5-1-1996

Enhancement of coastal dredge disposal sites to create habitat for endangered, threatened, and protected species

Mary Beth Simpson
Rowan College of New Jersey

ENHANCEMENT OF COASTAL DREDGE DISPOSAL SITES TO CREATE HABITAT FOR ENDANGERED, THREATENED, AND PROTECTED SPECIES

by
Beth Simpson

A THESIS

Submitted in partial fulfillment of the requirements of the
Master of Arts Degree in the Department of
Environmental Studies
Rowan College of New Jersey
1996

Approved by ______________________

Date Approved 5/1/96

ABSTRACT

Mary Beth Simpson - Enhancement of Coastal Dredge Disposal Sites to Create Habitat for Endangered, Threatened, and Protected Species

Advisor: Gary Patterson
Environmental Education (1996)

As human activities and development along the shoreline continue to increase, more and more wildlife habitat is lost, leaving many species with a precarious prospect for survival. Biologists and environmentalists are continually exploring options which may prevent plants and animals from becoming extinct. Strategic placement of new sites is becoming increasingly valuable as a management tool.

The purpose of this study was to develop a plan for enhancement of a cluster of dredged material islands, in order to create suitable habitat for four endangered, threatened, and protected animal species.

Four dredged material islands were assessed for suitability. Surveys were conducted on these islands to establish data on their composition and inhabitants.

Extensive research was done on the beneficial uses of dredged material, and numerous projects were reviewed.

The habitat needs of black skimmers, diamondback terrapins, least terns, and piping plovers were studied, and a successful colony site was visited and observed. From these studies and observations, comparisons were made between the existing study site, and sites where the target species were

colonized and/or nesting.

The author determined the main aspects of this enhancement project to be size, shape, elevation, substrate, vegetation, predators, timing, monitoring, and maintenance, and made final recommendations, drawn from research and field work, concerning each of these considerations.

MINI-ABSTRACT

Mary Beth Simpson - Enhancement of Coastal Dredge Disposal Sites to Create Habitat for Endangered, Threatened, and Protected Species

Advisor: Gary Patterson
Environmental Education (1996)

In this study, an environmental inventory was conducted on four dredged material islands, and the habitat needs of four endangered, threatened, and protected species were researched. All data was compiled to develop a plan to enhance the study site for habitat use by the target species.

ACKNOWLEDGEMENTS

I want to extend my gratitude to Dr. Roger Wood for being my mentor in this project. I also want to thank the Wetlands Institute, in Stone Harbor, New Jersey, for making available to me their boats and equipment, without which this thesis would not have been possible.

I am indebted to the numerous researchers whose works are referenced in this thesis, and whose advice and guidance over the telephone wire were invaluable.

My sincere appreciation goes out to Barbara Stratton, Special Projects person for the United States Army Corps of Engineers, for her encouragement and support, and for her help in obtaining necessary documents and reports.

I owe a special thanks to Bert Aspenberg for proof reading my work.

My highest respect and admiration, along with deep gratitude, go to Dr. Mary Landin who took the time to correspond with me. Her input was vital.

To Gary Patterson - teacher, friend - for finding the best in me.....thank you.

Most of all I want to thank and dedicate this work to my father -

who first walked with me on the marsh.

TABLE OF CONTENTS

LIST OF FIGURES

Figure | page

LIST OF TABLES

Chapter One

INTRODUCTION

The United States Army Corps of Engineers (USACE) is responsible for maintaining navigability of 25,000 miles of intracoastal waterway (U.S. Army Corps of Engineers, 1995) from Maine to Florida. In order to successfully do so it is periodically necessary to dredge certain areas to keep the channels deep enough for boat passage. In carrying out this responsibility the dredge spoils create artificial islands within salt marshes along the courses of the intracoastal waterway. There are basically two types of islands created: rectangular, steep sided heaps; and mounds of dredge spoil with no defined boundaries (Scrignoli, 1995) (figure 5).

The dredging of these waterways has been going on for approximately 20 years (telephone interview: Scrignoli, 1995). Consequently our coastal salt marshes are dotted with large numbers of dredge disposal islands of varying ages and sizes. These islands have not been managed. Until recently the Corps of Engineers (COE) was never concerned about what flora and fauna, if any, were making use of these sites

(Wood, 1995a).

Presently the Army Corps of Engineers seeks to manage these spoils in ways which will improve their value to the marsh ecosystem. They are currently looking for ways to use these sites that will be environmentally beneficial (Wood, 1995a)(Hecht, 1995).

PROBLEM

According to Eric Shreyding, a Wildlife Biologist for the U.S. Fish and Wildlife Service, to his knowledge, a plan to enhance a dredge spoil site along the New Jersey coast, for use by endangered, threatened, and\or protected species, has never before been developed.

PURPOSE

The author proposes to undertake a pilot study of a cluster of mound disposal islands located on the northern end of Gull Island, at the entrance of Great Sound, Middle Township, Cape May County, New Jersey, in order to develop a plan that will create suitable habitat for several species of Federal and State Threatened and Endangered species of birds, (namely the black skimmer, the least tern, and the piping plover) and the diamondback terrapin, which is protected by the state of New Jersey, and whose populations are declining. (Wood, 1995; c).

SIGNIFICANCE OF THE STUDY

This project is both significant and important to do because suitable nesting habitat for the previously listed species is becoming increasingly scarce as a result of coastal development and shoreline stabilization (Hecht, 1995). If the author's study indicates it is possible to modify dredge disposal islands into prime nesting habitat, there will be a new potential source of habitat which may enable these populations to survive.

The critical problem facing a number of Federal and State Endangered species, including those previously specified, is lack of suitable nesting habitat (Helmers, 1992). At least one other bird species, the common tern - not yet formally listed - appears to be rapidly diminishing for the same reason (Jenkins, 1995). Moreover, a State Protected species of saltmarsh dwelling reptile, the northern diamondback terrapin, is declining in numbers, at least in part, due to loss of suitable nesting habitat (Wood, 1995; a).

The significance of this study is actually two fold, as there is an ongoing question as to what to do with the waste from dredge areas.

ASSUMPTIONS AND LIMITATIONS

The assumption of this project is that if this study suggests that it is in fact possible and worthwhile to modify said specific dredge disposal sites, then the findings for this thesis project will have a much wider applicability to other similar sites along the mid-Atlantic coast, and will provide more nesting areas for species that need them.

It is assumed that what this author is doing for her thesis is merely one step in a several step process which would include getting the funding, permits, and so on that would lead to the actual modification of the island.

Beyond that, assuming that the dredge sites are modified, it would take several years to determine if the target species are using these sites for nesting.

It is further assumed that:

1. The author has sufficient background, knowledge, interest, and capability to carry out this project;
2. This study, involving a thorough review of related literature, visiting existing nesting sites of target species, and doing the necessary field work on the dredge spoil islands, can be done within the given time frame, which is two semesters; and
3. The financial costs will not exceed what the author is able to provide.

This project will be limited to:

1. the habitat needs of the black skimmer, the least tern, the piping plover, and the diamondback terrapin;
2. the time and space available to do the research within the time frame of the '95-'96 academic school year;
3. being site specific to the four dredge spoil islands located on the north end of Gull Island in Great Sound, Cape May County, New Jersey; and
4. The support and assistance provided by the author's mentor, Dr. Roger Wood.

This is not a marsh restoration study such as the one done on Drag Island on the south end of the Garden State Parkway, or as in the study being proposed for the Delaware Bay Coast by Public Service Electric and Gas. This author is not proposing to convert an area back into a salt marsh, as has been done in these studies. Rather, this author's focus is on enhancing a designated area as nesting sites for various endangered, threatened, and protected species.

DEFINITION OF TERMS

Barrier islands. Islands in the ocean that are close to the coast and parallel to it. They act as natural buffers to ocean storms and tides (Kane et al., 1992).

Beneficial uses. Placement or use of dredged material for some productive purpose (U.S. Army Corps of Engineers, 1992).

Colonize. The process by which a species of plant or animal enters an area not previously occupied by that species and establishes itself (Kane et al., 1992).

Crustacean. A member of the subphylum of the anthropods characterized by mandibles, antennae, and modified appendages. Included in this category are lobsters, crabs, barnacles, and shrimp (Kane et al., 1992).

Detritus. Dead and decaying plant or animal matter (Western Regional Environmental Education Council, 1987).

Disposal site or area. A precise geographical area within which disposal of dredged material occurs (U.S. Army Corps of Engineers, 1992).

Dredging. To remove sediment from our waterways and harbors (U.S. Army Corps of Engineers, 1995).

Dredged material. Material excavated from waters of the United States or ocean waters. The term dredged material refers to material which has been dredged from a water body, while the term sediment refers to material in a water body prior to the dredging process (U.S. Army Corps of Engineers, 1992).

Endangered species. A species threatened with extinction or extirpation (Kane et al., 1992).

Enhancement. An activity increasing one or more natural or artificial wetlands functions (Jones, 1993).

Environment. An organism's living and non living surroundings that affect and influence it (Kane et al., 1992).

Extinct. Describes a plant or animal no longer existing as a living species. Extinction occurs when the last individual of the species dies (Kane et al., 1992).

Extirpated. Locally extinct, that is, extinct in a particular state or county, but perhaps still present elsewhere (Kane et al., 1992).

Fauna. Animals, as opposed to plants (Kane et al., 1992).

Flora. Plants, as opposed to animals (Kane et al., 1992).

Fledging. The production of a complete set of flight feathers which enable the young bird to leave the nest (Kane et al., 1992).

Forage. The act of an animal searching for food (Kane et al., 1992).

Habitat. The natural environment of an organism where it most usually finds the food, water, shelter, and space it needs to live its full life cycle and reproduce others of its kind (Kane et al., 1992).

Herbicide. A chemical or combination of chemicals that kills plants (Kane et al., 1992).

Marsh. A non-wooded, permanent, usually well-drained wetland (Kane et al., 1992).

Mitigation. Consists of those measures taken to avoid, minimize, or compensate for adverse environmental impacts. Mitigation measures are authorized by Congress, or approved by the United States Army Corps of Engineers, to compensate for ecological resources unavoidably affected by a Corps project or activity (U.S. Army Corps of Engineers, 1997).

Nestling. A recently hatched bird that has not yet abandoned the nest (Kane et al., 1992).

Piracy. The harassment of one bird by another in order to force the first to give up food (Ehrlich et al., 1988).

Plastron. The lower portion of a turtle shell (Wetlands Institute, 1994).

Predator. An animal that kills and eats other animals (Kane et al., 1992).

Sea wrack. Dead vegetation along the shoreline; also called wrack line or wrack mat (Gochfeld & Burger, 1994).

Site tenacity. The tendency to return each season to the same nesting site (Ehrlich et al., 1988).

Species. A population of individuals that are more or less alike and are able to interbreed and produce fertile offspring under natural conditions (Kane et al., 1992).

Spoil. Commonly used term for dredged material; in most cases a misnomer (U.S. Army Corps of Engineers, 1995).

Swale. Low place in a tract of land (Flexner, 1993).

Threatened species. A species whose survival is in danger of becoming endangered or extirpated (Kane et al., 1992).

Upland. An area that is high and dry (Kane et al., 1992).

Wetland creation. The establishment of a wetland community where one did not previously exist (Jones, 1993).

Wetlands. Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that, under normal circumstances, do support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (U.S. Army Corps of Engineers, 1992).

Chapter Two

REVIEW OF RELATED LITERATURE

Various projects have been undertaken to modify and/or restore fresh and salt water wetlands. None of them are directly comparable to this study. However, some components of these have a bearing on this author's study site and its proposed modifications.

Much of the relevant literature on this topic is in the form of technical documents and reports as opposed to formal scientific publications in journals. As the author worked toward developing a plan to enhance a dredged material site for use by endangered, threatened, and protected species, she reviewed literature on dredging, beneficial uses of dredged material, various mitigation projects, marshes and estuaries, and the habitat needs of the black skimmer, the diamondback terrapin, the least tern, and the piping plover.

This chapter is divided into four sections including:

I. Marshes
   A. history
   B. destruction of
   C. values
II. Dredging
   A. history

B. beneficial use

III. Case studies

IV. Target Species

A. black skimmer

B. least tern

C. piping plover

D. diamondback terrapin

I. Marshes

Look how the grace of the sea doth go
About and about through the intricate channels that flow
Here and there
Til his waters have flooded the uttermost creeks and
the low-lying lanes,
And the marsh is meshed with a million veins
That like as with rosy and silvery essences flow
In the rose and silver evening glow.

The creeks overflow and a thousand rivulets run
'Twixt the roots of the sod; the blades of the marsh
grass stir;
Passeth a hurrying sound of wings that westward whir;
Passeth, and all is still; and the currents cease to run
And the sea and the marsh are one.
The tide is at his highest height
And it is night.
And now from the Vasts of the Lord will the waters
of sleep
Roll in on the souls of men.

from
"The Marshes of Glynn"
by
Sidney Lanier

There is no place on earth comparable to the salt marsh. In the fragile balance between land and sea exists one of the most productive of habitats - "Supporting more life per acre than the richest of prairie land" (Hitchcock, 1972, p. 738) - fertilized and cultivated by the tide. To walk on its great flat expanse of meadow; to smell the richness of the mudflats; to hear the wind blow through the reeds, and the flapping of wings on water; to watch the vast grasslands flood - it is easy to understand how enormously these areas have contributed to man, and so difficult to comprehend why man would so ruthlessly destroy them in return.

The sites in this author's study are located on an already existing area of salt marsh called Gull Island. Gull island, which is not an upland site, is located at the entrance to Great Sound, in Cape May County. The four dredged material sites, which are the focus of this study, are situated on this submerged island.
The author felt that the information reviewed in this section was particularly relevant and important to establish a solid background. Her study of the salt marsh proved to be extremely beneficial when she began her field work.

