	rose pogonia	S2	1
Polygonum caespitosum	long-bristled smart-weed	S5E	1
Polygonum hydropiperoides	mild water-pepper	S5	1
Polytrichum sp.	a moss	?	2
Proserpinaca palustris	mermaid weed	S5	2
Rhexia virginica	meadow beauty	S5	2
Rhynchospora alba	white-bract beak-rush	S3	1
Rhynchospora chalarocephala	a beak-rush	S4	1
Rhynchospora capitellata	small headed beak-rush	S5	2
Rhynchospora gracilenta	slender beak-rush	S2	1
Rhynchospora macrostachya	horned rush	S4	1
Rhynchospora scirpoides	long-beaked bald-rush	S2	1
Sabatia campanulata	slender marsh pink	S1	1
Scirpus cyperinus	wool grass sedge	S5	1
Scirpus pungens	three square sedge	S5	4
Solidago fistulosa	pine-barren goldenrod	S5	2
Solidago sempervirens	sea-side goldenrod	S5	2
Sphagnum sp.	sphagnum moss	?	3
Spartina patens	salt hay	S5	2
Spiranthes cernuua	nodding ladies-tresses	S4	1
Spiranthes vernalis	spring ladies-tresses	S2	1
Thelypteris palustris	marsh fern	S5	1
Triadenum virginicum	marsh St. Johns-wort	S5	2
Utricularia geminiscapa	hidden-fruit bladderwort	S2	1
Utricularia subulata	zig-zag bladderwort	S2	2
Viola lanceolata	lanceleaf violet	S5	2
Woodwardia virginica	Virginia chain-fern	S5	1
Xyris difformis var. *difformis*	yellow-eyed grass	S4	3
Xyris torta	slender yellow-eyed grass	S2	1

Woody Taxa:

Acer rubrum	red maple	S5	2
Aronia arbutifolia	chokeberry	S5	1
Baccharis halimifolia	high-tide bush	S5	1
Cephalanthus occidentalis	buttonbush	S5	1
Decodon verticillatus	water willow	S5	1
Ilex glabra	inkberry	S5	1
Liquidambar styraciflua	sweetgum	S5	1

Myrica cerifera	bayberry	S5	2
Pinus rigida	pitch pine	S4	1
Prunus serotina	black cherry	S5	1
Rhus copallina	winged sumac	S5	2
Rosa palustris	swamp rose	S5	1
Toxicodendron radicans	poison ivy	S5	1
Vaccinium corymbosum	highbush blueberry	S5	2
Vaccinium macrocarpon	cranberry	S3	3

Frequency Class: (based on 40 survey sites)

1 (1-5 occurrences, rare)
2 (6-13 occurrences, infrequent)
3 (14-26 occurrences, frequent)
4 (27-40 occurrences, common)

State Ranking Criteria:

S1 Extremely rare; typically 5 or fewer known occurrences in the state; or only a few remaining individuals; may be especially vulnerable to extirpation.

S2 Very rare; typically between 6 and 20 known occurrences; may be susceptible to becoming extirpated.

S3 Rare to uncommon; typically 21 to 50 known occurrences; S3 ranked species are not yet susceptible to becoming extirpated in the state, but may be if additional populations are destroyed.

S4 Common; apparently secure under present conditions; typically 51 or more known occurrences, but may be fewer with many large populations; usually not susceptible to immediate threats.

S5 Very common; demonstrably secure under present conditions.

SU Status uncertain; an uncommon species, but data is inadequate to determine rarity.

E Exotic in the state, not a part of the native flora.

WETLAND INDICATOR STATUS OF PLANT SPECIES ASSOCIATED WITH INTERDUNAL WETLANDS OF DELAWARE'S ATLANTIC COAST
(based on National List of Wetland Plants, Reed 1988)

Scientific Name	Common Name	Wetland Indicator Status
Herbaceous Taxa:		
Ambrosia artemisifolia	rag-weed	FACU
Ammophila breviligulata	American beach grass	FACU
Andropogon glomeratus (*virginicus* var. *abbreviatus*)	bushy broom-sedge grass	FACW+
Andropogon virginicus	broom-sedge grass	FACU
Bidens coronata	tickseed sunflower	OBL
Calopogon tuberosus	grass-pink orchid	FACW+
Campylium sp.	a moss	NOT LISTED
Carex canescens	a sedge	OBL
Carex longii	Long's sedge	OBL
Centella erecta	erect coinleaf	FACW
Cladium mariscoides	twig-rush	OBL
Cyperus filicinus	nut-sedge	OBL
Decodon verticillatus	water willow	OBL
Diodia virginiana	virginia buttonweed	FAC
Distichlis spicata	seashore salt-grass	FACW
Drosera intermedia	sundew	OBL
Dulichium arundinaceum	a sedge	OBL
Echinochloa walterii	Walter's millet	FACW
Eleocharis olivacea (*flavescens* var. *olivacea*)	spike-rush	OBL
Eleocharis palustris	spike-rush	OBL
Eleocharis parvula	saltmarsh spike-rush	OBL
Eleocharis quadrangulata	four square sedge	OBL
Eleocharis robbinsii	Robbin's spike-rush	OBL
Eleocharis tuberculosa	tuberculed spike-rush	OBL
Erianthus giganteus	giant plume-grass	FACW+
Eryngium aquaticum	button snakeroot	OBL
Eupatorium hyssopifolium	hyssop-leaf thorough-wort	NOT LISTED
Eupatorium leucolepis	white-bract thorough-wort	FACW+
Eupatorium rotundifolium	round-leaf thorough-wort	FAC-
Eupatorium rotundifolium var. *ovatum*	hairy thorough-wort	NOT LISTED
Euthamia tenuifolia	slender fragrant goldenrod	NOT LISTED
Fimbristylis autumnalis	fall fimbry	FACW+
Fimbristylis castanea	salt-marsh fimbry	OBL
Fuirena pumila	small umbrella grass	OBL
Fuirena squarrosa	umbrella grass	OBL
Hibiscus moscheutos	marsh mallow	OBL
Hydrocotyle umbellata	pennywort	OBL
Hypericum boreale	northern St. Johnswort	OBL
Hypericum canadense	Canada St. Johnswort	FACW
Hypericum mutilum	dwarf St. Johnswort	FACW
Hypericum stans	St. Peterswort	FACU
Juncus acuminatus	sharp-fruited rush	OBL
Juncus biflorus	grass-leaf rush	FACW
Juncus canadensis	Canada rush	OBL
Juncus dichotomus (*tenuis* var. *dichotomus*)	forked rush	FACW
Juncus effusus	smooth rush	FACW+
Juncus pelocarpus	brown fruited rush	OBL
Juncus scirpoides	sedge rush	FACW
Leersia oryzoides	rice cut-grass	OBL
Lindernia dubia var. *anagallidea*	slender false pimpernel	OBL

Ludwigia alternifolia	common seedbox	FACW+
Ludwigia palustris	water purslane	OBL
Lycopodium appressum	southern bog-clubmoss	FACW+
Lycopus virginicus	Virginia bugleweed	OBL
Lysimachia terrestris	swamp candles	OBL
Mikania scandens	climbing hempweed	FACW+
Nymphaea odorata	fragrant waterlily	OBL
Osmunda regalis	royal fern	OBL
Panicum longifolium	panic grass	OBL
Panicum scoparium	velvet panic grass	FACW
Panicm verrucosum	panic grass	FACW
Panicum virgatum	switch grass	FAC
Panicum roanokense (dichotomum)	panic grass	FAC
Phragmites australis	common reed	FACW
Platanthera blephariglottis	white-fringe orchis	NOT LISTED
Pluchea foetida	marsh flea-bane	OBL
Pluchea odorata	saltmarsh flea-bane	NOT LISTED
Pogonia ophioglossoides	rose pogonia	OBL
Polygonum caespitosum	long-bristled smart-weed	FACU-
Polygonum hydropiperoides	mild water-pepper	OBL
Polytrichum sp.	a moss	NOT LISTED
Proserpinaca palustris	mermaid weed	OBL
Rhexia virginica	meadow beauty	OBL
Rhynchospora alba	white-bract beak-rush	OBL
Rhynchospora chalarocephala	a beak-rush	OBL
Rhynchospora capitellata	small headed beak-rush	OBL
Rhynchospora gracilenta	slender beak-rush	OBL
Rhynchospora macrostachya	horned rush	OBL
Rhynchospora scirpoides	long-beaked bald-rush	OBL
Sabatia campanulata	slender marsh pink	FACW
Scirpus cyperinus	wool grass sedge	FACW+
Scirpus pungens	three square sedge	OBL
Solidago fistulosa	pine-barren goldenrod	FACW
Solidago sempervirens	sea-side goldenrod	FACW
Sphagnum sp.	sphagnum moss	NOT LISTED
Spartina patens	salt hay	FACW+
Spiranthes cernuua	nodding ladies-tresses	FACW
Spiranthes vernalis	spring ladies-tresses	FAC
Thelypteris palustris	marsh fern	NOT LISTED
Triadenum virginicum	marsh St. Johns-wort	OBL
Utricularia geminiscapa	hidden-fruit bladderwort	OBL
Utricularia subulata	zig-zag bladderwort	OBL
Viola lanceolata	lanceleaf violet	OBL
Woodwardia virginica	Virginia chain-fern	OBL
Xyris difformis var. difformis	yellow-eyed grass	OBL
Xyris torta	slender yellow-eyed grass	OBL

Woody Taxa:

Acer rubrum	red maple	FAC
Aronia arbutifolia	chokeberry	FACW
Baccharis halimifolia	high-tide bush	FAC-
Cephalanthus occidentalis	buttonbush	OBL
Decodon verticillatus	water willow	OBL
Ilex glabra	inkberry	FACW-
Liquidambar styraciflua	sweetgum	FAC
Myrica cerifera	bayberry	FAC
Pinus rigida	pitch pine	FACU
Prunus serotina	black cherry	FACU
Rhus copallina	winged sumac	UPL
Rosa palustris	swamp rose	OBL
Toxicodendron radicans	poison ivy	FAC
Vaccinium corymbosum	highbush blueberry	FACW-
Vaccinium macrocarpon	cranberry	OBL

APPENDIX B

FIGURES

MAP LEGEND
(natural community variants)

