2.3 HABITAT & HABITAT MODIFICATIONS

2.3.1 HISTORY

At the beginning of the 16th century, the land that would become the state of Delaware encompassed a region of outstanding natural diversity. Clear freshwater rivulets tumbled down rocky streams and rivers from the hills of the Appalachian Piedmont Plateau into the drowned Susquehanna and Delaware River valleys, recently flooded by a rising ocean. These river valleys broadened into two magnificent bays, the centers of two vast estuaries, bordered with productive coastal marshes, abundant with shellfish and waterfowl that isolated the intervening Coastal Plain lands into an elongated peninsula.

Today, following nearly 400 years of natural resource consumption and the conversion of habitats for agricultural, residential, and industrial purposes, Delaware's remnant natural areas — woodlands, rivers, swamps, and marshes — still provide a biological history of Delaware. Yet, these natural remnants are under continual pressure from humans. This portion of the document will assess the modifications that humans have made and continue to make to the habitats of the Inland Bays/Atlantic Ocean Basin of Delaware.

2.3.1.1 Prehistoric Human Impacts

Man first came to the Delmarva Peninsula as far back as 13,000 years ago. These earliest settlers left behind little except their stone tools, although some attribute the extinction of the megafauna to these skilled hunters (Martin 1984). These people brought another tool with them — fire, which they frequently applied to the landscape to drive game, maintain wildlife pastures, and for other uses (Pyne 1982). The introduction of anthropogenic fire, added to the much more infrequent natural fire regime, was a major factor in shaping the ecosystem on Delmarva. The introduction of fire favored fire-resistant species such as oak and pine over hemlock.

The descendants of these Native Americans followed similar lifestyle patterns until approximately 1,000 years ago, when they developed a more sedentary lifestyle based in part upon domesticated plants. Production of plants such as corn, beans, squash, and melons began to supplement the hunting and wild foods gathering traditions. However, seasonal burning of the landscape continued until the first Europeans landed in Delaware.

2.3.1.2 Historic Human Impacts

In 1631, the first European settlers in Delaware settled in present-day Lewes at a fort called Swanendael (valley of the swans). This Dutch settlement ended with an Indian massacre in 1632. In 1659, the Dutch again erected a fort in Lewes, called the Whorekil, which was seized by the English five years later. Beginning in 1680, Governor Edmund Andros encouraged the settlement of the Whorekil region, which included the coastal area of the Inland Bays/Atlantic Ocean Basin. The early settlers' economy was based on the export of agriculture and timber. This commerce limited settlement during the period to within 10 to 12 miles of the coast or to the tidal portions of eastern flowing streams (DeCunzo and Catts, 1990).

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European settlers adopted the Native American method of burning the landscape, partially out of defense, but also to clear the forest. They girdled the larger trees and planted under them, cutting the smaller trees and shrubs. Their homesteads were usually located with 300 feet of the stream they fronted. Transportation was by water, but erosion, dead logs and ship ballast blocked many previously navigable waterways.

By the beginning of the 18th century, most of the remaining Native Americans who had not been ravaged by disease had left the peninsula. The rapid growth of Delaware's population during this period, especially in "New Sussex," forced many new farmers to clear and farm land of poor quality. Streams and creeks were dammed to provide power for saw- and gristmills. The lumbering of the peninsula increased rapidly and continued unabated. Not only were the forests an impediment to agriculture, wood was needed for everything: new construction, energy, furniture, shipbuilding, bridges, and charcoal. Even the ancient, submerged, giant cypress logs that had fallen into the swamp long before the colonies existed were pulled from the Great Cypress Swamp and made into shingles (Scharf, 1888).

By the 1820s, agricultural production had fallen, and abandoned farms began to revert to healthy secondary young forests of loblolly pine. Still, by 1880, between 75 and 90 percent of each county was in agriculture, clearing almost all upland habitats.

2.3.2 ASSESSMENT OF CURRENT HABITATS

2.3.2.1 Upland Habitat

Baseline data for the original historic habitat in the Inland Bays/Atlantic Ocean Basin are not available. However, we do know that the Basin forest acreage was lowest in the late 19th century, as the demands for pastureland, wood for construction and energy, and farmland reached its zenith. Abandonment of unproductive farms during the Depression, followed by the industrialization and urbanization of the work force, led to a decline in the number of people working on farms. This phenomenon, coupled with the invention of the automobile and tractor, and the decreased need of wood for fuel, led to an overall increase in total forest acreage in the early 20th century. In many areas of Delaware, suburban development and economic prosperity, begun in the middle of this century, started to replace young forests with homes, roads, retail shopping centers, and commercial areas. A series of aerial photographs taken approximately every decade from 1926 until the present, provide a glimpse of changes in available habitat in the Basin. The permanent loss of upland habitat, although continuing, has not increased appreciably over the past 70 years in this Basin.

Assessments of forest cover have been conducted by the United States Department of Agriculture three times over the last 40 years, most recently in 1986. The document, *Forest Statistics for Delaware — 1972 and 1986* (Frieswyk and DiGiovanni, 1989), compares the last two forest inventories for each county in Delaware. Although total forest cover over this time decreased by 38,000 acres statewide, this loss was for the most part related to urbanization of New Castle County. Sussex County lost an estimated 4,000 acres of forest during this period.

2.3.2.2 Fragmentation of Habitat

In addition to the loss of available habitat, the remaining habitat in the Inland Bays/Atlantic Ocean Basin has become increasingly splintered and isolated. Fragmentation of forest was already significant by the beginning of the 19th century, largely due to land clearing for agriculture. Today privately owned forest tracts over 50 acres in size are becoming increasingly rare and isolated. Most of the remaining forest in the Basin is found along stream bottoms and floodplains that have remained unavailable for agricultural production.

The clearing of the Inland Bays/Atlantic Ocean Basin forest nearly 200 years ago has had lasting effects. Some non-game animal species, which require extensive mature forests to persist, have become significantly reduced in numbers or extirpated. The remaining fragmented habitats contain a high ratio of "edge" as opposed to interior forests. Edge effects on the forest include increased sunlight, wind exposure, drying of soils, higher temperatures, loss of interior species, and vulnerability to exotic species invasion. Fragmentation favors species that prefer an open patchwork of wood lots, edges, and meadows. Examples of such species include red fox, brown-headed cowbird, raccoon *(Procyon lotor),* and white-tailed deer. These animals have become more numerous and live closer to humans than ever. As the human population increases in the Basin, long-range management considerations become vital as human/pet/wild animal conflicts increase. Already, the increased threat from zoonotic diseases (Lyme disease, hanta virus, and rabies) has caused public health concerns as animal and human populations increasingly interact.

2.3.2.3 Modern Forestry

As silvicultural skills improved over the last 100 years, foresters developed forest management plans that maximized future production of forest products by eliminating competing "non-productive" elements in the forest. In Delaware, this planning resulted in the development of loblolly pine plantations in the Inland Bays/Atlantic Ocean Basin. These trees are actively managed by mechanical and chemical means to achieve the desired forest products within a projected 60-year harvest rotation. This practice has maintained the volume but not the quality of forest products. It has also reduced biological diversity by changing the structural and functional forest diversity. It "homogenized" the oak-pine forest.

An effort to develop "working forests" that promote biotic diversity while maintaining economic viability of forest products is currently under way. However, the vast majority of forestland in the state is not in public ownership, but rather under the management of state foresters. The Department of Agriculture directly manages less than 10,000 acres of forest. By comparison, forests owned by private forest industry total 30,000 acres. In 1986, the U.S. Forest Service estimated that private individuals owned 88 percent of Delaware's forestland. Much of the timber on these lands is being managed for short-term profit, essentially as it has been for 300 years. Although the total privately owned forest habitat does not appear to be decreasing significantly in the Inland Bays/Atlantic Ocean Basin, it is typically:

- Less than 50 years old;
- Smaller than 100 acres in size;
- Owned by several people;
- Too wet to clear for farmland;
- Occasionally used as supplemental grazing for livestock;
- Has been further fragmented by tax ditches; and
- Provides supplemental income through hunting leases, firewood, and timber products.

The white oak species were once the most abundant hardwood group in Delaware. Due to heavy timber harvesting, real estate development, clearing of woodlots for farming, and oak mortality and decline, the mature oak in the state are being reduced in number. Many of the oak stands in rural woodlots are composed of mature oaks and have been under stress during the decade of the 1980s and again in the 1990s. The potential for increased oak mortality and decline is a concern of the public in the infested areas.

Thirty-one percent (389,500 acres) of Delaware's land area is forested. Timberland totals 376,400 acres while non-commercial forestland totals 13,100 acres. Private landowners own 96 percent of the timberland in the state. Oak is a component in 73 percent of the timberland (275,300 acres) and is the major hardwood species in 28 percent of the timberland (105,400 acres). The white oak forest-type group alone totals 23,400 acres (Frieswyk and DiGiovanni 1989). In addition, most of the non-commercial forestlands (13,100 acres — urban forests) contain a large component of oak species.

Within the Basin, there is an estimated 55,000 to 60,000 acres of forested lands. Most of these forests are owned by private landowners, while the remainder is owned by the forest industry or public agencies. The forest vegetation in the Basin consists of oak-hickory, oak-pine, or oak-gum-red maple stands. Some of these stands are 65 percent or more oak, with the white oak group being the predominant oak species. On the bottomland sites, the forests are composed of oak-gum-red maple stands. In Sussex County, the forest type consists of an oak-pine mix, in which loblolly pine is the predominant conifer species.

Several tree species are found within the Basin, including loblolly pine, Virginia pine, Atlantic white-cedar, white oak, southern red oak, scarlet oak, water oak, willow oak, yellow-poplar, red maple, sweet gum, black gum, sassafras, and dogwood. Loblolly pine, the predominant commercial timber species, is managed through clear-cut harvests, since it requires virtually full sunlight to survive. Thus, loblolly pine stands are even-aged in that all the trees are virtually the same age. The hardwood species, particularly red oak, white oak, and to some extent, yellow-poplar, are typically managed through selection harvests whereby the mature and poor-quality specimens are harvested. This produces an uneven-aged forest with trees ranging in age from new seedlings to mature trees (60 – 80 years old). Hardwoods are managed in this fashion since they are more shade tolerant than the pines.

Loblolly pine is the predominant commercial timber species because it grows rapidly, thrives on a variety of soils, and its wood is utilized for a variety of products. Loblolly pine plantations are found throughout the Basin, although their frequency decreases closer to the coast. The DDA Forest Service estimates that approximately 12,000 to 13,000 acres of the forestlands within the Inland Bays/Atlantic Ocean Basin are managed primarily for loblolly pine. Most of these stands are intensively managed, as they contain hand-planted, genetically improved seedlings. Herbicides are applied to control brush and other competition, and these forests are often thinned prior to the final clear-cut harvest around age 40 to 50 in order to increase growth.

However, the eastern portion of this Basin contains some of the highest quality hardwoods found in Sussex County, namely white oak, red oak, and yellow poplar due to the lighter soils. Many of these areas are managed for production of these species through selection harvests every 25 to 35 years. Most of the hardwood species located on the western side of the Basin are poorer quality oaks along with maple and gum. Some landowners, particularly in the last 10 to 15 years, have decided to manage these areas for loblolly pine, rather than the maple and gum, in order to improve their financial return. Additionally, Atlantic white cedar is found along some streams within the Basin. This species is not common in Delaware, and is quite site-sensitive. The white cedar is seldom harvested now because very few mills now process this species.

2.3.2.4 Exotic Species

A major threat to fragmented natural areas in both public and private holdings has been the introduction of numerous invasive exotic or alien species of plants and animals. Unlike most introduced exotic plant species, which are benign additions to the landscape, invasive exotic plant species are overrunning forests, wetlands, open habitat, and aquatic communities. Native plant communities are in direct competition with introduced exotics. Exotic species, combined with habitat disturbance/fragmentation and an overpopulation of white-tailed deer, has placed the remaining natural habitat in the Inland Bays/Atlantic Ocean Basin under an additional threat. At present, fewer exotic species currently threaten the Basin's natural areas than in Piedmont habitats. But this is likely to change over the next few decades.