John and Mildred Teal give a comprehensive, historical overview of marshland in The Life and Death of the Salt Marsh (1969). According to this work, in the wake of the last ice cap our present salt marshes were established when windblown seeds began to sprout upon the rich soil. In the struggle between soil and water the root system of this new plant life eventually began to hold the soil in place. The seeds were fertilized by rock flours rich in nutrients. The plants flourished and grew in abundance. Migrating birds, stopping for refuge, dropped seeds that were carried in mud that had dried on their feet. Some of these new seeds germinated. Grasses began to grow at the edge of the water where the land became covered by the tides less than half of the time. A tall coarse grass, Spartina alterniflora, grew at the mid-tide level. Near the high tide level grew Spartina patens, a finer grass. Other plants such as sea lavender and marsh elder would grow, but the Spartinas would remain prominent. The salt marsh was firmly established.

According to Teal and Teal (1969) early man took only what he needed for survival from the marsh. The highly productive marsh provided more than enough for all. He practiced crop rotation, and fertilized with fish and seaweed. Man learned from the marsh; things such as how to find fish roe, by watching gulls carry a fish up to dry land and slit its belly open and feed.

Europeans first met the Indians on the marsh. It is here that the "uncorrupted epoch of the marsh ended" (Teal and Teal, 1969, p. 24). From then on the future of the marsh was in the hands of man, and according to Teal and Teal (1969), it has not fared well.

Teal and Teal (1969) give a detailed account of the impact of humans on the marsh. In summary: Villages grew quickly. Governments formed. As forests were removed, white-tailed deer came onto the marsh. Large birds of prey declined. There were fewer osprey and bald eagles. Soil left bare began to erode. Hay was overharvested in the marsh. Birds were overhunted. Night hunters, who blinded their prey with lights, brought home sacks full of waterfowl. Flocks were destroyed. Laws were passed making hunting with lights illegal. The age of machinery was born. The railroad moved in. The plundering of shorebirds finally saw the end of the passenger pigeon. Shorebirds were plentiful and very tame. In 1840 Audubon recorded it as common for a person to collect a hundred dozen eggs in one day. But hunting took a terrible toll. Eventually, a full day's hunt would only scare up a couple of birds. They became terrified of man's approaching footsteps. Finally, hunting was outlawed except for specified times of the year. Shorebird hunting was outlawed completely.

The marsh gradually became polluted from the wastes of summer colonies. The shores became greatly littered. DDT was introduced in 1943. Marsh pests, namely greenheads and mosquitoes, were finally controlled, to some extent. But this new miracle spray accumulated in the flesh of aquatic organisms, and the birds eating them began to have trouble reproducing. Other birds became agitated from the poison and often destroyed their own nests. Frequently eggs were infertile (Teal & Teal, 1969).

In New Jersey the "green ribbon of marshes extends almost the entire length of the coast, broken only by natural estuaries and rivers" (Teal and Teal, 1969, p. 69.) There are approximately 350 square miles of salt marsh in New Jersey. The marsh is defined by the types of plants which grow on it. Most plants cannot live on a salt marsh. Those that can have adapted to the large concentrations of salt water and oxygen-deficient soil (Teal and Teal, 1969).

"Death in the Marsh" by Tom Harris (1991) is a chronological summation of a journalist's tracking of selenium, a natural, but lethal, trace element found in the soil of marshes. This book outlines a first-hand account of an environmental tragedy concerning selenium that occurred in North Dakota. While the main point of this book is not relevant to this study, much of the focus throughout is on marshes in general. This text does not provide the history presented by Teal & Teal (1969), but does compare in citing basic marsh characteristics as Harris (1991) progresses through his chapters.

John Harding (1986), on the other hand, brings this broad, general perspective closer to home as he zooms in on the Delaware Estuaries and Jersey marshes, eloquently defining the interrelationships among living things in the biological community. As is consistent with Teal and Teal (1969) and Harris (1991), Harding (1986) notes the increasing and disruptive role of humans in the system.

For millennia the marsh has fought back, and nature's forces have more or less stayed in synchronization. But now, in this battle that has been waged for so long, man is emerging the victor. Or is he? In an article by Stephen Hitchcock (1972) entitled, "Can We Save Our Salt Marshes?", he mirrors writer John Teal's (1969) concerns for the future of the salt marsh when he asks, "Are we about to conquer nature, or about to conquer ourselves?" (1972, p. 729).

Only two events actually destroy salt marshes. One is the erosion of the protective barrier beaches by wave action. The pounding of the surf on the salt marsh muds can wash them away. The other is man (Hitchcock, 1972; Teal & Teal, 1969).

The imminent dangers to marshes are not natural, but caused by human activities. Directly, we destroy them by dredging, filling, and building (Teal, 1969). Indirectly, we destroy them by polluting. The battle between progress and nature rages on.

Oil slicks from power boats ride the water and settle on the mud flats. We dump sewage, garbage, detergents, heavy metals, and worst of all pesticides (Teal and Teal, 1969) into our waterways.

In contrast to Teal and Teal's (1969) doomsday outlook, Hitchcock ends his article on a more positive note when he says, "The marshes are surviving, and if we all awaken to the danger, it is not too late to save them" (Hitchcock, 1972, p. 765).

In "The Life of the Marsh" (1966), author William Niering, professor of Botany at Connecticut College, stresses the vital interrelationships between plants, animals and the physical environment. Where Teal and Teal (1969) explain that only organisms specially adapted to the marsh can survive in such a harsh environment, Niering (1966) gives detailed descriptions of adaptations of marsh plants and animals. He also provides in-depth information on food webs. Similar to Teal and Teal (1969), Niering emphasizes the importance of marshes to all citizens. Additionally, he offers an interesting account of the fur industry and its impact on the development of the West. In a chapter entitled "Wetlands or

Wastelands?" he compares the public view of marshes to its actual priceless productivity. He contrasts marshes to other valuable resources, such as oil wells and mines, stating, "A properly protected marsh cannot be depleted" (p. 166). He then goes on to discuss man's abuse of these productive wetlands. This publication, that was printed in 1966, spells out the dangers and lists certain species such as the dusky seaside sparrow and the Florida sandhill crane whose existence was, at that time, severely threatened. This author was left questioning man's priorities in light of the fact that thirty years have passed and in spite of such warnings, the dusky sparrow and the sandhill crane are both now extinct.

Alfred A. Porro, Jr., of Lyndhurst, New Jersey specializes in "marsh law". "Man is outwitting himself", he says. "Technology has taught us to conquer, and many marshes have lain undisturbed only because man at first couldn't modify them. Now wetlands are prime areas for development. Scientists say - for nature's sake, and for man's sake - don't blacktop it all. The scales must tip in favor of conservation and restoration. Land for development must be found elsewhere" (Hitchcock, 1972, p. 762).

According to Hitchcock (1972) the marsh grass that developers destroy, Spartina alterniflora, is the base of marsh life. Most marsh animals depend upon it. Its roots anchor fast the marsh muds. He states biologists suggest there may even be additional ways for man to make use of this food-rich detritus, possibly as a potential food source for our own country.

Many people consider marshes to be barren wastelands. But according to the Western Regional Environmental Council (1987) the salt marsh is an invaluable resource. This claim is supported by Kane, Rosselet, and Anderson (1992).

These two texts parallel Niering's (1966) discussion of the many values of the marsh. Countless numbers of birds are dependent on salt marshes for nesting areas and food. Herons, gulls, terns, and egrets are among the many species that can be found along the creeks at one time or another throughout the year. Ducks, hawks, and swans winter in the marshes. These areas are also extremely important to migrating birds. In the spring and fall huge flocks of shorebirds settle in salt marshes to rest and feed during migration. Terns, gulls, red-winged blackbirds, and clapper rails, among others, build nests and raise their young in the salt marsh (Kane et al., 1992; Western Regional Environmental Council, 1987).

A great variety of invertebrates spend their lives in the water and mud of the marsh. Some of these organisms convert plant detritus, which is at the bottom of the food chain, into animal protein, which may end up in a perigrine falcon or even a human. The muds are alive with snails, mussels, whelks, periwinkles, and other crustaceans and mollusks. Fiddler crabs are visible. Marsh pools are home to many aquatic turtles including the diamondback terrapin. Mammals, such as muskrats, rats, raccoons, voles, minks, and otters also take up residence in the marshes (Kane et al., 1992).

The distinct value of this habitat is further supported by Hitchcock (1972) and Wilson (1981) who state, respectively, that without the marshes there would be no fishing industry since more than 70% of all sport and commercial fish spend part of their life cycles in the marsh. Nearly all of the seafood caught along the east coast owes its existence to the salt marsh. In some areas, such as Virginia, "as much as 95% of the annual commercial catch is nurtured by the marshes" (Hitchcock, 1972, p. 729).

Spartina patens, better known as salt hay, which fed the cattle of the early settlers, is still in demand today for animal bedding and garden mulch. Thousands of acres of high marsh in south Jersey supply baled salt hay for the entire coast (Hitchcock, 1972).

The salt marshes are natural barriers for residential and commercial property (Wilson, 1981). They also control pollution by degrading and filtering out pollutants deposited by land runoff and rivers (Miller, 1995). Marshes absorb vast quantities of pollutants which otherwise could contaminate water (Jesuncosky, 1987).

The salt marsh is an important environment for numerous reasons, including its obvious aesthetic and recreational purposes. Theses vital, life-sustaining areas are threatened by pollution and development.

II. Dredging

A technical paper the author found most useful in gaining background on dredging and related projects is entitled "Concepts, History, and Examples of Beneficial Uses of Dredged Materials", by Dr. Mary Landin (1992). Historically, dredging dates back to the Phoenicians, who hand-dredged their harbors and ports along the Mediterranean Sea. In North America, as far back as before the War for American Independence, the settlers were dredging the river estuaries of the Gulf and Atlantic coasts with crude horse-drawn equipment. Most likely all sea-faring civilizations who faced the problems of too shallow waters met this challenge with some form of dredging (Landin, 1992b).

The U.S. Army Corps of Engineers (USACE) states that while improving and maintaining navigability of waterways is certainly a prime objective of dredging, there are other reasons for dredging projects as well. Dredging can be used as a means to remove polluted sediments and to alleviate water stagnation. Dredging is also used to control flooding by improving the flow rate of water in streams. Additionally, dredging is used as part of the superfund restoration of water quality at some sites (USACE, 1995).

By the turn of the century the United States Army Corps of Engineers was dredging to maintain 25,000 miles of waterway for transport of people and goods (USACE, 1995). In contrast to the undeniably serious disruptions to our natural ecosystems caused by dredging, it is important to note that secondary to project objectives many habitat related beneficial uses have also occurred (Landin, 1992b).

The author found it interesting that even though dredging has been practiced for generations, it wasn't until the 1970's, when congress enacted Public Law 91-611 (which directed the USACE to study the effects of disposed dredged material) that scientific information on the characteristics of dredged material was obtained. In a Corps of Engineers (COE) publication entitled "Dredging is for the Birds", it is clearly pointed out that approximately 90 percent of the material dredged is a "resource" that can be used productively, rather than a contaminated substance as the term "spoil" might imply.

New alternatives for the disposal of dredged material and their consequences on the environment were studied under the Dredged Material Research Program (DMRP). The COE continues this research at a present annual expenditure of $400 million (Hatch, 1987). Most of this research is done at the Waterways Experiment Station (WES) in Vicksburg, Mississippi. The author of this thesis has had the privilege of being in contact with some of the people directly involved with this research, including Dr. Mary Landin, and has been informed of the importance of long-range disposal management plans. While the COE supplies funds and manpower to carry out such projects, they do not, for the most part, design the plans.

Dr. Landin, who has been a research biologist with the United States Army Engineer Waterways Experiment Station since 1974, specializes in design and management of dredged material sites for natural resource development. Dr. Landin is the author of more than 200 technical papers, reports, and books including the Engineer Manual on the beneficial uses and applications of dredged material. These printed documents have proven invaluable to this author.

The concept of "beneficial use", or using dredged material in a productive way, is not a new one. Dr. Landin, in her report "Dredged Material: A Recognized Resource", documents the history of uses of dredged material. She has uncovered projects that were carried out before the Revolutionary War. There have been many urban and commercial benefits. In fact, Boston and Annapolis were both built upon dredged material, as well as parts of Baltimore, Washington D.C., Philadelphia, and New York City. Many of our present-day airports, including La Guardia and Washington National, were built on dredged material (Landin, 1994).

Dredged material is also used to restore or develop natural areas such as wetlands and bird nesting areas. Over 2000 acres of wetlands have been developed from dredged material. Dredged material is used for shoreline stabilization, beach nourishment, and lake and river restoration (Landin, 1994).

Because people have viewed placement sites as "waste disposal areas", many of them have been left virtually untouched. Free from human disturbance, these areas have become naturally colonized by birds and plants and various other wildlife (Landin, 1994).

The USACE places approximately 400,000,000 cubic yards of dredged material each year. This is enough to cover Washington D.C. to a depth of 5 feet (Hatch, 1987). It is only in the last twenty years that it's been recognized as being so environmentally useful (Landin, 1994). Knowing that it can be used to sustain wildlife, and with such an enormous amount of material to place, the USACE welcomes ideas and plans for potential projects. Henry Hatch, USACE Director of Civil Works, in reference to alarming statistics on nation-wide coastal habitat loss and reduced fishery landings suggests that, "Instead of continuing to try to resolve dredged material disposal problems and habitat loss problems separately, as we have done in the past, perhaps a better approach would be to define to what extent the two issues can be resolved collectively" (Hatch, 1987, p. 29).

Loss of wetlands as natural habitat is an ever-increasing problem. Concerned environmentalists of varied backgrounds and affiliations have been and continue to be exploring options and trying to set in place plans to aid in this age-old dilemma: the conflict between development and nature. As noted in "Dredging is for the Birds", spoil islands have been successfully modified in both Florida and North Carolina and are presently used extensively by wildlife. This author has reviewed many case studies as examples of the beneficial uses of dredged material.

A COE file memo sent to the author by the Special Studies contact person, Barbara Stratton, states:

> "Section 204 of WRDA 92 authorized the Army Corps of Engineers to carry out projects for the protection, restoration, and creation of wetlands and other aquatic habitats, in connection with dredging for construction, operation, or maintenance by the Corps of an authorized navigation project. The two major benefits of this program are to restore environmental resources and resolve some historic problems with disposal of dredged material."