● - *Juncus scirpoides-Scirpus pungens* association

■ - *Scrub-shrub/mixed herbaceous* association

▼ - *Cladium mariscoides-Eryngium aquaticum* association

⬢ - *Mixed orchid/Sphagnum-Vaccinium marcrocarpon* association

▲ - *Emergent, mixed sedge/mixed scrub-shrub-mixed herbaceous* association

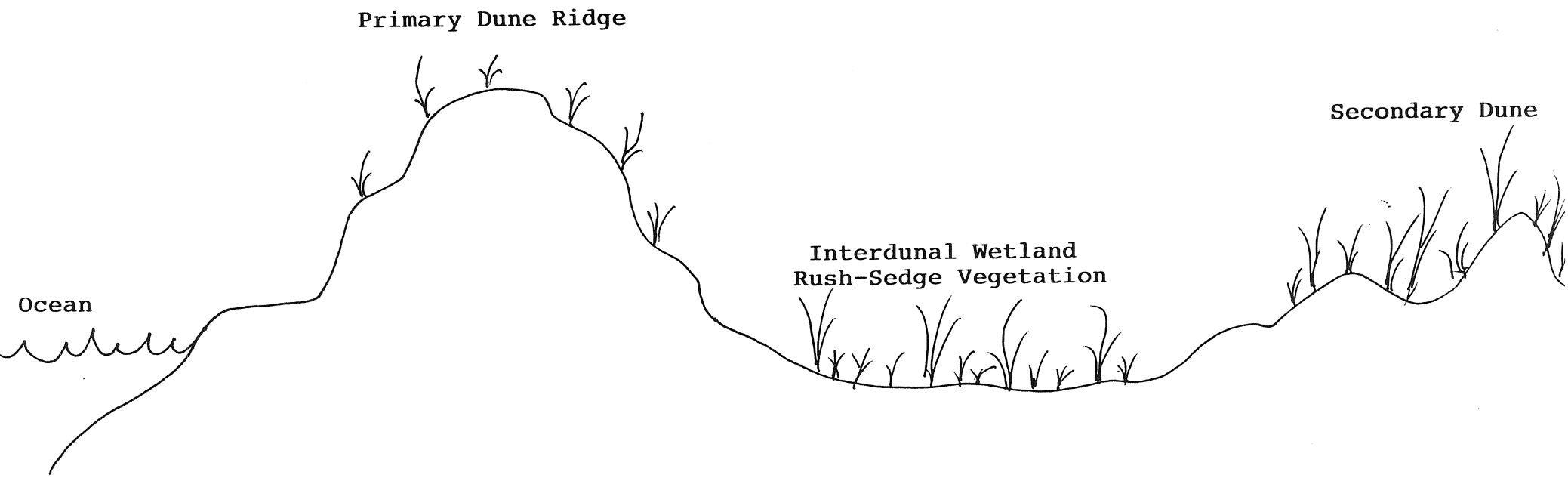

Figure 1: profile of a typcal iterdunal wetland in Delaware

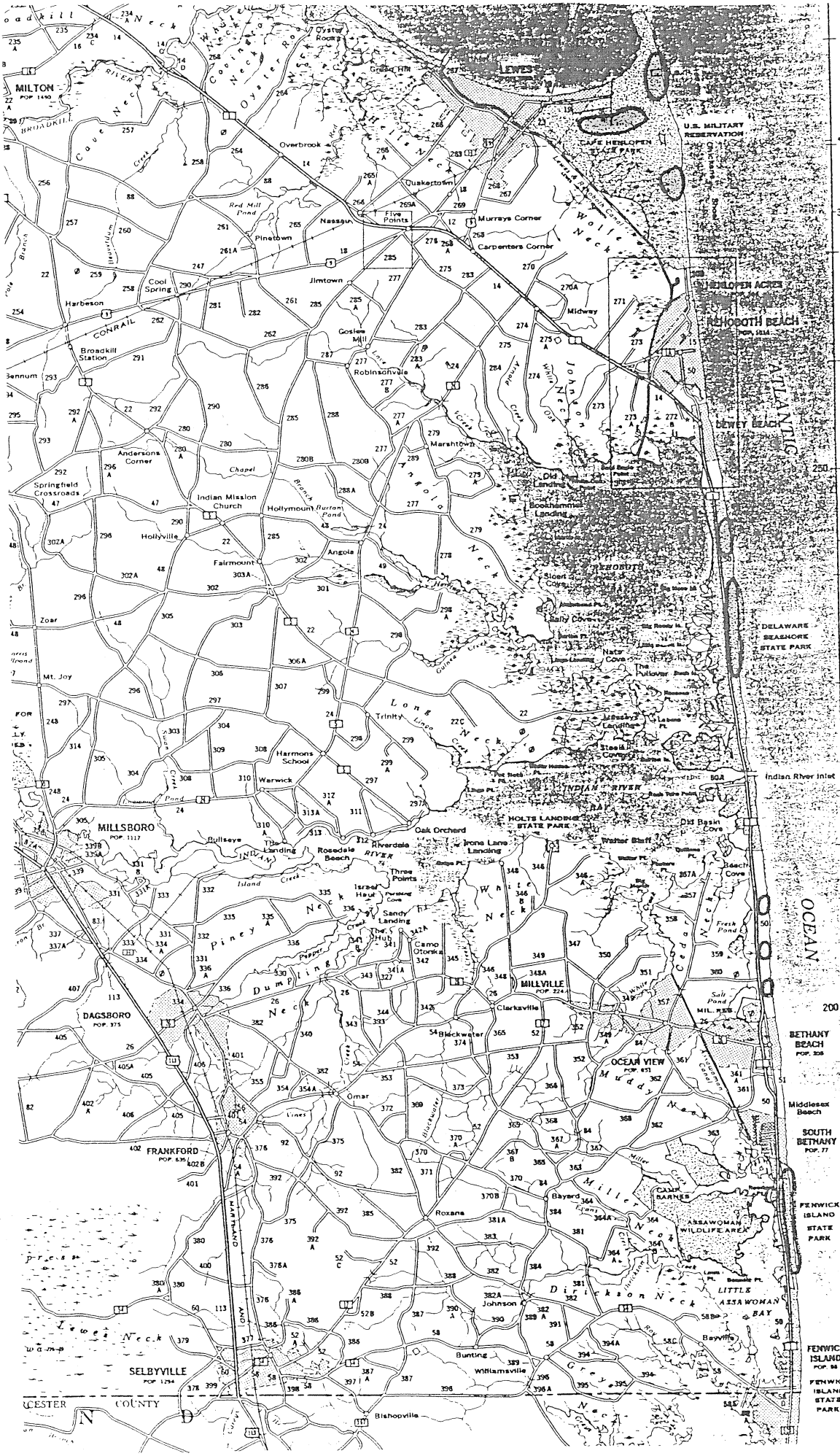

Figure 2: General, overall known distribution of interdunal

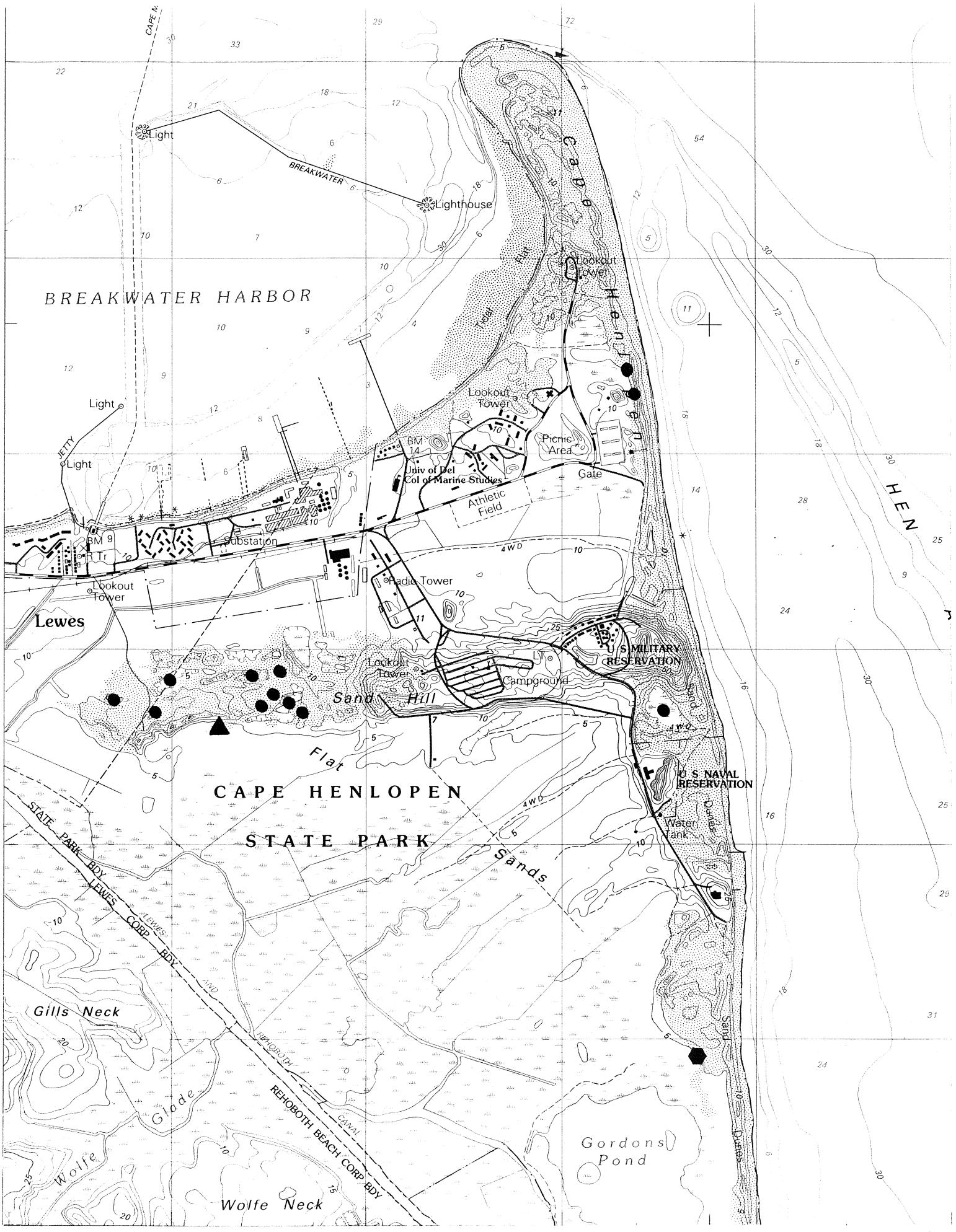

Figure 3: Cape Henlopen quadrangle

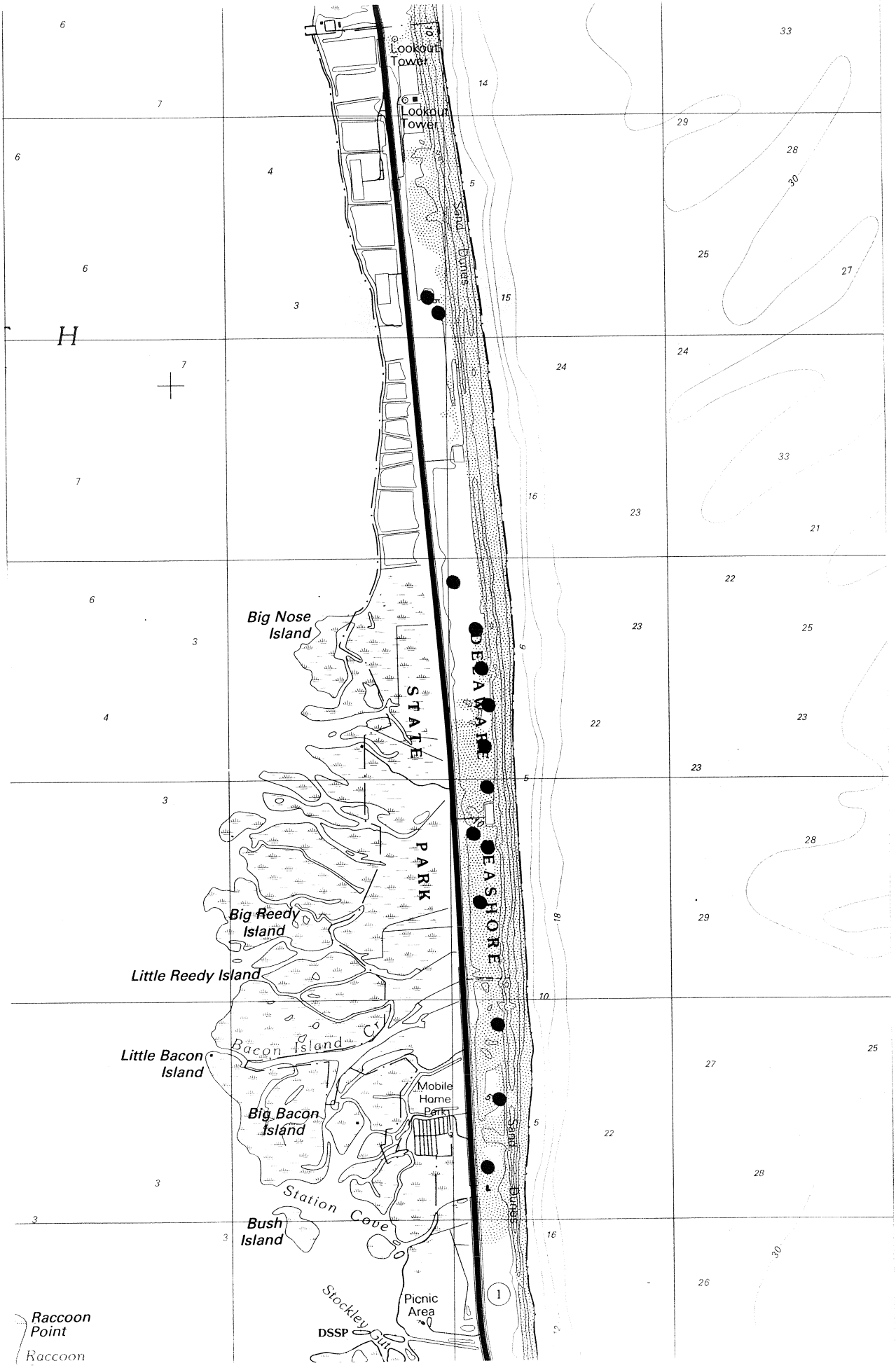

Figure 4: Rehoboth Beach quadrangle

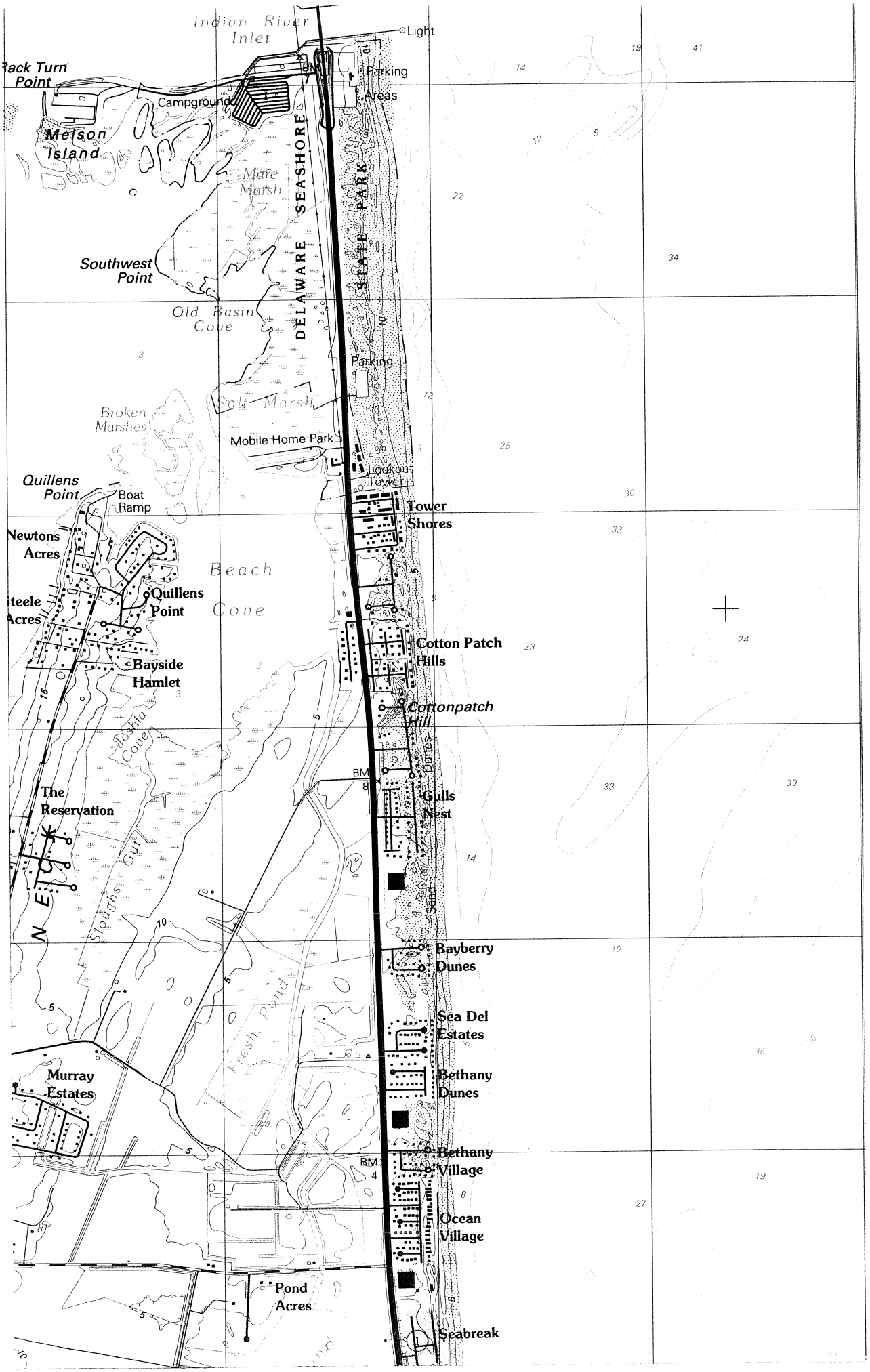

Figure 5: Bethany Beach quadrangle

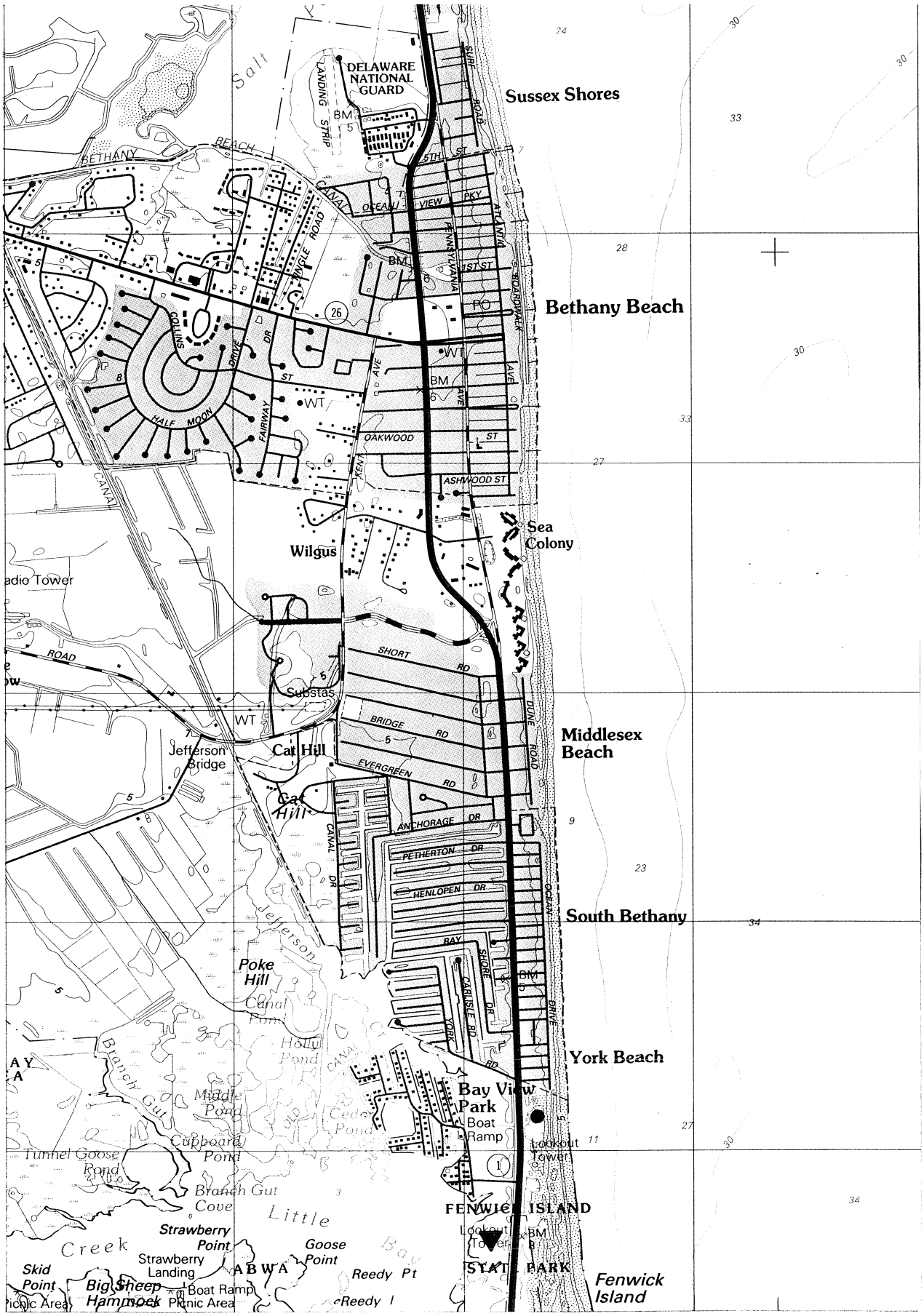

Figure 6: Bethany Beach quadrangle

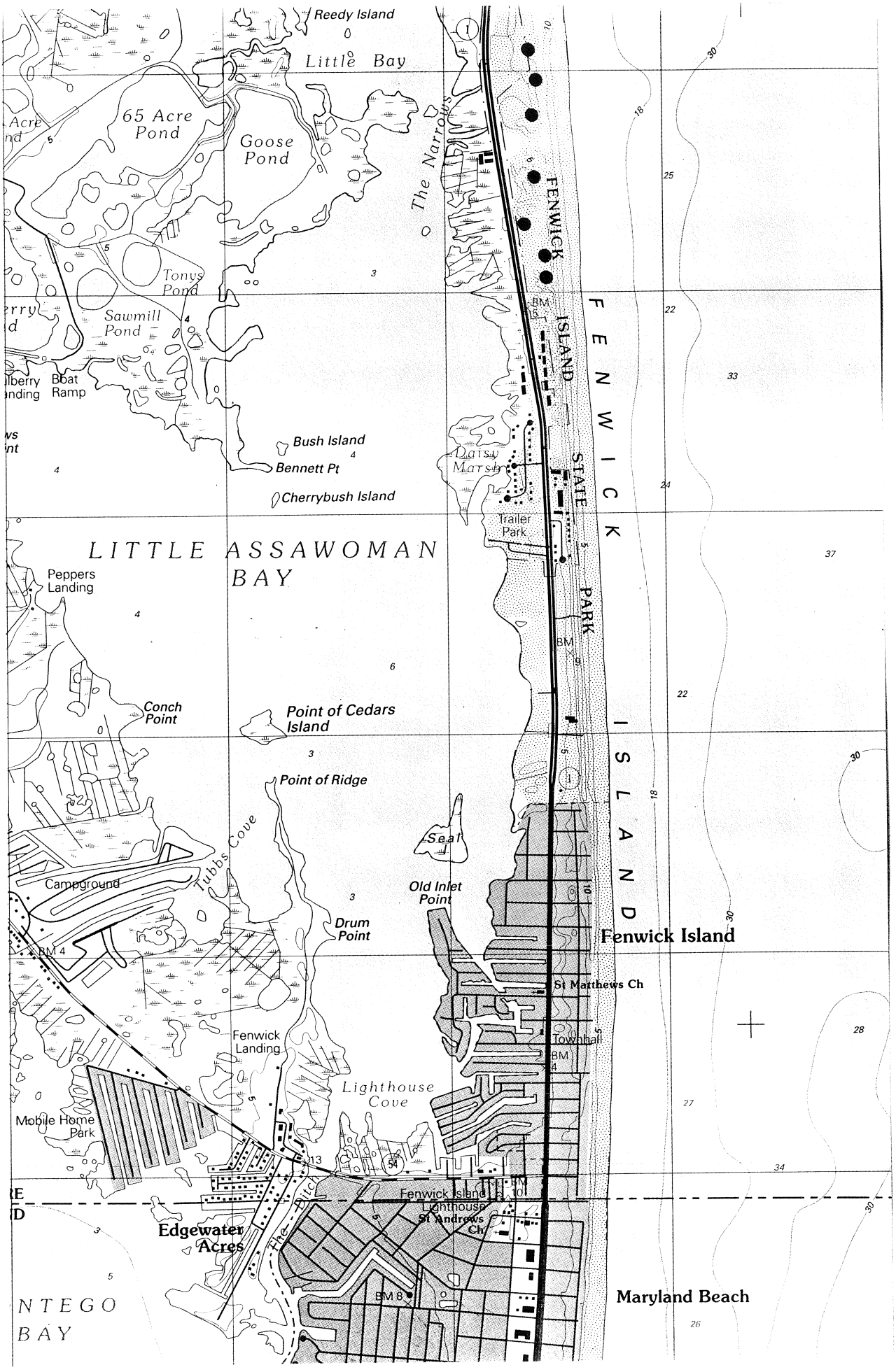

Figure 7: Assawoman Bay quadrangle

PART II. COASTAL PLAIN POND WETLANDS

INTRODUCTION

Coastal Plain Ponds (also known as Carolina or Delmarva bays, whale wallows, pot holes, seasonal ponds, etc.) are characterized as isolated, non-alluvial wetlands that are often elliptically-shaped (but also ovate, or round-shaped) shallow depressions. Topographically, bays (bays and coastal plain ponds will be used interchangeably throughout this report) may exhibit a prominent rim which is most pronounced along the southeast side, or bays may have subtle or non-detectable rims. Bays are frequently oriented with their long axis along a northwest-southeast alignment. Many of the bays are irregularly flooded; these sometimes are referred to as vernal, seasonal, or intermittent ponds. Others may be permanently inundated; these are usually the larger, deeper bays found in the Carolinas. Pond size varies considerably, ranging from less than 50 m (164 feet) to 8 km (5 miles) in length (Sharitz and Gibbons 1982). Bays are distributed along the Atlantic Coastal Plain from New Jersey to Florida, with most occurring in the Carolinas (Johnson 1942, Rasmussen 1958, Savage 1982, Tyndall et al. 1990). Some estimates place the number of these ponds in the hundreds of thousands. In his popular book, *The Mysterious Carolina Bays*, Savage (1982) writes eloquently about these unique features on the landscape:

> "Up and down and across the level lands of the plain and into the sandhills, hundreds of thousands of these bay swamps, on close examination, reveal the unmistakable oval shapes of the "bays that are not bays." Unique, mysterious, and fascinating formations, these bay swamps, of clear and signal distinction, march across the region, under the banner of "Carolina Bays" - Carolina because their characteristics were first recognized in the Carolinas, the area of their greatest concentration, and bays simply as a shortened version of "bay swamps."
>
> It is surprising to discover on the gentle terrain of the Atlantic Coastal Plain, with no concealing cover or topography, one of the earth's most immense, spectacular, and intriguing topographical phenomena. Seen from the air, the Carolina bays are an astounding, unforgettable revelation. But though hundreds of thousands lie clearly visible, scattered across the Atlantic Coastal Plain from Maryland into northern Florida, they are often all but unrecognizable to the uninitiated eyes of groundlings."