Over one-third of the species in Delaware's flora are exotic. Several dozen species have the capability of permanently altering habitat. To date, only the largest, oldest, most intact, or most isolated forest tracts have been able to resist the exotic intrusion, but even these forests are ultimately vulnerable to shade-tolerant exotic species such as Norway maple *(Acer platanoides)*. Many sites are in grave need of exotic species control and habitat restoration.

Although the presence of exotic species is well known, very little data (other than "present/absent" designation) have been collected that document the extent of the exotic infestation in Delaware. Invasive exotic species issues have not been a priority with land managers, planners, or heritage databases. Meanwhile, new species of plants are being introduced into natural areas, sometimes intentionally. As the exotic plant species compete with native species for the already reduced available habitat, they do so without the threat of disease or insect herbivores that affect natives.

Common events (such as the blow-down of a large tree during a thunderstorm) create available habitat for exotic invasion, especially by vines, i.e., Asiatic bittersweet *(Celastrus orbiculatus)*. Once established in sunny gaps created by the death of a mature tree, the vines smother the normal successional replacement of the fallen tree by native saplings. Clambering over the young trees, covering them with their leaves, denying them sunlight, the vines maintain an exotic tangle that native species cannot penetrate. In the normal successional process, this canopy gap would eventually become forest once more. Today, once the exotic vines become established, the forest cannot recover without human intervention. Instead, the vines slowly kill surrounding trees, gradually expanding the gap in an ever-widening circle.

For additional information on exotic and invasive species, refer to Section 2.5.

2.3.2.5 Non-Tidal (Freshwater) Habitat

Ingrams and Millsboro ponds, located in the Indian River watershed, are the only public freshwater ponds within the Inland Bays/Atlantic Ocean Basin. However, there are other freshwater ponds under private ownership in the watershed. The fish communities of Ingrams and Millsboro ponds are probably typical of the freshwater ponds within the Basin. Sport fish species include largemouth bass *(Micropterus salmoides),* bluegill *(Lepomis macrochirus),* black crappie *(Pomoxis nigromaculatus),* pumpkinseed *(Lepomis gibbosus),* white perch *(Morone americana),* yellow perch *(Perca flavescens),* and chain pickerel *(Esox niger)*. Golden shiner *(Notemigonus crysoleucas),* blue-spotted sunfish *(Enneacanthus gloriosus),* creek chub sucker *(Erimyzon oblongus),* yellow bullhead *(Ameiurus natalis),* and swamp darter *(Etheosoma fusiforme)* are the most common forage-fish species. Historically, black-banded sunfish *(Enneacanthus chaetodon),* a species designated S2 (typically 6 to 20 occurrences or factors making it very vulnerable in Delaware), has been present in Ingrams Pond. Common carp *(Cyprinus carpio)* and gizzard shad *(Dorosoma cepedianum)* constitute a large portion of the biomass in Millsboro Pond.

Ingrams Pond, the only pond in the Basin surveyed by Ritter (1981), was characterized as highly eutrophic, ranking seventh highest among the 28 Delaware locations sampled. This rank was achieved due to high-priority ratings for aquatic weed abundance and eutrophication status. Many of the ponds within this Basin historically have exhibited over-abundant aquatic weeds due to high nutrient levels. As early as 1966, Lesser mapped heavy coverage of aquatic weeds in Ingrams, Betts, Morris Mill, and Burtons Ponds. By 1975, fanwort *(Cabomba caroliniana)* was cited as a serious problem in Ingrams Pond (Martin, 1976). Another non-native plant species, hydrilla *(Hydrilla verticillata)* began to compete with fanwort and by 1983 was present in 11 Sussex County ponds including Ingrams, Betts, and Burtons ponds (Martin, 1984). Morris Mill Pond, upstream of Millsboro Pond, has also exhibited heavy aquatic weed coverage including floating mats of algae (primarily *Pithophora*).

An evaluation of triploid grass carp for aquatic weed control, primarily hydrilla, was conducted from 1986 to 1995 in Ingrams Pond (Martin, 1996). Hydrilla was nearly eliminated from Ingrams Pond by 1994. Although still present in the pond in small amounts, the plant has not increased substantially since that time. However, grass carp from the last stocking (1993) are still present in the pond and may be keeping it in check. The owner of the pond immediately upstream (Lakeview) also stocked triploid grass carp to control hydrilla, but heavy coverage of hydrilla is still evident.

Hydrilla is also present in Millsboro Pond. Applications of the herbicide Sonar SRP have been conducted annually in portions of Millsboro Pond for hydrilla control since 1993. An early season application generally provides effective control throughout the year (Zimmerman, 1998).

A survey of the biological communities and physical habitat of Kent and Sussex County non-tidal streams (including some within the Basin) indicated that only 29 percent exhibited "good" biological quality (Maxted, et al. 1992). Eighty percent of the sites with "poor" biological quality were limited by poor physical habitat, including both in-stream and riparian measures.

2.3.2.6 Tidal Estuarine Habitat

Tidal estuaries have long been recognized as valuable ecosystems that provide essential habitat for a multitude of species that are both economically and recreationally regarded by the public. These estuaries provide nursery and breeding grounds, as well as refuge for birds, fish and invertebrates that lure sportsmen, tourists, and others to Delaware's Inland Bays throughout the year. Their natural vistas entice sightseers to walk its shores, sail and swim its waters, and harvest its natural resources. In short, it provides rich resources for man and nature alike. The tidal-estuarine system provides habitat for all those species that inhabit the bays.

An estuarine system is characterized and defined as an embayment in which fresh water from the land mixes with salt water from the ocean. This mixing zone is, by nature, dynamic and controlled by physical forces driven, in part, by tides, winds, storms and other meteorological and climatological events on both a short- and long-term basis. Estuaries have long been recognized for having extremely high primary production that supports a considerable biomass and diversity of primary consumers (Schelske and Odum, 1962). Several reasons for this extremely high level of primary production are:

- Multiple types of primary production units (marsh grass, benthic algae, macroalgae, phytoplankton, and in healthy estuaries, sea grasses), which ensure maximum utilization of light at all seasons;
- A transport system consisting of ebb and flood of water movements resulting from tidal action;
- Abundant supplies of nutrients; and
- Rapid regeneration and conservation of nutrients due to the activity of microorganisms and deposit/filter feeders.

The rich diversity of habitat types within estuarine systems results, in part, from the physical landform setting found within the estuary embayment, including beaches, channels, sandbars and mud flats, rock revetments, lagoons and deltas, and sediment types, and includes the water column itself. Ranges in salinity through time (annual rainfall patterns) and distance (ocean to freshwater tributary mixing) coupled with seasonal temperature variations further add to the mix of environmental parameters to which an organism must continually adapt successfully in order to seek out a niche for its survival and production.

Hydrology

Water quality determines the quality, diversity, and value of estuarine habitats. The bays' water column supplies dissolved oxygen to living resources and provides a medium through which fish, other aquatic species, and their food move or are carried from place to place. All elements in an estuarine system relate back to the quality of the water that supports that system. Without quality water, the estuarine components in the system cannot function in an optimal way.

Experience has shown that all estuarine systems are not alike and indeed function much differently from each other for a number of reasons. Delaware's Inland Bays cannot be homogeneously grouped together because they are quite different based on physical structure, hydrodynamics, biology, and chemistry. Indian River and Bay are the classic drowned river valley definition of an estuary in which the upland freshwater input from Millsboro Dam mixes with the Atlantic Ocean seawater entering through the Indian River Inlet. They exhibit a two-layer stratified flow with saltier, cooler, denser ocean water riding upstream on the bottom while fresher, less dense, warmer water flows out on the surface toward the inlet and ocean.

Rehoboth Bay, by comparison, is characterized as a semi-enclosed lagoon with the majority of its saltwater input arriving through multiple large connections with Indian River Bay on its south side, around both sides of Lynch Thicket and Middle Islands. Additional saline water enters this bay via the Lewes-Rehoboth Canal from the north. Minimal freshwater surface input arrives into Rehoboth Bay, mainly from three tributaries — Herring, Guinea, and Love Creeks. Surface-water input for both the Rehoboth and Indian River Bays only accounts for 20 percent of the fresh water flux with the majority influx, 80 percent, derived from ground-water seepage along their shorelines and bottoms.

Little Assawoman Bay is a typical barrier-island tidal lagoon with minimal connection to the sea, resulting in the lowest consistent salinity (mesohaline) of Delaware's Inland Bays. Its minimal connection with the ocean is through the Assawoman Canal to the north and the Ocean City Inlet (via Big Ditch). The majority of its freshwater input is also derived from ground-water seepage. It is the most turbid of the three bays and supports no submerged aquatic vegetation or macroalgae due to light limitations.

Sediment

An important factor controlling the distribution and diversity of estuarine inhabitants is benthic sediments. In a thesis describing the sediments of the bays, Chrzastowski (1986) produced several maps that illustrate the complexities of the benthic sediments and their distributions within the bays. In general, the eastern portions of the bays adjacent to the Barrier Islands to approximately mid-bay are characterized as predominately fine sand. West of this north-south line finer sediments dominate, which consist of various mixes of clay and silt. This clay-silt dominance continues up into the low-energy tributaries that feed the bays. Sediment types, along with salinity range and water quality, are among the most important parameters that determine the distribution of marine epibenthos. Even within the sediment matrix itself, the pore-water salinity may be vastly less saline than the overlying water due to fresh ground-water outflow through the sediments into the bay. Any borrowing organism in this situation must be able to adjust to a wide salinity range within a distance of only a few millimeters.

Background and Status

The Inland Bays have a drainage area of about 313 square miles and a tidal water surface area of 32 square miles. This results in a drainage area to surface-water ratio of about 10:1, which is quite high for a poorly flushed coastal estuary. The circulation and flushing within the bays is extremely limited, with an estimated flushing time of 90 to 100 days. Combine the high land-surface to open-water-surface ratio with the physical configuration of the bays and the limited flushing, and the result is a sediment and nutrient sink or trap. Any water unit entering the bays will take three months or longer to exit the system through the Indian River Inlet. Sediment particles may take longer to exit, if at all. This is true of nutrient flow, particularly phosphorus that is bound to sediment particles until released and thus rendered available for plant uptake and utilization. This low flushing rate combined with the sediment sink function is an extremely important factor contributing to the problematic eutrophic conditions impacting the Inland Bays.

Physiobiochemical constraints such as sediment type, temperature range and extremes, wave energy/current, salinity levels and ranges, light availability, and nutrient flux dynamics all combine to either enhance or impair an organism's ability to survive and produce under a specific set of environmental conditions. While many environmental constraints may not totally preclude an organism's existence in a particular setting, it may severely limit its spatial and temporal distribution and its productivity during its life cycle.

Many studies have been conducted during the past few decades by state, federal, academic, and independent agencies. Compiling these studies, which range in the hundreds, is a daunting task, but over the years a number of state and independent groups have analyzed and compiled a number of status and trends reports on the Inland Bays. One such document is the Inland Bays Estuary Program's characterization of the bays [Inland Bays Estuary Program (IBEP) Management Conference, 1995; Appendix F].

A number of these studies (IBEP, 1995; ANS, 1988) have documented current status and developed trends. Benthic organisms are one of the best indicators of estuarine trends. Some of these species are long lived, exhibit limited home range, and are of sufficient sensitivity that they make excellent environmental indicators. The Environmental Monitoring and Assessment Program (EMAP) study took full advantage of these species and combined those biometrics with water quality and toxicity data to conduct a multi-state regional assessment comparing a healthy balanced system (Chincoteague Bay) with various segments of the Inland Bays. Overall, major portions of the bays (upper Indian River and Little Assawoman Bay) have been degrading over the past three decades despite increased flushing and dilution as a result of the deepening of the Indian River Inlet channel. The culprit, which has been documented and verified by numerous studies, is eutrophication, the excessive abundance of nutrients entering the bays from its watershed. The symptoms exhibited by eutrophication in the bays include:

- excessive macroalgae growth;
- harmful algal blooms (HABs);
- fish kills;
- low dissolved oxygen (hypoxia and anoxia);
- release of toxic sulfides;
- stimulation of toxic plankton blooms (e.g., *Pfiesteria*);
- habitat alteration/destruction;
- extinction of marine Submerged Aquatic Vegetation (SAV);
- reduction of primary and secondary production;
- reduced species diversity and unit biomass; and
- loss of adequate fish habitat.