In other words, the purpose of a project under the authority of Section 204 is to identify a beneficial use for dredged material removed from a Federal navigation project, which is both environmentally acceptable and economically feasible. This memo also includes a list of 47 areas approved for implementation. There are no New Jersey sites on the list.

At the present time (in the U.S. waterways) there is a scarcity of undisturbed, bare sand habitat for species such as the skimmer, tern, plover, and terrapin. Dr. Landin (1994) emphasizes the need for plans to be made to develop these islands beneficially by using one, or a combination of three, techniques: habitat establishment, habitat manipulation, and habitat protection. Although manipulation is the most commonly used technique (Landin, 1994), the author of this study proposes to establish new habitat, which is needed when a nesting habitat is lacking.

In chapter 9 of Dr. Landin's Handbook of Dredging Engineering, "Need, Construction, and Management of Dredged Material Islands for Wildlife" (1992c), planning construction is outlined and broken down to specifics including: location, timing, physical design, protective structures, size, configuration, nesting substrate, elevation, and management. These guidelines will be of great use to this author in chapter 4.

As a follow-up to this "how to" handbook, Dr. Landin's publication "Achieving Success in Wetland Restoration, Protection, and Creation Projects" discusses measuring success or failure of a project. She defines success as "achieving the stated goals and objectives" (1992c, p. 2), and lists the main reasons for failure in these kinds of projects as:

1. poor location
2. improper design
3. sloppy construction
4. lack of commitment by the permit applicant and\or contractor
5. incorrect hydrology
6. incorrect elevation
7. not enough protection from wind and wave action
8. incorrect planting of vegetation.

Supportive to this research done by Dr. Landin is a manual by Hayes and Palermo called "Engineering Aspects of Wetland Design". They agree on the factors Dr. Landin listed as keys to success. In addition, this manual focuses heavily on the importance of substrate (1992).

III. Case Studies

The cases this author studied were many and varied. The following summaries of some of these cases should provide the reader with a basic general understanding of ways in which dredged material has been used to benefit the environment. The author was able to make many comparisons and contrasts between these cases. After an extensive search, and contact with key personnel, this author did not find any evidence indicating a project like hers has been done. There are projects with similarities, however, which the author will discuss below.

Graduate student, Christopher Jones (1993), in his thesis evaluated 11 mitigation projects within the state of New Jersey. The projects he studied were designed to determine whether or not artificial wetlands were successful; the criteria for success being the confirmation of the presence of wetlands based on soils, hydrology, and vegetation sampling. His study found only two of the wetlands projects to be successful. In his conclusions he stated that attempts to create wetlands "have largely resulted in failures" (Jones, 1993, p. 102).

Initially this author felt it important to note that these unsuccessful projects were freshwater projects as opposed to salt water, and that they were "wetland creation" projects as opposed to "enhancement" projects, which is the type of project this author is proposing. The need to point this out was to mollify this author's fears that her project would be judged a failure before it even began. But further research negated the relevance of distinguishing between the two as there are numerous success stories of varied mitigation activities, which stand in sharp contrast to Mr. Jones's conclusions. According to Dr. Landin, "Properly built wetlands compare very well with natural wetlands" (Landin, 1987, p. 64). Her response to wetlands projects that have failed is, "Most of the wetlands that have not been successful are those built in the permit approval process, not built or monitored by the COE, and not necessarily involving dredging" (Landin, 1987, p. 69).

In Michigan, the Pointe Mouillee State Game Area was at one time one of the best fishing and waterfowl hunting marshes in the Great Lakes region. But in the 1950's a barrier island that protected it was completely eroded away. This left the site exposed to open water wave activity which quickly and severely damaged the state game area. A cooperative effort was made by the Detroit COE and the Michigan Department of Natural Resources (MDNR) to build a 900 acre confined disposal facility from dredged material, the size and shape of the original barrier island. Construction was completed in 1983. Fishing piers, hiking trails, picnic facilities, a visitors' center, and a marina have been built on the dredge site (Landin, 1994).

While construction of the disposal facility was underway a draft long-term management plan for the site was drawn up. This plan included the following features:

1. gated culverts to allow for water to flow through the marsh;
2. access cross dikes;
3. dredged material island formation within the marsh for nesting waterfowl; and
4. intensive wildlife management.

Another management technique carried out was widespread planting of food crops for resident wildlife and migratory waterfowl by game management employees. The MDNR intends eventually to allow water levels to fluctuate for vegetation manipulation within the marsh (Landin, 1994).

Monitoring on this site has not been extensive. However data on vegetation and wildlife have been collected since 1979, and water quality, contaminant testing, and recreational use surveys have been conducted. The results have shown that:

- soon after placement the dredged material was colonized by wetland and upland plant species,
- marsh vegetation is increasing inside the eroded wetland portion of the game area,

- increases in resident, migratory, and nesting species of wildlife and fish have been exhibited,
- contaminants have not been found (Landin, 1994).

A placement site was needed for dredged material in Mobile Bay, Gaillard Island, Alabama. To fulfill this need, a 1300 acre confined facility was built in 1981. Each year since completion of construction, 16,000 - 25,000 seabirds have nested there. (This is a first for Gaillard Island.) In 1987 over 1,500 brown pelicans used the island, many of which nested successfully. This was the first recorded nesting by brown pelicans in Alabama in this century (Landin, 1994).

The purpose of this project was to fill a need for a placement site, which stands in obvious contrast to the goals set for the Pointe Mouillee project, which were to build a protective barrier island and to restore an eroded marsh area. The barrier island was a confined disposal area. Gaillard Island was built with hydraulically placed, gently sloping dikes. No bulkheads or rip-rap was used to contain it. Its shorelines have been protected by a combination of stone armouring and salt marsh plantings, which was actually a secondary objective. In 1981 the COE began experimenting with combinations of wetland plantings and temporary breakwaters, to determine if areas such as Gaillard Island, which receive only moderate wave activity, could be stabilized with vegetation rather than engineering structures. Specifically, over 35 acres of cord grass were planted behind floating tire breakwaters, in erosion controlling mats, and in plant rolls. On the north side of the island, behind the plantings, swales have formed. These swales have been colonized by salt-marsh cordgrass, saltmarsh bulrush, cattail, and other high marsh species. Muskrats and marsh-nesting birds are present. On the other sides of this island the cordgrass is either still in place or has colonized (Landin, 1994).

This placement site replaced bay bottom habitat with island, wetland, and upland habitats. Before choosing the location for it, the researchers of this plan had to find an area of relatively low benthic productivity to keep the negative environmental impacts to a minimum (Landin, 1994).

An original feature of this case is a large, ungated weir that was installed to permit inter-tidal flow into a 700 acre containment pond. As filling continues, the pond will become part of the island.

As on Pointe Mouille, a long-term management strategy was put into place. Its primary goals are to:

- maximize the life of the placement site;
- allow for more efficient use by agencies who need to use the site for placement needs; and
- allow for an arrangement whereby the site can continue to be used by seabirds (Landin, 1994).

The Gaillard Island project was done by the Mobile COE. It has been used by The COE and the US Navy. This site demonstrated that environmental and engineering activities are compatible. This project won the COE Environmental Honour Award in 1985 (Landin, 1994).

In a more local example, the New Jersey Department of Environmental Protection (NJDEP) issued a final New Jersey Pollutant Discharge Elimination System Permit for the Salem Generating Station in July, 1994. There are several Special Conditions in this permit that address concerns about "the loss of aquatic organisms resulting from the Station's operation" (PSE&G, 1995, p. 1).

The Special Conditions in the Permit require Public Service Electric and Gas Company (PSE&G) to take a number of actions including implementing a program to "restore, enhance, and preserve a minimum of 8,000 acres of wetlands along the Delaware Estuary and an additional 2,000 acres of wetland and\or 6,000 acres of upland buffer" (PSE&G, 1995, p. 1).

Among the areas chosen for restoration and enhancement in this project are salt hay farms. According to PSE&G these farms, which are diked to control tidal inundation, contribute very little to the aquatic production of the Delaware Estuary, and are prime breeding areas for mosquitoes. PSE&G states that the elimination of salt hay farms, which are a great human disturbance, will benefit marsh species; and that the restoration of the marsh ecosystem will increase habitat diversity, which was present prior to the establishment of salt hay farms. They claim that salt hay farming "attempts to create a monoculture that results in lower plant diversity and consequently, lower habitat complexity" (PSE&G, 1995, p. 24). PSE&G proposes to construct new inlets and channels to these areas, which will revive daily tidal flow, thus returning the salt hay farms to natural wetlands habitats (PSE&G, 1995).

The goals of this wetlands project are:

- to increase aquatic production;
- to protect aquatic habitat; and
- and to provide public access in a fashion consistent with above stated goals (PSE&G, 1995).

The methodology used by PSE&G in preparation for their proposal included: site investigations in 1994 and 1995; wildlife inventory field studies; supplemental information obtained from literature documentation; review of historic aerial photographs to identify the historic locations of channels; evaluations of surface topography to determine the locations for the new drainage network; archaeological investigations of the site; and computer models to develop a restoration design (PSE&G, 1995).

This project is different from most others reviewed by this author in that its main focus is not on dredged material. The key components in this project are restoration of tidal flow to currently-diked areas, and permanent protection of these areas through a Deed of Conservation Restriction. The new channels however, will be excavated; and the material excavated from the channels will be used to raise low areas or for internal berm construction on the site (PSE&G, 1995).

Another element that set this case apart from the others was the proposal for maintenance. The features incorporated in this undertaking have been specifically designed to minimize the need for maintenance. Inspections of the channels will be made seasonally for the first two years and after severe storms. After that the inspections will be conducted annually (PSE&G, 1995). This impressed the author because, with increasing numbers of wetlands projects in the making, if they all have complex and time-consuming (not to mention expensive) maintenance plans, follow-through may become unrealistic.

At the time of this literature review, the Commercial Township Salt Hay Farm Wetland Restoration Plan had not been implemented. PSE&G was in the process of acquiring the necessary permits and approvals. They estimated commencement of this project to be the spring of 1996 (PSE&G, 1995).

Still another example is the Tennessee-Tombigbee Waterway which was constructed at the expense of the "dense and diverse" (Landin, 1994, p.17) flora and fauna that inhabited the Tombigbee River. In 1985 the COE placed two gravel bars in an abandoned channel of the Tombigbee River to provide habitat for the organisms that had been displaced. Colonization of macroinvertebrates was rapid. Forty-two species of fish have been collected at the site including the crystal darter, which is listed as endangered in Mississippi (Landin, 1994). This is an example of dredged material being placed, and simply letting nature take its course.

A similar case took place in Tampa Bay in the 1930's when the COE placed an island of dredged material which came to be called Bird Island. In 1951 they placed another island that eventually became attached to Bird Island. This dredged material site was turned over to the Audubon Society for the management and control of more than 30,000 waterbirds that nest there each year (Landin, 1994).

A more complex site is Miller Sands Island. It is a 235 acre island in the Columbia River within the Lewis and Clark National Wildlife Refuge in Oregon. It was built entirely of dredged material in 1932. In the 1970's three distinct habitats were made on the island: sand dunes, upland meadow, and inter-tidal marsh. These habitats have been monitored since 1974, to document success in terms of wildlife, vegetation, establishment of soils, fisheries, survival, and reproduction. (Only 10 other COE habitat development sites in the United States are being monitored as this one is.) The findings to date are promising. Species abundance and wildlife use have increased. Shorebirds, waterfowl, and songbirds inhabit the area in large numbers. Mammals including deer, seals, and sea lions, are also found at Miller Sands. Twenty-one species of fish have been caught there. Benthic samples indicate no change. The wetland site has been colonized by numerous species of marsh vegetation, but is dominated by Lyngbye's sedge and tufted hairgrass (Landin, 1994).

Down through our country's history, the Chesapeake Bay has been an area of concentration for wildlife habitat. However, it has not been able to escape the impact of human activity and has, in fact, been severely degraded. Pollution and development, along with the forces of nature, have taken a toll on the bay's aquatic resources. One of the places these hardships manifest themselves is on Bodkin Island, Queen Anne's County, Maryland. The author was able to get a copy of a project called the Bodkin Report, which is a plan to restore and create habitat on Bodkin Island. This report has been indispensable to this author's research in that it includes significant detailed data and it relates more closely to this author's project than any other she has found.

Bodkin Island was once the site of the densest black duck population in all of North America. Since 1847, Bodkin Island has been eroded from 50 acres to less than one acre. In 1984 a bulkhead was constructed around the island to prevent further erosion. The decline in the size of the island obviously corresponds to a great loss of black duck habitat. The last survey, conducted in 1991, found only 34 active nests (USACE, 1994).

Hens with newly-hatched ducklings leave the nesting site to find a brood habitat. Areas closely surrounding Bodkin Island historically have provided for this need. But development of these areas eliminated most of the prime brood habitats. Now hens and their young must travel a minimum of five miles, which is too long a journey for many ducklings, and consequently results in an enormously high mortality rate (USACE, 1994).

The Bodkin Report documents a plan to utilize dredged material to create brood habitat and to restore existing nesting habitat for black ducks. The design for the restoration of this island includes enlarging the existing island to accommodate 50,000 cubic yards of dredged material from the Federal navigation channel at Chester River and containing it with geotextile tubes. It will include high marsh zones, low marsh zones, tidal pools, and upland nesting habitat. After the material has settled, the island will be planted. The planted vegetation will help stabilize the material. The Bodkin Report outlines specifically which vegetation will be planted in each zone to ensure proper habitat and also to deter the growth of undesirable plant species. Once vegetation is established on the island, sea grasses will be introduced in the tidal pools (USACE, 1994).

This plan, which has not yet been implemented, differs from the one this author is researching in primarily two ways. The species they are working with, black ducks, have previously used Bodkin Island for nesting, and it is likely they will continue to use it after it is restored and enlarged, thus setting favorable conditions for the black duck population to increase. In contrast, the author of this plan is attempting to attract species that have never before occupied her study site. The other main difference is that Bodkin Island is to be contained, whereas this author does not propose to contain her site at Great Sound.