The full extent of these bays, their numbers and sizes, only became apparent after complete aerial photography of the southeastern Coastal Plain took place in 1937 by the Department of Agriculture (see Savage 1982). Carolina bays are known to be most abundant (tens of thousands), reach their greatest size (several miles in length), and frequently exhibit a parallel alignment, in the Carolinas. Farther north and south, the bays are less uniform in shape and orientation and are, for the most part, smaller than their counterparts in the Carolinas.

The term "bay" used to describe these landscape features is derived

from the prevalence in the more southern ponds of certain bay trees (e.g. swamp bay, *Persea palustris*; loblolly bay, *Gordonia lasianthus*; sweet bay, *Magnolia virginiana*). These species, with the exception of *M. virginiana*, are not found in Delaware, and the latter species is not usually associated with bays in Delaware, except occasionally along the perimeter.

Origin

Recognition of this phenomenal feature of the Atlantic Coastal Plain was slow in coming and required almost 300 years before its real magnitude was realized. From 1700 through the 1800s only a few articles were published that described these habitats; since 1900 dozens of papers and several books have been written on the subject. The reader is referred to Savage (1982) for a thorough and interesting account of the history of the discovery of the Carolina bays.

The origin of the Carolina bays remains a mystery, and over the last 100 years, dozens of hypotheses have been proposed to explain their origin. These have been debated in the literature, and evidence, often circumstantial, has been presented to support or refute each hypothesis. Currently no single hypothesis has been accepted as the unequivocal explanation for the origin of Carolina bays. However, anyone who has studied these bays will agree they are unique geologic and physiognomic entities. Although this report is not designed to answer questions regarding the origin of these fascinating bays, the following (taken from Rasmussen 1958) summarizes the hypotheses developed to explain this phenomenon and it is presented here to illustrate the wide diversity of viewpoints regarding the origins of this unique geologic phenomenon:

(1) The undermining action of "underground drains," accounts for the formation of circular lakes (Tuomey 1848);

(2) "Wind deflation" - wind scoured out the bays (anonymous, pre-1895);

(3) "Soundlet, waves, bar" - each bay was a soundlet, connected to the sea when the strandline stood at higher altitudes than present, the headlands were beaten back by waves, and a bar was thrown across the mouth (Glenn 1895);

(4) The sea left "giant ripplemarks" (i.e. bays) upon the coastal plain separated from each other by sand ridges, after the sea receeded these ripplemarks became apparent (Glenn 1895);

(5) "Solution sink holes" were thought to form the bays (Smith 1931);

(6) "Meteorites" - the Atlantic Coastal Plain was bombarded by thousands of meteorites, striking from the northwest, creating thousands of bays, and leaving ridges on the southeast side of each bay (Melton and Schriever 1933);

(7) "Segmented-lagoon" and "crescent-shaped keys" hypothesis suggested that the bays were former lagoons, rimmed on their southeast side by

crescentic keys or bars, winds resulted in rotating water currents in the lagoons, which eroded elliptical hollows with long axes parallel to the prevailing wind (Cooke 1933);

(8) "Lacustrine" hypothesis emphasized that freshwater lakes were formed along a beach plain, and winds from the southeast set up an undertow directed toward the southeast; erosion of soft sands resulted in symmetry and nw-se elongation; dune ridges were formed on the southeast (Johnson 1934);

(9) "Air shock wave" is a revised meteorite theory in which the major part of the elliptical crater was formed by an air-shock wave that follows an in-falling meteorite (Prouty 1935);

(10) "Solution-lacustrine-aeolian" hypothesis is characterized by calcareous beds beneath a sand mantle are dissolved to form slump depressions in the surface, uprising waters from lake basins, winds generate waves which perfect oval form (Johnson 1936);

(11) "Artesian-solution-lacustrine-aeolian" complex hypothesis similar to 10 but with artesian springs forming ground water mounds (Johnson 1937);

(12) "Tidal eddies" on tidal flats during higher stands of the sea in combination with tidal forces and earth's gyroscopic properties formed Carolina bays (Cooke 1940);

(13) "Schools of fish" facing into the prevailing wind, during spawning activities over artesian springs on the shallow sea floor created the bays, "whale-wallows" (Grant 1945);

(14) "Stranded icebergs" - a cataclysmic event caused by a meteor set-off tidal waves that broke up the ice shelf and, in a tremendous surge, threw icebergs far up on the Coastal Plain, where they melted and formed the bays (Kelly and Dachville 1953);

(15) "Streamline solution" hypothesis proposed that solution of a near-surface artesian aquifer composed of limestone resulted in subsidence of overlying clay, flow around the obstacle caused enlargement of the sink on the downgradient side (LeGrande 1953);

(16) "Frost-thaw" hypothesis attributes the origin of New Jersey bays (which may be different from those of the Carolinas) to frost-thaw actions and subsidence in the peri-glacial zone of the Coastal plain in Pleistocene time (Wolfe 1953);

(17) "Pingo remnants" are mounds of ground ice formed by the hydrostatic pressure of water, and the force of ice crystallization, when the ice was exposed the pingo melts leaving behind a depression [(this hypothesis was proposed for the Atlantic Coastal Plain of Holland) (Maarleveld and Van den Toorn 1955)];

(18) "Underground erosion" - circulating ground waters may remove a portion of granular material in which they flow, forming underground cavaties, which collapse forming depressions (Schultz and Cleaves 1955);

(19) "Surface and groundwater drainage" - valley-widening of surface streams and by groundwater drainage along fractures (Lattman and Tator 1955);

(20) "Collapse sink" - collapse of small solution cavaties in a substrate

of calcareous sand (Shockley et al. 1956).

A more recent hypothesis suggests that the bays originated from shallow water bodies that were elongated by strong winds from the southwest, creating end-to-end currents and leaving beach-like rims (Thom 1970, Bliley 1974, Gamble at al. 1977, Pettry et al. 1979).

Geology and Soils

Carolina bays occur in the sandy soils of the Atlantic Coastal Plain, from New Jersey to Florida, and are positioned on several different geologic formations (Prouty 1952, Gamble et al. 1977). On the Delmarva, the coastal plain ponds are found to occur on the Wicomico, Talbot, and Pamlico terraces, between sea level and 90′ altitude, in Pensauken and Calvert formations (Rasmussen 1958, Pickett and Spoljaric 1971, Benson and Pickett 1986, Stolt 1986, Stolt and Rabenhorst 1987b). While age estimates for the bays range from 10,000 years before present (YBP) to as much as 250,000 years YBP (Wells and Boyce 1953, Gamble et al. 1977), Stolt and Rabenhorst (1987b) determined ages for two Maryland bays to be of late Pleistocene, between 16,000-20,000 YBP.

Coastal Plain ponds are low depressions that are generally only a few feet lower than the surrounding upland. Soil studies in bays are limited. In Maryland these closed depressions typically consist of poorly to very poorly drained soils of low pH (from 3.6 to 4.6) that range from silt loam to silty clay loam at one extreme to loamy sand at the other (Stolt and Rabenhorst 1987b). In addition to occasional muck and clay sediments, the above soil types were frequently found in Delaware bays (pers. obs.). The sediments of the basins of Coastal Plain ponds have been referred to as 'basin fill,' and may be upto 5 m thick (Stolt and Rabenhorst 1987a, 1987b). Stolt and Rabenhorst also proposed that the source of the basin fill in bays was from loess derived from the Susquahanna River, and Chesapeake and Delaware Bays.

Stolt and Rabenhorst note that, in Maryland, the bay soils have not been mapped as separate units, but rather have been grouped with poorly drained soils such as Pocomoke or Elkton. Similarly, soils in Delaware's bays were included within the soil series of the surrounding habitat; e.g., Fallsington, Sassafras, Woodstone, or Pocomoke soils (U.S.D.A. Soil Conservation Service 1970, 1971, 1974). Soils in depressions of bays in Virginia were found to be well-drained to poorly drained, and contained more silt and organic matter than the soils of the rims, which were typically sandy (Bliley 1974, Pettry et al. 1979). It was also found that, at depths below three meters, the basin sediments were sandy and similar to the soils on the rims. Bays in the Carolinas varied from basins containing silt loam or loamy sand to clay- or peat-based substrates (Buell 1946, Peroni 1988, Schafale and Weakley 1990). It has been postulated that the general absence of peat deposits in many bays apparently results from periodic drawdown and oxidation

of exposed substrates (Frey 1950, Schalles and Shure 1989).

Hydrology

Despite the fact that Carolina bays are common landscape features on the Atlantic Coastal Plain, their hydrology dynamics are poorly known. In addition to other factors, the community structure (i.e. vegetation) of a pond is linked to its hydrologic regime. Much of the information on pond hydrology presented here is of a qualitative nature and, as such, is based on observations. Pond hydrology is driven by changes in groundwater levels. These changes may be due to high rates of evapotranspiration from pond vegetation, groundwater pumping (e.g. for farming purposes), and by precipitation. All of the Coastal Plain ponds on Delmarva have fluctuating water levels. The water in these ponds will vary in depths and duration of flooding; both of these will dictate the type of vegetation present. Delaware ponds typically begin to "fill-up" starting in early to mid-fall and by spring are often several feet deep due to winter precipitation replenishing the groundwater. Conversely, by mid- to late summer, due to low precipitation rates and high evapo-transpiration rates, the ponds may completely draw down (DNHI unpublished database 1994; pers. obs.). In wetter years these ponds may be flooded throughout the year. According to Rasmussen (1958) permanently flooded conditions were the rule rather than the exception. He reported that in 1957 "... the driest summer on record completely dried all the ponds in Delaware for the first time in the memory of residents." More data are needed to determine what sorts of long-term trends are operating in pond hydrology:

(1) are there cycles of wetter periods, alternating with drier periods?;

(2) are all coastal plain ponds successional and, therefore, will ultimately develop into forests?, or are the dynamics of drawdown and flooding, and perhaps periodic burns, sufficient enough to maintain them in a sub-climax stage?; and

(3) are there unknown factors operating on the groundwater (e.g. unnaturally high depletion rates caused by human consumption) that may be adversely impacting the hydrology of the ponds?

In Rasmussen's (1958) hydrologic study of the bays and basins of Delaware he showed that the water table beneath a large bay (Huckleberry Pond) fluctuated in depth below the surface on a diurnal, as well as seasonal, basis. The water table high was due to recharge from underflow and the diurnal low resulted from evapo-transpiration. Rasmussen also stated that evaporation and transpiration from the water table were the only forms of groundwater discharge at Huckleberry, and he calculated that the rate of evapotranspiration from here was about 1 million gallons per day.

Although Rasmussen's study did not directly address lateral extent of the groundwater responsible for recharging coastal plain ponds, he did suggest that the "groundwater divide may extend beneath much wider sections of the adjacent plain, and bring water to the bays from a fairly extensive area."

Results of hydrologic studies of Coastal Plain ponds at Blackbird State Forest by Phillips and Shedlock (1993) revealed a number of interesting and unanticipated results. These investigators found that there were three distinct seasonal water table configurations operating at the site and that these configurations were related to differences in water table response to rainfall, location of maximum water table altitude and to the presence or absence of standing water in the ponds. During the summer and fall months, a water table trough underlies the sandy ridges separating the seasonal ponds, and maximum water table altitudes prevail in the sediments beneath the dry pond bottoms. As the ponds fill with water during the winter, they noted that the maximum water table altitudes shifted to the upland-margin zone adjacent to the seasonal ponds. In other words there were "localized" ground water systems that were transient and that these small systems were affecting pond hydrology. The largest increases in pond stages occurred during periods of transient mound formation.

Water chemistry studies of Carolina bays have shown that the waters are very soft and acidic (Newman and Schalles 1990), and biological production is low to moderate (Tilly 1973, Sharitz and Gibbons 1982, Schalles and Shure 1989). While Rasmussen (1958) reported near neutral (6.2 to 7.1) pH values for pond water at Huckleberry pond, Phillips and Shedlock (1993) noted pH below 5.0 for the Blackbird ponds. Newman and Schalles (1990) measured a median pH value of 4.6 from 49 bays in South Carolina.

Communities within bays differ according to hydroperiod and related degrees of fire frequencies and peat accrual (Buell 1946, Wharton 1978, Sharitz and Gibbons 1982). The absence of fire results in bay succeeding to a climax broadleaf bay forest. This process seems likely to be operating on the Delmarva as many low depressions that at one time were probably open ponds are now forested wetlands, though comprised of different hardwood species (e.g. red maple, sweet gum, poplar, oak).

A review of the maps prepared by the U. S. Fish and Wildlife Service for the National Wetland Inventory (NWI) showed that the following wetland types were designated for Coastal Plain ponds in Delaware:

POWZ - Palustrine, open water, intermittently exposed/permanent
PEMF - Palustrine, emergent/aquatic bed, semi-permanent
AB
PEM5C - Palustrine, emergent, narrow-leaved persistent, seasonal
PEM5E - Palustrine, emergent, narrow-leaved persistent, seasonally

saturated

PEM3F - Palustrine, emergent, narrow-leaved non-persistent, semi-permanent

PEM5F - Palustrine, emergent, narrow-leaved persistent, semi-permanent

PFO1A C - Palustrine, forested, broadleaved deciduous, temporary/ seasonal

PFOIE - Palustrine, forested, broadleaved deciduous, seasonal saturated

PFO1E SS - Palustrine, forested/scrub-shrub, seasonal saturated

PSS1E EM - Palustrine, scrub-shrub, broadleaved deciduous, seasonal saturated/emergent, seasonally saturated

PSS1F - Palustrine, scrub-shrub, broadleaved deciduous, semipermanent

PSS1F EM5 - Palustrine, scrub-shrub, broadleaved deciduous/emergent, narrow-leaved persistent, semipermanent

Succession

The natural ecological progression that takes place in Carolina bays has not been entirely quantified. Many of the statements made about succession have been inferred from observations. Buell (1939, 1946) was one of the first investigators to comment on succession in Carolina bays. He stated that "Jerome Bog represents an ancient lake that has been filled in with a peat deposit." Buell further stated that fires are a frequent occurrence and that "as far as the present vegetation is concerned there is no question that fire is and has been for a long time the dominant factor concerned in the control of the communities. Fire-scarred pine trunks and charred stumps of fallen trees are common."

Wharton (1978) stated that many of the Carolina Bay vegetation types are partly maintained by fire, and that in the absence of fire, peat accumulates and the changing substrate conditions allow for new plant species to invade. Christensen (1988) stated that "these bays are quite varied vegetationally and appear in many cases to be undergoing a typical hydrarch succession from lake to bog to forest." Tyndall (1989) found that in an aerial photograhy study of eight Carolina bays in Maryland, all but one showed herbaceous cover decreases from 28 to 83% between 1938 and 1980. The eighth pond had an herbaceous cover decrease of only 3% during this period. Tyndall believed that woody plant succession in these ponds may have been intensified by a recent drought.

There is a paucity of data available related to vegetation succession of bays in Delaware. Preliminary analyses of data gathered from one pond suggests that fire was an important factor in determining vegetation composition (Sneddon 1990). Field investigations of apparent bays (as indicated on U.S.G.S. topographic maps) revealed that many were no longer herbaceous dominated ponds but are now completely forested (Delaware Natural

Heritage Inventory database 1994). In addition, a comparison of aerial photography from 1938 to 1977 showed that one of the largest bays on the Delmarva (Huckleberry pond) had a nearly 50% decrease in herbaceous cover.

Succession in Carolina bays apparently proceeds from a lake-like system to a forested pond, and that the rate of succession is determined by a number of factors, including frequency of fires, flooding regimes, length and severity of local droughts, changes in groundwater levels, and draining and ditching activities.

Fauna

The available faunal data from Carolina bays are rather limited; most of the published data are from bays occurring in the Carolinas. An excellent summary of these data are found in Sharitz and Gibbons (1982). Although most animal species observed in Carolina bays are wide-ranging and are not thought to be dependant on the bays for their survival, some are believed to require the bay habitat for at least a portion of their lives. A plethora of animal species have been observed in bays in both the Carolinas and in Delaware; though less quantified data are available for the latter.

From a sample of bays at the Savannah River Plant in South Carolina less than 10% are known to have resident fish populations (Shields et al. 1980, as cited in Sharitz and Gibbons 1982); "the majority do not have permanent fish inhabitants because of their transitory aquatic status" (Frey 1951, Bailey and Frey 1958 as cited in Sharitz and Gibbons 1982). Up to 25 fish species have been noted in bays studied in North Carolina (see Sharitz and Gibbons 1982, pp. 53-54); several of these (the glassminnow and the darter) were found to be endemic to a specific bay (Lake Waccamaw). In Delaware, Fleming (1978) reported the presence of several fish (mud minnow, *Umbra pygmaea*, and red-finned pickerel, *Esox americanus*) from one Delmarva bay. However, as resident fishes are generally lacking from Carolina bays, the opportunity presents itself for other species to take advantage of this habitat without fear of predation. Sharitz and Gibbons discuss the use of bays by several mollusks, an abundance of herptiles, birds, amphibians, and mammals.

In Delaware's Coastal Plain ponds numerous animal species have been observed (see list below). It is believed that for some of these species the pond habitat is critical, at least for a portion of their life histories (e.g. as breeding sites). However, it is believed that the majority of species observed, utilize the pond habitat primarily for foraging purposes. The following data were primarliy compiled by Christopher M. Heckscher and Jim White, with contributions from Keith Clancy (pers. obs.) and published data (Fleming 1978).