All of these symptoms are counter to a healthy, productive estuarine system. They may express themselves individually or collectively. The degrees to which they degrade or reduce the functions and/or values to the estuarine system indicate the degree of impairment or degradation.

Primary Production

In an estuarine system, primary production drives its biotic components. Green plants, the base of the food pyramid, through photosynthesis, convert sunlight to biomass that sustains the primary and secondary consumers in the estuary. This aquatic primary-production process is conducted within three major "compartments" or levels: plankton, benthic micro/macroalgae, and SAV.

The degree to which any one of these three pathways dominates in an estuary is also an indicator of the level of eutrophication at that time and place. The most eutrophic estuaries generally are dominated by phytoplankton, that by their nature increase the turbidity proportionally to the degree of nutrient load entering the water body. This turbidity can prevent adequate light from reaching the bay's bottom and thus prevent benthic algae and SAV. Under extreme conditions, dense blooms of phytoplankton are self-limiting in that only phytoplankton at or near the surface have sufficient light for photosynthesis and primary production. If phytoplankton below the photic zone do not receive adequate light, death will result and upon decomposition will deplete the water of life-sustaining oxygen resulting in fish kills.

Under less eutrophic conditions, macroalgae can survive and dominate since they require only about one percent of the ambient surface light to photosynthesize and produce. The shallow nature of the Inland Bays provides an ideal environment for the growth of benthic algae (macro and micro) provided the water is clear enough for adequate light penetration to the bay bottom. Most benthic algae need a holdfast by which they anchor themselves to a point on the bay bottom that provides suitable habitat parameter requirements for survival. With the exception of sea lettuce *(Ulva),* if the holdfast attachment is broken, the algae will die and decompose. This situation is of particular concern following severe weather where large volumes of macroalgae are torn loose and beach or windrow along shorelines or deposit in shallow protected coves. Within a short time-frame, a massive die-off results in depleted oxygen (hypoxia, anoxia) and the release of toxic decomposition products (e.g., hydrogen sulfides), both of which are devastating to the estuaries' living resources.

By comparison, SAV growing at the lowest level of eutrophication or low ambient nutrient conditions, has the highest requirement for clear water and light. With a light requirement of between 15 and 25 percent of surface ambient sunlight, it places the highest premium on a healthy estuary and water quality for its continued survival and production. For this reason, SAV is regarded as an excellent indicator species and its presence is indicative of healthy environmental conditions. Two species of SAV *(Zostera* and *Ruppia)* were found in both Rehoboth and Indian River bays as late as the early 1970s, but continued deterioration of water quality is thought to have eradicated both types of plants from the open waters of the Inland Bays.

Evaluating the three levels of dominant primary production gives us a gross indication as to the trophic condition of the estuary. A 1985 study detailed the extent of the trophic conditions over a year-long study of the Inland Bays (ANS, 1988). It found that excessive nutrients (eutrophication) stimulated phytoplankton production throughout the bays and thus limited the penetration of light through the water column so severely that benthic alga (micro or macro) could survive and reproduce in only the shallowest of areas. The result of the extreme turbidity was that estuarine primary production was reduced and that benthic micro- and macroalgae, as well as SAV, were limited or precluded from the bays. The elimination of these valuable plant resources reduced the primary production value (trophic support) and biological habitat diversity of the bays as breeding and nursery grounds for many commercially and recreationally valuable estuarine and oceanic fish and shellfish, as well as important forage species. In essence, the aquatic habitat of the bays was limited by poor water quality.

Under an ideal set of environmental conditions, an estuary can be one of the most productive ecosystems in the world. The study observed that if nutrient load reductions were initiated and maintained, macroalgae and SAV could possibly return to the bays. The early 1990s noted a shift toward the return of macroalgae as an annual event in Rehoboth and eastern Indian River bays. Excessive phytoplankton continue to dominate the upper Indian River and Bay and Little Assawoman Bay. Recent efforts to reintroduce SAV (eelgrass and Ruppia) into the bays have met with limited success due to SAV habitat degradation by excessive macroalgae growth.

Biological Habitat Structure — Submerged Aquatic Vegetation (SAV)

As previously mentioned, the bay bottoms are composed of various types of sediments that result in a fairly uniform flat plain without structure or topography. By itself, this lack of "terrain" provides no relief or structure for estuarine species to find protection, short of burrowing into the sediments. The lack of physical structure is overcome to some extent by a biological component in the form of aquatic macrophytes, seaweeds, and sea grasses. This is somewhat analogous to forest cover on otherwise flat terrain in terrestrial situations. With the addition of a mature forest cover, the wildlife functions and values of that area have increased significantly. The same is true in an aquatic setting. The addition of vegetated cover to an otherwise flat, unremarkable bay bottom provides many additional attributes and enhances the functional values over what had existed previously. The physical plant body, in turn, provides structural habitat that results in refuge and nursery grounds for a wide range of fish and invertebrates.

SAV defines that vegetation (macrophytes) which is attached to the sediment bottom and does not rise through the surface of the water. This definition includes both macroalgae (seaweeds) and aquatic vascular rooted plants (sea grasses). Both of these groups of aquatic plants provide a number of functions and values within the estuarine system. Both groups are primary producers that, through photosynthesis, utilize sunlight and dissolved nutrients to produce biomass — the plant itself. In turn, this plant material provides a food source (trophic support) for numerous species of waterfowl, fish, and invertebrates.

Sea grasses provide additional functions over seaweeds based on their structure. Sea grasses were land plants that have evolved and returned to the water, similar to marine mammals. As such, they have true roots and vascular tissue and reproduce entirely underwater. The pollen is released underwater, and the current hopefully carries it to receptive sea-grass flowers. Having roots, sea grasses bind sediments in place, preventing erosion; and the sea-grass beds break and dampen wave and current energy, thus trapping sediment particles and increasing the clarity of the water. If the beds are located close to shorelines, they also can prevent shoreline erosion. In addition, the associated filter-feeding organisms attached to the plants themselves clear the water of suspended material. It is not unusual to find highly turbid-water conditions outside a mature sea-grass bed, while a few feet inside the bed's perimeter, the water is crystal clear.

Sea grasses provide food and shelter to many animals. They are eaten directly by waterfowl and small mammals, and they provide detritus to fish, snails, and amphipods. SAV beds are the primary nursery grounds to crabs and many species of fish. Eelgrass, a marine species of sea grass, begin growing in spring and continue through the late fall. They flower in May and release their seeds in June through August. Temperatures and oxygen levels determine seed germination, either in late fall or early spring. Eelgrass germinated from seedlings will not produce seeds until the next complete growing season. Some of the animals that grow on the sea grasses or their beds include sea squirts, barnacles, and sponges, while snails, sea slugs, worms, and amphipods graze over the plants. Many animals such as sharks and rays, crabs, sea horses, sticklebacks, pipefish, anchovies, shad, spot, croaker, weakfish, drum, and herring feed or seek shelter between the grasses.

Sea grasses supply a site of attachment for numerous other small plants and animals that grow on these macrophytes. Many of these small-attached invertebrates are filter feeders which strain phytoplankton from the water and improve its clarity. These attached species are, in turn, fed upon by grazing species, thus moving carbon and energy up the food web. The nutrient value to grazers is generally many times the nutrient value of the underlying host plant itself, and in effect enriches the nutrient value of the plant alone many-fold.

Under high levels of eutrophication, excessive levels of biofouling will result on the sea-grass surface, limiting the amount of sunlight reaching the sea grass under this coating. This excessive coating can limit the plant's growth and under excessive biofouling will actually kill the sea grasses. These nutrient limits have been documented through extensive research and have been adopted into the state's water-quality standards in order to protect sea grasses and their required water-quality conditions as valued biological habitat.

The accumulation of biofoulers is not the same when comparing sea grasses with seaweeds. This attachment by opportunistic species (biofoulers) has an interesting revelation when one looks at certain species of seaweeds (macroalgae). Taylor (1995) found that certain species of green *(Ulva)* and brown *(Fucus)* macroalgae had a natural chemical bioactive agent that kept biofoulers from attaching to their frond or leaf. Using raw extracts of the plants, Taylor demonstrated in a controlled study with blue mussels that this yet-to-be-synthesized plant material had an antifouling effect on estuarine fouling colonizers. Not only did it keep the blue mussels from attaching to the treated substrate, but after a short time actually killed the mussels. The biological activity or strength of this raw macroalgae extract equaled or surpassed that of a commonly used chemical used in antifouling boat paint, copper oxide (CuO). This research raises the question of the impact of large buildup of certain species of macroalgae followed by rapid decomposition and sudden release into the water of this biological antifouling agent. Does this bioactive antifouling agent impact the biota of a region under conditions of low energy and flushing? The answer to this question has yet to be determined.

Benthic macroalgae is a term applied to a wide variety of seaweeds, which exhibit green, brown, or red pigment. These plants are attached to suitable hard substrate by a holdfast. Part of the population is detached and drifting. Seaweeds are not rooted in the sediment and are not vascular plants like eelgrass.

Delaware's Inland Bays contain many species of macroalgae, but the seaweed community is dominated by three genera. *Ulva,* or sea lettuce, is a green alga, which forms flat sheets. This is the predominant form of macroalgae found in Indian River Bay. The red algae *(Agardhiella* and *Gracilaria)* are branching in structure and predominate in Rehoboth Bay.

The distribution of macroalgae and the relative density of the standing stock are based on several factors including availability of suitable substrate for attachment, the level of dissolved nutrients, and light penetration in the water column. In general, macroalgae thrive under conditions of intermediate water quality. In severely eutrophic areas, phytoplankton dominate, limiting light penetration and reducing or eliminating macroalgae. Under extreme conditions of low dissolved nutrient levels, sea grasses dominate. When light penetration is excellent, nutrient levels are insufficient to support phytoplankton blooms or dense macroalgae stands. Sea grasses, such as eelgrass, are rooted and get nutrients from the sediment. At intermediate dissolved nutrient levels, macroalgae have sufficient light penetration to thrive and can compete successfully with sea grasses by absorbing nutrients directly from the water. When both are present, macroalgae will foul the leaves of sea grasses and outgrow them if nutrient levels are high enough to support rapid macroalgae growth.

Rehoboth Bay has the most macroalgae habitat. Extensive areas in northern and southwestern Rehoboth Bay have sufficient light penetration to support macroalgae throughout the depth range. Upper Indian River Bay is phytoplankton dominated. *Ulva* is common in the shore zone from Oak Orchard to Indian Landing. Light penetration is not sufficient to support macroalgae in the deeper areas of the bay.

Detached macroalgae can lead to seasonal water quality and nuisance problems. Prevailing southeasterly winds during the summer tend to windrow detached macroalgae in northern Rehoboth Bay. This macroalgae eventually rots, reducing dissolved oxygen and producing a hydrogen sulfide odor, which can persist for weeks and is offensive to neighboring landowners. In 1997 and 1998, rotting windrowed macroalgae killed clams in several areas in Indian River Bay. In 1998, over 8 acres were impacted and an estimated 100,000 clams were killed.

Despite problems with windrowed macroalgae, attached macroalgae has been demonstrated to provide preferred habitat for blue crabs and fish. Targett and Epifanio (work in progress) used beam trawls and throw traps to document the use of vegetated and unvegetated habitats in Rehoboth Bay by fish and blue crabs. Many species of resident fish were found in much higher concentrations in macroalgae, most preferring the red algae species. Blue crabs were also found in higher concentrations within macroalgae of all types. This confirms work done in New Jersey's coastal bays by Dr. Ken Able and his students (Rutgers University).