Also of particular interest to this author was an environmental study done on Sturgeon Island. Sturgeon Island is the property of the Wetlands Institute and was formerly used as a dredge disposal site. It is located near Gull Island, upon which the author's study sites are situated. Several species of birds' nests were recorded. Of these, none were even partially successful. All eggs were either missing or destroyed. Mammal traps were set, and all caught only one species; Rattus norvegicus (the Norway rat). It is hypothesized that this mammal is solely responsible for the lack of avian productivity on this island.

The kinds of projects reviewed in this section show that:

1. no one has yet under taken a project exactly like this one;
2. the COE is, in fact, interested in creative solutions for dredged material placement; and
3. dredged material islands can be successful habitat areas.

IV. Target Species

There are numerous technical reports produced by the U.S. Fish and Wildlife Service pertaining to birds and reptiles. The author has reviewed all available Facts Sheets and Habitat Suitability Index (HSI) Models pertaining to species that do occur at, or might in the future use her study site. These models are scaled to produce an index between what is an optimum habitat and what is an unsuitable habitat. They provide specific information on feeding, nesting, habitat needs, and predation, as well as special considerations pertinent to particular species. Unfortunately, HSI's are not usually available for endangered species. According to New Jersey Fish and Game biologist, Dave Jenkins (telephone interview, 1995), this is for fear that these reports will give developers the idea that it is acceptable to destroy habitat if they can obtain written instructions on how to build new ones. The author has studied HSI models for the least tern and the diamondback terrapin, as well as the great blue heron, the red-winged blackbird, the laughing gull, and the forster's tern. At present there are no obtainable models for the black skimmer or the piping plover.

In addition to the above-mentioned reports, the author has studied a variety of survey sheets, summaries, various texts, publications, and newspaper articles regarding the black skimmer, the least tern, the piping plover, and the diamondback terrapin. The author also consulted a comprehensive baseline survey on the fishes in the the feeding vicinity of her target sites.

The further this author delved into available literature the more convinced she became that her project was, not only feasible, but also necessary. She received another green light when she came across the Piping Plover Recovery Plan (1995). According to this study, an essential task to be carried out in working toward reaching the objective of being able to remove this species from the Federal List of Endangered and Threatened Wildlife and Plants is compensating for disruption of natural processes and creating and enhancing habitat by encouraging deposition of dredged material.

Text books used in the research of this section such as Shorebirds (Alan, 1988) and The Birders Handbook (Ehrlich et al., 1988) give only broad, general information. This information was helpful in establishing a starting point, but the author found early on that sources with more specific and detailed facts were necessary. The Piping Plover Recovery Plan (1995) is one such source. This technical draft, prepared by the Atlantic Coast Piping Plover Recovery Team for the U.S. Fish and Wildlife Service, describes recovery progress to date as well as delineates further actions required for recovery and protection of this species. Included in this report are detailed habitat needs of the species along with guidelines for establishing such. These guidelines encompass such details as needs concerning substrate, vegetation, elevation, predation, and diet. Though these guidelines were written chiefly for the Piping Plover, in cross-referencing notes she has taken throughout her research, this author finds many of the habitat needs of all four species in her study overlap.

Additional information was obtained from the Shorebird Management Manual (1992). It is geared more toward managing species. This document gives a general account of shorebird ecology. While it does not include the habitat needs detailed in the Recovery Plan, it does contain historical accounts and describes present-day threats, which are accompanied by examples of case studies.

Lee Carney reports on a recent study done by a student from Richard Stockton College on predation of diamondback terrapins. His article, "Terrapins Are Taking a Beating" holds natural predators responsible for wiping out the nests and hatchlings of the turtles. The predators identified as the culprits are red foxes and raccoons, which destroy nests and eggs. This report calls the 1995 hatching season a disaster. He goes on to discuss how in the early 1900's the species experienced great population decline because of its popularity as a food delicacy. Although these animals are no longer hunted, its numbers are still diminishing, not only because of intensive natural predation, but also because of disruptive human activities (Wood, 1995). This conjecture is supported by Palmer (1988) who attributes the main reason for the mortality of the terrapin population to predation, aside from crab pots and loss of habitat. All agree that the population of this gentle species continues to suffer great loss. The diamondback terrapin is now a candidate for the Federal List of Threatened and Endangered Species (Carney, 1995).

In this chapter the author has examined literature related to habitat creation and enhancement. As the author prepares to make recommendations to create habitat on a dredged-material island this material will be useful. In the next chapter the methods used to make these recommendations will be discussed.

Chapter Three

DESIGN OF THE STUDY

Study Area

For purposes of this study the target area is Gull Island, which is located at the entrance to Great Sound, in Cape May County, New Jersey (figure 1). While this project is site specific to Gull Island, and the recommendations presented in chapter four are specifically designed for enhancement of this site and to accommodate the habitat needs of the black skimmer, diamondback terrapin, least tern, and piping plover, the basic outline of methodology following may be applicable to other projects.

Methodology

The following methods were used by the author in preparing this report.

Before doing any field work, marsh and beach habitats were studied, as outlined in chapter two.

The author made field trips to the proposed study area to do a feasibility assessment to make sure the site was suitable for this project. Four dredged-material sites are located on Gull Island, in close proximity to one another. The author decided to include all four sites in the study.

A baseline survey was conducted to establish a general broad concept of the composition of the site, and to gather data on any inhabitants present. The author took photographs, and kept a journal during all field work.

Preliminary vegetation identification was done. Several types of plants were recorded on the site. Photographs or samples of others were brought to shore and studied at the Wetlands Institute, using field guide identification books, and conferring with various personnel. When the author had doubts, samples were taken to specialists for confirmation of identification.

Elevation measurements were taken using the Emory-horizon method. The author was aided by Dr. Wood and one of his interns in carrying out this procedure.

General observations were done, including counting nests, checking for signs of predation (tracks, droppings, nest destruction), collecting any relevant specimens, and noting any wildlife present or nearby.

The author visited Champagne Island, in the Hereford Inlet of Stone Harbor; a large active black skimmer nesting colony (figure 6). This is also an area where piping plover and least tern nesting has occurred. Here the author was able to observe first hand an already established and successful nesting area and make notes on vegetation, substrate, elevation, and protective measures. Comparisons and contrasts between this site and the Gull Island site were then made.

The author also visited Sturgeon Island, a nearby dredge disposal island, which is owned by the Wetlands Institute.

Extensive background research was critical for the author's success in developing this project. The basic habitat needs of the target species were studied in relation to the habitats presently existing on Gull Island. Beneficial uses of dredged material was also thoroughly researched. Obtaining relevant literature was time consuming, and at times difficult. Persistence was vital and proved worthwhile. Among the most useful information were reports from the Waterways Experiment Station (WES) in Vicksburg, Mississippi. However, this author was only able to get these reports after a Corps of Engineers special projects person ran interference for her. Another avenue that proved invaluable was a bibliography sent by a WES secretary. This listed various dredged-disposal projects that have been done. From this list the author was able to make new contacts and obtain additional documents.

Fishes of the Hereford Inlet were studied to be sure the necessary foraging habitat was present (tables 2, 3, & 4).

A 7.5 minute quadrangle map of Avalon and Stone Harbor was obtained from the state to delineate the average maximum flight distance zone around the perimeter of the potential nesting area. The author walked this area. The author obtained and reviewed aerial photographs for accurate geographical layout.

Personal contacts were key sources of help and information. Biologists, representatives from the U.S. Fish and Wildlife Service, New Jersey Fish and Game, and people from various branches of the U.S. Army Corps of Engineers gave this author invaluable suggestions and advice.

Once the author completed acquisition and review of pertinent reports and documents, she drafted a series of recommendations and distributed them to assorted specialists with a request for comments. Based on their feedback the author wrote her thesis.

After studying many reports on dredged-material projects, as documented in chapter two, and reviewing different project formats, the author found no one format to be entirely appropriate. The format that came closest to fitting the needs of this report were those used in the Bodkin Report. With numerous revisions the author has developed the following format to be used for her thesis, which will be presented as data in the form of recommendations.

I. Introduction
  A. Purpose of Study
  B. Study Area
    1. Location
    2. History
    3. Existing Usage
    4. Current Physical Descriptions
II. Overview of Target Species

A. Black Skimmer
B. Diamondback Terrapin
C. Least Tern
D. Piping Plover

III. Discussion and Considerations
A. Size and Shape
B. Elevation
C. Substrate
D. Vegetation
E. Predators
F. Timing
G. Monitoring
H. Maintenance

IV. Final Recommendations for Habitat Enhancement
A. Size and Shape
B. Elevation
C. Substrate
D. Vegetation
E. Predators
F. Timing
G. Monitoring
H. Maintenance

Background of the Author

The author is a 1980 graduate of Lock Haven University where she majored in education. She has a Bachelor of Science Degree in Elementary Education (K-8), and Health and Physical Education (K-12). Presently the author teaches sixth grade at the Upper Township Middle School in Tuckahoe, New Jersey. The author has been a matriculated student in the M.A. Degree Program in Environmental Education at Rowan College of New Jersey for the past three years. In 1996 she was inducted into Phi Delta Kappa.

In the summer the author teaches at a zoo camp at the Cape May County Zoo in Cape May Court House, New Jersey. She is also actively involved with a small grass-roots group which, for the last two years, has been trying to establish an Environmental Commission in Upper Township, New Jersey.

The author approached Dr. Roger Wood, Director of Research at the Wetlands Institute in Stone Harbor, New Jersey, and Professor of Zoology at Stockton State College, for suggestions on research that needed to be done that could be used as a thesis project. Dr. Wood suggested this project, and agreed to sign on as this author's mentor.

The Wetlands Institute is very interested in this project because of its broader implications, and they agreed to make available to the author all boats and equipment required to successfully complete it.

Despite a limited formal background, this author has spent her entire life in and around New Jersey marsh lands, and is both familiar with and connected to the habitat and wildlife therein. She is passionate about the preservation of our natural environment, and driven by that passion to successfully complete this broad-based project.

Chapter Four

PRESENTATION AND ANALYSIS OF DATA

The format of this chapter is as follows:

I. Introduction
   A. Purpose of Study
   B. Study Area
      1. Location
      2. History
      3. Existing Usage
      4. Current Physical Descriptions
II. Overview of Target Species
   A. Black Skimmer
   B. Diamondback Terrapin
   C. Least Tern
   D. Piping Plover
III. Discussion and Considerations
   A. Size and Shape
   B. Elevation
   C. Substrate
   D. Vegetation
   E. Predators
   F. Timing
IV. Final Recommendations for Habitat Enhancement
   A. Size and Shape
   B. Elevation
   C. Substrate
   D. Vegetation
   E. Predators
   F. Timing

INTRODUCTION

This report presents the data necessary for using maintenance-dredged material from the intracoastal waterway in Middle Township, New Jersey, for habitat enhancement on Gull Island, New Jersey.

This report was developed with information obtained from field work, published and unpublished literature, and communications with professional biologists and other specialists familiar with specific aspects of a project like this one.

In each area of concern, the author consulted numerous sources and conferred with more than one expert. There are certain instances where the author received conflicting views and information. At these times the author further investigated the issue at hand and made an educated decision based on all available information.

Purpose of the Study

The purpose of this study was to establish data on the existing target site, determine the habitat needs of the target species, and to develop a plan to enhance the existing site to accommodate these needs.

Study Area

Location

The intracoastal waterway, which runs the length of the east coast of the United States, flows through Great Sound, in Middle Township, New Jersey. Gull Island, which is a submerged island, is located at the entrance to Great Sound (figure 1). The study area for this project is composed of four upland dredged-material islands which are situated on Gull Island (figure 2).

History

Since 1974 Gull Island has been a disposal site for material dredged from the intracoastal waterway in Cape May County, New Jersey (telephone interview: Scrignoli, 1995).

Historically, the material has been placed on four separate upland sites, all located on the northern tip of Gull Island. The dredged material has been composed of different combinations of mud, silt, and sand. The amounts of material placed range from 12,000 to 120,000 cubic yards (Scrignoli, 1995). These islands have no current or historic accounts of use by black skimmers, least terns, or piping plovers.

Existing Usage

This area is currently used by The U.S. Army Corps of Engineers for placement of dredged-material every two to four years (Scrignoli, 1995).

Current Physical Descriptions

The following information, unless otherwise cited, was taken from the journal the author kept during field work. The four dredged-material islands at this site will from here on be referred to as 1, 2, 3, and 4. Islands 1 and 2 are separated from each other only at high tide. The author estimates 3 and 4 to be a couple hundred yards away, across knee deep marsh mud and tide water. (figure 2).

1 and 2 (figure 2) are colonized by herring gulls. Eliminating these predators from the study site proved to be the greatest challenge in establishing suitable habitat for the target species. Herring gulls pose a substantial threat to the target species, as they compete for space and disturb nests (Wood, 1995). Many avenues were explored concerning this issue, including burning, setting up osprey nests for avian predator control, and "timed disturbance" - a method using volunteers to purposely disturb the site by boat riding nearby, walking, playing, and running dogs on the island. This should be done during the gull nesting period, but before the terns and skimmers arrive. Obviously, the goal is to create enough disturbance to force the gull colony to abandon the site and nest elsewhere (telephone interview: Jenkins, 1995).

There are also signs of mammals on the site: raccoon tracks (figure 7), rat tracks, and a decomposed mammal carcass were observed. There are great piles of clam shells on the north end of site 2, which the author hypothesizes are resultant of being located right at the mouth of the sound. Wave action forms shell berms on the front and top of sandy areas, especially in harbors and protected areas (telephone interview: Landin, 1996). The clams are easy gull prey.

On these islands there is one elevated mound, surrounded by sandy beach. The approximate elevation is 2.15 m above water level.

Sites 1 and 2 (figure 2) are the least vegetated. The following plant life was identified: cocklebur (Xanthium pensylvanicum), marsh elder (Iva frutescens), sea rocket (Cakile edentula), sea lavender (Limonium carolinianum), salt meadow cordgrass (Spartina patens), smooth cordgrass (Spartina alterniflora), glasswort (Salicornia europaea), and common reed (Phragmites austratis), which is most prominent. At least sixteen terrapin nests were observed, most of which had been dug up by unknown predators (figure 7). This appears to be an area of high predation.