SPECIES ASSOCIATED WITH COASTAL PLAIN PONDS OF DELAWARE

COMMON NAME	SCIENTIFIC NAME	STATE RANK
Amphibians and Reptiles:		
Eastern tiger salamander	*Ambystoma tigrinum*	S1*
Spotted salamander	*Ambystoma maculatum*	S2*
Marbled salamander	*Ambystoma opacum*	S3*
Red spotted newt	*Notophthalmus v. viridescens*	S4
Northern cricket frog	*Acris c. crepitans*	S5**
Fowler's toad	*Bufo woodhousii fowleri*	S5
Cope's gray treefrog	*Hyla chrysoscelis*	S2*
Green treefrog	*Hyla cinerea*	S3
Barking treefrog	*Hyla gratiosa*	S1*
Gray treefrog	*Hyla versicolor*	S4*
Northern spring peeper	*Pseudacris c. crucifer*	S5
New Jersey chorus frog	*Pseudacris triseriata*	S4**
Bullfrog	*Rana catesbeiana*	S5
Green frog	*Rana clamitans melanota*	S5
Pickerel frog	*Rana palustris*	S5
Wood frog	*Rana sylvatica*	S4**
Southern leopard frog	*Rana u. utricularia*	S5**
Eastern spadefoot	*Scaphiopus h. holbrookii*	S4*
Spotted turtle	*Clemmys guttata*	S3**
Common snapping turtle	*Chelydra s. serpentina*	S5
Eastern painted turtle	*Chrysemys p. picta*	S5
Eastern mud turtle	*Kinosternon s. subrubrum*	S5
Common musk turtle	*Sternotherus odoratus*	S5
Northern water snake	*Nerodia s. sipedon*	S5
Eastern ribbon snake	*Thamnophis s. sauritus*	S5**
Black rat snake	*Elaphe o. obsoleta*	S5
Birds:		
Ring-necked ducks	*Aythya collaris*	S4N
Fishes:		
Mud minnow	*Umbra pygmaea*	S5
Red-finned pickerel	*Esox americanus*	S5
Invertebrates:		
Blue pirate	*Pachydiplex longipennis*	S5
Cherry-faced meadowfly	*Sympetrum internum*	S4
Common green darner	*Anax junius*	S5
Disjunct spreadwing	*Lestes disjunctus*	S3**

Fragile forktail	*Ischnura posita*	S5
Green jacket	*Erythemis simplicicollis*	S5
Praying mantid	*Tenodera aridifolia*	S5
Red saddlebags	*Tramea carolina*	S4
Ruby meadowfly	*Sympetrum rubicuridum*	S4
Slender spreadwing	*Lestes rectangularis*	S4
Spotted spreadwing	*Lestes congener*	S3**
Sweetflag spreadwing	*Lestes forcipatus*	S3**

Mammals:

White-tailed deer	*Odocoileus virginianus*	S5

* species which are found primarily in Delaware coastal plain ponds
**species that are highly dependant on Delaware coastal plain ponds

The above list of taxa is far from complete and additional animal surveys are much needed.

Community Structure/Vegetation

Coastal Plain ponds consist of a diversity of community types with varying floristic compositions. The community dynamics are not altogether fully understood, but are believed to be determined primarily by soil differences, hydrologic regimes, fire frequencies, and to variations in water chemistry. Ecological studies lag behind those dealing with the geology and origin of the bays. The Nature Conservancy, in cooperation with state Natural Heritage programs, are currently undertaking studies of the hydrology and vegetation of coastal plain ponds on a regional basis. In comparison to the bays found in Delaware, the following briefly summarizes the types of vegetation and communities present in bays from the Carolinas to the Mid-Atlantic (including New Jersey and Maryland). Community structure and vegetation for bays in Delaware will be discussed in the Results and Discussion sections that follow.

North/South Carolina

The bays found in these states contain the greatest variation in terms of species composition, community structure, and dynamics. Most are very unlike the bays on the Delmarva. The following are brief descriptions illustrating the diversity of bay and natural community types found in this area and are taken from Buell (1946), Sharitiz and Gibbons (1982), Christensen (1981, 1988), and Schafale and Weakley (1990). The vegetation ranges from a dense, tree-dominated community at one extreme, to open herbaceous-dominated communities at the other. Examples include:

(1) The **Bay Forest** of peat-filled wetlands dominated by combinations of loblolly bay (*Gordonia lasianthus*), sweet bay (*Magnolia virginiana*), and red bay (*Persea palustris*). Other

tree species in lesser amounts include pond pine (*Pinus serotina*), water tupelo (*Nyssa biflora*), red maple (*Acer rubrum*), loblolly pine (*Pinus taeda*), and Atlantic white cedar (*Chamaecyparis thyoides*). The shrub layer may be dense or open and consists of species such as fetterbush (*Lyonia lucida*), male-berry (*L. ligustrina*), ti-ti (*Cyrilla racemiflora*), large gallberry (*Ilex coriacea*), and dahoon (*I. cassine*);

(2) An **Atlantic White Cedar Forest** occurring in bays is dominated by *Chamaecyparis thyoides*, with lesser numbers of *Pinus taeda, P. serotina, Acer rubrum, Nyssa biflora*, and *Taxodium ascendens*. The understory may be open or dense with such bay species as *Gordonia lasianthus*, *Magnolia virginiana*, and *Persea palustris*, and other species such as *Lyonia ligustrina, L. lucida, Cyrilla racemiflora, Ilex glabra, Gaylussacia frondosa*, and *Ilex coriacea*;

(3) A **Pond Pine Woodland** which may have an open or closed-canopy and is dominated by *Pinus serotina*. Other less abundant tree species here include *Magnolia virginiana, Acer rubrum, Pinus taeda, Persea palustris, Chamaecyparis thyoides, Cyrilla racemiflora, Lyonia lucida, L. ligustrina, Ilex coriacea, I. glabra, Clethra alnifolia, Gaylussacia frondosa*, and *Persea palustris*. Giant cane (*Arundinarea gigantea*) and laurel-leaf greenbrier (*Smilax laurifolia*) may also be prevelant. Herbs are sparse but may contain Virginia chain fern (*Woodwardia virginica*), netted chain-fern (*W. areolata*), and *Sphagnum* spp;

(4) **Pocosins** (high and low) that occur in bays are typically comprised of a dense shrub layer that may be of tall (upto 10') or short (less than 3') stature. These communities are quite diverse and may contain species such as *Cyrilla racemiflora, Lyonia lucida, L. ligustrina, Pinus serotina, Persea palustris, Gordonia lasianthus, Magnolia virginiana, Zenobia pulverulenta*, and *Smilax laurifolia*. Small openings may be dominated by *Chamaedaphne calyculata, Carex striata, Woodwardia virginica, Sarracenia flava, Andropogon glomeratus, Sphagnum* spp., and rarely *Vaccinium macrocarpon*;

(5) **Cypress Savanna** bays consist of an open canopy dominated by pond cypress (*Taxodium ascendens*), with scattered *Nyssa biflora, Pinus taeda, P. serotina, Liquidambar styraciflua, Ilex amelanchier, Lyonia lucida, Leucothoe racemosa, Cyrilla racemiflora*, among woody species, and important herbs such as *Panicum hemitomon, P. verrucosum, Panicum* spp., *Carex striata, Erianthus alopecuroides, Rhynchospora* spp., *Scleria reticularis, Eleocharis melanocarpa, Lachnanthes caroliana, Leersia hexandra, Boltonia* sp., *Sagittaria isoetiformis, Utricularia inflata*, and *Pluchea rosea*, among others;

(6) **Vernal pool** is a seasonally flooded depression dominated by herbs (the species compositions vary from pond to pond),

including *Schizachyrium scoparium, Panicum* spp., *Leersia hexandra, Carex* spp., *Centella asiatica, Drosera* spp., and *Utricularia* spp.; and

(7) **Small Depression Ponds** are usually permanently flooded in the center and contain a diversity of vegetation, often in distinct concentric zones. The deeper portions contain such species as white waterlily (*Nymphaea odorata*), floating heart (*Nymphoides aquatica*), spatterdock (*Nuphar lutea*), mermaidweed (*Proserpinaca pectinata*), and bladderworts (*Utricularia* spp.). In shallower portions a diversity of species may be present, including *Panicum hemitomon, Panicum* spp., *Sacciolepis striata, Eleocharis* spp., *Rhynchospora* spp., *Drosera intermedia, Centella asiatica*, and *Woodwardia virginica*. Scattered trees may also be present (e.g. *Nyssa biflora, Taxodium ascendens*).

Virginia

There is a paucity of literature related specifically to Virginia bays. Brief mention was made of this habitat in the Proceedings of a symposium on *Virginia's Endangered Species* (Virginia Department of Game and Inland Fisheries 1991). A **pocosin** type community occurs in some of the bays in this state which is very similar to pocosins in the Carolinas and is characterized by the presence of pond pine (*Pinus serotina*) as a dominant tree, and a dense shrub layer composed of *Magnolia virginiana, Gordonia lasianthus, Ilex glabra*, and *Persea palustris*.

Maryland

Shreve et al. (1910) briefly described coastal plain ponds on Maryland's Eastern Shore. In discussing the Wicomoco terraces they mentioned that this terrace "...also gives rise to many swamps or ponds occupying small abrupt depressions without outlet, which represent original depressions on the floor of the Wicomoco sea. The ponds which occupy the largest and deepest of these depressions are of interest as being the only natural ponds in the state. They are often intermittent and usually too small to have been noted on the United States Geological Survey, indeed the depressions themselves often occur at such levels as not to be indicated by contour lines." No mention was made of the vegetation of these ponds.

More recently, Sipple and Klockner (1984) described the ecology and biology of, what they referred to as "Eastern Shore potholes," and described three basic types based on vegetation:

(1) **Glades** dominated by *Erianthus giganteus, Carex striata*, and twig-rush, *Cladium mariscoides*, with less abundant species such as *Polygonum* sp., *Sphagnum* sp., *Cephalanthus occidentalis, Eleocharis obtusa, Juncus canadensis, J. repens, Leucothoe racemosa, Clethra alnifolia, Liquidambar styraciflua, Magnolia*

virginiana, *Nyssa sylvatica*, *Panicum* spp., *Proserpinaca pectinata*, *Quercus palustris*, *Q. phellos*, *Rhexia virginica*, *Rhynchospora macrostachya*, and *Diospyros virginiana*;

(2) **Shrub-swamps** dominated by *Cephalanthus occidentalis* and/or *Decodon verticillatus*, with other less abundant species including scattered persimmon (*Diospyros virginiana*), smartweeds (*Polygonum* spp.), *Bidens frondosa*, *Carex striata*, *Echinochloa* sp., *Fimbristylis autumnalis*, *Rhexia virginica*, *Proserpinaca pectinata* and *Leersia oryzoides*. The pond perimeter typically consists of *Acer rubrum*, *Liquidambar styraciflua*, *Quercus palustris*, *Q. phellos*, *Clethra alnifolia*, *Leucothoe racemosa*, and *Smilax rotundifolia*; and

(3) **Forested swamps** that are dominated by *Acer rubrum*, *Liquidambar styraciflua*, and/or *Quercus palustris*, and *Q. phellos*. The shrub and herb layers are generally lacking or very sparse.

Tyndall et al. (1990) undertook in-depth studies of the vegetation of six Carolina bays and described five zonal community types:

(1) A ***Leucothoe racemosa*-dominated zone** with lesser numbers of *Clethra alnifolia*, *Panicum verrucosum*, *Rhododendron viscosum*, *Vaccinium corymbosum*, and *Acer rubrum*;

(2) A ***Carex striata*-dominated community** with lesser amounts of *Cephalanthus occidentalis*, *Panicum hemitomon*, and *Quercus phellos*;

(3) A ***Panicum verrucosum*-dominated community**, more diverse than the previous communities, consisting of additional species such as *Panicum dichotomiflorum*, *P. hemitomon*, *Paspalum dissectum*, *Fimbristylis autumnalis*, *Dulichium arundinaceum*, *Cephalanthus*, *Rhexia virginica*, *Hedyotis uniflora*, *Scleria reticularis*, *Rhynchospora macrostachya*, *Scirpus cyperinus*, *Ludwigia sphaerocarpa*, and *Proserpinaca pectinata*, among others;

(4) A ***Rhexia virginica*-dominated community**, also extremely diverse with co-occurring species such as *Scleria reticularis*, *Nymphaea odorata*, *Panicum verrucosum*, *P. hemitomon*, *P. spretum*, *Fimbristylis autumnalis*, *Rhynchospora chalarocephala*, *R. macrostachya*, *R. scirpoides*, *Scirpus cyperinus*, *Drosera* spp., and *Lachnanthes caroliana*, to name a few; and

(5) A low diversity ***Panicum hemitomon*-dominated community** with scattered *Carex striata*, *Cladium mariscoides*, *Rhexia virginica*, *Liquidambar styraciflua*, and *Quercus phellos*.

Tyndall et al. found that the most frequently occurring community type was dominated by *Leucothoe racemosa*, and was restricted to the forested-perimeter (dominated by *Acer rubrum* and *Liquidambar*

styraciflua) of the pond. The *Carex striata* and the *Panicum hemitomon* communities were also found to be restricted to the pond perimeter, while the more diverse *Rhexia virginica* and *Panicum verrucosum*-dominated communities were restricted to the innermost zone of the pond.

New Jersey

Limited studies have been undertaken in Coastal Plain ponds of New Jersey. Breden (1989) found the ponds to consist of either herbaceous-dominated or shrub-dominated communities. The herbaceous ponds were comprised of dominants such as *Carex striata, Panicum verrucosum, Scleria reticularis, Panicum capillare, Coreopsis rosea, Cladium mariscoides, Panicum mattamuskeettense, Muhlenbergia torreyana*, and *Eleocharis microcarpa*. Numerous rare species have been found in these ponds including *Lobelia canbyi, L. boykinii, Nymphoides cordata, Sagittaria teres, Panicum wrightianum, P. hirstii, Rhynchospora nitens, Paspalum dissectum, Ludwigia linearis, Coelorachis rugosa, Xyris smalliana*, and *Eleocharis equisetoides*. Several peatmosses are commonly found (e.g. *Sphagnum macrocarpon, S. macrocarpon* var. *floridanum, S. lescurii*). The shrub-dominated ponds usually contain an abundance of *Chamaedaphne calyculata, Vaccinium corymbosum*, and *Ilex glabra*. *Woodwardia virginica* and *Sphagnum* spp. are common in the herb and ground layers (Breden 1989). Breden acknowledges the need for additional survey work in these ponds.

McCarthy (1987) studied the spatial and temporal distribution of plants in two herb-dominated Coastal Plain ponds in Atlantic County, New Jersey. She found that there were 26 species and 20 species, respectively, in quadrats in the two ponds. One pond (Hirst's) in 1984 was dominated by several species of bladderworts (*Utricularia purpurea, U. vulgaris, U. juncea*), followed next by *Proserpinacea pectinata* and *Carex striata* in abundance. Other species observed in Hirst's Pond included *Coreopsis rosea, Gratiola aurea, Hypericum mutilum, Juncus canadensis, J. pelocarpus, Lachnanthes caroliana, Ludwigia linearis, Nymphoides cordata, Panicum spretum, P. verrucosum*, and *Rhexia virginica*. The *Carex* was primarily restricted to the pond's perimeter. The second pond (Little Goose) was dominated by *Eleocharis robbinsii*, followed next by *Panicum hemitomon, Eriocaulon* spp., and *Carex striata* in abundance. The woody species along the pond perimeter were dominated by *Chamaedaphne calyculata* and *Acer rubrum*. Other species observed here included *Cladium mariscoides, Juncus pelocarpus, Lachnanthes, Panicum spretum, P. verrucosum, Rhexia virginica, Scleria reticularis*, and *Xyris* sp.

Delaware

Prior to the current investigation, literature on the vegetation and community structure of Coastal Plain ponds were lacking, though cursory information could be gleaned from Tatnall's (1946) *Flora of*

Delaware and the Eastern Shore. Biologists with the Delaware Natural Heritage Inventory have been collecting data on the flora and fauna of these ponds since 1984; these data as well as information on the distribution of these bays are described in the Results section that follows.

RESULTS

Vegetation/Community Structure of Delaware's Coastal Plain Ponds

Although the Coastal Plain ponds of Delaware are very diverse floristically (see Appendix A), and are comprised of a number of different natural community types, they are less diverse than their counterparts in the Carolinas. This section describes the various natural community types, or associations, found in these ponds; where applicable, the presence of rare species will be noted (also see Appendix B).

The natural communities found in Coastal Plain ponds in central Delaware are represented by only a few main types, with minor variations on species compositions, while the more southern ponds in the state have a greater diversity of community types. A variation is usually a substitution of one or more species for another species or combination of species. The general community structure remains the same. The following natural community types, or associations, are described for Delaware's Coastal Plain ponds (please note that this does not represent the full range of variability observed for pond vegetation):

(1) *Cephalanthus occidentalis/Polygonum coccineum-Bidens frondosa* Wetlands Association [buttonbush/smartweed-beggar's tick pond]

This wetland community type is most abundant in the region of greatest pond concentration; i.e. northwest Kent/southwest New Castle County region (see below). The buttonbush may either be present in great numbers throughout the pond, restricted to the central region, found along the pond's perimeter, or occurs as scattered individuals. The smartweed and beggar's-tick are often co-dominants in the herb layer; sometimes *Glyceria pallida* or *G. septentrionalis* may be a co-dominant in addition to the other two species, or may substitute for one of the species (usually replacing *Bidens*). Although this community is often relatively depauperate in species composition (with just the above macrophytes present), occasionally there may be a few or many additional species present (usually in low numbers): e.g., *Cyperus strigosus, Echinochloa crusgalli, Dulichium arundinaceum, Hypericum virginicum, Lindernia dubia, Lycopus rubellus, Panicum verrucosum, Polygonum punctatum, Rhexia virginica, Scirpus cyperinus, Carex lupulina, C. striata*, and *Proserpinaca palustris*.

In several ponds with the above vegetation one or more **rare plant or animal species** have been discovered, including the following:

teal love grass, *Eragrostis hypnoides* (**S1**); featherfoil, *Hottonia inflata* (**S2**); large sedge, *Carex gigantea* (**S3**); Harper's fimbristylis, *Fimbristylis perpusilla* (**S1, C2**); spotted salamander, *Ambystoma maculatum* (**S1**); tiger salamander, *Ambystoma tigrinum* (**S2**); Cope's gray treefrog, *Hyla chrysoscelis* (**S1**); and barking treefrog, *Hyla gratiosa* (**S1**).

(2) *Cephalanthus occidentalis* Shrub Wetland Association (buttonbush ponds)

This community type often consists of a nearly monospecific buttonbush stand, with an herbaceous stratum lacking or relatively sparse. The perimeter of this pond is usually comprised of combinations of *Acer rubrum, Liquidambar, Diospyros virginiana, Nyssa sylvatica, Quercus palustris, Q. phellos*, and *Populus heterophylla*. The *Populus* may also be found in the center of the pond. This wetland community may reflect a latter stage in pond community succession, or a temporary condition favored by increased flooding durations; conversely, if flooding durations are reduced herbaceous species may become established. This community type is prevelant in the region of major pond concentration.

(3) *Cephalanthus occidentalis*/Mixed Herbaceous Wetland Association (buttonbush/mixed herbs pond)

Similar to community number one (above) but with a greater diversity of herbs, including *Bidens frondosa, Carex gigantea, C. lupulina, Cyperus strigosus, Echinochloa crusgalli, Glyceria pallida, Hypericum virginicum, Lindernia dubia, Panicum dichotomiflorum, P. verrucosum, Polygonum* spp., *Proserpinaca palustris, Rhexia virginica*, and *Scirpus cyperinus*. Although this community may have the same species as in community one (above), the lack of any dominant herb and a greater diversity seems to warrant establishing a distinct association.

(4) Forested Coastal Plain Pond

A Coastal Plain pond that has succeeded, either naturally or through disturbance, to a closed-canopy forested community that is typically composed of one or more of the following species: *Acer rubrum, Liquidambar styraciflua, Nyssa sylvatica, Populus heterophylla*, and *Quercus palustris*. Given enough time and continued siltation these sites might no longer be recognizable as Coastal Plain ponds. Likewise, extensive flooding periods may "open" these ponds to an herbaceous-dominated community.