On balance, although macroalgae causes localized problems, it also provides thousands of acres of preferred, protective habitat for blue crabs and some species of fish.

Since the early 1990s, macroalgae has been going through a resurgence of growth that has resulted in large amounts of windrowed algae to accumulate along shorelines and protected coves in such numbers that its value as productive structural habitat is diminished or eliminated. The driving force in this excessive buildup of biomass is an over-abundance of nutrients entering the watershed and thus the bays.

Recent investigations of aquatic habitat within the Inland Bays (Targett, 1999) have clearly demonstrated that macroalgae habitat value to both fish and blue crabs is diminished as algal density increases, resulting in a decrease of dissolved oxygen (DO) within the seaweed matrix. As algal density increases, or the seaweed begins to decompose, severe decreases in DO result in hypoxia (DO <2 parts per million) or anoxia, the absence of DO, and the release of toxic sulfides. Both of these conditions result in serious consequences for all organisms that inhabit that immediate area of impact, the water column, and benthic sediments.

The DO problem may, in part, be a function of the structure of the green alga *Ulva* blade or frond, which is a large flat sheet that acts as a baffle, impeding water circulation within the immediate vicinity of the algal matrix. When in dense stands with little current flow, the seaweed may utilize the available DO in the water that cannot be resupplied by the plant itself or the surrounding water, resulting in hypoxia. The other forms of the bays' macroalgae, which have a branching stem or fond, do not seem to exhibit this baffling effect, except in extremely dense stands that impede water circulation and DO distribution immediately around the plants. Perhaps for this reason, the branching red and brown algae appear to provide a higher-quality refuge for fish and invertebrates as Targett's research suggests.

Another factor limiting the beneficial values of dense *Ulva* stands or windrows is the effect of self-shading. Although the *Ulva* blade is only two cells thick, the amount of light that passes through this blade is significantly reduced. Investigations done by various researchers have documented that 25 percent of the light striking the *Ulva* blade is absorbed. The significance of this high rate of light attenuation is that a beam of light is totally absorbed after passing through only four blades of *Ulva*. This means that any other algae below the uppermost four blades of *Ulva* are no longer receiving sufficient light to conduct photosynthesis and are now consuming, rather than producing, oxygen. Under these conditions, it is only a matter of time before the underlying strata of algae suffocate and die.

The thickness and mass of the algal buildup or windrow, the circulation and wave energy, and other physical and chemical parameters regulating decomposition determines the duration of the total breakdown or dissemination of the biomass. It is not uncommon for large algal windrows or mats to exceed 5 or 6 feet in thickness and cover an area of 5 or more acres. A number of analytical samplings of decaying macroalgae have resulted in extremely high biological oxygen demand (BOD). This indicates the stress upon the water column and the need to supply sufficient oxygen to decompose a unit of macroalgae. Upon decomposition of the algae, nutrients are re-released to the water column to further stimulate growth and nutrient over-enrichment, thus perpetuating the eutrophication cycle.

This condition is a classic example of a beneficial plant type, in this case macroalgae, which under moderate growth conditions is a valuable structural habitat, but under excessive growth conditions, fueled by an overabundance of nutrients, can result in lethal conditions for estuarine species. The duration of this decomposition process in the bays has persisted, in some instances, for over three months. During that time span, the area of impact is devoid of oxygen, resulting in a total die-off of all bottom-dwelling species, essentially putting the entire area off-limits for use by estuarine species until the area recovers. Complete recovery to pre-anoxic conditions may take years to achieve.

Price (1998) compiled a summary of a number of reports and studies in progress to develop an environmental classification of Delaware's Inland Bays. Using a combination of environmental parameters, indicators, and criteria, such as Delaware's Water Quality Standards and the Chesapeake Bay Program's SAV Living Resource Habitat Indicators, Price ranked the Delaware/Maryland coastal bays in terms of overall ecological health. The highest-ranking segment or bay was SE Chincoteague Bay followed by Lower Indian River and Rehoboth bays. Next ranked Upper Rehoboth Bay, Mid-Indian River Bay, and Little Assawoman Bay. Finally, Upper Indian River holds the dubious distinction of being the most degraded in this study and the same ranking when compared throughout all estuarine systems in Region III. The indicators included in Price's analysis were, in part:

- Percent area chlorophyll a and nutrient criteria satisfied;
- Chlorophyll a and total suspended solids (TSS) concentrations;
- Light attenuation/turbidity;
- Seaweed abundance/diversity;
- Night-time dissolved oxygen (DO) levels;
- Benthic invertebrate diversity; and
- Fish sensitivity to low DO levels.

This study was a successful attempt to integrate a wide and diverse list of physical, chemical, and biological parameters into a comprehensive ecological framework for assessment and management purposes.

Eutrophication of the ambient waters within the watershed has been the greatest debilitating factor impacting the estuarine habitat of the bays. Eutrophication stimulates excessive phytoplankton and macroalgae (seaweed) production that may rob the water of dissolved oxygen and increases turbidity and biofouling that inhibits or eliminates SAV growth. Under certain environmental conditions, harmful algal blooms (HABs) result from eutrophication. Since the early 1990s, excessive macroalgae HABs have been an annual re-occurring event in both Rehoboth and Indian River bays. Windrowing of macroalgae along shorelines, protective coves, and shallows has been resulting in massive algal die-off that causes hypoxia or anoxia, mortality of fish and shellfish and other living resources, aquatic habitat destruction, and noxious conditions for nearshore residents.

Excessive eutrophication in a number of segments of the Inland Bays has changed the population dynamics of the plankton community and altered the overall habitat value of that estuarine segment. Throughout the 1970s and 1980s, the majority of the Inland Bays were characterized as being dominated by a phytoplankton-dominated community (ANS, 1988). Under this dominance, the bays' primary production was focused almost entirely on phytoplankton at the expense of benthic micro/macroalgae and SAV. A shift in that dominance structure may seem to be making a shift from phytoplankton toward that of macroalgae dominance.

2.3.2.7 Ocean Habitat

Delaware's Atlantic coast is approximately 24 miles in length, from Cape Henlopen to Fenwick Island. Depths within state waters run from the shore zone to 40 to 60 feet in depth, 3 miles offshore. Federal waters include the remainder of the continental shelf with depths running from 40 feet to thousands of feet in depth, 200 miles offshore. This is a relatively high-energy environment nearshore, and coarser sediment (sand) predominates in most areas. Some finer sediments, such as silt or clay, are associated with deeper holes and swales surrounded by protective shoals.

Ocean habitat supports extensive fish and shellfish populations. If estuarine habitats are especially important as nursery areas for juvenile fish, ocean habitat is especially important habitat for adults. Many pelagic species virtually never enter estuaries. The vast majority of commercially and recreationally important fish species move offshore in the fall and inshore in the spring. Deeper ocean water is more protected from winter storms and is warmer in winter than nearshore waters. Recognizing the importance of fishery habitat, additional safeguards were written into federal law. Regional Fishery Management Councils were directed to identify Essential Fish Habitat for all species with approved Fishery Management Plans (FMPs). The intent of this provision is to conserve fish habitat from degradation from conflicting activities. For Delaware, the council is the Mid-Atlantic Marine Fisheries Council.

Fish habitat within state waters is of relatively limited diversity in the Mid-Atlantic region. Rock outcrops, which offer physical protection and structurally complex substrate for a very productive invertebrate community, do not exist in Delaware waters. The Delmarva Peninsula is made up of alluvial deposits resulting from melting following various ice ages. Bedrock is not near the surface and is not part of the nearshore marine environment as is common in New England waters. Similarly, there are no biological reef builders such as corals that provide the same function in the southeast region.

Delaware's nearshore bathymetry is gently sloping, featureless sand or mud bottom. Exceptions are shoals that are actively maintained by dynamic processes such as wind, waves, and currents. These areas offer vertical relief and increased biological diversity that is attractive to many species of fish. Shoal edges are preferred habitat for surf clams, a commercially important mollusk in nearshore waters. In addition to actively maintained shoals, there are relic shoal formations in Delaware's territorial sea. These elevated structures were formed and then left behind through the process of sea-level rise and westward migration of the coastline, which has been occurring over the last 10,000 to 12,000 years. Relic shoal habitat is also important fish and shellfish habitat, which will not be replaced if removed, as there are no longer any dynamic physical forces at work.

One threat to relic shoal habitat is beach replenishment activities. When relic shoal formations are near the beach, they are a convenient source of sand for a beach replenishment borrow area. An example is Hen and Chickens Shoal. Part of this shoal, near the Cape Henlopen point, is a dynamic ebb-tide shoal maintained and nourished by the northern longshore transport of sand along the beach and subsequent transport to the southeast by strong ebb-tide currents. As you move southeast along Hen and Chickens Shoal, the dynamic aspects decline and the shoal becomes a relic formation, formed and left behind by the westward migration of the coastline.

Shoal formations of both types are known to be preferred habitat for surf clams, striped bass, and coastal sharks, and are believed to be important to many other species of commercially and recreationally important fish species.

2.3.3 HABITAT LOSS AND MODIFICATION

The Inland Bays/Atlantic Ocean Basin has gone through dramatic changes since pre-colonial times. On the land, forests have been severely reduced in area, wetlands drained and filled, rivers and creeks dredged, dead-end lagoons created from creeks, uplands, and wetlands, shorelines bulkheaded and riprapped, eliminating shallow-water habitat, and navigational channels dredged. These activities have degraded, and in some cases destroyed, the habitat that the living resources are dependent upon in this Basin.

2.3.3.1 Dredging

Dredging is the process of hydraulically or mechanically excavating bottom sediments from intertidal or sub-tidal areas for the purpose of creating or maintaining safe navigable channels for recreational or commercial boating purposes. In Delaware, dredging is also used for obtaining sand for beach restoration activities, for removing unwanted sediments and aquatic vegetation from state-owned ponds and lakes, and for controlling sediment deposits in inland waters. In most cases, dredging involves removing sediment, whether silt, sand, or gravel, from a physical, chemical, and biological system in equilibrium.

History

Delaware's dredging program began in 1968 when a report prepared by the Delaware Soil and Water Conservation Commission recommended that certain Sussex County creeks be dredged to attract more visitors and permanent residents, thereby stimulating southern Delaware's economy. While federal and state regulatory agencies found many of the early dredging projects, including beach replenishment and others, to be environmentally acceptable, the navigational channel projects, particularly in the Inland Bays, were often considered questionable at best. There was speculation that these projects would result in rapid expansion of property subdivisions and development in the vicinity of the new channels, leading to long-term damage to the bay's fragile ecosystem.

Although there is no conclusive way to determine if the dredging program was a factor, development in Sussex County occurred at an extremely rapid rate during the period from 1960 to 1980. Although, it may be coincidental that the program was initiated during the same period when rapid development was occurring in coastal Sussex County, it became apparent that a reassessment of the overall goals and objectives of the dredging program was necessary. New guidelines with respect to channel dredging projects needed to be established focusing on environmental rather than economic concerns.

In 1984, Governor Pierre S. du Pont IV, appointed a task force to develop recommendations for the resolution of numerous problems plaguing the Inland Bays. One of the task force's recommendations included the development of a dredge plan for the Inland Bays and their tributaries to address dredging needs and priorities, dredged material spoil disposal considerations and options, environmental effects and mitigation, and the public/state costs and benefits of navigational channel projects. The most important aspect of the Inland Bays Dredging Study was a map of the region indicating all creeks and their suitability for dredging *(Map 2.3-1 Dredged Areas)*. The Department adopted the plan as policy in 1986. With the exception of federally authorized channels, any proposed inland waterway channel dredging project in the state is now evaluated using this procedure before applications are submitted to the federal and state regulatory agencies, as part of the mandatory permit review process. The

Department is currently updating the Inland Bays Dredging Study to ensure that the most current aquatic habitat and living resources impact assessment methods will be used in all future dredging projects to minimize adverse impacts. The revised plan will also include criteria specifically designed to assess the impacts associated with dredging private ancillary channels to connect with main navigational channels in creeks, rivers, and tributaries in the bays. It will include an updated look at dredged material disposal alternatives and design guidelines.