Site 3 (figure 2) is heavily encroached by common reed.

Site 4 (figure 2) is the oldest of the four islands. This is apparent by the deneseness of the plant growth (figure 8)(figure 9). It is heavily vegetated by cordgrass, grounsel (Senecio vulgaris), lavender, wild black cherry (Prunus serotina), seablite (Suaeda sp.) thistle (Cirsium vulgaris), evening primrose (Oenothera biennis), and common reed. Three black-crowned night herons (Nycticorax nycticorax) were observed, but no signs of nesting. On this island, at least a dozen terrapin nests were found.

All four islands have round mounds. The author estimates each one to be approximately one acre in size. The area is difficult to get to. Even in a small boat the trip required walking and dragging the boat over a few hundred yards of deep marsh mud covered by tidal water to get to the islands. This should keep the site essentially free from human disturbance.

This is not an area of high wave activity. Therefore, potential erosion should not be a critical factor. For this reason the author will not be recommending the site be contained in any fashion.

Suitable feeding conditions are present for the target species. Least terns are visual feeders and catch small fish near the surface of the water. Black skimmers are non-visual feeders and catch any food items their bill encounters. Piping plovers feed along sandy, unvegetated beaches. Diamondback terrapins eat insects, fruits, and vegetables (Landin, 1996).

It has been proven that the construction and enhancement of islands for birds and other wildlife is feasible (USACE, 1987). The deposition of dredged-material to enhance or create habitat is strongly encouraged (U.S. Fish and Wildlife Service, 1995b). The design of this site will be such that future maintenance dredging of the nearby navigation channel may be added to create more extensive bare sand habitat. Though the author does not predict severe erosion problems, additional dredged-material should subvert any potential problems in this area. It will help to prevent vegetation encroachment as well.

OVERVIEW OF TARGET SPECIES

Black Skimmer (Rynchops niger)

A sister group of terns and gulls, the black skimmer resembles a gull, with a white underside, black back, and long narrow wings. It's most distinguishing characteristic is its brilliant red bill. The lower mandible is longer than the upper, which is hinged and can be elevated and clamped shut (Gochfeld & Burger, 1994)

In the early 1800's this bird was a common breeder in New Jersey. But gradually, eggers eliminated colonies. They were also greatly affected by the millinery trade and hunting. Skimmers were not sought directly for their feathers or food, but their nesting associates were. By the turn of the century skimmers were all but absent (Gochfeld & Burger, 1994).

In 1979 the black skimmer was listed as an endangered species in the state of New Jersey. Since the enactment of protection laws, the population decline has primarily been due to disturbance and habitat loss. Vehicles, pets, recreational beach users, and predation all contribute to nest failure (U.S. Fish and Wildlife Service, 1995a).

Black skimmers nest in colonies. They select their colony site strongly based on the presence of other species. Typically they will choose to share a site with terns, gulls, or plovers. They prefer to nest with terns. This is because terns provide early warnings and defense against intruders. Skimmers form distinct subcolonies in the middle of tern colonies. They usually occupy the same site year after year (Gochfeld & Burger, 1994).

The black skimmer nests almost exclusively on the coast; specifically on shell banks, barrier islands, salt marshes, and dredged-material islands (Gochfeld & Burger, 1994). They prefer flat, sandy areas with little vegetation. They are known to nest on wrack mats (U.S. Fish and Wildlife Service, 1995a).

Though skimmers prefer open, sandy beaches, most of our present day beaches are not suitable because of recreational use. Many of their formerly used nesting areas have been developed (Gochfeld & Burger, 1994).

In New Jersey black skimmers avoid islands > 20 ha and < .5 ha (49 acres - 1.235 acres). They prefer islands with < 20% vegetation, often nesting where there is no vegetation at all. Their eggs are best camouflaged on plain sand and shell substrate. Also, vegetation provides shelter for predators (Gochfeld & Burger, 1994).

Skimmers arrive in May. They make scrapes, shallow depressions, in the sand for nests. A female will lay two to five eggs, usually in early June. (They will, however, lay eggs later if there is a nest loss.) Both adults incubate the eggs for approximately twenty-two days (Gochfeld & Burger, 1994).

Black skimmers eat crustaceans and a variety of fish including pipefish (Syngnathus fuscus), herring (Clupea spp.), killifish (Fundulus kansae), mullet (Mugil spp.), and silversides (Menidia spp.) (Line & Russell, 1976). They forage mainly in tidal waters of salt marsh pools, estuaries, bays, lagoons, ditches, and creeks. Feeding areas should be roughly ≤ 8 km from the colony site (Gochfeld & Burger, 1994).

Skimmers are tactile feeders. They rarely locate prey by sight (Ehrlich, 1988). They glide low over the water, usually with their wings motionless, skimming the surface at an average 20 feet per second with the lower mandible (Line et al., 1987). When the mandible makes contact with a fish, the maxilla clamps down. (The anterior end of the esophagus has a strong pseudosphincter to prevent the swallowing of water while skimming.) The prey is then swallowed or carried back to the nest. Though they are reportedly nocturnal feeders, they regularly feed during the day, depending on the tide cycle (Gochfeld & Burger, 1994). Young are fed regurgitant, as the lower mandible does not elongate until adulthood (Ehrlich, 1988). They are solitary feeders; rarely do they feed in flocks. However, two or three are often seen feeding in tandem. At present it is unknown whether or not their foraging habitat is threatened (Gochfeld & Burger, 1994).

The main predators of skimmers are herring gulls (Larus argentatus), Norway rats (Rattus norvegicus), raccoons (Procyon lotor), squirrels (Sciurus carolinensis), and foxes (Vulpes fulva), as well as cats, dogs, and humans (Gochfeld & Burger, 1994).

To fend off intruders, adults will circle while making loud, threatening calls. Often they will swoop downward. They will also fly low over the sand, paddling the ground with their feet, appearing to run at the intruder, "belly-flop" on the ground, then appear to collapse. These individual distraction displays are more common than mobbing, and increase in intensity and frequency during the hatching period (Gochfeld & Burger, 1994).

Black skimmers are agile on ground. In flight they are graceful. No information is available on their swimming abilities; they have been observed in the water only when bathing. However, they are seen walking in shallow water to cool themselves. While sitting in flocks, they are often observed lying down with their necks extended flat on the ground to rest and to reduce radiant heat uptake (Gochfeld & Burger, 1994).

Presently there are about 900 pairs of black skimmers in New Jersey. Habitat protection is critical for their survival. Skimmers are protected by international treaties, but are still exploited in Central America and Mexico, where many of them winter (Gochfeld & Burger, 1994).

Diamondback Terrapin (Malaclemys terrapin terrapin)

About 200 million years ago turtles appeared on earth and survived whatever trauma ended the lives of their dinosaur relatives. They can be found in virtually every habitat. Turtles live in the open ocean, in fresh water ponds and streams, in marshes, in forests, and even in deserts. Turtles have been an important part of human culture. They have provided us with food and other products, have been kept as pets, and have appeared in literature around the world (Wetlands Institute, 1991).

Turtles are vertebrates and belong to a class called reptiles. They share one very important characteristic with snakes, lizards, tuatara, and crocodilians that separates them from other vertebrates, and enables them to colonize near every habitat away from the poles. Reptile skin is covered with scales composed of keratin. The scales provide a water tight barrier that amphibians, the ancestors of reptiles, lack. Most amphibians can breathe through their skin, but in order to do so the skin must be kept moist.

Therefore, amphibians must remain close to a water source. Reptiles have been freed from this tie to water by their scales (Wetlands Institute, 1994).

There are over 250 species of turtles in the world today (Wood, 1995a). They live on every continent except Antarctica, and in most of the world's seas (Stone, 1989).

Diamondback terrapins are the only turtles exclusively adapted to brackish water (Wood, 1994). They appear only in the salt marshes along the Atlantic and Gulf coasts of the United States (Stone, 1989).

Diamondback terrapins are very distinctive in color and markings. The shell, which is often grooved and marked with patches, ranges in color from yellow to orange to green to brown to black. Their legs and heads are often flecked or spotted (Wood, 1995b)

Females are much larger than males. The length of the shell of a full grown female is six to nine inches, while the shells of males only grow four to five and one half inches in length (Wood, 1995b). Also, females have large rounded heads, and short stubby tails. Males have narrow pointed heads, and relatively long tails (Wetlands Institute, 1994).

Terrapins have very mild dispositions, and are not aggressive. But they do have very sharp claws, and strong hind legs. If picked up, they may panic and flail their legs wildly, scratching the hands that hold them. Often an unsuspecting human reacts to their struggling and scratching by dropping them. Injury to the turtle may occur if this should happen. Terrapins will not transmit any diseases to humans as a result of handling them (Wetlands Institute, 1991).

About a century ago, these turtles were regarded as gourmet delicacies (Wood, 1995b). This popularity resulted in their being hunted to near extinction. This led many states to pass protective legislation, which has been largely responsible for their eventual recovery (Wood, 1994). Diamondback terrapins are protected by law in the state of New Jersey in the following ways:

- Closed season for terrapins is April 1st to November 1st, $20 fine for each taken in closed season;
- Terrapins may not be taken by net, trap, seine, etc., $50 fine for violation;
- No terrapin may be captured with a plastron length of less than 4 inches, $25 fine for violation;
- No terrapin eggs may be taken, $25 fine violation per egg (Wetlands Institute, 1991).

Though diamondback terrapins have made a significant comeback, there is evidence supportive of a renewed interest in them for food. This could severely threaten their populations once again (Wood, 1995a).

Diamondback terrapins spend most of their lives in marshes and swamps (Wetlands Institute, 1994). Rarely are they seen far from shore or in fresh water (Wood, 1995a). Those we see on land are females looking for places to dig nests and lay their eggs. Their nests must be located above the normal high tide line (Wood, 1995b). In the past, terrapins favored the long stretches of sand dunes as nesting areas. Today, most of these areas are gone to development, and terrapins have been forced into new nesting sites, which often require them to cross roads and highways. For lack of a better environment, they sometimes lay their eggs in people's yards or on the shoulders of roads. During this annual nesting period, which lasts from five to six weeks - from early June through mid-July (Wood, 1995b) - literally thousands of them are killed by cars on the highways (Wood, 1994).

A significant number of terrapins are also killed by being taken for pets by people with good intentions. Diamondback terrapins will almost certainly die in captivity because they do not naturally occur in fresh water, and most people do not have the necessary salt water aquaria, which are very expensive and difficult to maintain (Wetlands Institute, 1991).

Besides habitat destruction, the greatest threat to this species currently is commercial crab traps. It is estimated that tens of thousands of terrapins per year drown in the 50,000 crab traps set off the New Jersey coast (Wood, 1995b). The Wetlands Institute has developed a device called a Bycatch Reduction Apparatus to prevent terrapins from entering crab traps. It has a 90% success rate, but presently they are used on a voluntary basis only (Wood, 1995b). Hopefully they will be required in the future.

Terrapin nests are consistently constructed in sandy substrate, or sand mixed with shell fragments, above the high tide level. They prefer flat areas within dunes. Nesting areas must be within 250 m of a tidal creek or other estuarine waters (Palmer & Cordes, 1988).

The density and percentage of vegetation surrounding nests varies greatly, from completely bare areas to areas with 75% cover. The vegetation typically associated with terrapin nesting is dune or beach grass (Ammophila breviligulata) (Palmer & Cordes, 1988).

Vegetation provides protection for terrapins, but it also provides habitat for predators. Optimum suitability occurs when the shrub cover is ≤ 25%, the grass cover is 5% to 25%, and the mean slope of the sandy area is ≤ 7 degrees (Palmer & Cordes, 1988).

The diamondback terrapin lays from 4 to 18 eggs. A typical nesting female will lay about 10 (Wetlands Institute, 1991). After the soft, leathery eggs are laid, the female fills in the rest of the nest with earth, then covers it with any available debris. This completed, she leaves. A baby turtle will never know who its mother is. (Wetlands Institute, 1994). Sometimes a female will nest more than once in a season (Wetlands Institute, 1991).

The eggs take approximately 60 days to hatch, depending on such factors as humidity, temperature, depth, and location. Each hatchling carries on its belly a yolk sac to feed on until it learns to catch its own food (Wetlands Institute, 1994). All of the eggs hatch in the late summer or early fall. Occasionally hatchlings will remain in the nest through the winter, and emerge the following spring. Only a few of them survive to adulthood, which is five to six years after hatching (Wetlands Institute, 1991).

The sex of the young is determined by the temperature in the nest during the incubation period. Usually females will instinctively lay their eggs in an intermediate temperature range to assure a mixture of sexes developing (Wood, 1995a). Hatchlings break through the shell with a special egg tooth, which is not really a tooth at all, but a growth of keratin, which falls off after hatching (Wetlands Institute, 1994). The habitat requirements of terrapin hatchlings is virtually unknown (Wood, 1995a). Biologists are also uncertain how long diamondback terrapins reproduce and live. Their life span is over forty years (Wetlands Institute, 1994).

Diamondback terrapins feed mainly on a variety of mollusks, crustaceans, and other invertebrates including hermit crabs (<u>Pagurus spp.</u>), fiddler crabs (<u>Uca pugnax</u>), mud snails (<u>Ilyana spp.</u>), mussels (<u>Mytilus edulis</u>), silversides (<u>Menidia menidia</u>), saltmarsh snails (<u>Melampus bidentatus</u>), and the syphons of clams (Palmer & Cordes, 1988; Wood, 1995a). Subtidal mudflats and shallow tidal creeks are the most important feeding areas for terrapins (Palmer & Cordes, 1988).

Predators such as red foxes (<u>Vulpes fulva</u>), raccoons (<u>Procyon lotor</u>), gulls (<u>Larus atricilla</u>), and crows (<u>Corvus brachyrhynchos</u>) are a threat to terrapins on land. Full grown terrapins can usually take care of themselves, but hatchlings are easy prey. Eggs and hatchlings in the nest are often dug up by predators (Palmer & Cordes, 1988).