(5) *Dulichium arundinaceum-Panicum* spp. Herbaceous Wetland Association (three-way sedge-panic grass wetland)

This community association may occur throughout a pond or may be restricted to a distinct zone within the pond. *Dulichium* and the *Panicum* species (which include *P. dichotomiflorum, P. spretum, P.*

verrucosum) are co-dominants. Other species are generally lacking, though occasionally *Juncus canadensis* or *Scirpus cyperinus* may replace the *Panicum*.

(6) *Cephalanthus occidentalis/Scirpus cyperinus-Carex striata* Wetland Association

This natural community association is variable in species' dominance and composition; in some examples *Cephalanthus* is entirely lacking. A ***Scirpus cyperinus* Variant** may be present whereby the woolgrass forms monospecific stands, likewise, a ***Carex striata* Variant** may occur that is comprised entirely of this sedge; both of these sedges can be aggressive colonizers outcompeting other species. Additional species, some that are rare, that may be present include *C. barrattii* (**S3**), *C. gigantea* (**S3**), *C. crinita*, *Juncus effusus*, *Rhynchospora corniculata* (**S2**), *Panicum spretum*, and *Lindernia dubia*. In some cases, *Carex gigantea* may replace *C. striata*.

The above natural communities, or plant associations, are frequently encountered in northwest Kent and southwest New Castle Counties, the area of greatest concentration of Coastal Plain ponds. Several additional vegetation types are found in ponds in lower Delaware (i.e. southeastern Kent and Sussex Counties); see below.

(7) *Nymphaea odorata-Utricularia gibba* Wetland Association (water lily-bladderwort wetland)

This community type occurs in apparently deeper ponds, with longer hydroperiods. An example occurs at Black's Pond where, in addition to the above co-dominants, other species present (including several rare ones) were *Echinochloa walteri, Eleocharis obtusa, E. quadrangulata* (**S3**), *Hottonia inflata* (**S2**), *Ludwigia palustris, Myriophyllum pinnatum* (**S2**), *Pologonum hydropiperoides*, and *Potamogeton pulcher*. This may be a non-persistent community that is dependent on appropriate flooding conditions. In 1993, at time of survey (October), the pond surface was completely dry and there was no evidence of the water lily or bladderwort.

(8) *Eleocharis palustris-Panicum dichotomiflorum* Wetland Association

An example of this community type occurred in a pond on Milford Neck. In addition to the above spikerush and panic grass other species present included *Echinochloa walteri, Eleocharis parvula, Hydrocotyle umbellata*, and *Schoenoplectus tabernaemontanii*. The presence of several species (e.g. *Schoenoplectus, E. walteri*, and *Eleocharis parvula*) suggest that this pond may periodically experience brackish conditions.

(9) Mixed Graminoid Wetland Associations

Highly diverse Coastal Plain pond communities characterized by a preponderance of grasses and sedges. Several species may be dominant throughout or in one or more distinct zones, or may be present in large clumps, or colonies. These ponds often have several to many rare species, including a few that are globally rare. Relatively pristine examples of these community types are found at Huckleberry, Still, and Assawoman Ponds (see below for more details).

Distribution

More than one thousand Carolina bays are known to occur in Delaware (Fig. 1). The majority of these bays are found in central Delaware (northwest Kent/southwest New Castle Counties), primarily on the Clayton, Middletown and Kenton quadrangles, with lower numbers on the Marydel quadrangle. Stolt and Rabenhorst (1987a) estimated there were between 1500-2500 bays on the northern Delmarva Peninsula. In Delaware most are less than one acre in size, only a few are in the 2-5 acre size range, and only one bay is known to have an opening greater than 10 acres in size (Huckleberry Pond). From observations of aerial photographs and topographic maps it is estimated that more than half the Carolina bays in Delaware have been destroyed, or severely impacted due to anthropogenic activities (e.g. farming practices, construction of sub-divisions and roads, filling, draining, etc.). The following describes specific bays in different regions of the state, beginning with the central Delaware bays and concluding with several ponds in the Assawoman Bay Wildlife Area of southeastern Sussex County. Finally, brief mention will be made of ponds occurring elsewhere in the State.

Central Delaware Ponds

Clayton/Millington Quadrangles

Hundreds of small Coastal Plain ponds are found on the Clayton Quadrangle, with just a few found on the Millington Quadrangle (see Figs. 2-5). Rasmussen (1958) stated that there was a total of 1280 bays and basins on the Clayton quadrangle; he did not mention how many of these were basins rather than bays. Rasmussen defined basin as a land form having centripetal drainage, is outlined by a closed contour line and a depression contour, and has an irregular shape. The bays in this area range from small forest openings of less than ¼ acre to bays of several acres in size. While many of the bays may have a nw-se orientation, a like number have variable orientations; most of the bays are elliptic or round shaped. In addition, the majority of the bays on this quadrangle occur in the northern half. Finally, while many of these bays are "intact" forest interior bays, a similar number are considered "remnant," destroyed, or degraded bays, primarily occurring in agricultural fields. An analysis of Greenhorne and O'Mara's (1991) identification of Coastal Plain ponds on their Freshwater Wetlands map of a region of

the Clayton Quadrangle indicated that the level of accuracy (based on a comparison to Natural Heritage data on ponds of the region) was quite high; only a few habitats identified by Greenhorne and O'Mara as ponds are questioned.

I. Blackbird Ponds.

These ponds occur in the northeast quadrant of the Clayton Quadrangle (Fig. 2). Data from nearly 20 ponds in this area have been collected. Ponds numbered 1-8 consist of relatively good quality ***Cephalanthus occidentalis/Polygonum coccineum-Bidens frondosa* Wetland Associations.** The ponds vary in size from small to medium and are, generally, less than one acre in size. In addition to the three species listed in the community name, the following taxa may also be present: e.g., *Saururus cernuus, Cyperus strigosus, Echinochloa crusgalli, Eleocharis obtusa, Eragrostis hypnoides, Pucinellia pallida, Glyceria septentrionalis, Hottonia inflata, Hypericum virginicum, Lindernia dubia, Lycopus rubellus, Panicum verrucosum, Polygonum hydropiperoides, P. pensylvanicum, Rhexia virginica*, and *Scirpus cyperinus*. Ponds numbered 9-11 were found to be ***Cephalanthus occidentalis* Shrub Wetlands;** these consisted of low diversity ponds with a dense buttonbush cover. Pond numbered 12 is characterized as a ***Cephalanthus occidentalis*/Mixed Herbaceous Wetland Association;** this is a relatively small pond with abundant buttonbush and a diversity of herbaceous species (see above for list of species). Ponds numbered 13-16 have succeeded to forested wetlands and ponds numbered 17-18 were found to be relatively degraded systems. In addition, several other ponds (e.g. those numbered 1, 2, 3, 9, 13) are rather degraded but have maintained their community structure and hydrology.

The forested perimeter of the bays in this region are typically comprised of *Acer rubrum, Liquidambar styraciflua, Quercus palustris, Q. phellos, Diospyros virginiana, Populus heterophylla, Nyssa sylvatica*, and an occasion water willow, *Salix nigra*. In addition to the above trees, the pond margin may contain such shrubby species as *Clethra alnifolia, Leucothoe racemosa, Vaccinium corymbosum*, and the vine *Smilax rotundifolia*.

Rare Species:

Several State rare species are known to be found in these ponds. There is a tremendous potential for discovering additional rare species with further inventory work.

Eragrostis hypnoides	**S1**	Teal love grass
Hottonia inflata	**S2**	Featherfoil
Carex gigantea	**S3**	Large sedge

II. Vandyke Ponds. Numerous, small to medium-sized ponds occur in the northwest portion of the Clayton Quadrangle, in an area bounded

by Dexter Corners-McKays Corners-Vandyke-Grears Corners (Fig. 3). For purposes of this report, data were collected from 12 ponds in this region. Several high quality ponds were surveyed in the Vandyke Tract of the Blackbird State Forest; a few of these are being threatened by development adjacent to the State Forest (Fig. 4).

Ponds 1-9 are common ***Cephalanthus occidentalis/Polygonum coccineum-Bidens frondosa* Wetland Associations**, ponds 10-11 are **Cephalanthus occidentalis Shrub Wetlands** dominated by tall, dense buttonbush (with limited herbaceous layer), and pond 12 is considered to be a **Forested Coastal Plain Pond** and is dominated by *Acer rubrum* and *Liquidambar styraciflua*. In addition, pond 12 consists of a very small opening that contains a few individuals of *Cephalanthus occidentalis*, *Bidens frondosa* and *Glyceria* sp., suggesting that it previously may have been more open and dominated by buttonbush and herbaceous vegetation. The largest of these ponds (no. 1), bissected on one side by a road and measuring about 1.5 acres, is known to be breeding grounds for several rare amphibians (e.g. tiger salamander, *Ambystoma tigrinum* (**S2**); spotted salamander, *A. maculatum* (**S1**); Cope's grey treefrog, *Hyla chrysoscelis* (**S1**); and barking treefrog, *H. gratiosa* (**S1**). This pond (known locally as Horse's Pond) and a pond designated as Teardrop Pond are described more fully below. Pond 9 is highly disturbed with a farm drive bissecting its northern end, with very little available buffer, and significant amounts of trash.

Horse's Pond (no. 1) is primarily comprised of a ***Cephalanthus occidentalis/ Polygonum coccineum-Bidens frondosa* Wetland Association.** This medium-sized (≈ 1.5 acre) elliptically shaped pond is of moderate quality, but is threatened by a county road bissecting its northwest side. In addition to the above taxa, *Pucinellia pallida, Panicum verrucosum, P.* cf. *spretum, Rhexia virginica, Scirpus cyperinus*, and *Riccia fluitans* are also found in this pond. On survey date (7/8/93) there was an abundance of undetermined filamentous algae present in ca. 12-14" of standing water. There was also an enormous amount of dead vegetation (primarily of *Glyceria*). Dragonflies were present in large numbers. The perimeter of the pond is comprised of *Acer rubrum, Liquidambar styraciflua, Diospyros virginiana, Clethra alnifolia*, and *Salix nigra*. Several rare amphibians have previously been identified from this pond [tiger salamander, *Ambystoma tigrinum* (**S1**); spotted salamander, *A. maculatum* (**S2**); Cope's grey treefrog, *Hyla chrysoscelis* (**S2**); and barking treefrog, *H. gratiosa* (**S1**)].

Teardrop Pond (no. 4) is a medium-sized, diverse pond with several ± distinct vegetative zones: **(1) *Cephalanthus occidentalis/ Polygonum coccineum-Bidens frondosa* Wetland Association** which occurs as an irregular band encircling the pond's outer portions; **(2) *Dulichium-Panicum* spp. Herbaceous Zone** that is relatively diverse occuring in the very outer portion of the pond and is comprised of *Dulichium arundinaceum, Panicum spretum*, and *P.*

verrucosum as dominants, with lesser amounts of *Bidens frondosa, Diospyros virginiana, Cephalanthus occidentalis, Rhynchospora macrostachya, Polygonum coccineum, Rhexia virginica, Smilax rotundifolia,* and *Viola lanceolata;* **(3) *Bidens frondosa-Panicum dichotomiflorum-Polygonum coccineum* Herbaceous Zone** that is rather wide and quite diverse. The above three species are co-dominants, while other less abundant species in this zone include *Eleocharis obtusa, E. olivacea, Echinochloa crusgali, Fimbristylis autumnalis, Glyceria acutiflora, Pucinellia pallida, Panicum verrucosum, Leersia oryzoides,* and *Rhynchospora macrostachya;* and **(4) *Eleocharis* spp. Zone**, a relatively narrow zone containing some of the same species as in the previous zone but with a preponderance of *E. obtusa*, and *E. olivacea*. The forested border of this pond consists of *Acer rubrum, Liquidambar styraciflua, Nyssa sylvatica, Quercus phellos, Clethra alnifolia,* and *Vaccinium corymbosum*. No rare species were observed in this pond, however, additional surveys are still needed on a yearly basis. Animal surveys are also lacking from here.

Rare Species:

While only a few rare species have been identified from the above ponds, the potential is great for the discovery of additional rare species with further field work.

Glyceria acutiflora	**S2**	Sharp-scaled manna grass
Ambystoma tigrinum	**S1**	Tiger salamander
Ambystoma maculatum	**S2**	Spotted salamander
Hyla chrysoscelis	**S2**	Cope's gray treefrog
Hyla gratiosa	**S1**	Barking treefrog

III. Cypress Branch/County Line Ponds. South of McKays Corners, north of Delaneys Corners, and west of the Cypress Branch occur several dozen small coastal plain ponds within a large forest tract; an additional cluster of ponds occur east of Delaneys Corner along the county line (Fig. 5). These ponds are mostly less than one acre in size, and the majority contain similar species' compositions. Several rare sedges (see below) seem to be concentrated in this area of the state. Likewise, a number of these ponds contain weedy species, indicating a certain level of disturbance. Two of the ponds are notable for the presence of the Federal Candidate (**C2**) species, Harper's fimbristylis, *Fimbristylis perpusilla* (**S1**).

Although more than two dozen ponds of this region have been surveyed, for purposes of this study, data from 18 ponds are provided. Three (3) ponds (numbered 1-3) surveyed consisted of the prevelant ***Cephalanthus occidentalis/Polygonum coccineum-Bidens frondosa* Wetland Association;** three (3) ponds (numbered 4-6) were characterized as ***Cephalanthus occidentalis* Shrub Wetlands;** eleven (11) ponds (numbered 7-17) were characterized as ***Cephalanthus occidentalis/Scirpus cyperinus-Carex striata* Wetlands** (this

community type is quite variable in species' dominance and composition; see descriptions of community types in previous section); and one pond (numbered 18) has not been classified to community type. This latter site consisted of a small woodland open depression with a few scattered *Diospyros virginiana* trees, and only a few herbaceous species (e.g. *Arctium* sp., *Cyperus strigosus*, and *Eleocharis obtusa*).

Rare Species:

Carex barrattii[a]	**S2**	Barratt's sedge
Carex bullata[b]	**S2**	Button sedge
Carex gigantea[c]	**S3**	Large sedge
Eragrostis hypnoides[d]	**S1**	Love tealgrass
Fimbristylis perpusilla[e]	**S1, C2**	Harper's Fimbristylis
Glyceria acutiflora[f]	**S2**	Sharp-scaled manna-grass
Hedyotis uniflora[g]	**S2**	Clustered bluets
Hottonia inflata[h]	**S2**	Featherfoil
Rhynchospora corniculata[i]	**S2**	Short-bristled hornrush

a, in 4 ponds; **b**, in 2 ponds; **c**, in 9 ponds; **d**, in 1 pond; **e**, in 2 ponds; **f**, in 1 pond; **g**, in 1 pond; **h**, in 6 ponds; **i**, in 5 ponds

The two ponds that contain the globally rare Harper's fimbry, *Fimbristylis perpusilla* are described in detail.

Pond 1 *Cephalanthus occidentalis/Polygonum coccineum-Bidens frondosa* Coastal Plain Pond: a small (< 1.0 acre), but significantly high quality pond, surrounded by hardwood forest. The presence of the **Federal Candidate** species, *Fimbristylis perpusilla*, is noteworthy. The buttonbush is a dominant species, particularly along the pond's margin and in its center, while *Glyceria* is abundant in shrubless areas of the pond. Other species found in this pond include *Bidens frondosa, Cyperus strigosus, Panicum dichotomiflorum, Fimbristylis perpusilla, Hottonia inflata, Lindernia dubia, Carex lupulina, C. gigantea, Dulichium arundinaceum*, and *Scirpus cyperinus*. The forested border of the pond is composed of such species as *Acer rubrum, Liquidambar styraciflua, Quercus phellos, Q. palustris, Diospyros virginiana, Nyssa sylvatica, Betula nigra, Clethra alnifolia, Leucothoe racemosa, Smilax rotundifolia*, and *Vaccinium corymbosum*.

Rare Species:

Carex gigantea	**S3**	Large sedge
Fimbristylis perpusilla	**S1, C2**	Harper's Fimbristylis
Glyceria acutiflora	**S2**	Sharp-scaled manna grass
Hottonia inflata	**S2**	Featherfoil

Pond 4 *Cephalanthus occidentalis* Coastal Plain Pond: a small pond with an abundance of *Cephalanthus occidentalis* in the middle portion. Other species include *Lindernia dubia*, and *Polygonum persicaria*. A significant find in this pond was the discovery of the rare (Federal Candidate species for listing) Harper's fimbristylis, *Fimbristylis perpusilla*. This small sedge was found in a dense 5 x 3' mat in an opening between the buttonbush and the tree-shrub pond margin. First discovered here in 1991, *F. perpusilla* did not appear in 1992. However, it reappeared in 1993 surveys, but only 10 stunted plants, covering an area of 1 x 2' were observed (plants appeared as though they had been grazed by deer).

Middletown Quadrangle

Dozens of small coastal plain ponds occur in the southeastern quadrant of the Middletown Quadrangle near Townsend; most of these are less than 1.0 acre in size. These ponds, generally, consist of similar vegetation (see below) and occur either in wet-mesic hardwood forest or are isolated in agricultural fields. The forested ponds may either be surrounded by young second growth or mature forest. Descriptions are provided for eight ponds in this region (Fig. 6).

Ponds 1-6 *Cephalanthus occidentalis/Polygonum coccineum-Bidens frondosa* Wetland Association: these small ponds are in close proximity to each other and consist of very similar vegetation. They are primarily dominated by buttonbush, which often occurs as a dense zone in the pond's central region; the. The herbaceous stratum is usually quite sparse, but may consist of *P. coccineum* and *Bidens* as co-dominants, *Polygonum persicaria*, *P. hydropiperoides*, and *Scirpus cyperinus* are often present, but in low numbers. *Sphagnum* sp. is usually found along the pond perimeter, which more often than not consists of a narrow zone of bare soil.

Ponds 7-8 *Dulichium arundinaceum-Panicum* spp Herbaceous Wetland Association: a small and a medium-sized pond dominated by three-way sedge (*Dulichium*). In these ponds, *Juncus canadensis* (in the medium-sized pond), and *Scirpus cyperinus* (in the small pond), replace the panic grasses as co-dominants. Shrubs, especially *Cephalanthus*, are typically restricted to the pond margin. Other herbaceous species found in these ponds include *Polygonum hydropiperoides, Glyceria* sp., *Typha angustifolia, Ludwigia alternifolia, Nuphar lutea, Bidens* sp., *Lycopus* sp., *Utricularia* sp., and *Sphagnum* sp. The *Sphagnum*, may be found in dense mats either along the margin, or throughout the pond. Woody plants along the perimeter of these ponds consist of *Acer rubrum, Liquidambar styraciflua, Clethra alnifolia, Leucothoe racemosa, Diospyros virginiana*, and *Decodon verticillatus*. No rare species were identified from these ponds, but additional surveys are still needed.