Over the years, Delaware's dredge program has been responsible for pumping over 4 million cubic yards of material, digging over 40 miles of channel and completing over 140 projects. Demands for the dredge program continue to grow due to increasing sedimentation in waterways, eutrophication in state-owned ponds, and other factors. As projects evolve, a great deal of consideration will be given to utilizing innovative techniques for dredge material disposal, where material will be used for beneficial environmental enhancement purposes (e.g., wetlands creation, shorebird and shellfish habitat creation).

The state and the U.S. Army Corps of Engineers are also involved with conducting dredging projects offshore of the Atlantic coastline to obtain sand for beach nourishment projects that restore sand lost from Delaware's beaches. The addition of sand to the beach increases the elevation and width of the beach, thereby restoring the recreational beach as well as providing storm protection to structures and infrastructure landward of Delaware's shoreline.

Environmental Impacts

Despite its benefits, dredging also has some negative environmental impacts. The major impacts of dredging navigational channels in the Inland Bays and excavating sand from offshore borrow sources for beach nourishment projects are the physical alteration of the bottom and resuspension of bottom sediments. The sediment provides habitat to a wide variety of organisms that may be commercially important themselves or food for such harvestable resources. Removal of bottom material may destroy benthic organisms that inhabit the substrate. In addition, dredging may cause a temporary increase in turbidity and, in some instances, it may cause the release of toxins attached to the bottom sediments. This increased water turbidity is usually localized and temporary and less than turbidity levels created by natural processes, such as storm events and wind stress on the shallow waters of the Inland Bays and creeks. The effects of dredging are usually short term with recolonization of benthic fauna taking place within a period of several months to a year. However, shifts in the benthic community may occur following re-colonization.

Depths of dredged channels are generally shallow (4 to 6 feet below mean low water) so that the stream bottom still lies within the euphotic zone. Deep channels should be avoided since increasing the depth of the water, and thus bottom depth, prevents sufficient sunlight from reaching the new bottom depth, taking that portion of the bay's bottom out of primary production. By limiting the primary production, and thus trophic support for primary and secondary consumers, the overall carrying capacity of that segment of the tributary or bay is reduced causing a decrease in its functional value. This can put severe limitations on the estuarine community of the impacted area. Full community recovery in these situations has been shown to take from years to decades to reach pre-impact levels (Muir, 1998).

Dredging has had the effect of decreasing areas of low salinity or freshwater tidal portions of the Inland Bays by allowing the more saline waters to project farther up tidal tributaries than would otherwise be possible (Weston, 1993). This has reduced or eliminated potential breeding areas for many valuable anadromous species that utilize the bays (e.g., striped bass, white perch, etc.).

Sediments dredged from the state's Inland Bays have historically been clean (e.g., low levels of heavy metals, no detectable PCBs), minimizing pollution potential. In addition, dredging and disposal techniques utilized by the state are considered to be the least environmentally damaging of all dredging and disposal methods. State dredging operations are conducted with hydraulic cutterhead suction dredges, which remove material with a rotary cutter, pick it up with dilution water by suction pipe, and transport it through the pump and discharge line. This method produces less agitation and resuspension of bottom sediments than mechanical dredges, such as a clam-shell dredge. Excavated materials are usually disposed via pipeline in confined, upland disposal areas, significantly diminishing the potential for damage to the estuarine environment.

Prior to conducting dredging projects in the Delaware Bay and Atlantic Ocean for beach nourishment, site investigations are conducted to determine the suitability of selected offshore borrow sources. Investigations are performed to determine environmental and archaeological impacts and the suitability of the sediments for nourishment projects. Archaeologists conduct magnetometer surveys to determine if any historical artifacts (e.g., shipwrecks) or ordinances from WW II are present in the proposed borrow site.

In Delaware, dredging operations, both public and private, are regulated and permitted through the Department and the U.S. Army Corps of Engineers. State regulations are handled through the Wetlands and Subaqueous Lands Section of the Department, under the Subaqueous Lands Act and the Wetland Law. The state also issues 401 Water Quality Certification for dredging projects. Prior to the issuance of a federal permit by the U.S. Army Corps of Engineers (Philadelphia District), a permit application and any supporting documentation must be reviewed and approved by both federal and state resource agencies, including the U.S. Environmental Protection Agency, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the state Division of Historic and Cultural Affairs, and the Department's Coastal Management Program.

2.3.3.2 Sensitive/Rare Habitats

The Inland Bays/Atlantic Ocean Basin includes several rare plant communities that are listed on the Natural Heritage Inventory. For some of these rare associations, the Inland Bays/Atlantic Ocean Basin is their primary location in Delaware. The Rush-Three Square Herbaceous Wetland is ranked by the Delaware Natural Heritage Program as S2, meaning that there are between 6 and 20 known occurrences in the state. There are 11 occurrences of this rare habitat in the Inland Bays/Atlantic Ocean Basin. This demonstrates the significance of this Basin as a sanctuary for this type of wetland. There are two occurrences of Twig Rush-Pipewort-"Acidic" Fen in this Basin. This habitat is ranked as S1 and G1, meaning that there are fewer than five occurrences statewide and globally. The global listing, especially, lends support to the importance of the Inland Bays/Atlantic Ocean Basin as refuge for this habitat type. Other rare habitat types found in the Inland Bays/Atlantic Ocean Basin include Coastal Plain ponds, interdunal swale, and beach heather assemblages.

2.3.4 SHORELINE PROTECTION/ LOSS OF SHORELINE

2.3.4.1 Ocean Shoreline

Early man understood that the shoreline shifted and changed location over time and that storms could dramatically change the width and profile of the beach and dune system. Knowing this, he built his home well behind the beach and protective dune or in back-bay areas. This landward location provided substantial buffer between the buildings and the sea. Some early inhabitants of barrier islands even had the forethought to build their homes so that they could be moved farther landward if needed. Modern development, on the other hand, has occurred within feet of the beach, and in many cases protective dunes have been leveled so that buildings can be closer to the water. This practice of building on shifting shorelines has put many buildings in a vulnerable location, has reduced the level of storm protection a wide beach and dune can provide, and has reduced the area available for recreation.

Failure to understand the dynamic nature of the shore and of the processes of barrier island migration and sea-level rise has resulted in a problem portrayed as beach erosion. However, the perceived erosion problems do not exist without human development. In a natural system, the barrier island is able to migrate in a landward direction through over-wash during storm events and eolian processes, and sand is able to move along shore through littoral drift processes unimpeded. In the natural system, the beach and dune still exist, just in a different location. Once a line has been established by construction of buildings or placement of property markers, people unreasonably expect that line to stay put. They exacerbate the problem by destroying the dunes for construction and by relocating over-washed sand following storms. Once the geology of the shoreline becomes apparent and structures become threatened, people intervene and make attempts to "hold the line." These attempts to stop loss of sand and to stabilize the area and protect it from damaging waves are sometimes successful. However, on other occasions, they are disastrous and can lead to greater erosion problems. Erosion rates are not constant, but are influenced by sand supply and storm frequency and intensity. There are periods of time with little storm activity where very little erosion of the shoreline occurs and some areas gain beach. At other times, increased storm activity may cause significant erosion rates. Most of the sand may be replaced during calmer periods as sand is carried along shore by littoral drift; however, if the updrift sand supply is depleted, erosion will continue to occur or increase.

Beach erosion did not become a significant problem for Delaware until the early 1900s when tourism and development increased and the economic impact of beach erosion became apparent. It was at that point that we began to see evidence of Delaware's attempts at holding the line. In some cases, these attempts have been successful; however, in other cases they have created problems down-drift of the project site.

Erosion rates vary considerably along Delaware's coastline depending on location and sand supply. In some areas, such as Cape Henlopen, the beach is accreting at an extremely fast rate as sand eroded from the Atlantic coastline is deposited. At the other extreme is the nodal point located somewhere around or south of South Bethany (it migrates) where little or no sand enters the area through littoral drift, but large volumes are carried outside of the area. Coastal managers and scientists have monitored and mapped those rates and use the information in determining the best options for holding the line. There are several shoreline protection options available including stabilization of the dune system, construction of hard structures, trapping of sand, and replacement of lost sand through beach nourishment.

Dune Stabilization

Dunes are natural features that protect inland areas and structures located behind them during storms. They are also sand storage areas that supply sand for offshore transport and berm building during coastal storms, causing storm waves to break farther offshore, thereby reducing wave energy before it reaches shore. Even when dunes have been breached or destroyed during storms, they gradually rebuild themselves to provide protection against future storms. Enhancement of the natural dunes increases their ability to protect inland areas from wash-over and flooding during storms. Erecting sand fences, planting and fertilizing beach grass, and limiting public access to the dunes, accomplish this enhancement or stabilization.

Vegetation plays a big part in the development and maintenance of the dune by trapping wind-blown sand, causing it to drop and build the dune in elevation and width. The plant roots also help to add structure and stability. Dunes should be allowed to grow in elevation to a level high enough to prevent wash-overs during minor storms; however it must be acknowledged that building dunes high enough to prevent wash-overs may also prevent the wind transport of sand in a landward direction and development of a secondary dune. Over time, con-tinued rise of sea level will eventually take over the primary dune. If all of the sand is tied up in the primary dune, the resulting damage may be worse than if the dune were left to migrate at its natural rate.

In the past, dunes were leveled to make way for development; however, recognizing their importance, coastal managers have changed programs toward creation and maintenance of the dune system. Delaware's Shoreline Management Program has a program dedicated to maintaining existing dunes and rebuilding storm-damaged dunes. Cape American Beach Grass is planted along all of Delaware's public beaches and in the state parks, where infrastructure exists, and sand fencing is erected in front of and behind dunes in public areas to prevent people from walking on them.

Delaware's Construction Regulations Program requires that all new construction take place landward of the existing dune when possible and that disturbance to the dune during construction is minimized. The program encourages property owners to construct structures that withstand beach erosion and coastal storms. In addition, it encourages property owners to rebuild dunes following coastal storms and provides them with information on proper dune maintenance.

Construction setback requirements, even at their most successful level, will only temporarily protect the primary dune. As the coastline continues to migrate landward, the dune must migrate ahead of the beach. Where buildings exist landward of the dune, the dune can not migrate; therefore, the dune will become increasingly narrow over time as the reach of high tide gets progressively closer, until it eventually disappears. This has occurred in the communities of South Bethany and North Indian Beach where homes which were once constructed on top of the dune are now located on the beach where the high-tide line is commonly located underneath the structures during the winter months. Many attempts have been made by property owners to maintain a dune in these areas, but sand that has been repeatedly placed underneath and in front of the structures is continuously carried away from the property during storms.

Hard Structures

"Shoreline hardening" refers to the construction of all types of structures built to retain sand, to interfere with waves or currents in order to reduce their damaging effects, or to protect property by reflecting waves and holding back the ocean. Armoring of the shoreline with hard structures such as seawalls, bulkheads, and revetments (riprap) for the purpose of protecting buildings is usually one of the first actions considered by waterfront property owners once the threat of storm damage to property is realized. An oceanfront resident must only look a short distance up or down the beach to find another property with some form of hard structure "protecting" it.

Bulkheads and seawalls, which are built essentially parallel to shore, have the primary purpose of preventing land from falling into the water (bulkheads) or of protecting land from wave damage (seawalls or revetments). However, these structures provide protection only to the land and structures behind them and do nothing to stop erosion of the beach. Because they are located where the dune should be, they can exacerbate erosion problems during a coastal storm. Areas with hard structures and areas lacking dunes may experience waves breaking closer to shore as the storm progresses because there is no movement of sand offshore, and as a result no offshore berm to dissipate the force of the waves. In areas where the sand supply is insufficient and there are high rates of sea-level rise, the distance between the water and the bulkhead will eventually decrease to the point where there is no longer a dry, sandy, recreational beach. Over time, these structures begin to weaken and deteriorate, then fail when they are most needed during a storm.