The diamondback terrapin is presently being considered as a candidate for the national list of endangered and threatened species (Wood, 1995a).

Least Tern (*Sterna antillarum*)

Once a plentiful shorebird, the least tern was nearly exterminated by plume hunters at the turn of the century, when a typical seasonal kill was about 100,000 birds (Ehrlich et al., 1988). Passage of hunting laws allowed for stabilization of the species, which, eventually, suffered immense loss of habitat and feeding areas primarily due to human activities.

Least terns tend to share their habitats with black skimmers and piping plovers. Traditionally, they nest on flat, unvegetated substrate, including islands, sandbars, and beaches. But because of increased development and human disturbance, dredged-material sites are proposed as alternatives (Kotliar & Burger, 1986).

The nesting habitat suitability of the least tern is related to type of substrate, percentage and height of vegetation cover, amount of predation and human disturbance, and susceptibility of flooding. It is possible to use decoys as an intervention to attract terns to a potential nesting area.

Substrate composition is strongly correlated with colony site selection. Terns usually select a site with a substrate composed of sand mixed with pebbles, shells, or shell fragments. This mixture best camouflages chicks and eggs. Least terns avoid silt and clay substrates (Kotliar & Burger, 1986).

Nesting on spoil sites has been successful. Islands, as opposed to sites on the mainland, are more attractive to terns, as they provide greater protection from human disturbance and ground predators. However, spoil islands are often small in size, enabling vegetation encroachment to occur at a rapid rate (Ehrlich et al., 1988).

The least tern breeds at two years of age (Ehrlich et al., 1988). They nest in scrapes, separated by no more than 100 m. May and June are generally the months of peak reproductive efforts of least terns (Carreker, 1985). After laying the eggs, the mother will cool them by dipping them in water, or shaking water on them (Ehrlich et al., 1988).

Chicks abandon the nest only a few days after hatching. Parents often lead them to the edge of the colony into areas of some cover for protection (Ehrlich et al., 1988).

Total vegetation cover in the least tern's habitat rarely exceeds 20% (Carreker, 1985). Vegetation can provide cover for predators, therefore increasing predation on chicks and eggs. It also reduces terns' ability to manoeuver on ground, and inhibits construction of scrapes (Kotliar & Burger, 1986).

Vegetation can provide protection for chicks, but in areas with little or no vegetation, beach debris can serve the same purpose. Optimum suitability is between 0% and 15%. Least terns will not nest in tall vegetation. They generally choose sites where the vegetation is $\leq$ 40 cm high (Carreker, 1985). Vegetation control is often necessary to maintain nesting suitability (Kotliar & Burger, 1986).

To avoid inundation, terns will often nest some distance from the high tide line, and may select the more elevated sections of a breeding site (Carreker, 1985).

Terns often nest with skimmers, though both are territorial. Skimmers arrive first. When the terns come, some degree of competition for space is inevitable. Invariably the skimmers shift to the center of the site, while the terns form their colony along the periphery. The boundary between the two colonies is thin, and usually the area of most turf battles. Both sexes of both species take part in these confrontations. For the most part, these disputes end as each colony settles in to nest. Should they continue to be aggressive toward each other on into the breeding season, the chicks become the targets of their aggression (Burger & Gochfeld, 1992).

Terns can be extremely intimidating. This is the main reason why skimmers choose to share a colony site with them. This use of another species is called "social parasitism"

(Burger & Gochfeld, 1992). Many predators will leave when pursued by terns. Even humans respond to their screeching, circling, and diving. They will also hover and defecate over intruders (Ehrlich et al., 1988).

Least tern colonies can display high site fidelity. In New Jersey, colony sites are abandoned only when human disturbance, predation, or encroachment of vegetation reaches intolerable levels (Carreker, 1985).

Least terns feed primarily on crustaceans and small fish including menhaden (*Brevoortia tyrannus*), silver anchovy (*Engraulis eurystole*), silversides (*Menidia menidia*), herring (*Clupea spp.*), killifish (*Fundulus kansae*), and mummichogs (*Fundulus heteroclitus*) (Carreker, 1985).

Least terns feed in large areas of shallow water. Colony sites must be located near feeding areas. The maximum distance that terns will fly to forage is not known, but it is assumed to be approximately 3.2 km. Potential least tern foraging habitat is "any open body or channel of water known to contain, or suspected of containing, fish ≤ 10 cm long that swim near the surface" (Carreker, 1985, p. 10). They hunt by hovering and diving from a few feet above the water surface. Occasionally they will feed on insects on land (Carreker, 1985).

The presence of predators can prevent least terns from nesting. It may also cause them to abandon previous nesting sites. Least terns may avoid nesting on dredged-material islands that are > 8 ha, because of predator habitation.

Predators include skunks (<u>Mustelidae</u>), Norway rats (<u>Rattus norvegicus</u>), foxes (<u>Vulpes fulva</u>), and house cats (<u>Felis catus</u>). Eggs and chicks are also preyed upon by numerous avian species (Carreker, 1985).

Suitable nesting areas are characterized by low cover and height of vegetation, protection from human disturbance, and the presence of shells or shell fragments in a sandy substrate. Therefore efforts should be made to manage these conditions. Dredged-material islands have excellent potential as colony sites because they are isolated from many predators and humans. But it is noted that in New Jersey many of these sites have become unsuitable due to vegetation encroachment (Kotliar & Burger, 1986).

In conclusion, the conflict between human activities on beaches, and the habitat requirements of least terns, has led the least tern to be listed as endangered in the state of New Jersey (Kotliar & Burger, 1986). Improvement of this status may largely depend on habitat management.

Piping Plover (<u>Charadrius melodus</u>)

The piping plover is a small North American shorebird. They are usually beige with white underparts. Their dark eyes stand out from their pale faces. Outstanding physical characteristics include a single, white stripe along the edges of the wings, a single black breastband, and a black bar across the forehead. In summer the bill and legs are orange. In winter the bill becomes black, the orange legs fade to yellow, and the black bands disappear (U. S. Fish and Wildlife Service, 1995b).

In the 19th century, Audubon described the piping plover as "common" on the Atlantic coast. But by the turn of the century, uncontrolled egg collecting and hunting left this species close to extirpation. The Migratory Bird Treaty Act, which was passed in 1918, allowed for population recovery to some extent. But again populations declined when great expanses of habitat were lost due to construction of roads and summer homes at the shore. In the 1970's the plover was included in the National Audubon Society's "Blue List" of birds with deteriorating status (U.S. Fish and Wildlife Service, 1995b).

Table 5 summarizes counts of nesting pairs. It should be pointed out, however, that when these counts appear to go up, it is actually because of increased census effort. (In New Jersey, the N.J. Division of Fish, Game, and Wildlife conjectures that about one third of the population increase can be attributed to increased survey intensity) (U.S. Fish and Wildlife Service, 1995b).

Piping plovers nest in shallow scrapes above the high tide line on coastal beaches, barrier islands, sandflats, and dredged-material islands. They prefer areas with little or no vegetation. They will nest under American beachgrass (Ammophila breviligulata). Substrates range from sand, to mixtures of sand and shells, pebbles, or cobble (U.S. Fish and Wildlife Service, 1995b). Nests are seldom placed closely together. Normally they are at least 100 feet apart. Extra scrapes are made, but not used (Ehrlich et al., 1988). Adults tend to return to previous nesting sites (U.S. Fish and Wildlife Service, 1990).

Piping plovers may begin laying their eggs as early as mid-April, or as late as the end of July. However, few hatch after July 15. Clutches usually average 4 eggs, one laid every other day. Incubation time is about 27 to 30 days, and is shared by both sexes (Richards, 1988). Females often desert broods before males (Ehrlich et al., 1988). If the initial clutch is destroyed, the pair will often renest. The nests and eggs, which are very well camouflaged, are extremely hard to detect (U.S. Fish and Wildlife Service, 1990). Piping plovers are monogamous, and breed by one year of age (U.S. Fish and Wildlife Service, 1995b).

Chicks often leave the nest within hours of hatching. The adults tend to them by sheltering them from harsh weather, protecting them from predators, and leading them to feeding areas. The chicks remain with their parents until they fledge (U.S. Fish and Wildlife Service, 1995b).

Coloration is the main defense of piping plovers. They are also known to crouch and become motionless to avoid intruders. Adults, in order to defend their young, may display distracting behaviors such as feigning injury, or running (U.S. Fish and Wildlife Service, 1995b).

The diet of piping plovers consists primarily of mollusks, crustaceans, fly larvae, marine worms, and beetles (U.S. Fish and Wildlife Service, 1995b, 1990). Their main feeding areas are mudflats, wrack lines, salt marshes, and shorelines. They feed by either foot-stomping to locate food before pecking, or by means of quick, short runs interspersed by random, rapid pecks (U.S.Fish and Wildlife Service, 1990).

The present decline in population numbers is caused by: 1) predation, 2) habitat loss and degradation, and 3) disturbance by humans and domestic animals.

Predators include raccoons (Procyon lotor), red foxes (Vulpes fulva), skunks (Mustelidae), opossums (Didelphis virginiana), Norway rats (Rattus norvegicus), gulls (Larus atricilla), ravens (Corvus corax), and domestic and feral cats and dogs. Nesting gulls competing for space are a great threat to plovers (U.S. Fish and Wildlife Service, 1990).

"Eighty-three percent of the 178 current and potential U.S. breeding sites support other Federal or State listed species" (U.S. Fish and Wildlife Service, 1995b, p. 43). For example, nesting plovers often coalesce with seabeach amaranth; but it is now extirpated from Delaware, Maryland, Massachusetts, New Jersey, Rhode Island, and Virginia. Also, beech tiger beetles, which used to be plentiful on ocean beaches from New Jersey to Massachusetts, presently occur on two sites only; both of which are in Massachusetts, and are also used by piping plovers (U.S. Fish and Wildlife Service, 1995b).

In 1986 the piping plover was listed as threatened and endangered under provisions of the Endangered Species Act of 1973 (U.S. Fish and Wildlife Service, 1995b).

Disturbance by humans and pets, predation, and habitat loss and degradation are currently the main causes of the on-going population decline of the piping plover. As a result of this small population size, the species is risking loss of genetic diversity. This makes them very vulnerable to extinction (U.S. Fish and Wildlife Service, 1995b).

Intensive protection efforts are presently being implemented, and there is some evidence of recovery. The population has increased from 800 pairs in 1986 to 1150 pairs in 1994. However, as previously noted, this increase is highly attributable to increased survey efforts.

Delisting of the piping plover may be considered when the following criteria are met in the four recovery units which consist of New England, New York-New Jersey, Southern (DE-MD-VA-NC), and Atlantic Canada:

1. The number of breeding pairs reaches 2000, and this number is maintained for 5 years;
2. It is verified that 2000 pairs are sufficient to maintain long term diversity in the species;
3. The breeding pairs average 1.5 fledged chicks;
4. Long term agreements are established to assure management and protection to maintain the target species;
5. Long term agreements are established for maintenance of wintering habitat.

Full recovery is anticipated by the year 2010 (U.S. Fish and Wildlife Service, 1995b).

DISCUSSION AND CONSIDERATIONS

Innovative uses of dredged material are becoming necessary to meet the demands of environmental, engineering, and economic standards for disposal of dredged material. Use of dredged material for habitat enhancement is both feasible and encouraged.

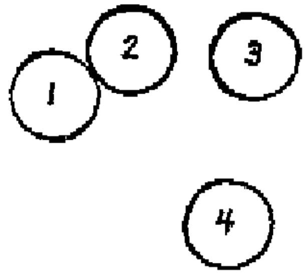
There are dangers involved in trying to attract nesting birds to new islands. First, in an area such as Stone Harbor, which is a busy tourist/recreation area, even a seemingly secluded island, such as Gull Island, will be frequented by people. Disturbance to nests by humans is inevitable to some degree. Measures must be taken to keep this disturbance as minimal as possible. Second, this island is not far from mainland beaches, marshes, and towns, therefore enabling easy access for predators such as Norway rats, raccoons, snakes, and foxes.

The recommendations made in this chapter are based on this author's observations, without ready access to prior studies conducted in Stone Harbor.

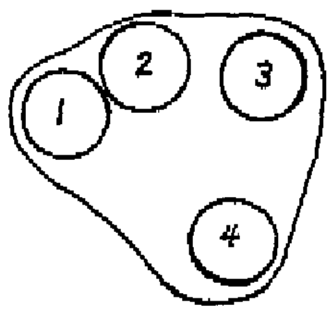
Options and considerations are discussed below, followed by a list of the authors final recommendations for the enhancement of Gull Island.

Size and Shape

Presently, the four existing dredged-material islands stand in relation to one another as illustrated below:



Connecting the four existing with dredged material would result in a somewhat triangular configuration:



All corners should be rounded off to limit erosion. Most likely this rounding off will occur naturally.

The finished product should be a gently sloping, triangular island, well rounded at the corners. The slopes should be no greater than 1 m rise per 30 linear m; at no point less than 10 m wide above the mean high tide line. The author estimates this island will be an area that is approximately 6 acres, which is suitable size.

Elevation

The overall elevation of this island should not be so high that the substrate will not become stabilized due to

wind erosion, but high enough to prevent flooding of the colony site. Optimal elevation is between 1 - 3 m. (Coarser materials stabilize at higher elevations than finer materials.) An elevation of about 3 m is recommended because vegetation becomes established at a slower rate at a higher elevation, and this will be above most high tides.
3 m = 10 feet x 6 x 1612 cubic yards = 96,720 cy of solids. After consolidation, settling, and sorting of dredged material, it will take well over 97,000 cy to be sure elevation and slope are correct. (This is based on the author's estimation that the completed island will be roughly 6 acres.)