Rare Species:

Several rare species have been identified as occurring in ponds of this region.

Carex barrattii	**S2**	Barratt's sedge
Carex bullata	**S2**	Button sedge
Carex gigantea	**S3**	Large sedge
Eragrostis hypnoides	**S2**	Love tealgrass
Hedyotis uniflora	**S2**	Clustered bluets
Ambystoma maculatum	**S1**	Spotted salamander

South-Central Delaware Ponds

Kenton Quadrangle

There is an abundance of small to medium-sized ponds on this quadrangle; many of these are disturbed, or otherwise degraded, isolated in agricultural fields, or completely destroyed. Data are provided for five rather high quality small to medium-sized ponds in the western portion of Kenton Quadrangle, west of Hartly (Fig. 7). All of these ponds are fairly similar in vegetation composition, though two appear to be filling-in with woody species.

Two ponds (numbered 1-2) may be characterized as ***Cephalanthus occidentalis*/Mixed Herbaceous Wetland Associations:** one of these ponds (#2) is a medium-sized pond (i.e. ≈ 3.0 acres), that is dominated by a diversity of graminoids and broadleaved herbs (with nearly 100% cover value throughout the pond). Low stature *Cephalanthus* shrubs occur in small scattered clusters (≈ 20% cover value), but tend to be concentrated around the pond's perimeter. *Panicum spretum* is highly abundant, while additional herbs present include *Dulichium arundinaceum, Carex striata, Decodon verticillatus, Rhexia virginica, Rhynchospora macrostachya, Proserpinacea pectinata, Scleria reticularis, Nymphaea odorata, Fimbrisytlis autumnalis, Paspalum dissectum, Juncus canadensis, Rhynchospora scirpoides*, and *Sphagnum* sp. One side of the pond has a distinctive zone (ca. 5 m in width) of a nearly monospecific stand of *Panicum hemitomon*, while another similar *Carex striata* zone is also conspicuous. This is a shallow, flat depressional pond (deepest point in the pond is less than one foot deeper than the pond perimeter). Rare species occurring in this pond include *Carex bullata* (**S2**), *Cladium mariscoides* (**S3**), *Rhynchospora inundata* (**S1**), *Scleria reticularis* (**S2**), *Paspalum dissectum* (**S2**), and *Rhynchospora scirpoides* (**S2**). Pond numbered 1 is smaller and not quite as diverse. It has a significant component of small-statured *Cephalanthus* shrubs and an abundance of *Dulichium arundinaceum*. Additional species include *Bidens frondosa, Euthamia tenuifolia, Juncus canadensis, Ludwigia alternifolia, Panicum spretum, Rhexia virginica, Proserpinacea palustris*, and *Hypericum virginicum*. The forested margin includes *Acer, Liquidambar, Diospyros, Clethra*

alnifolia, Leucothoe racemosa, Vaccinium corymbosum, and *Decodon verticillatus*. The globally rare Harper's fimbry, *Fimbristylis perpusilla* (**S1, C2**) was previously identified from this pond.

Ponds numbered 3-5 are characterized as ***Cephalanthus occidentalis/Scirpus cyperinus-Carex striata* Wetland Associations:** these ponds are small and contain an abundance of woody species "filling-in" the open areas. The central portion of one of the ponds consists of a nearly 75-80% shrub cover of *Cephalanthus, Acer, Clethra, Diospyros*, and *Smilax*). *Panicum spretum* replaces *Scirpus* (which occurs in low numbers) as a dominant in two of the ponds, and *Cephalanthus* is the dominant shrub; *Carex striata* occurs in lesser amounts but nevertheless is an important component of the pond. Other species present in the open areas include *Scirpus cyperinus, Rhexia virginica, Proserpinica palustris, Dulichium arundinaceum, Hypericum virginicum, Decodon verticillatus* (abundant at one end of pond 5), *Bidens frondosa, Polygonum coccineum*, and *Sphagnum* sp. The forested perimeter consists of *Acer, Liquidambar, Quercus phellos, Magnolia virginiana, Nyssa sylvatica, Leucothoe, Itea virginica, Clethra alnifolia, Diospyros*, and *Vaccinium corymbosum*.

Rare Species:

Carex bullata	**S2**	Button sedge
Fimbristylis perpusilla	**S1, C2**	Harper's fimbristylis
Paspalum dissectum	**S2**	Walter's paspalum
Rhynchospora inundata	**S1**	Drowned hornrush
Rhynchospora scirpoides	**S2**	Long-beaked baldrush
Sagittaria engelmanniana	**S2**	Engelmann arrowhead
Scleria reticularis	**S2**	Reticulated nutrush

Marydel Ponds

Marydel Quadrangle

A few small and widely scattered ponds are found in the western half of this quadrangle. Most of the ponds that have been surveyed on this quadrangle are of poor quality and somewhat degraded. Only two ponds are described for purposes of this report (see Figs. 8-9).

Pond 1 (Fig. 8), located northeast of Mud Millpond, is a small woodland open depression within a dry oak-maple woods. The forested perimeter of the pond includes *Quercus alba, Q. phellos, Q. palustris, Nyssa sylvatica, Acer rubrum, Liquidambar styraciflua, Sassafras albidum, Clethra, Rhododendron viscosum, Leucothoe racemosa*, and *Gaylussacia frondosa*. The opening is mostly devoid of vegetation except for colonies of *Sphagnum* sp., and *Carex gigantea*. At this time a natural community name is not assigned.

Rare Species:

Carex gigantea	**S3**	Large sedge

Pond 2 (Fig. 9), known as Sandtown Pond, is located just south of Sandtown. This small pond (< 0.5 acre) is of surprisingly good quality considering that it is surrounded by agricultural land to the north, west and south and a road borders its eastern side. The vegetation would fall within the ***Cephalanthus occidentalis/Scirpus cyperinus-Carex striata* Wetland Association**, but with *Panicum hemitomon* and *Juncus canadensis* as co-dominant herbs. *Panicum hemitomon* is abundant on the eastern side. Other species present include *Dulichium arundinaceum, Proserpinaca pectinata, Scirpus cyperinus, Decodon verticillatus, Panicum spretum, Rhynchospora macrostachya, R. scirpoides*, and *Carex striata*.

Rare Species:

Panicum hemitomon	**S2**	Maidencane
Paspalum dissectum	**S2**	Walter's paspalum
Rhynchospora scirpoides	**S2**	Long-beaked baldrush

Southeastern Kent County/Milford Neck East Ponds

Frederica Quadrangle

Several dozen mostly small (though there is one large) Coastal Plain ponds occur on this quadrangle, with the majority on Milford Neck; these occur east of Frederica, and between the Murderkill River and the saltmarshes at Bennetts Pier (Fig. 10).

The following are brief descriptions of individual pond sites and consist of notes on species compositions, water depths, size, etc.:

Pond 1, known locally as Black's Pond, consists of a ***Nymphaea odorata-Utricularia gibba* Wetland Association**. This is a relatively large Coastal Plain pond [ca. 1200 x 500 ft. (13 acres)] with a relatively low diversity. It may occasionally experience an influx of salinity from the nearby saltmarsh. Several State rare species have been observed here (see below). A survey undertaken on 06 October 1993 showed that the pond had completely drawn-down (i.e. was dry). The pond is elliptically-shaped, with its long axis in a southeast-northwest orientation, and it is surrounded by a very narrow wooded buffer (portions have been logged recently). The species composition may vary from year to year; more thorough studies are needed to assess overall species composition and variations from year to year. Surveys in July 1991 revealed a pond dominated by dense colonies of white water lily, *Nymphaea odorata*, and humped bladderwort, *Utricularia gibba* (**S2**), while surveys in October 1993 revealed a pond that was dry and practically devoid of vegetation (except around its perimeter where dense stands of *Phragmites* and *Typha angustifolia* were present). The bare mud of the pond opening was extensively cracked and had an abundance of a white crusty substance that may have been an accumulation of salts.

Additional species observed in this pond from surveys in 1991 and 1993 include the following: *Echinochloa walteri*, *Eleocharis* cf. *obtusa*, *Eleocharis quadrangulata* (**S3**), featherfoil, *Hottonia inflata* (**S2**), *Ludwigia palustris*, *Myriophyllum pinnatum* (**S2**), *Polygonum hydropiperoides*, and *Potamogeton pulcher*. Several clumps of the large sedge, *Carex gigantea* (**S3**) were observed immediately adjacent to the pond in the forested perimeter. Species present in the forested border of the pond opening include red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), oaks (*Quercus phellos*, *Q. alba*, *Q. rubra*, *Q. palustris*), poplar (*Liriodendron tulipifera*), *Ilex opaca*, *Magnolia virginiana*, *Clethra alnifolia*, *Cornus florida*, *Smilax rotundifolia*, *Amelanchier* sp., *Phytolacca americana*, *Thelypteris palustris*, *Hypericum virginicum*, *Boehmeria cylindrica*, *Toxicodendron radicans*, *Decodon verticillatus*, *Cephalanthus occidentalis*, and *Bidens frondosa*, among others.

Rare Species:

Carex gigantea	**S3**	Large sedge
Eleocharis quadrangulata	**S3**	Squarestem spikerush
Hottonia inflata	**S2**	Featherfoil
Myriophyllum pinnatum	**S2**	Cutleaf water-milfoil
Utricularia gibba	**S2**	Humped bladderwort

Pond 2, located immediately across Rd 121 from Black's Pond (Pond #1) is a medium-sized pond (ca. 5 acres), with a sw-ne orientation, that consists of a ***Cephalanthus occidentalis/Ludwigia sphaerocarpa-Polygonum* sp. Wetland Association**. No standing water was present on survey date (6 Oct 1993) and the pond was overgrown with a dense cover of vegetation. Only a limited amount of forested buffer surrounds this pond; the dense vegetation may be resulting from nutrient enrichment from agricultural run-off. Buttonbush (*Cephalanthus*) was the dominant woody species in the pond (with a cover value of ca. 10%). The diverse herbaceous stratum was dominated by *Ludwigia* and *Polygonum*, while other less abundant species included *Bidens frondosa*, *B. laevis*, *Cuscuta sp.*, *Cyperus sp.*, *Echinochloa walteri*, *Glyceria septentrionalis*, *Proserpinica palustris*, *Rhynchospora macrostachya*, and *Xanthium* sp.

Rare Species:

On a previous visit (6/91) several State rare species were observed: featherfoil, *Hottonia inflata* (**S2**), and small swollen bladderwort, *Utricularia radiata* (**S3**). The black-fruited spikerush, *Eleocharis melanocarpa* (**S2**), was discovered here in 1983, but not observed during recent surveys, and the large sedge, *Carex gigantea* (**S3**) was observed along the pond's perimeter during 1993.

More work is needed to appropriately classify the following ponds.

Pond 3 is a small pond (< 1.0 acre) north of Nos. 1 and 2, along

the west side of RD 121. This pond is very near the marshes of the Murderkill River and may be under irregular tidal influence. This pond was not surveyed during 1993, but previous surveys revealed that it is herbaceous-dominated and is comprised of the following species: common reed, *Phragmites australis*, widgeon-grass, *Ruppia maritima*, squarestem spikerush, *Eleocharis quadrangulata*, and cutleaf water-milfoil, *Myriophyllum pinnatum*. The presence of widgeon-grass suggests that this pond may be somewhat brackish.

Rare Species:

Eleocharis quadrangulata	**S3**	Squarestem spikerush
Myriophyllum pinnatum	**S2**	Cutleaf water-milfoil

Pond 4 is another small pond (< 1.0 acre), located just north of Pond 1 and is also immediately adjacent to saltmarshes. Surveys during 1991 revealed the presence of the following species: *Glyceria septentrionalis*, *Hibiscus moscheutos*, *Hottonia inflata*, *Ludwigia palustris*, *L. sphaerocarpa*, *Myriophyllum pinnatum*, *Nymphaea odorata*, *Phragmites australis*, *Polygonum* sp., *Pontederia cordata*, *Proserpinica palustris*, *Ruppia maritima*, and *Typha angustifolia*. Woody species, generally occurring around the pond's perimeter (which has a very small forested buffer) include *Acer rubrum*, *Liquidambar styraciflua*, *Myrica cerifera*, and *Nyssa sylvatica*. The presence of *Ruppia* and the pond's proximity to salt marshes indicate brackish conditions may be present.

Rare Species:

Hottonia inflata	**S2**	Featherfoil
Myriophyllum pinnatum	**S2**	Cutleaf water-milfoil

Pond 5: another small pond (< 1.0 acre) that is located due north of Pond 4. This herbaceous-dominated pond, surveyed in 1991, contained the following assemblage of species: *Carex straminea*, *Cladium mariscoides*, *Eleocharis* sp., *Hibiscus moscheutos*, *Hydrocotyle umbellata*, *Hypericum virginicum*, *Juncus canadensis*, *Myriophyllum pinnatum*, *Panicum wrightianum*, *Spartina patens*, and *Typha angustifolia*. Woody species included *Acer rubrum*, *Myrica cerifera*, *Nyssa sylvatica*, and *Rosa palustris*. Due to its proximity to the saltmarshes and the presence of *Spartina patens* this pond may be slightly brackish.

Rare Species:

Myriophyllum pinnatum	**S2**	Cutleaf water-milfoil
Panicum wrightianum	**S2**	Wright's panic grass

Pond 6: a small (< 1.0 acre) Coastal Plain pond across RD 121 from Pond 3. This pond was surveyed in 1991 and was found to be devoid of vegetation; additional surveys are needed.

Southern Delaware Ponds

The coastal plain ponds in this area of the state are different from those of Kent and New Castle Counties; buttonbush and other shrubs are either lacking or in few numbers, and there is a greater diversity of herbaceous species, particularly of sedges.

Milton Quadrangle

In his study of the "bays" and basins of Delaware, Rasmussen (1958), after reviewing aerial photography and field surveys, identified 243 bays and basins on the Milton Quadrangle. It is not clear how many of these he considered to be bays, but after studying the topographic map and reviewing recent photography it seems that there are less than 20 bays on this quadrangle; and many of these are now forested or otherwise degraded. Only one pond from this quadrangle is described for this report (Fig. 11).

The pond encircled in red on Fig. 11 is known as **Huckleberry Pond** and is characterized as a **Mixed Graminoid Wetland Association.** This pond represents one of the largest and highest quality ponds on the Delmarva Peninsula. An exceptionally diverse wetland that is dominated by herbaceous species, with nearly 100% cover. The following species are quite abundant in this pond, as they are either scattered throughout or form large colonies: *Panicum spretum*, *P. verrucosum*, *P. dichotomiflorum*, *Scleria reticularis*, *Rhynchospora nitens*, *R. macrostachya*, *Eleocharis microcarpa*, *E. quadrangulata*, *E. robbinsii*, *Coreopsis rosea*, and *Lachnanthes caroliana*. Scattered red maple, persimmon, sweet gum, and loblolly pine trees are found in several areas of the pond opening, which measures nearly 12 acres in size. More than half of the pond has been invaded by woody trees such as maple, gum, and oak and is now completely forested.

With its elliptical shape, nw-se orientation, and prominent southeastern rim, Huckleberry Pond is a classic example of a Carolina bay. The rim, nearly 20 feet above the low point of the pond interior, consists primarily of sandy soils compared to the basin soils that are comprised of sandy loam, silty loam, or muck. The shallow pond surface varies less than 0.5 meter in depth from the center to the pond edge.

A comparison of an historical 1938 aerial photograph of Huckleberry Pond (by the Soil Conservation Service) versus a 1992 color-infrared photograph revealed a nearly 50% reduction in herbaceous cover as a result of woody plant invasion. The circular-shaped forest tract immediately adjacent to Huckleberry pond (Fig. 11) appears to be a Carolina bay that has become completely filled-in by trees. The 1938 photograph indicates that there were scattered, small openings in the bay hinting that at one time it was an open herbaceous-dominated bay.

Rare Species:

A dozen State rare species have been discovered at the Huckleberry Pond site: blue maiden-cane, *Amphicarpum purshii* (S2); wrinkled-jointgrass, *Coelorachis rugosa* (S1); pink tickseed, *Coreopsis rosea* (S1); black-fruited spikerush, *Eleocharis melanocarpa* (S2); squarestem spikerush, *E. quadrangulata* (S3); Robbin's spikerush, *E. robbinsii* (S3); three-angle spikerush, *E. tricostata* (S1); Carolina redroot, *Lachnanthes caroliana* (S1); Wright's witchgrass, *Panicum wrightianum* (S2); Walter's paspalum, *Paspalum dissectum* (S2); loose-headed beakrush, *Rhynchospora nitens* (S1); and Small's yellow-eyed grass, *Xyris smalliana* (S2).

It is likely that additional rare species will be discovered with more surveys; animal surveys are incomplete. It should be mentioned that annual surveys of the vegetation of this pond since 1984 has revealed a dynamic landscape with changes in the flora as some species disappear for a year or more and other species appear for the first time. These changes are probably influenced by variations in the pond's flooding depths and durations.

Fairmount Quadrangle

Several ponds are known to occur on this quadrangle; only one of these ponds will be described (encircled in red on Fig. 12).

A medium-sized (ca. 7.5 acres) pond kown as **Still Pond** occurs west of Lewes. This pond is characterized as a **Mixed Graminoid Wetland Association.** It is a very high quality pond that is dominated by herbaceous perenniels in several distinctive zones: a ***Panicum* spp. zone** consists of an abundance of *P. verrucosum, P. wrightianum, P. dichotomiflorum*, and *Paspalum dissectum*. This zone is highly diverse with additional species such as *Leersia oryzoides, Scleria reticularis, Rhynchospora macrostachya, Viola lanceolata, Rhexia virginica*, and *Bidens frondosa* from among nearly 30 species recorded from a 3x3 m plot. This community intergrades into a less diverse ***Panicum verrucosum-Rhynchospora macrostachya* zone**; further inward *Eleocharis robbinsii* appears as a co-dominant. The previous community changes into a narrow ***Eleocharis quadrangulata* zone** which borders a ***Pontederia cordata-Panicum dichotomiflorum* zone** occupying the center of the pond at its deepest point. The *Panicum* occurs as "floating" mats. *Nymphaea odorata* is also present in this zone. The pond's forested perimeter is characterized by the presence of *Acer rubrum, Liquidambar styraciflua, Nyssa sylvatica, Quercus phellos, Magnolia virginiana, Ilex opaca, Vaccinium corymbosum*, and *Leucothoe racemosa*.

This pond is deeper than the Huckleberry pond with its central portion nearly 2.5 feet deeper than the pond's perimeter. A distinct sandy rim occurs on the pond's southeast side. Due south of this pond is another pond (not surveyed) of approximately the same dimensions separated from each other by a narrow forested

bridge (see Fig. 12).