Failure of bulkheads occurred in several of Delaware's communities during the January 1992 and February 1998 storms. When this occurs, property owners and communities must make a decision regarding replacement of the bulkhead. Delaware's Coastal Construction Program works with property owners to look at what is best for the property and community and what effect it will have on the beach and dune. Many property owners have come to realize that bulkheads are not always the best option for protection of structures and have chosen not to replace them, but instead to maintain a dune and allow flood waters to flow underneath their structures.

Sand Traps

Groins and jetties — structures built perpendicular to the shoreline — intercept littoral drift and stabilize inlets. These structures, which extend from the dry beach to the surf zone and beyond, can provide localized success by trapping sand moving parallel to the shoreline in the nearshore zone. However, because they trap sand on the up-drift side of the structure without adding new sand to the beach system, adjacent and down-drift sections of the beach begin to erode.

Groins, usually constructed in groups called groin fields, have a service life of 25 to 30 years and need to be repaired or replaced after that time in order to be effective. The top of the groin is usually located at the desired beach profile so that it traps the sand moving from the up-drift direction, and it is constructed long enough out into the water to trap sand that is moving along shore. Once the desired profile is reached, the sand moves over the top and around the groin to the next groin compartment or to down-drift beaches. If there is insufficient sand available to fill the first groin compartment and to supply sand to down-drift beaches, erosion will begin to occur on the down-drift side of the groin shortly after construction. This erosion will eventually occur in all groin compartments and down-drift of the groin field if sufficient sand is not available. In order to prevent this erosion from occurring after initial construction, sand is usually placed between the structures to fill up the space between the groins.

When properly constructed and filled, large groin fields like those in Rehoboth and Bethany Beach are useful in maintaining a wider beach. In addition to the groins in Rehoboth and Bethany beaches, groins can be found at Deauville Beach, Henlopen Acres, North Shores, and Cape Henlopen State Park. Construction of these groins dates back to 1922 when the first groins were constructed in Rehoboth Beach.

Jetties are constructed at the mouth of a river or inlet to stabilize the channel and prevent closing of the inlet. Like groins, jetties trap sand on the up-drift side of the structure. Because sand is not able to easily pass around the jetty with the current, the sand supply to the down-drift side of the jetty is cut off resulting in erosion of the down-drift side. The jetties located at Indian River Inlet provide a classic example of the effects of cutting off the sand supply to down-drift beaches. The two jetties at the mouth of the Indian River Inlet were constructed in 1939 to stabilize the inlet. Prior to construction of the jetties, the south side of the inlet eroded at a rate of 4 to 5 feet per year and the north side eroded at a rate of approximately 7 feet per year. After installation of the steel and rock structure, sand began to accumulate on the south side of the inlet, and erosion on the north side tripled to over 21 feet per year between 1939 and 1954 (Kraft et al., 1976). Erosion became so great on the north side of the inlet and within the inlet channel itself that the bridge on Delaware Route 1 was in danger of being undermined. In order to save the bridge and the highway, the State of Delaware conducted several beach fill projects on the north side of the inlet beginning in 1957. In 1989, the Corps of Engineers and the State of Delaware constructed a sand bypass plant at the inlet to pump sand across the inlet from the south side to the north side, stabilizing the north side of the inlet without depleting the south-side beach. The plant has proven to be a tremendous success and is now an international showpiece.

Offshore breakwaters are designed to protect the beach from wave action by refracting waves and absorbing some of their energy. Generally constructed parallel to shore, they cause deposition of littoral material in their lee (between the breakwater and the shore) by dissipating the wave action that causes longshore transport. These structures are expensive and can have potentially negative impacts due to the possibility of accelerated beach erosion in down-drift areas. Construction of a breakwater offshore would result in some beach being sacrificed unless a breakwater extended along Delaware's entire Atlantic coastline. The presence of a breakwater offshore would also affect the recreational value of the protected area because the larger waves desired by swimmers and surfers would be reduced.

Beach Nourishment

Many hard structures have been used in Delaware to help stabilize the beach and minimize property damage. However, none of these hard structures has been successful in making up for the sand that has been lost to erosion. They only rearrange and control the movement of the sand. Beach nourishment directly addresses the problem of sand loss by adding sand to the beach and nearshore areas in order to restore it to its former width. The addition of sand to the beach by dredging and pumping sand from offshore areas, inland bays, or inlet shoals, or by bringing sand in by trucks from an inland borrow source, results in a wider beach that improves natural protection and provides additional recreational area.

While nourishment projects are not permanent and must be maintained by conducting new projects every three to five years, they do temporarily restore the protective beach and dune, something that hard structures such as bulkheads and revetments can not do. Nourishment projects have grown in acceptance as the preferred method of protection against shoreline erosion. While they can be expensive to conduct, it has been found that the benefits (property protection, increased recreational beach, increased tourism, and revenues) they bring to a community, far outweigh the costs. Unlike hard structures, nourishment does not adversely affect the beach or adjacent properties. However, many factors must be taken into consideration to make a nourishment project successful. The rate of loss and characteristics of the natural beach system must be understood. A borrow source that contains sand with the grain size and composition similar to that of the natural beach must be located. The distance (increased distance = increased costs) to the borrow source and the environmental effects (including the effects on the biological ecosystem) that may occur as a result of removing the material from the source must be considered. The overall costs must be weighed against the benefits.

In Delaware, small nourishment projects have been occurring since 1954. In 1962, following the March northeaster, an emergency beach fill was conducted along most of the coastline in order to repair the beaches that had been devastated as a result of the storm. Since 1988, the Division of Soil and Water Conservation has been conducting large nourishment projects along the ocean coast. Projects have been conducted on public beaches including Fenwick Island, South Bethany Beach, Bethany Beach, Dewey Beach, Rehoboth Beach, and Lewes Beach. These beaches that are usually less than 1 mile in length are spaced out with state parks and private communities located between them. Since these projects do not cover the entire stretch of coastline, it is becoming increasingly difficult to maintain the nourished sections of coastline as the adjacent beaches continue to migrate landward. State officials have been successful in recent projects in convincing private communities located adjacent to public beaches to become involved in the nourishment projects. This has led to an increased length of the project area and more success in maintaining sand within the area.

There may come a time when beach nourishment is no longer the answer due to rising costs, frequency of renourishment, and the inability to find suitable beach quality sand. When this occurs, retreat may become our only option if we wish to maintain a recreational beach in Delaware. Retreat involves the removal of oceanfront structures as the shoreline moves in a landward direction in order to maintain the distance between the buildings and the water. This option has not been pursued anywhere in a proactive manner. Some states have taken a position of not allowing reconstruction of structures following storms, but the legal rights of the states to go to this extreme remain questionable due to a question of "taking" of property without just compensation to the owner. If a governmental agency does consider prohibiting reconstruction of structures, or building new structures within the beach and dune zone, it will likely require purchase of the property by the government. Efforts to remove structures as the beach advances landward will be costly and extremely unpopular with the local residents.

It is important to consider the potential impact on the state and local economies if the recreational beach is lost and tourism dollars are not generated within a community in the summer months. Retreat options must be employed while there is still beach area between structures and the water if it is to be used as a beach preservation strategy. One option would be to purchase properties right after a damaging coastal storm when they are in a diminished state to avoid paying top market price. Another would be to remove incentives such as government-backed flood insurance, disaster assistance, and funds for infrastructure reconstruction following storm damage. Perhaps if these incentives were not available, people would be less inclined to build in a vulnerable location.

2.3.4.2 Inland Bays Shoreline

The shoreline surrounding Delaware's Inland Bays is a unique and critical part of the ecosystem. The banks of the waterways, commonly referred to as the riparian zone, provide a buffer for water quality by serving as a filtration system for sediment nutrients, provide habitat, serve to store storm-water surges, and provide a source of energy for aquatic life. Shallow water adjacent to these riparian areas serves as habitat for a myriad of bottom-dwelling organisms as well as an important breeding and nursery area for finfish.

Both natural and man-induced activities adversely impact shorelines. Two of the more common natural forces that cause the loss of shorelines are sea-level rise and wind-driven waves. These forces of nature ultimately replace the shoreline at a different location. New shorelines formed by the accumulation of land normally offset erosion. Man-induced activities are put in place to stop erosion and to deepen shallow water for navigation improvement.

Historically, vertical walls, or bulkheads, constructed with chemically treated wood have been used in the Inland Bays to prevent erosion. These bulkheads have numerous adverse impacts. The vertical wall reflects wave energy, causing the scouring of adjacent shallow-water habitat; chemicals in the wood escape into the surrounding aquatic environment, and the natural shoreline is lost. As in the case of ocean bulkheads, areas adjacent to the "hardened" shoreline typically exhibit increased erosion. This type of shoreline stabilization leads to loss of habitat, impaired water quality, and flooding.

Alternatives to bulkheading to prevent the loss of land are being used with increased frequency. These include stone or riprap, natural vegetation, and bio-engineering. If the decline in water quality is to be reversed in the Inland Bays, these alternatives must be used. The natural shoreline and the adjacent riparian areas should be managed so that they resemble a natural situation. Although the Department has a program in place for permitting the construction of shoreline stabilization structures, there is no program that addresses the loss of riparian areas.

Shallow-water habitat and water quality are also adversely affected by human activity. This impact mainly comes from boats operating in shallow water and dredging in nearshore zones. Boat propellers "wash" bottom sediments, destroying benthic organisms important to the aquatic vegetation that may remain in the Inland Bays and their tributaries, and resuspend sediment, causing increased turbidity that hinders the natural photosynthetic process. Dredging has similar effects in shallow-water areas.

Every effort should be made to retain the natural state of riparian and shallow-water areas of the Basin. In addition, consideration should be given to restoring degraded shoreline in an attempt to improve the water quality and living resources of the Inland Bays.

The long-term placement and use of bulkheads and riprap to retard shoreline erosion has resulted in the widespread loss of nearshore shallow-water habitat. Much of this consists of intertidal shoreline and shallows that are used by shorebirds as required feeding areas. The diamondback terrapin cannot traverse riprap or bulkheads to reach their upland breeding areas. An effort has been made to reduce the use of bulkheading in so-called natural areas of the Inland Bays, but the practice is still allowed in dead-end lagoons despite their degraded conditions. Lately, the Department has encouraged the use of biological alternatives for shoreline protection, but so far the public has been slow to accept the more “green” technologies. Efforts need to be made to limit any further loss of bay shoreline habitat and to retrofit or replace lost habit with more environmentally appropriate solutions.

2.3.5 MOSQUITO CONTROL

Open Marsh Water Management (OMWM) is a technique used by mosquito control agencies in the eastern U.S. to control salt-marsh mosquito production by physically altering marsh habitats. Ponds and ditches are selectively excavated in marshes with isolated breeding “potholes” or depressions that periodically flood and dry. Constructed ponds and ditches create a permanent water habitat that favors the survivorship of fishes (*Gambusia* and *Fundulus* spp.) that prey upon mosquito larvae. OMWM provides a biological mosquito control, greatly reducing the need for chemical abatement, the primary means of mosquito control prior to OMWM.

In the 1930s, salt marshes were systematically drained with ditches spaced at regular intervals (usually 300 feet apart) in a grid pattern. This technique assumed a drained marsh had less mosquito-breeding habitat. The systematic nature of ditches or “grid-ditching” was either ineffective or exacerbated the problem by isolating breeding spots at higher elevations in the marsh above the influence of daily tidal action. Delaware began experimenting with OMWM techniques in 1981. Early OMWM projects favored open and semi-open systems, a slight structural modification that retained the tidal nature of the grid-ditch system without attempting to drain the marsh. The system evolved through a systematic evaluation and experimentation process.

Current thought on OMWM design heavily favors the “closed” system design, where constructed ponds and ditches have no free connection to tidal sources. This design is favored over open and semi-open systems because of minimal impacts observed on the sub-surface-water table and floral community structure.

Chemical applications have been reduced by 58 percent since 1980 while several thousand acres of Delaware salt-marsh OMWM projects have been created. Each acre of salt marsh modified by OMWM removes approximately 15 to 25 acres from the annual spray program. OMWM has been performed at 12 sites totaling 600 acres of salt marsh surrounding the Inland Bays.