This site should contain higher sand mounds (approximately 2 m high), as well as some flatter areas. The habitat must be located at a higher elevation than the floodwater to prevent inundation during the nesting period. Under severe storm conditions, even this height may be overtopped by waves. However, a higher elevation will cause blowing sands. The strategy is to provide enough surface above mean high tide water that the birds can find area away from the most exposed edge, but where predators and humans won't find them. It is recommended that the mean high water tidal datum be used to represent floodwater elevation. This information is maintained by the National Ocean Service (Carreker, 1985).

The mean slope should be 15:1 to 30:1 (1 foot rise in 15 feet to 1 foot rise in 30 feet). Gradual slopes seem to dissipate wave energy better than steep slopes.

Substrate

To accommodate the nesting needs of the target species in this project, a fragmentary substrate is preferable. Dredged material has certain percentages of fine-grained material (silt, clay) which cannot be separated out. Substrate consisting of all silt and/or clay is susceptible to washout during spring and early summer torrential precipitation. An all sand substrate is unstable during high winds. An all fragmentary substrate is unattractive to skimmers and terns. Ideally, the recommendation for substrate is 60-80% sand and 20-40% fragmentary material (pebbles, shells, broken shells, cobble). Realistically, this precision is not controllable.

Vegetation

Bird use of an island is directly related to the vegetation found on it (Soots & Landin, 1978).

The author recommends all previously established vegetation be smothered with dredged material, and controlled by a combination of burning and spraying with Rodeo. This chemical is a restricted use herbicide put out by Monsanto (Atzert, 1995), that has been approved for use in New Jersey wetlands (Landin, 1996). A licensed aerial sprayer may be contacted. But because aerial spraying is expensive, and it is often difficult to control off-site application (telephone interview: Schrading, 1996), manual spraying is also an option. A third option is a combination of these two methods, using manual spraying along the edges of the project site to limit aerial off-site application.

Spraying should be done in the fall. After spraying, dead vegetation can be removed by burning. If burning is to take place, a fire management plan must be written and approved by the New Jersey State Forest Fire Service.

Two sprayings may be necessary. If so, the second spraying would most likely not have to be as heavy as the first, and should take place the following fall.

Once this vegetation has been cleared away, any necessary earth moving and shaping should be done. Disking and harrowing should be carried out to maintain bare ground.

Many options were explored concerning planting of vegetation. Possible recommendations include:

Plant sparse, low growing vegetation in scattered, dispersed clumps. Vegetation encroachment will cause loss of habitat. Dense vegetation provides cover for predators. It may also inhibit construction of nest scrapes.

Some vegetation may be necessary to protect chicks and eggs from exposure to weather and predators. Other materials, such as debris deposited from the water, will serve this purpose also.

This island should be a combination of bare substrate and sparse herbs, i.e. about 5% vegetation. The author considered using the following vegetative propagules and fertilizing with a general purpose fertilizer. Fertilizer should be applied initially, then at intervals for the first two years.

American beachgrass (<u>Ammophila</u> <u>breviligulata</u>)

- best propagule type = transplants
- collection periods = Oct - Mar
- temporary storage = wet sand beds or pots of sand
- planting periods = Feb - May
- mature height = 1.5 m

Saltmeadow cordgrass (<u>Spartina</u> <u>patens</u>)

- best propagule type = transplants, seedlings
- collection periods = year round (south)
  Mar - Oct (north)
- temporary storage = wet sand beds or pots of sand
- planting periods = Feb - June
- mature height = to 1 m

Saltwort (<u>Salsola</u> <u>kali</u>)

- best propagule type = transplants
- collection periods = Sept - Mar
- temporary storage = sand beds or pots of sand
- planting periods = Mar - June
- mature height = to .6 m

A potential problem to consider is that beachgrass spreads rapidly and tends to quickly become less than optimal for target species. Also, the high marsh species require flooding.

After careful consideration the author concluded the best option for this project is to NOT plant the new island. There should be enough of a seed bank in any dredged material used to join the four islands, that the problem will be keeping vegetation off, not planting and encouraging growth.

Predators

As mentioned, this is an area of high predation. The site is colonized by herring gulls, and there is evidence of what the author believes to be Norway rats. Terrapin nests have been destroyed, most likely by raccoons.

Between the burning and spraying of vegetation, and the placement of new material, habitat changes may be enough to discourage these predators. Herring gulls do not prefer bare ground. Once the new island is established, the open sand and sparse vegetation should not attract them. However, herring gulls do tend to return to their nesting sites, often even after they have been altered. To further deter them, if it is necessary, "timed disturbance" may be used. This is done before the terns and skimmers return to nest. If enough disruption occurs, the gulls may choose another nesting site. This is a risky option in that the possibility exists that it could virtually eliminate skimmers and terns. "Timed disturbance" has been tried before, in other regions of the

United States, with partial success (telephone interview: Landin, 1996).

Another method is exclusion. This is done by suspending fine wires or nylon monofilament line over the island. The wires should be hung in long parallel spans up to 80 feet apart. Gulls will rarely fly under, or between, fine parallel wires. The reasons for this are unknown (Solomon, 1986). This is not a new technique. It was devised in Victoria, British Columbia, in 1927. In 1971 wire exclusions were installed at Big Canyon Reservoir, and in 1975 at San Joaquin Reservoir (Orange County, CA), both areas of excessive gull intrusion. It is reported that the affect on gull flocks was immediate. Once descending close enough to observe the wires, all gulls departed. Success was complete (Clark, 1980). There are several other reported success stories using this technique, as well, including over crops, buildings, ponds, dumps, and other areas where gulls have been a nuisance.

Fencing is also an option, if necessary. However, fencing can spook terns and skimmers (Landin, 1996). Fencing may also quicken the dune/vegetation growth process (telephone interview: Turner, 1996).

The idea of placing osprey nests at each end of the island was explored. Ospreys will keep away aerial predators. They may also deter the avian target species from nesting. Also, terns may attack the osprey (Jenkins, 1996).

Assorted scaring devices such as distress and alarm calls, shotgun shells, gas-powered exploders, shellcrackers, as well as chemical frightening agents, are additional alternatives for dealing with predators.

Timing

Timing is a critical factor. Every step needs to be thoroughly planned in advance according to environmental windows and time limitations. For example, the spraying and burning must be completed so that dredging can be done either in Sept-Oct or Mar-April. Months of peak reproductive effort must be avoided. Construction should be completed within a time frame that will allow material to settle and sort by late spring.

Monitoring

This site should be monitored for success: (success being the colonization and reproductive success of one, or any combination of, the target species). Great care should be taken not to cause significant colony disruption during all monitoring and maintenance processes.

In order for any wildlife management plan to be effective, population data on the species involved needs to be obtained and updated periodically. This island will also need to be monitored for natural predators.

It is imparative that erosion of this site be monitored. The author has anticipated this to be an area of low wave activity, and has therefore not recommended any means for containment. Substrate can be stabilized by strategic planting, but the author is recommending no planting. Therefore, stabilization of substrate will be completely dependant upon low wave conditions, low wind fetches, and natural colonization of vegetation.

NOTE: The person(s) conducting monitoring should be aware of existing information on status of the target species, levels of breeding populations in the area, and should be qualified to conduct censuses, if necessary. Any census causing too much disruption should be discontinued.

Maintenance

Long-term maintenance of this site will be necessary. This plan has been designed to require limited maintenance.

Additions to the island (additional applications of dredged material in later years) may be used as a management tool in the following ways:

1. to help control erosion,
2. to maintain elevations,
3. to provide additional bare substrate, and
4. to help slow down vegetation encroachment.

Colonies have responded favorably to island additions in other regions of the United States (Landin, 1996).

FINAL RECOMMENDATIONS

Size and Shape

1. Connect the four existing dredged material islands with additional dredged material. 1612 cubic yards (of solids) = 1 acre/foot. Dredged material is 20-30% solids (Landin, 1996).
2. Be sure the slopes are no greater than 1 m rise per 30 linear m.
3. At no point should the island be less than 10 m wide above the mean high tide line.

Elevation

1. Average elevation should be 3 m.
2. Island should be a combination of higher sand mounds (2 m) and flatter areas.
3. Mean slope = 15:1 to 30:1.

Substrate

1. The substrate should be sand mixed with a high percentage of fragmentary material (shells, broken shells, pebbles).

Vegetation

1. Smother previously established vegetation with dredged material.
2. Spray with Rodeo. This should be done in the fall.

3. Burn dead vegetation. Conduct burn after the first spraying (between Jan and Mar).
4. If a second spraying is necessary, conduct the following fall.
5. Allow this island to colonize naturally to a combination of bare substrate and sparse vegetation. Do not plant.

Predators

1. Alter the habitat by removing vegetation.
2. When the Norway rats return, have them trapped and removed from the island as quickly as possible.
3. If gulls return, use the exclusion method of suspending parallel wires across the island approximately 15 - 20 feet apart. Use any of the following:
   A. fine steel wire; 0.015 in. or 0.4 mm diameter,
   B. stainless steel fishing line; 0.25 mm diameter/ tensile strength of 7.2 kg,
   C. .015 in. diameter, coated, stainless steel spring wire (similar to piano wire),
   D. nylon monofilament line.

Timing

1. Time all construction activities so that the island is ready to accommodate the target species by spring.

Monitoring

1. Annual monitoring should be conducted.

2. Monitoring should include:

   A. Soil sampling

      - analysis of ph, salinity, and availability of major nutrients,
      - elevational changes.

   B. Vegetation sampling

      - success of the vegetation removal program - record species, paying particular attention to undesirable species, such as common reed,
      - colonization rates/percent cover,
      - condition of plants (vigor, abnormal growth, stunting, chloratic tissue, disease, insect infestation, wildlife damage).

   C. Documentation of wildlife use

      - diversity
      - observation (droppings, tracks, nests),
      - check for signs of predation,
      - censusing (every 2 years),
      - check for existing success of target species.

Maintenance

1. Vegetation

   A. Remove periodically to prevent encroachment.

B. Maintain approximately 5% - 10% vegetation.

C. Completely avoid common reed.

D. Use any combinations of the following methods to keep percent of cover down:

- tilling
- herbicides
- control burning
- spraying site with salt water or Ureabore (a highly concentrated salt solution)
- depositing additional dredged material.

2. Predators

A. Check periodically for signs of predation. If the removal of predators is warranted, trapping can be done successfully. A professional trapper should be contacted for removal programs.

B. Check exclusion wires for breakage. Repairs, if necessary, must be done immediately.

3. Post signs on the island for protection, and to provide information to boaters trying to access the island (figure 10).

4. Continue to add additional dredged material to the island.

5. Remove debris and drift lines that may harbor Norway rats.

6. Remove piles of clam shells.

7. Encourage local environmental groups to adopt this maintenance program as an ongoing project.

Figure 1

7.5 minute quadrangle map of Gull Island, Stone Harbor, NJ.