Rare Species:

An array of rare species have been identified from this pond: pink tickseed, *Coreopsis rosea* (S1); squarestem spikerush, *Eleocharis quadrangulata* (S3); Robbin's spikerush, *E. robbinsii* (S3); hairy umbrella sedge, *Fuirena squarrosa* (S3); clustered bluets, *Hedyotis uniflora* (S2); creeping St. Johns-wort, *Hypericum adpressum* (S2); brown-fruited rush, *Juncus pelocarpus* (S2); Carolina redroot, *Lachnanthes caroliana* (S1); large flowering heart, *Nymphoides aquatica** (S1); small floating heart, *N. cordata* (S1); Wright's witchgrass, *Panicum wrightianum* (S2); Walter's paspalum, *Paspalum dissectum* (S2); toothcup, *Rotala ramosior* (S3); grassleaf arrowhead, *Sagittaria graminea* (S2); reticulated nutrush, *Scleria reticularis* (S2); and small swollen bladderwort, *Utricularia radiata* (S2) among plant species and tiger salamander, *Ambystoma tigrinum* (S1), and barking treefrog, *Hyla gratiosa* (S1) among the animals.

* reportedly needs verification

Like Huckleberry pond, the species assemblages in this pond varies from year to year, with some species disappearing for one or more years, and some species newly appearing with subsequent surveys.

Although the Nature Conservancy has a management agreement with the landowner, the quality of this pond is threatened by agricultural run-off and lawn maintenance activities of an adjacent landowner whose property extends to the edge of the pond. A number or weedy species, suggesting nutrient enrichment or disturbance, occur in the pond, including the noxious common reed, *Phragmites australis*, *Paspalum ciliatifolium*, *Polygonum pensylvanicum*, and *Ambrosia artemisifolia*.

Assawoman Bay/Bethany Beach Quadrangles

In the region of the Assawoman Bay Wildlife Area, in southeastern Sussex County occur about 10 freshwater Coastal Plain ponds (Fig. 13). In addition to these naturally occurring ponds, there are several salt/brackish ponds within saltmarsh habitats, some of these may be excavated open marsh water management (OMWM) ponds. Nearly all of the freshwater ponds surveyed were found to have one or more rare species, including one pond with several Federal Candidate species (see below). For purposes of this report only two ponds will be described.

A medium-sized (ca. 4.0 acres) pond (numbered 1) with an east-west orientation, known as **Assawoman Pond** is highly diverse and of global significance. It may be characterized as a **Mixed Graminoid Wetland Association**, with *Cladium mariscoides-Panicum spretum-*

Coelorachis rugosa as co-dominants. Although this pond is a graminoid-dominated herbaceous wetland, there is also a significant component of woody plants. In addition to the above three graminoids, the following species (in lesser numbers) are also present: *Sclerolepis uniflora* (though may be abundant in patches), *Rhexia virginica, Proserpinaca pectinata, Xyris smalliana, Hypericum denticulatum, Rhexia aristosa*, and *Sphagnum* sp (in large numbers). One side of the pond contains an extensive *Carex striata* zone that may be spreading, and a large cluster of *Acer rubrum* and *Liquidambar styraciflua* (which also may be spreading) occurs in the pond's middle. Additional species observed from previous years surveys included *Rhynchospora inundata, Boltonia asteroides, Panicum hirstii, Panicum verrucosum, Juncus repens, J. canadensis, Dulichium arundinaceum, Eriocaulon compressum, Sabatia difformis, Rhynchospora harperi*, and *Panicum longifolium*. The woody perimeter of the pond is dominated by *Acer rubrum*, and *Liquidambar*, with lesser numbers of *Diospyros virginiana, Nyssa sylvatica, Clethra alnifolia*, and *Ilex opaca*. The surrounding upland forest is diverse and is comprised of *Acer, Quercus alba, Q. palustris, Pinus taeda, P. virginiana, Sassafras, Rhododendron viscousum, Vaccinium corymbosum, Leucothoe racemosa, Gaylussacia frondosa, Magnolia virginciana, Cypripedium acaule, Mitchella repens*, and *Isotria verticillata*, to name a few.

The margin of the pond is only about one foot higher than the deepest cental portion of the pond. The sandy rim on the pond's east side is not at all conspicuous as the land gradually rises to the uplands. There is a nearly 10 foot increase in elevation from the pond's edge to a distance of about 300 feet, with most of the increase occurring in the last 100 feet; this point is adjacent to a sandpit. It does not appear that this increased elevation resulted from excavated material from the sand pit.

Rare Species:

The significance of this pond is due to the presence of several globally rare species, including the Federal (for listing as Endangered or Threatened) Candidate species, Hirst's panic grass, *Panicum hirstii* (**S1, C2**), and the awned meadowbeauty, *Rhexia aristosa* (**S1, C2**). Other rare species include two-formed pink, *Sabatia difformis* (**S1**); pink bog-button, *Sclerolepis uniflora* (**S1**); flattened pipewort, *Eriocaulon compressum* (**S2**); aster-like boltonia, *Boltonia asteroides* (**S2**); wrinkled jointgrass, *Coelorachis rugosa* (**S1**); Small's yellow-eyed grass, *Xyris smalliana* (**S2**); reticulated nutrush, *Scleria reticularis* (**S2**); coppery St. John's-wort, *Hypericum denticulatum* (**S2**); drowned hornrush, *Rhynchospora inundata* (**S1**); and Harper's beak-rush, *R. harperi* (**S1**). The latter species has just recently been determined to occur in Delaware. It was previously known only from five sites in Georgia, Florida, and Alabama, but more recently has been discovered in the Carolinas, Maryland, and Delaware (LeBlond 1994).

Although this pond is owned by the State, is part of the Assawoman Bay Wildlife Area, and is a State designated Natural Area, it is still threatened by further invasion of woody species and changes to the pond's hydrology. A nearby sandpit may be impacting the pond's hydrology. The spread of woody species should be curtailed and removal of some of the trees be considered, and the affect the sandpit has on the pond's hydrology should be determined.

East of **Assawoman Pond** occurs a small (< 1.0 acre) pond (numbered 2) known by the Natural Heritage Inventory as **Sweet-Boltonia Pond.** This pond may be classified as a **Mixed Graminoid Wetland Association** that is dominated by the following taxa: ***Boltonia asteroides-Sclerolepis uniflora-Juncus repens***. Other less abundant species in the pond include *Ludwigia alternifolia, Panicum spretum, Proserpinaca palustris, Rhynchospora macrostachya,, Rhexia virginica, Polygonum hydropiperoides, Xyris smalliana, Pluchea foetida*, and *Juncus* sp. Immediately adjacent to the herb zone is a narrow zone (ca. 30-50 feet wide) comprised of a dense thicket of sweet gum, *Liquidambar styraciflua* that completely encircles the pond. This zone is near the pond's perimeter, immediately interior to a narrow *Sphagnum* zone. The adjacent upland forest is a mix of pines and hardwoods (see description above for Assawoman Pond).

Rare Species:

Several rare species occur in this pond, including aster-like boltonia, *Boltonia asteroides* (**S2**); pink bog-button, *Sclerolepis uniflora* (**S1**); and Small's yellow-eyed grass, *Xyris smalliana* (**S2**).

Additional surveys are needed at this pond, and efforts should be undertaken to control the sweet gum (e.g. by cutting or burning).

The preceeding provides an overview of the locations of the majority of Coastal Plain ponds in Delaware and describes the community structure and vegetation of representative examples. Though not comprehensive, the data presented should be useful as a guide to the photo-interpretation and mapping of Category I Coastal Plain pond wetlands. In addition to the above locations, Coastal Plain ponds are known to occur (though in much lower numbers) on the following quadrangles: Whaleysville (Great Cypress Swamp), Sharptown, Ellendale, Mispillion River, Harrington, Burrsville, Wyoming, Dover, Smyrna, Elkton, St. Georges, and Newark East. Of these quadrangles there are generally more ponds on the Ellendale quadrangle than the others; many of these are degraded but are nevertheless habitat for many rare plant species.

DISCUSSION

There are probably no more than 500 relatively intact (though some of these may have varying degrees of degradation) Coastal Plain ponds in Delaware, with the majority occurring in the west-central portion of the state. An additional 1000 ponds (a rough

approximation) appear to have been severely impacted or destroyed by anthropogenic activities (primarily due to agricultural practices and development projects). Not a single pond can be characterized as pristine as all have been impacted to one degree or another. These impacts include complete clearcutting of surrounding forest habitat, ditching to facilitate draining of adjacent lands, and perturbations to the associated ground water. In spite of the degradations to these habitats, their unique geo-hydro-ecological attributes warrant protection and restoration efforts and their classification as Category I freshwater wetlands.

Justification for Category I Freshwater Wetland Designation

The following enumerate the reasons for designating Coastal Plain ponds (i.e. Carolina Bays) in Delaware as Category I freshwater wetlands:

- Coastal Plain ponds are geologically unique. Though relatively abundant from Florida to New Jersey, they are thought to have originated from some common, as yet undetermined, abiotic force(s) operating on the landscape. These indeterminate forces formed thousands of distinct, shallow depressions on the Atlantic Coastal Plain. Recurring features of these ponds include: elliptical or oval shapes, nw-se orientation, seasonally flooded (except for the deepest ponds), and sandy rims more pronounced on the southeast side.

- Delaware's Coastal Plain ponds may harbor numerous State species of special concern or federally listed endangered, threatened, or candidate plant species: e.g., awned meadowbeauty (*Rhexia aristosa*), Hirst's panic grass (*Panicum hirstii*), Harper's fimbry (*Fimbristylis perpusilla*), bog St. John's-wort (*Hypericum adpressum*), pink tickseed (*Coreopsis rosea*), to name only a few.

- Coastal plain ponds may be critical habitat for a number of rare animal species: e.g., spotted salamander (*Ambystoma maculatum*), tiger salamander (*A. tigrinum*), Cope's gray treefrog (*Hyla chrysoscelis*), and barking treefrog (*H. gratiosa*), and are important habitats for a host of other more common animal species.

- High quality, intact Coastal Plain ponds are relatively rare and, therefore, it is imperative that these ponds receive the highest level of protection.

- Coastal Plain ponds are significant because they are primary groundwater driven and their community structure (i.e. species composition and zonal patterns) are determined by water depths and duration of flooding. These systems have unique hydrologic regimes.

- Coastal Plain ponds are critical groundwater recharge areas, and therefore, are important from an agricultural standpoint and for providing and maintaining drinking water.

- In addition to the extensive suite of rare species found in Coastal Plain ponds, there is often a unique assemblage of characteristic or "signature" plant species. Although these species, alone, are not unique to Coastal Plain ponds, their presence in recurring assemblages may be a unique characteristic of these ponds.

- Coastal Plain ponds on the Delmarva seem to be distinct from those found elsewhere and thus may even be rarer entities.

- Coastal Plain ponds are under significant and continual threats from anthropogenic activities.

Category I Freshwater Wetland Mapping Criteria

1. Figs. 1-13 (individual topographic maps) will direct photo-interpreters to known, field identified Coastal Plain ponds. By comparing topographic maps with aerial photography a so-called "signature" for Coastal Plain ponds may be developed.

2. Coastal Plain ponds typically possess an identifiable shape (e.g. round, oval, or elliptical), are generally open non-forested features (but many may also be forested), and contain standing water at least for a protion of the year (this is particularly evident in spring aerial photography). They appear as dark, glossy spots on color infrared photography. Non-category I, excavated ponds are usually identifiable by their shape (e.g. rectangular) and are typically deeper than natural ponds (though not certain if this is recognizable from aerial photography).

3. For purposes of Category I designation, those ponds that are: in forested habitats (and are either open or forested wetlands), possess a distinct sandy ridge, especially on the southeast side (not certain that this can be observed by photo-interpreter), and have a definite regular shape (e.g. round or elliptic) shall be mapped as Category I wetlands. Please note: one or more of the above features may be lacking.

4. Ponds that are isolated in agricultural fields and are completely cleared of all vegetation or are without perceptible forested buffer should not be mapped as Category I wetlands. However, Natural Heritage staff should be able to ammend the maps if any ponds of this type are determined to harbor rare species, continue to maintain hydrologic functions (i.e. seasonally flooded, groundwater driven), and are candidates for restoration.

5. Ponds that have characteristics described in 2, but that occur within coastal salt marshes, for obvious reasons, will not be mapped as Category I freshwater wetlands.

6. Generally, it is not possible to determine the quality of Coastal Plain ponds from photo-interpretation. The presence of

ditches are often obscured by vegetation cover and the species present are not identifiable from spring photography. Therefore, it is recommended that all ponds within forested habitats, be mapped as Category I; those ponds not yet inventoried by Natural Heritage should then be field-checked to determine the extent of possible degradation. Those identified as degraded Coastal Plain ponds should then be re-classified as Category II and the feasibilty or potential for their restoration to Category I status should be evaluated.

7. Although pond hydrology is known to be primarily groundwater driven, the overall hydrologic dynamics of Coastal Plain ponds are poorly understood. It is not possible to determine from aerial photography the geographic area that influences pond hydrology, therefore, the pond's outer boundary should be mapped to the upland ridge (if apparent) that encircles the pond. While this would encompass lands not technically designated as wetlands, it does include land that is believed to be critical to maintaining the pond's structural and biological integrity (Phillips and Shedlock 1993). Furthermore, those ponds that have extensive forested margins that may obscure the pond boundary should also be mapped to the upland ridge (if apparent).

LITERATURE CITED

Benson, R. N. and T. E. Pickett. 1986. Geology of south-central Kent County, Delaware. Geologic Map Series #7. Delaware Geological Survey, Newark, Delaware.

Bliley, D. J. 1974. Soils and morphology of Carolina bays, eastern shore Virginia. Master of Science Thesis. Virginia Polytechnic Institute and State University. Blacksburg.

Breden, T. F. 1989. A preliminary natural community classification for New Jersey. Pages 157-191 in E. F. Karlin (ed.) New Jersey's rare and endangered plants and animals. Institute of Environmental Studies, Ramapo College, Mahwah, NJ. 280 p.

Buell, M. F. 1939. Peat formation in the Carolina bays. Bull. Torr. Bot. Club 66:483-487.

Buell, M. F. 1946. Jerome Bog: a peat-filled Carolina bay. Bull. Torr. Bot. Club 73:24-33.

Christensen, N. L. 1981. Fire regimes in southeastern ecosystems, pp. 112-136 in H. A. Mooney, T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reinsers (eds.) Fire regimes and ecosystem properties. USDA Forest Service Technical Report WO-26.

Christensen, N. L. 1988. Vegetation of southeastern Coastal Plain, pp. 318-363 in M. G. Barbour, W. D. Billings (eds.) North American Terrestrial Vegetation. Cambridge University Press. Cambridge.

Delaware Natural Heritage Inventory. 1994. Unpublished database. Delaware Department of Natural Resources and Environmental Control, Dover.

Fleming, L. 1978. Delaware's outstanding natural areas and their preservation. Delaware Nature Education Society, Hockessin, DE.

Frey, D. G. 1950. Carolina bays in relation to the North Carolina Coastal Plain. Jour. of the Elisha Mitchell Sci. Soc. 66:44-52.

Gamble, E. E., R. B. Daniels, and W. H. Wheeler. 1977. Primary and secondary rims of Carolina bays. Southeastern Geol. 18:199-212.

Greenhorne and O'Mara. 1991. State of Delaware freshwater wetlands inventory pilot project. Unpublished report. Greenbelt, Maryland.

Ireland, W. and E. D. Mathews. 1974. Soil Survey of Sussex County, DE. United States Department of Agriculture, Soil Conservation Service, in cooperation with Delaware Agricultural Experiment Station. U. S. Government Printing Office, Washington D. C.

Johnson, D. W. 1942. The origin of the Carolina bays. Columbia University Press. New York.

LeBlonde, R. J. 1994. Note of the distribution and identification of *Rhynchospora harperi* Small. Manuscript submitted for review. *Castanea* 59:000-000.

Mathews, E. D. and O. L. Lavoie. 1970. Soil Survey of New Castle County, DE. United States Department of Agriculture, Soil Conservation Service, in cooperation with Delaware Agricultural Experiment Station. U. S. Government Printing Office, Washington D. C.

Mathews, E. D. and W. Ireland. 1971. Soil Survey of Kent County, DE. United States Department of Agriculture, Soil Conservation Service, in cooperation with Delaware Agricultural Experiment Station. U. S. Government Printing Office, Washington D. C.

McCarthy K. A. 1987. Spatial and temporal distribution of species in two intermittent ponds in Atlantic County, New Jersey. Master of Science Degree, Rutgers University. New Brunswick.

Newman, M. C. and J. F. Schalles. 1990. The water chemistry of Carolina Bays: a regional survey. Arch. Hydrobiol. 118:147-168.

Peroni, P. A. 1988. A vegetation history of the North Carolina Nature Conservancy clay-based Carolina Preserve with recommendations for future research. Unpublished report submitted to The Nature Conservancy, Southern Heritage Task Force, Chapel Hill, North Carolina.

Pettry, D. E., J. H. Scott and D. J. Bliley. 1979. Distribution and nature of Carolina bays on the eastern shore of Virginia. Virginia J. of Science 30:3-9.

Phillips, P. J. and R. J. Shedlock. 1993. Hydrology and chemistry of groundwater and seasonal ponds in the Atlantic Coastal Plain in Delaware, USA. Jour. of Hydrology 141:157-178.

Picket T. E. and N. Spoljaric 1971. Geology of the Middletown-Odessa Area. Geologic Map Series #2. Delaware Geological Survey, Newark, Delaware.

Prouty, W. F. 1952. Carolina bays and their origin. Geol. Soc. Bull 63:167-224.

Rasmussen, W. C. 1958. Geology and hydrology of the "bays" and basins of Delaware. Ph.D. Dissertation, Bryn Mawr College, Bryn Mawr, Pennsylvania.

Reed, P. B. 1988. National list of plant species that occur in wetlands: northeast (Region 1). U. S. Fish and Wildlife Service

Biol. Report 88 (26.1). U. S. Department of the Interior, Washington, D. C.

Savage, H. 1982. *The Mysterious Carolina Bays*. University of South Carolina Press, Columbia. 121 p.

Schafale, M. P. and A. S. Weakley. 1990. Classification of the natural communities of North Carolina. Third approximation. North Carolina Natural Heritage Program, North Carolina Department of Environment, Health and Natural Resources. Raleigh.

Schalles, J. F. and D. J. Shure. 1989. Hydrology, community structure and productivity of a dystrophic Carolina bay wetland. Ecol. Monographs 59:365-385.

Sharitz, R. R. and J. W. Gibbons. 1982. The ecology of southeastern shrub bogs (pocosins) and Carolina bays: a community profile. U.S. Fish & Wildlife Service/OBS-82/04. U.S. Government Printing Office, Washington D. C.

Shreve, F., M. A. Chrysler, F. H. Blodgett and F. W. Besley. 1910. The plant life of Maryland. The Johns Hopkins Press. Authorized 1969 reprint. Reprints of U. S. floras, J. Cramer (ed.), vol. 5. Verlag von J. Cramer, New York.