2.3.6 CURRENT HABITAT PROTECTION & MANAGEMENT EFFORTS

To date, a comprehensive management and protection scheme to protect and manage the tidal estuaries of the Inland Bays region has never emerged. While there are laws and regulations that afford some protection and management, the strategy is fragmented and utilizes a piecemeal approach for only segments of the estuary or its biota. For example, state fishing regulations only limit over-harvesting of certain species and do not protect forage species as an integral part of trophic support of that species. State wetland and subaqueous lands regulations have a permit review process that cannot meaningfully assess cumulative impacts and have resulted in a proliferation of docks, piers, and marinas throughout the bays. It is imperative that procedure and criteria be developed that will allow for the evaluation and quantification of cumulative impacts within the bays in the permit process.

Attempts have been made to evaluate and manage the bays through the Management Conference of the Inland Bays Estuary and later through the Center for the Inland Bays (CIB). While some progress has been made, it is slow and still fragmented due to funding and resource constraints. The CIB is currently sponsoring a number of habitat restoration projects in the Inland Bays, as well as some research. Additionally, the CIB is funding a revision of the Inland Bays Dredge Plan that will fully address all areas of concern.

2.3.6.1 Public Lands

Delaware’s wildlife represents a vital recreational resource base. Both consumptive recreation such as hunting, and non-consumptive recreation, such as birding, depend on the health of the state’s natural resources. The Inland Bays/Atlantic Ocean Basin has a variety of public lands providing resource protection and recreational opportunities. The Basin includes two wildlife areas — Assawoman and Piney Point; five fishing access areas —

Ingrams and Millsboro Ponds, Strawberry, Mulberry, and Sassafras Landings on Assawoman Wildlife Area; four boating access areas — Massey's Landing, Rosedale Beach, Love and Pepper Creeks; and four state parks — Cape Henlopen, Delaware Seashore, Fenwick Island, and Holts Landing *(Map 2.3-2 Sensitive Habitat Areas)*. These areas include places to hunt, hike, bird-watch, camp, and enjoy nature.

Overlap between state and federal habitat protection programs occurs on public lands. A Natural Area called the Assawoman Pond was established on the Assawoman Wildlife Area in 1985 to protect a rare plant site. The Division of Fish and Wildlife administers farming leases on state wildlife areas. Some farmland has been enrolled into the Conservation Reserve Program (CRP) at Assawoman Wildlife Area as either shallow-water wildlife ponds, or permanent wildlife habitat. More lands will be enrolled into subsequent CRP and Conservation Reserve Enhancement Program sign-ups, particularly on farmed wetlands, and in areas needing filter strips for water-quality protection.

The Delaware Department of Agriculture (DDA) Forest Service helps landowners to better manage their forests for a variety of objectives, including timber production, wildlife habitat enhancement, and recreational activities. This assistance ranges from supervising tree planting and timber stand improvement activities to assistance with timber harvests, to preparation of forest management plans. The DDA Forest Service also monitors forest management activities, primarily timber harvests, to ensure these activities minimize erosion and sediment into Delaware waters. The DDA Forest Service, through a cooperative agreement with the Maryland Forest Service, also offers tree seedlings at minimal costs to landowners.

In addition to technical assistance, the DDA Forest Service helps landowners receive federally funded cost shares for forest management activities. The Forestry Incentives Program (FIP), administered by the USDA Natural Resources Conservation Service, provides cost shares to landowners to reimburse up to 65 percent of their costs for tree planting and timber stand improvement activities. A landowner can receive up to $10,000 of cost shares annually, as long as they own between 10 and 1,000 forested acres (a waiver is available for up to 5,000 acres).

The Stewardship Incentives Program (SIP), administered by the USDA Farm Services Agency, provides cost shares to landowners for a variety of management practices including wildlife habitat enhancement, soil and water-quality protection, recreational opportunity enhancement, and timber production. Similar to FIP, landowners can receive up to $10,000 per year as long as they own between 5 and 1,000 acres of forests (a waiver to 5,000 acres is also available).

The forests of Delaware's Inland Bays are a wonderful mixture of pine and hardwood. The DDA Forest Service, working with private landowners, strives to continue to improve these forests for future Delawareans.

2.3.6.2 Natural Areas Program

In February 1978, the State of Delaware enacted the Natural Areas Preservation System Act. This legislation and the subsequent regulations provide the state, through the Office of Nature Preserves in the Division of Parks and Recreation, the ability to dedicate public and private nature preserves, to identify and maintain a statewide Natural Areas Inventory, and to establish a Natural Areas Advisory Council to review and make recommendations to the Department Secretary regarding the identification, protection, and acquisition of natural areas throughout the state.

The definition of a natural area in the State of Delaware enabling legislation (Natural Areas Preservation System, 7 *Del. Code,* Ch. 73) is an area "of land or water, or both land and water, whether in public or private ownership, which either retains or has re-established its natural character (although it need not be undisturbed), or has unusual flora or fauna, or has biotic, geological, scenic or archaeological features of scientific or educational value." Natural character refers to the native plant and animal species and associations that occupied Delaware under the influence of Native North Americans at the time of European occupation. The following are products of the Natural Areas Program.

The Natural Areas Inventory

The Natural Areas Inventory has identified 10 natural areas (out of the 67 identified in the state) as within, or partially within, the Inland Bays/Atlantic Ocean Basin *(Map 2.3-2)*. A previously digitized GIS layer for the inventory is currently undergoing comparison with Delaware Natural Heritage Program element occurrences. The finished maps will form the basis of a Natural Areas Directory, which will be used as a planning document to help protect Delaware's dwindling natural areas. Once the directory is completed and distributed to interested parties, the task will shift toward updating the inventory by identifying and adding qualified new areas previously excluded, and deleting areas recently destroyed. The Natural Areas Advisory Council must vote to amend the inventory before any changes can be made. Updates of the directory will be sent to government agencies, non-governmental organizations, developers, and land planners. It is hoped that the directory will facilitate the protection of some of Delaware's most important natural areas.

Currently in Sussex County, protection of natural areas is voluntary. In New Castle County, however, protection is not voluntary, and the owner must produce a Critical Natural Areas Report prior to the county's acceptance of any development plan. Even in this case, New Castle County will have to make the ultimate decision about whether to protect a natural area; it is not a state decision. Sussex County should enact a similar policy.

In selecting a state-recognized natural area, the Office of Nature Preserves, in conjunction with the Natural Areas Advisory Council, evaluates a site based on the following non-prioritized criteria: representativeness; biological rarity; uniqueness; diversity; size; viability; defensibility; research, education, or scenic value; and outstanding geological, archaeological, or aquatic features. The Natural Areas Inventory was not intended to include every natural area remaining in Delaware, but only the areas that were of statewide significance. As a result, many areas that meet the criteria were not included in the inventory.

During the 18 years since the inventory was established, a tremendous amount of suburban expansion has taken place in Delaware. Areas not currently included in the inventory are being reconsidered for inclusion. Among the concerns and priorities of this review is providing adequate upland buffer to wetlands, stream and river corridors, and protecting the larger isolated upland forest patches and rare habitats scattered throughout the region.

State Nature Preserves

Four of Delaware's 20 dedicated state nature preserves are located within the Inland Bays/Atlantic Ocean Basin: Cape Henlopen, Blackwater Creek, Doe Bridge, and Polk Hill *(Map 2.3-2)*. Natural Area Protection Plans are being developed to maintain the natural conditions that merited the original dedication of these preserves. Numerous other possible additions to the preserve program exist within the Basin. Additional high-quality properties are being identified for possible inclusion in the program. Nature preserve dedication is the highest legal protection available within the state, requiring the concurrence of the governor and the legislature to remove or "deactivate" a nature preserve.

2.3.6.3 Open Space Program

In 1990, the General Assembly expanded the ability of the Division of Parks and Recreation to acquire land through the passage of the Land Protection Act, which created the Open Space Program. Under this program, 20 state resource areas (SRAs) were created, comprising 250,000 acres, including state, federal, local, and private conservation lands, and in holdings and potential additions to these areas. Part of the mission of the Open Space Program is to protect lands within these SRAs through purchase, donation, or conservation easement. The nine-member Open Space Council prioritizes and approves acquisition of lands with open-space funding. While the Division of Parks and Recreation administer this program, lands purchased under the program are purchased for the Division of Parks and Recreation, Division of Fish and Wildlife, Division of Forestry, and the Division of Historical and Cultural Affairs.

SRAs within the Inland Bays/Atlantic Ocean Basin include the Inland Bays, Cape Henlopen, and portions of the Great Cypress Swamp. In the Inland Bays/Atlantic Ocean Basin, 4,511 acres of land have been protected since 1990 at a cost of $34.4 million *(Map 2.3-2)*.

The Open Space Program receives $3 million annually from the state's real estate transfer tax until the principal of the Delaware Land and Water Conservation Trust Fund reaches $60 million in approximately 2003. The Open Space Program is expected to receive an additional $15 million from the Bond Bill for fiscal year 2001.

2.3.6.4 Conservation Easements

The Department and other land conservation agencies also use conservation easements to protect land that provides important habitat. Under a conservation easement, a landowner voluntarily places permanent restrictions on the future use of the land. Terms of the conservation easement are tailored to the piece of land and circumstance. The conservation agency that holds the easement enforces the restrictions. Currently, in the Inland Bays/Atlantic Ocean Basin, the Department holds four conservation easements totaling 76 acres.

2.3.6.5 Wetland Protection Programs

There are a variety of programs in place to protect wetlands. The regulatory programs are discussed at length in Section 2.4. Non-regulatory programs are discussed in this section.

The Magnuson-Stevens Act of 1996 established the concept of "essential fish habitat" that encompasses every biogeochemical element a federally managed fish species encounters throughout its life cycle. It protects these elements, such as primary forage species to migratory fish passages, and prevents any degradation of these elements that might threaten the species' regional population. The regulations and procedures to support this act are still being defined, and it remains to be seen how effective this act will be when fully implemented. Potentially, it may hold great promise for protecting estuarine habitat, a valuable component of essential fish habitat of most of the regulated species.

Notification, Recognition, and Registration

Landowner notification and recognition are voluntary mechanisms that are legally non-binding but are important in making contact with landowners as a precursor to more permanent agreements. Such an effort lets the landowner know that he or she has a wetland within a property that merits protection and is subject to regulatory oversight.

There are several federal acquisition programs that have provided protection for Delaware's wetlands. Most of these efforts have focused on tidal wetland fisheries and waterfowl habitat: the Migratory Bird Conservation Act of

1929, the Duck Stamp Act of 1934, the Sport Fish Restoration Act of 1950, and the North American Waterfowl Management Plan of 1986. A few of these programs either directly or indirectly provide for the acquisition of non-tidal wetlands in Delaware.

Section 301 of the Emergency Wetlands Resources Act recognizes the need to more actively protect wetlands through the establishment of a National Wetlands Priority Conservation Plan to specify, by region, the types of wetlands to be prioritized for federal or state acquisition. The list of sites identified for Delaware by the U.S. Fish and Wildlife Service, Region 5, in 1990, includes 16 critical wetlands, all of which include a non-tidal component, including forested, shrub-scrub, and emergent wetlands.

Conservation Reserve Program

The Conservation Reserve Program (CRP), created by the Food Security Act of 1985, provides incentives for the removal of erodible and flood-prone lands from crop production to restore them for conservation purposes. There are currently approximately 1,000 acres under CRP contract at an annual rental payment per acre per year of between $60 and $85 to the landowner. All of this acreage is planted in 70- to 100-foot grass filter strips that are maintained under 10-year contracts for sediment and nutrient/pesticide abatement purposes. Participation in the CRP, in Delaware, has been low, probably due to Delaware's relatively high bids among competing states and regions.