Sipple, W. S. and W. A. Klockner. 1984. Uncommon wetlands in the coastal plain of Maryland. In: A. W. Norden, D. C. Forester, and G. H. Fenwick (eds.), Threatened and endangered plants and animals of Maryland. Proceedings of a symposium held Sep 3-4, 1981, at Towson State University, Towson, Maryland. Maryland Natural Heritage Program, Department of Natural Resources, Annapolis, Maryland.

Sneddon, L. 1990. Vegetation and fire history of Double Pond: a summary of progress. Unpublished report submitted to the Delaware Natural Heritage Inventory, Department of Natural Resources and Environmental Control, Dover.

Stolt, M. H. 1986. Distribution, characterization, and origin of Delmarva bays on Maryland's eastern shore. Master of Science Thesis. Univeristy of Maryland, College Park.

Stolt, M. H. and M. C. Rabenhorst. 1987a. Carolina bays on the Eastern Shore of Maryland: I. Soil characterization and classification. Soil Sci. Soc. Am. J. 51:394-398.

Stolt, M. H. and M. C. Rabenhorst. 1987b. Carolina bays on the Eastern Shore of Maryland: II. Distribution and origin. Soil Sci. Soc. Am. J. 51:399-405.

Tatnall, R. R. 1946. Flora of Delaware and the Eastern Shore. The

Society of Natural History of Delaware. Hockessin.

Thom, B. G. 1970. Carolina bays: genesis age. Geol. Soc. of Amer. Bull. 81:783-813.

Tilly, L. J. 1973. Comparative productivity of four Carolina lakes. American Midland Naturalist 90:356-365.

Tyndall, R. W. 1989. Aerial photo analysis of woody plant succession in eight Delmarva bays. Unpublished report submitted to The Nature Conservancy, Maryland Field Office, Chevy Chase.

Tyndall, R. W., K. A. McCarthy, J. C. Ludwig, and A. Rome. 1990. Vegetation of six Carolina Bays in Maryland. Castanea 55:1-21.

Virginia Department of Game and Inland Fisheries. 1991. Virginia's endangered species: proceedings of a symposium. K. Terwilliger (coord.). McDonald and Woodward Publ. Comp., Blacksburg, VA.

Wells, B. W. and S. G. Boyce. 1953. Carolina bays: additional data on their origin, age and history. Jour. of the Elisha Mitchell Sci. Soc. 69:119-141.

Wharton, C. H. 1978. The natural environments of Georgia. Georgia Department of Natural Resources, Atlanta.

Herbaceous Species

Agrostis perennans	S5	Perennial bentgrass	FACU
Ambrosia artemisiifolia	S5	Ragweed	FACU
Amphicarpum purshii	S2	Blue maidencane	FACU
Asclepias incarnata	S5	Swamp milkweed	OBL
Asclepias lanceolata	S1	Few-flower milkweed	OBL
Bidens frondosa	S5	Beggar-ticks	FACW
Bidens polylepis	S5	Awnless b.-ticks	FACW
Boehmeria cylindrica	S5	False nettle	FACW+
Boltonia asteroides	S2	Aster-like boltonia	FACW
Brasenia schreberi	S4	Watershield	OBL
Carex barrattii	S2	Barratt's sedge	OBL
Carex bullata	S2	Button sedge	OBL
Carex crinita	S5	Fringe's sedge	OBL
Carex festucacea	S4	Fescue sedge	FAC
Carex gigantea	S3	Large sedge	OBL
Carex intumescens	S5	Bladder sedge	FACW+
Carex lupulina	S5	Hop sedge	OBL
Carex lurida	S5	Shallow sedge	OBL
Carex striata	S5	Walter's sedge	OBL
Carex typhina	S2	Cattail sedge	FACW+
Centella erecta	S2	Erect coinleaf	FACW
Cladium mariscoides	S4	Twigrush	OBL
Coelorachis rugosa	S1	Wrinkled jointgrass	OBL
Coreopsis rosea	S1	Pink tickseed	FACW
Cuscuta sp.		A dodder	-
Cyperus erythrorhizos	S4	Red-root flatsedge	FACW+
Cyperus odoratus	S5	Fragrant galingale	FACW
Cyperus strigosus	S5	A cyperus	FACW
Decodon verticillatus	S5	Water willow	OBL
Drosera intermedia	S4	Slenderleaf sundew	OBL
Dulichium arundinaceum	S5	Three way sedge	OBL
Echinochloa crusgalli	S5	Barnyard grass	FACU
Echinochloa muricata	S5	Barnyard grass	FACW+
Echinchloa walteri	S5	Walter's millet	FACW+
Eleocharis microcarpa	SU	Smallfruit spikerush	OBL
Eleocharis obtusa	S4	Blunt spikerush	OBL
Eleocharis olivacea	S5	Green spikerush	OBL
Eleocharis palustris	S5	Swamp spikerush	OBL
Eleocharis parvula	S4	Small spikerush	OBL
Eleocharis quadrangulata	S3	Squarestem spikerush	OBL
Eleocharis robbinsii	S3	Robbin's spikerush	OBL
Eleocharis tricostata	S1	Three-angle spikerush	OBL

APPENDIX A. Vascular plant species observed in Coastal Plain ponds in Delaware. The list is not comprehensive, as further inventory may result in additional species. Wetland Indicator Status is given for each species, using Regional Indicator Status when possible (Reed 1988).

Scientific Name	State Rank	Common Name	Wetland Indicator Status
Woody Species			
Acer rubrum	S5	Red maple	FAC
Amelanchier canadensis	S5	Service berry	FAC
Aronia arbutifolia	S5	Chokecherry	FACW
Betula nigra	S4	River birch	FACW
Cephalanthus occidentalis	S5	Buttonbush	OBL
Clethra alnifolia	S5	Sweet pepperbush	FAC+
Cornus amomum	S5	Silky dogwood	FACW
Diospyros virginiana	S5	Persimmon	FAC-
Hibiscus moscheutos	S5	Swamp mallow	OBL
Ilex laevigata	S5	Smooth holly	OBL
Ilex opaca	S5	American holly	FACU+
Itea virginica	S4	Virginia willow	OBL
Gaylussacia frondosa	S5	Dangleberry	FAC
Leucothoe racemosa	S5	Fetterbush	FACW
Liquidambar styraciflua	S5	Sweetgum	FAC
Magnolia virginiana	S5	Sweet bay magnolia	FACW+
Myrica cerifera	S5	Southern bayberry	FAC
Nyssa sylvatica	S5	Black gum	FAC
Pinus taeda	S5	Loblolly pine	FAC-
Populus heterophylla	S5	Swamp poplar	FACW+
Quercus bicolor	S2	Swamp white oak	FACW+
Quercus lyrata	S1	Overcup oak	FAC-
Quercus palustris	S5	Pin oak	FACW
Quercus phellos	S5	Willow oak	FAC+
Rhododendron viscosum	S5	Swamp azalea	OBL
Rosa palustris	S5	Swamp rose	OBL
Salix nigra	S5	Black willow	FACW+
Smilax rotundifolia	S5	Common greenbrier	OBL
Vaccinium corymbosum	S5	Highbush blueberry	FACW-

Eragrostis hypnoides	**S1**	Teal lovegrass	OBL
Erechtites hieracifolia	S5	Fireweed	FACU
Erianthus brevibarbis	**S1**	Shortbeard plumegrass	OBL
Erianthus giganteus	S4	Sugarcane plumegrass	FACW+
Eriocaulon compressum	**S2**	Flattened pipewort	OBL
Euthamia tenuifolia	S5	Slender frag. goldenrod	FAC
Fimbristylis autumnalis	S5	Slender fimbry	FACW+
Fimbristylis perpusilla	**S1**	Harper's fimbry	FACW+
Fuirena squarrosa	**S3**	Hairy umbrella-sedge	OBL
Galium tinctorium	S5	Stiff marsh bedstraw	OBL
Glyceria acutiflora	**S2**	Creeping manna-grass	OBL
Glyceria septentrionalis	S5	Manna-grass	OBL
Glyceria striata	S5	Fowl manna-grass	OBL
Gratiola aurea	S4	Golden hedge-hyssop	OBL
Hedyotis uniflora	**S2**	Clustered bluets	FACW
Helianthus angustifolius	**S3**	Swamp sunflower	FACW
Hottonia inflata	**S2**	Featherfoil	OBL
Hydrocotyle umbellata	S5	Many-flower pennywort	OBL
H. verticillata var. *verticillata*	**S2**	Whorled pennywort	OBL
Hypericum adpressum	**S2**	Creeping St. John's-wort	OBL
Hypericum canadense	S5	Canada St. John's-wort	FACW
Hypericum denticulatum	**S2**	Coppery St. John's-wort	FACW-
Hypericum mutilum	S4	Dwarf St. John's-wort	FACW
Hypericum virginicum	S5	Marsh St. John's-wort	OBL
Juncus acuminatus	S4	Sharp-fruited rush	OBL
Juncus canadensis	S5	Canada rush	OBL
Juncus elliotii	**S1**	Bog rush	FACW+
Juncus repens	S5	Creeping rush	OBL
Juncus roemarianus	S4	Needlegrass rush	OBL
Lachnanthes caroliniana	**S1**	Carolina redroot	OBL
Lemna minor	S5	Duckweed	OBL
Leersia oryzoides	S5	Rice cutgrass	OBL
Leersia virginica	S5	White grass	OBL
Lindernia dubia	S4	Yellow-seed pimpernell	OBL
Lindernia dubia var. *anagallidae*	S4	False pimpernell	FACW
Lobelia canbyi	**S2**	Canby's dropwort	OBL
Ludwigia alternifolia	S5	Bush seedbox	FACW+
Ludwigia linearis	S4	Narrowleaf seedbox	OBL
Ludwigia palustris	S5	Water purslane	OBL
Ludwigia sphaerocarpa	S5	Roundpod water purslane	OBL
Lycopus rubellus	S4	Taper-leaf bugleweed	OBL
Lycopus sp.		A bugleweed	-

Myriophyllum humile	S4	Low water-milfoil	OBL
Myriophyllum pinnatum	S2	Cutleaf water-milfoil	OBL
Nuphar lutea	S5	Spatterdock	OBL
Nymphaea odorata	S5	White waterlily	OBL
Nymphoides aquatica	S1	Big floating heart	OBL
Nymphoides cordata	S1	Little floating heart	OBL
Onoclea sensibilis	S5	Sensitive fern	FACW
Osmunda cinnamomea	S5	Cinnamon fern	FACW
Osmunda regalis	S5	Royal fern	OBL
Panicum agrostiodes	S4	Red-topped panic grass	FACW+
Panicum dichotomiflorum	S5	Fall panic grass	FACW-
Panicum hemitomon	S2	Maiden cane	FACW+
Panicum hirstii	S1	Hirst's panic grass	OBL
Panicum longifolium	SU	Panic grass	OBL
Panicum spretum	S4	A panic grass	-
Panicum verrucosum	S5	Warty panic grass	FACW
Panicum wrightianum	S2	Wright's panic grass	FAC
Paspalum ciliatifolium	S4	Bead grass	-
Paspalum dissectum	S2	Walter's paspalum	OBL
Phragmites australis	S5	Common reed	FACW
Pluchea foetida	SU	Camphor weed	OBL
Pluchea odorata	S5	Camphor weed	OBL
Polygonum coccineum	S5	Water smartweed	OBL
Polygonum hydropiperoides	S5	Swamp smartweed	OBL
Polygonum pensylvanicum	S5	Pennsylvania smartweed	FACW
Polygonum persicaria	SE	Lady's thumb	FACW
Polygonum punctatum	S5	Punctate smartweed	OBL
Pontederia cordata	S5	Pickerelweed	OBL
Potamogeton diversifolius	S4	Water thread pondweed	OBL
Potamogeton pulcher	S5	Spotted pondweed	OBL
Proserpinaca palustris	S5	Marsh mermaid weed	OBL
Proserpinaca pectinata	S5	Combleaf mermaid weed	OBL
Pucinnelia pallida	S4	Pale manna grass	OBL
Ranunculus flabellaris	S1	Yellow water-crowfoot	OBL
Rhexia aristosa	S1	Awned meadowbeauty	OBL
Rhexia virginica	S5	Virginia meadowbeauty	OBL
Rhynchospora cephalantha	S2	Capitate beakrush	OBL
Rhynchospora chalarocephala	S4	Loose-head beakrush	OBL
Rhynchospora corniculata	S2	Short-bristled beakrush	OBL
Rhynchospora filifolia	S1	Threadleaf beakrush	FAC
Rhynchospora harperi	S1	Harper's beakrush	FAC
Rhynchospora inundata	S1	Drowned beakrush	OBL
Rhynchospora macrostachya	S5	Tall beakrush	OBL
Rhynchospora nitens	S1	Shortbeak baldrush	OBL

Rhynchospora scirpoides	**S2**	Threadleaf beakrush	FAC
Rotala ramosior	**S3**	Toothcup	OBL
Rumex verticillatus	S5	Swamp dock	OBL
Ruppia maritima	S5	Widgeon grass	OBL
Sabatia difformis	**S1**	Two-formed pink	OBL
Sagittaria engelmanniana	**S1**	Engelmann's arrowhead	OBL
Sagittaria graminea	**S2**	Grassleaf arrowhead	OBL
Saururus cernuus	S5	Lizard's tail	OBL
Schoenoplectus pungens	S5	Three square bulrush	FACW+
Schoenoplectus tabernaemontani	S5	Softstem bulrush	OBL
Scirpus cyperinus	S5	Wool grass	FACW+
Scleria reticularis	**S2**	Reticulated nutrush	OBL
Sclerolepis uniflora	**S1**	Pink bog-button	OBL
Sium suave	S5	Water parsnip	OBL
Sparganium sp.		Burreed	OBL (all)
Spartina patens	S5	Salt hay	FACW+
Thelypteris palustris	S5	Marsh fern	FACW+
Typha angustifolia	S5	Narrowleaved cattail	OBL
Typha latifolia	S5	Broadleaf cattail	OBL
Utricularia biflora	**S2**	Two-flower bladderwort	OBL
Utricularia geminiscapa	**S2**	Hidden fruit bladderwort	OBL
Utricularia gibba	**S2**	Humped bladderwort	OBL
Utricularia inflata	**S1**	Swollen bladderwort	OBL
Utricularia purpurea	**S2**	Purple bladderwort	OBL
Utricularia radiata	**S2**	Sm. swollen bladderwort	OBL
Utricularia vulgaris	S5	Common bladderwort	OBL
Viola lanceolata	S5	Lance-leaf violet	OBL
Viola primulifolia	S5	Primerose violet	FACW+
Wolffia brasiliensis	S4	Watermeal	OBL
Woodwardia areolata	S5	Netted chain fern	FACW+
Woodwardia virginica	S5	Virginia chain fern	OBL
Xanthium strumarium	S5	Spiny cocklebur	FAC
Xyris difformis var. *difformis*	S5	Common Y. eyed grass	OBL
Xyris smalliana	**S2**	Small's Y. eyed grass	OBL

APPENDIX B. Rare species observed in Coastal Plain ponds in Delaware. The list is not comprehensive, as further inventory may result in additional species.

Scientific Name	State Rank	Common Name
Plants:		
Amphicarpum purshii	S2	Blue maidencane
Asclepias lanceolata	S1	Few-flower milkweed
Boltonia asteroides	S2	Aster-like boltonia
Carex barrattii	S2	Barratt's sedge
Carex bullata	S2	Button sedge
Carex gigantea	S3	Large sedge
Carex typhina	S2	Cattail sedge
Centella erecta	S2	Erect coinleaf
Coelorachis rugosa	S1	Wrinkled jointgrass
Coreopsis rosea	S1	Pink tickseed
Eleocharis quadrangulata	S3	Squarestem spikerush
Eleocharis robbinsii	S3	Robbin's spikerush
Eleocharis tricostata	S1	Three-angle spikerush
Eragrostis hypnoides	S1	Teal lovegrass
Erianthus brevibarbis	S1	Shortbeard plumegrass
Eriocaulon compressum	S2	Flattened pipewort
Fimbristylis perpusilla	S1	Harper's fimbry
Fuirena squarrosa	S3	Hairy umbrella-sedge
Glyceria acutiflora	S2	Creeping manna-grass
Hedyotis uniflora	S2	Clustered bluets
Helianthus angustifolius	S3	Swamp sunflower
Hottonia inflata	S2	Featherfoil
Hydroctyle verticillata var. *verticillata*	S2	Whorled pennywort
Hypericum adpressum	S2	Creeping St. John's-wort
Hypericum denticulatum	S2	Coppery St. John's-wort
Juncus elliotii	S1	Bog rush
Lachnanthes caroliniana	S1	Carolina redroot
Lobelia canbyi	S2	Canby's dropwort
Myriophyllum pinnatum	S2	Cutleaf water-milfoil
Nymphoides aquatica	S1	Big floating heart
Nymphoides cordata	S1	Little floating heart
Panicum hemitomon	S2	Maiden cane

Panicum hirstii	S1	Hirst's panic grass
Panicum wrightianum	S2	Wright's panic grass
Paspalum dissectum	S2	Walter's paspalum
Quercus bicolor	S2	Swamp white oak
Quercus lyrata	S1	Overcup oak
Ranunculus flabellaris	S1	Yellow water-crowfoot
Rhexia aristosa	S1	Awned meadowbeauty
Rhynchospora cephalantha	S2	Capitate beakrush
Rhynchospora corniculata	S2	Short-bristled beakrush
Rhynchospora filifolia	S1	Threadleaf beakrush
Rhynchospora harperi	S1	Harper's beakrush
Rhynchospora inundata	S1	Drowned beakrush
Rhynchospora nitens	S1	Shortbeak baldrush
Rhynchospora scirpoides	S2	Threadleaf beakrush
Rotala ramosior	S3	Toothcup
Sabatia difformis	S1	Two-formed pink
Sagittaria engelmanniana	S1	Engelmann's arrowhead
Sagittaria graminea	S2	Grassleaf arrowhead
Scleria reticularis	S2	Reticulated nutrush
Sclerolepis uniflora	S1	Pink bog-button
Utricularia biflora	S2	Two-flower bladderwort
Utricularia geminiscapa	S2	Hidden fruit bladderwort
Utricularia gibba	S2	Humped bladderwort
Utricularia inflata	S1	Swollen bladderwort
Utricularia purpurea	S2	Purple bladderwort
Utricularia radiata	S2	Sm. swollen bladderwort
Xyris smalliana	S2	Small's Y. eyed grass

Animals:

Ambystoma tigrinum	S1	Eastern tiger salamander
Ambystoma maculatum	S2	Spotted salamander
Ambystoma opacum	S3	Marbled salamander
Clemmys guttata	S3	Spotted turtle
Hyla chrysoscelis	S2	Cope's gray treefrog
Hyla cinerea	S3	Green treefrog
Hyla gratiosa	S1	Barking treefrog
Lestes disjunctus	S3	Disjunct spreadwing
Lestes congener	S3	Spotted spreadwing
Lestes forcipatus	S3	Sweetflag spreadwing