Another intent of the CRP is to encourage landowners to restore forested wetlands through the re-establishment of native bottomland hardwood trees on croplands, through federal government cost shares of up to 50 percent, for both wildlife and water-quality purposes. Provisions for wildlife food plots and shallow-water areas are included so long as the acreage does not exceed 50 percent of the restored-forested area. There has been no forested wetland re-establishment under this program in Delaware, nor in any of the eastern states, although Pennsylvania has created some freshwater emergent marshes under CRP.

Water Quality Incentive Program

Another program designed specifically for water-quality improvement in agricultural areas is the Water Quality Incentive Program. Under this program, farmers are paid from between $10 and $125 per acre per year to implement pesticide and nutrient management and wetland wildlife practices within certain watersheds.

Wetland Reserve Program

The Wetland Reserve Program (WRP), administered by the Natural Resources Conservation Service, authorizes the direct purchase of permanent easements from landowners by the restoration of prior-converted croplands. Other eligible lands include buffer and riparian areas, natural wetlands, and wetlands restored under the CRP or other federal or state programs. The objectives of the WRP are to restore wetland hydrology and vegetation to its native state and to protect wetland functions and values. The program is a cooperative venture, with implementation responsibilities shared among the eligible landowners, Natural Resources Conservation Service, Fish and Wildlife Service, Forest Service, Conservation District, Extension Service, state agencies, and Environmental Protection Agency.

The WRP provides an opportunity for farmers to be compensated for marginally productive cropland as well as federally regulated wetlands, and buffer areas. This program holds significant promise for the acquisition of degraded, restorable, or natural wetlands associated with agricultural development.

Federal Programs

State wetland development grants, offered through the Environmental Protection Agency, provide funds for wetland planning and development projects. Although direct wetland acquisition is not eligible from this funding source, the grant funding assists in all facets of state wetland planning efforts, including the recent directions in watershed planning such as implementation of wetland acquisition and restoration projects.

The Delaware Division of Fish and Wildlife acquires non-tidal wetlands under federal programs sponsored and funded primarily by the Department of the Interior. Other non-tidal wetland protection efforts related specifically to fisheries include use of funds authorized under the Federal Sport Fisheries Restoration Program for the purchase of ponds and their associated wetlands.

2.3.7 DATA GAPS AND RECOMMENDATIONS

1. Promote the acquisition and protection of wetlands and natural heritage sites.
2. Limit further human disturbance of Delaware's remaining Coastal Plain ponds. Research should be initiated to gain a better understanding of the geological origins and hydrological dynamics of Delaware's Coastal Plain ponds. Additional inventories are needed to fully assess the presence of rare plant and animal species.
3. Develop a series of Best Management Plans (BMPs) for all sources of erosion in order to keep sediment and nutrients out of wetlands, waterways, and the bays in general. Develop management plans to designate and develop riparian buffers and establish habitat criteria for maintaining said buffers. *Lead Agency: Nutrient Management Commission*
4. As reservoirs of rare species in Delaware, every effort should be taken protect the integrity of interdunal swale wetlands.

5. Produce a brochure on bioengineering for shoreline stabilization.
6. The Department should work with Sussex County and the Basin's municipal governments to develop open-space ordinances that provide for recreation areas and buffer streams and other water bodies. *Lead Agency*: *Sussex County and Municipalities*
7. The statewide Wetland Mapping Project data should be compared with the Natural Heritage Inventory to identify areas where additional research and/or protection are needed.
8. Care should be taken when creating habitat to make sure that other valuable habitat is not destroyed in the process.
9. Promote resource conservation areas for reestablishment and protection of habitat.
10. Identify restoration possibilities to increase connectivity between available habitats (include cooperative opportunities with Maryland).
11. The Department needs to assess the cumulative impacts of the development of individual parcels of property. Currently, there is no coordination of the numerous permitting processes for well construction, sewage disposal, storm-water runoff, wetlands construction, subaqueous lands construction, coastal zone consistency, and others. A developer may be able to comply with all of the requirements of these individual programs, but when looked at as a whole, the impacts may be unacceptable.
12. Condition Shoreline Protection Permits such that all shoreline protection structures are based on documented and demonstrable need (e.g., evidence of substantial erosion that requires that class/level of erosion control) and that the mitigation measure have the least adverse impact on the shoreline habitat and its living resources. Mitigation measures should consider a tiered approach using innovative accepted biological measures prior to more aggressive mechanical/engineered solutions (riprap, bulkheads, groins, etc.). Promote natural shorelines and buffers around the shorelines of the bays and their tributaries. Develop a set of public brochures illustrating the benefits to both the landowner and the living resources stressing the enhanced quality of life to all concerned.
13. Develop a suite of aquatic resource benchmarks that will define living resource habitat/water-quality conditions (both status and trends) of the Inland Bays. These will consist of living resource keystone or resident important species (RIS). In addition, standard water-quality parameters as well as macrobenthic biometrics will be utilized in the overall assessment suite. (Look at what benchmarks are being used elsewhere, such as the Chesapeake Bay.) *Lead: Coastal Management & Center for the Inland Bays*
14. Develop and refine a plan to deal with excessive macroalgae. This would consist of early season macroalgae surveillance in order to determine the size and causal mechanisms that will lead to the development of a management plan to control excessive deleterious outbreaks. Harvesting of nuisance macroalgae should minimize by-catch of crabs and fish.
15. Recognize the value of relic shoals when looking for borrow sites for beach nourishment projects.
16. Minimize dredging activities other than necessary maintenance.
17. Do not allow any new spur channels.
18. Deep channels should be avoided since increasing the depth of the water, and thus bottom depth, prevents sufficient sunlight from reaching the new bottom depth, taking that portion of the bay's bottom out of primary production.
19. Encourage re-use of dredge materials and disposal of spoils on uplands.
20. Develop BMPs for disposal sites.
21. Where frequent dredging is needed, determine source of sediment and take care of the source.
22. Sensitive areas should be accorded special status and given special attention when a development is proposed on or adjacent to such an area. It is recommended that state and local governments care for these areas. Their actions and decisions should reflect a major commitment toward protecting and conserving these resources.
23. Promulgate regulations to prohibit new dead-end canals and all other man-made water bodies that do not possess those flushing and circulation characteristics that will maintain optimal water quality and habitat in order to maintain a healthy functioning aquatic biotic community.
24. A survey of the Inland Bays/Atlantic Ocean Basin should be conducted as soon as possible to identify remaining upland forests and to evaluate the quality of these areas using such factors as biodiversity, size, age, and exotic infestation. Appropriate actions should then follow such as natural area designation for qualifying tracts, legal protection, and/or restoration.
25. A survey of rare habitats should be conducted and summarized. Appropriate actions should be taken to protect these areas, including natural area designation for qualifying tracts, legal protection, and/or restoration.
26. Incorporate Delaware Natural Heritage Program databases with other planning databases, including those in Maryland, so that rare species are identified prior to development.

27. Do not allow overboard disposal of dredge spoils.
28. Promote the establishment of forested wetlands and upland forest to supplement and/or restore natural riparian buffers.
29. Sussex County should enact an ordinance, similar to that of New Castle County, that gives Natural Areas special consideration in the land development process.
30. Every effort should be made to retain the natural state of riparian and shallow water areas of the Basin. In addition, consideration should be given to restoring degraded shoreline in an attempt to improve the water quality and living resources of the Inland Bays.
31. Efforts need to be made to limit any further loss of bay shoreline habitat and to retrofit or replace lost habitat with more environmentally appropriate solutions.
32. All efforts should be made to protect mature hardwood and mixed forest in the Basin. Landowner involvement in forest/habitat conservation programs available through the Delaware Division of Fish and Wildlife and the Delaware Department of Agriculture should be actively marketed. Acquisition of quality forest tracts by state, federal and private conservation agencies by conservation easement or outright purchase should be aggressively pursued.
33. Initiate an intensive monitoring program at productive amphibian breeding sites within the Basin to determine population trends.
34. Monitor range expansion for nutria and develop a strategy for control and containment. Publish literature for landowners with nutria problems.

2.3.8 REFERENCES

Academy of Natural Sciences. 1988. *Phytoplankton, Nutrients, Macroalgae and Submerged Aquatic Vegetation in Delaware's Inland Bays, 1985–1986.* Report produced for DNREC, 140 pp.

Chrzastowski, M. L. 1986. *Stratigraphy and Geologic History of a Holocene Lagoon: Rehoboth and Indian River Bay, Delaware.* Ph. D. dissertation, Geology Department, Univ. of Delaware, Newark, DE. 337 pp.

De Cunzo, L. A., and W. P. Catts. 1990. *Management Plan for Delaware's Historical Archaeological Resources.* Newark, DE: Univ. of Delaware, Dept. of Anthropology.

Frieswyk, T. S., and D. M. DiGiovanni. 1989. *Forest Statistics for Delaware — 1972 and 1986.* Northeastern Forest Experiment Station, Resource Bulletin NE-109, Forest Service, U.S. Dept. of Agriculture. 86 pp.

Inland Bays Estuary Program Management Conference. 1995. *Comprehensive Conservation and Management Plan.* Dover, DE: DNREC.

Kraft J. C., E. A. Allen, D. F. Belknap, J. J. Chacko, and E. M. Maurmeyer. 1976. *Delaware's Changing Shoreline.* Technical Report Number 1, Delaware Coastal Zone Management Program, Dover, DE, 319 pp.

Kraft, J. C. 1977. "Late Quaternary Paleogeographic Changes in the Coastal Environments of Delaware, Middle Atlantic Bight, Related to Archaeological Settings." *Annuals of the New York Academy of Sciences* 288:35–69.

Lesser, C. A. 1966. *Aquatic Vegetation Survey.* Annual Rept., Federal Aid in Fish Restoration Project F-21-R. Dover: Delaware Game and Fish Commission.

Martin, C. C. 1976. *Delaware Fishery Survey of Lentic Waters.* Final Rept., Federal Aid in Fish Restoration Project F-26-R. Dover: Delaware Division of Fish and Wildlife.

Martin, C. C. 1984. *Delaware Pond Management Program.* Final Rept., Federal Aid in Fish Restoration Project F-32-R. Dover: Delaware Division of Fish and Wildlife.

Martin, C. C. 1996. *Evaluation of Triploid grass carp in Delaware: 1986-1995.* Annual Rept., Federal Fish Restoration Project F-41-R, Job 6. Dover: Delaware Division of Fish and Wildlife.

Maxted, J., E. Dickey, and G. Mitchell. 1992. *Biological Integrity and Habitat Quality of Non-Tidal Streams of Kent and Sussex Counties, Delaware.* Appendix C (Delaware 1992 305(b) Report). Dover: Delaware Division of Water Resources.

Price, Kent S. 1998. "A Framework for a Delaware Inland Bays Environmental Classification." *Environmental Monitoring and Assessment* 51:285–298.

Pyne, S. J. 1982. *Fire in America, A Cultural History of Wildland and Rural Fire.* Princeton, NJ: Princeton Univ. Press. 654 pp.

Ritter, W. F. 1981. *Survey and Classification of Delaware's Public Lakes.* By Univ. of Delaware for Delaware Division of Fish and Wildlife (EPA).

Scharf, J. T. 1888. *History of Delaware, 1609– 1888.* Vols. I and II. Philadelphia: L. J. Richards and Co.

Schelske, Claire L., and E. P. Odum. 1961. "Mechanism Maintaining High Productivity in Georgia Estuaries." *Proc. Gulf and Carib. Fish. Inst.* 14:75–80.

Targett, T. E., et al. 1999. *Importance of Sea Lettuce and Other Marine Macroalgae to Fishes and Macroinvertebrates of Delaware's Inland Bays.* By Univ. of Delaware for DNREC.

Taylor, G. T., and D. Zheng. 1995. *Natural Products for Mitigation of Fouling by the Blue Mussel,* Mytilus edulis, *in Marine Water Intake Systems.* Proceedings of the 5th International Zebra Mussel and other Aquatic Nuisance Organisms Conference, Toronto, ON, pp. 447–459.

Zimmerman, M. 1998. *Aquatic Vegetation Control Summary.* Dover: Delaware Division of Fish & Wildlife