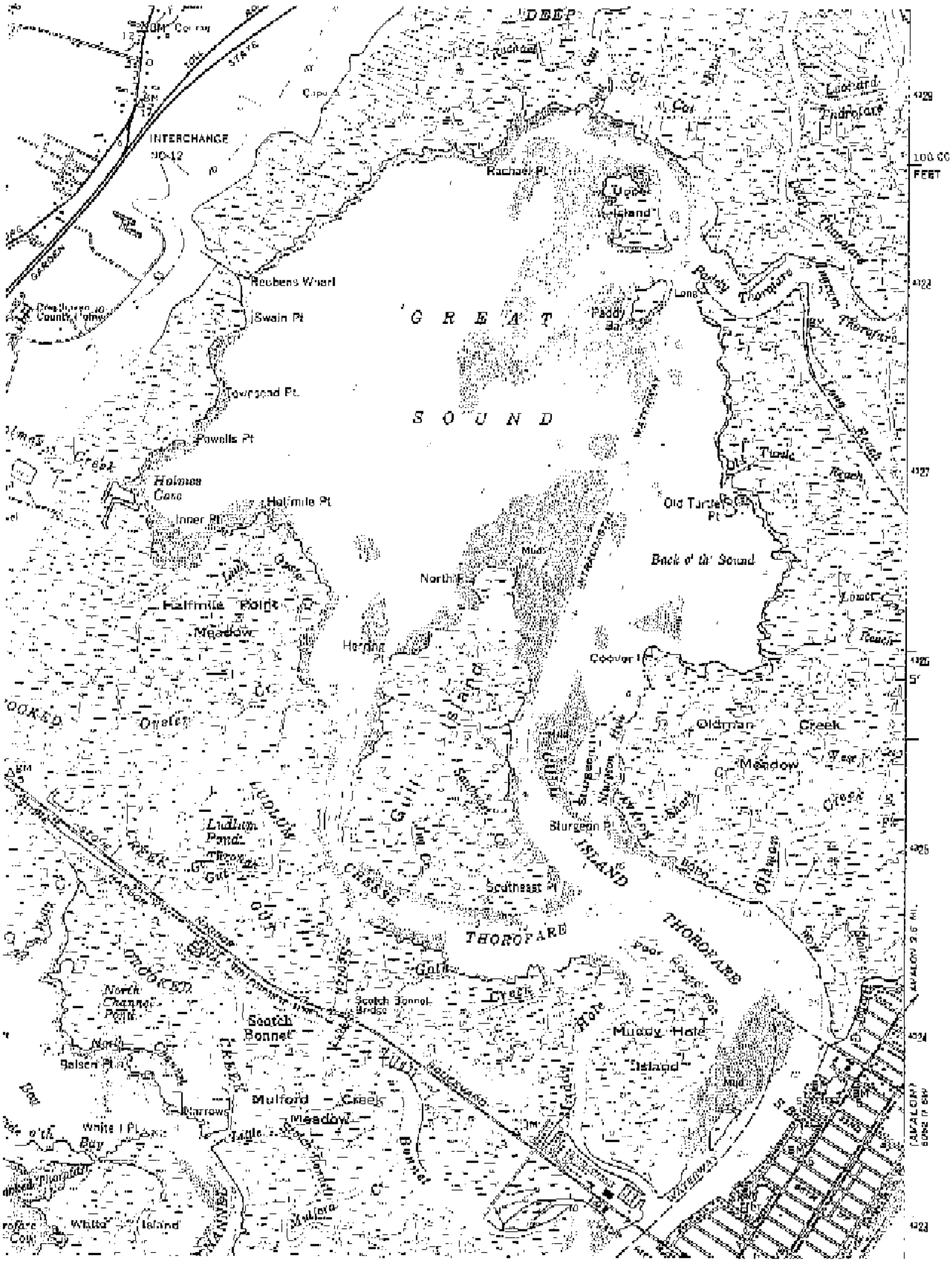
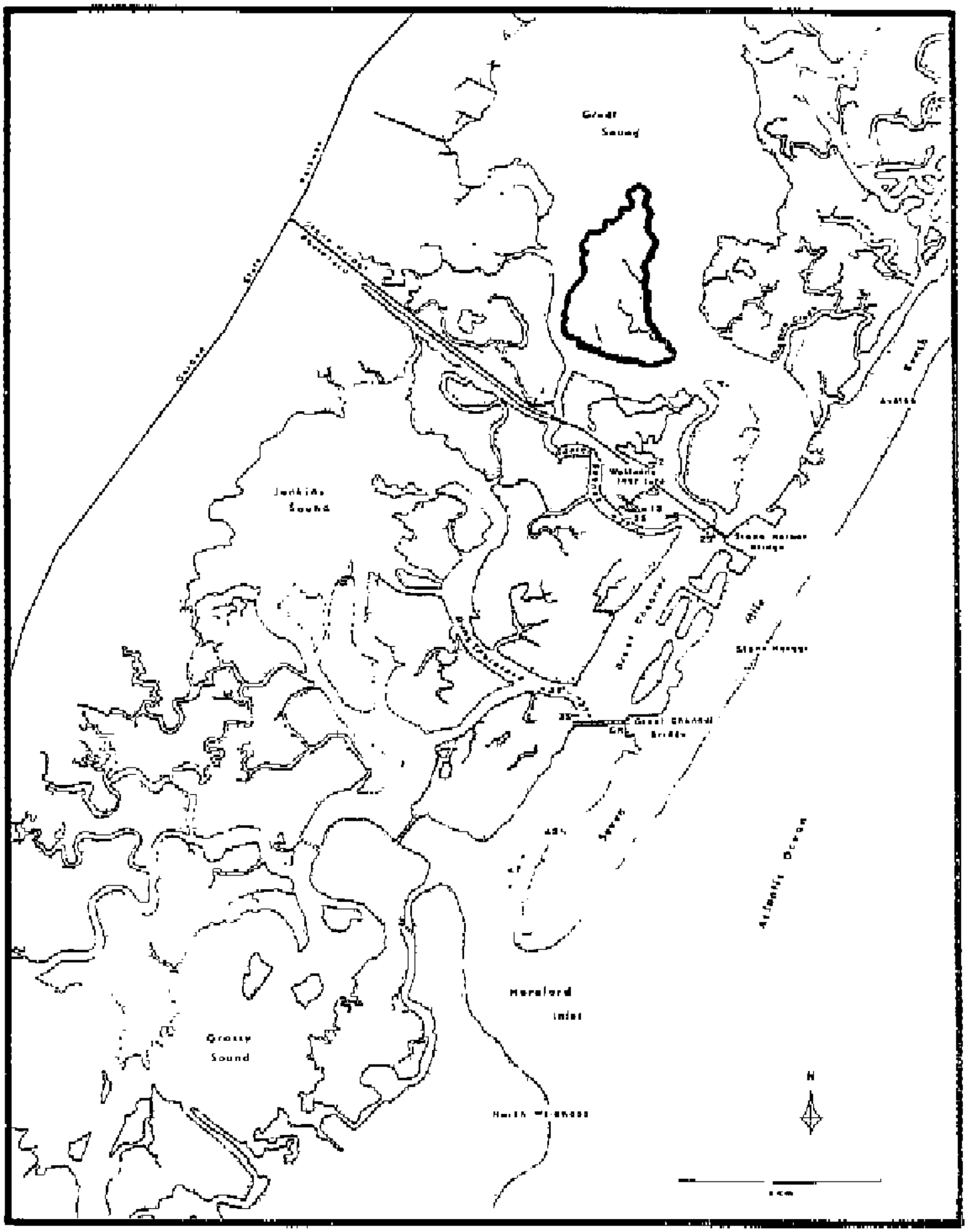


Figure 2

Aerial photograph of Gull Island

Figure 3

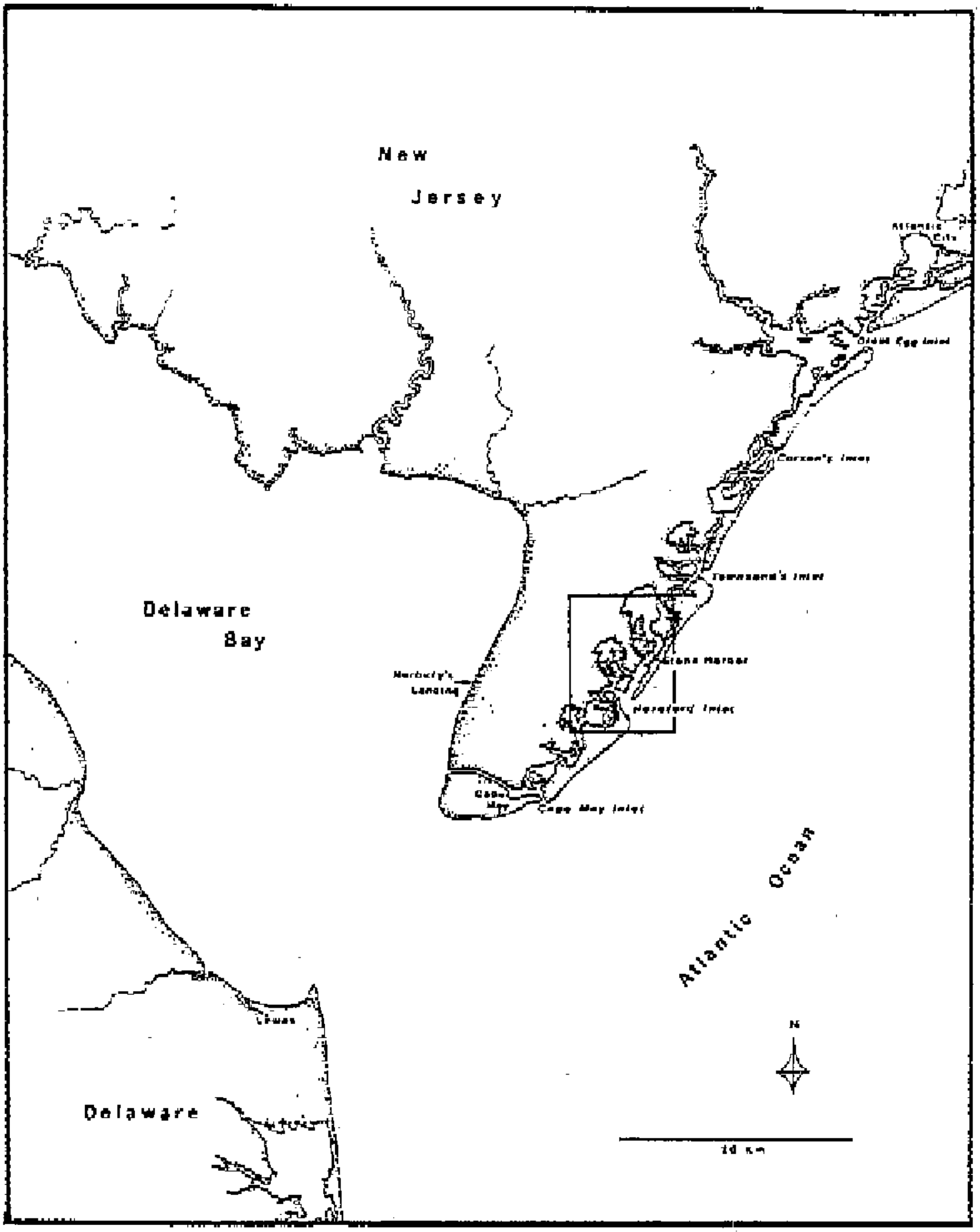
Study Area for Finfish Survey



Allen et al., 1978

Figure 4

Hereford Inlet

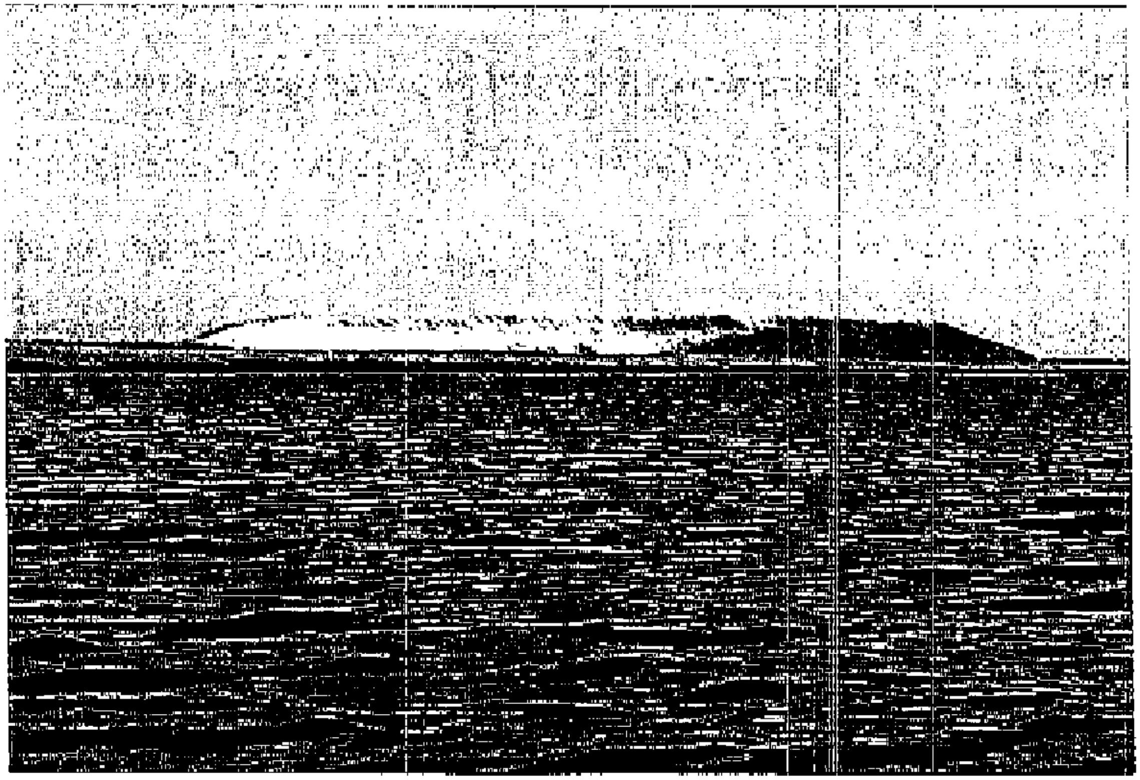


Location of Hereford Inlet and relationship with other inlets in southern New Jersey.

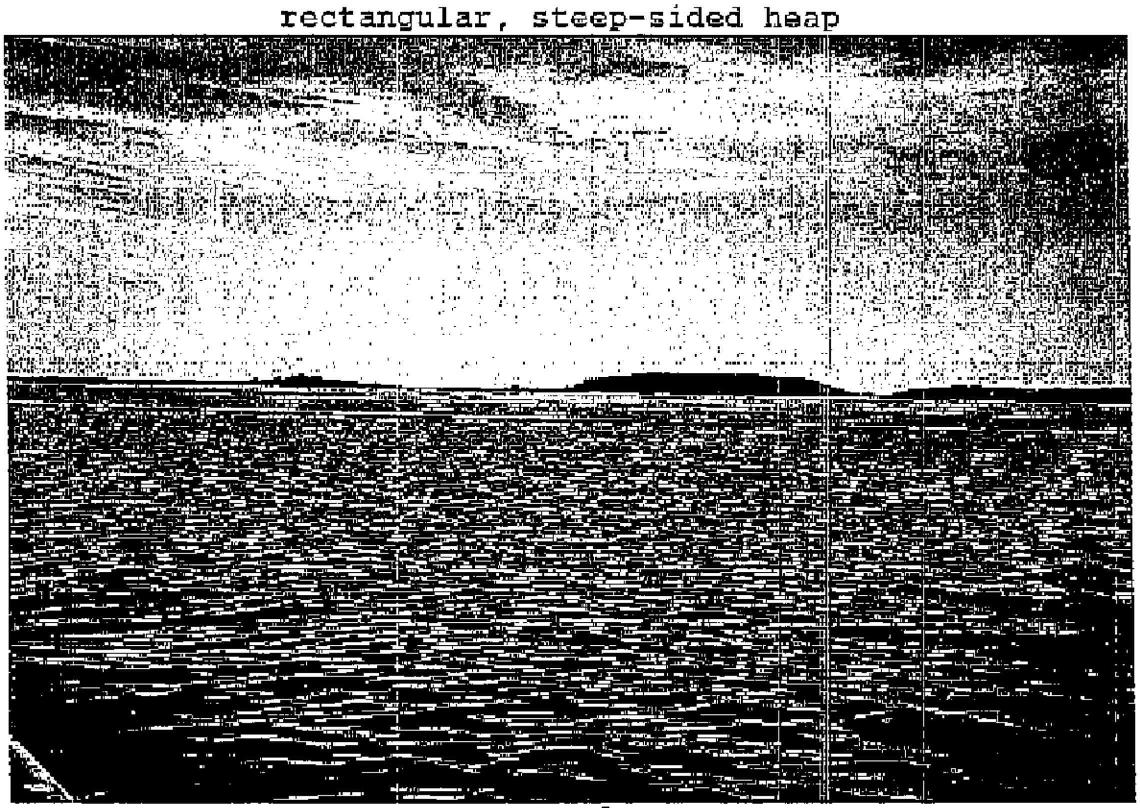
Allen et al., 1978

Figure 5

Two Types of Dredged Material Islands



rectangular, steep-sided heap



mound

Figure 6

Champagne Island

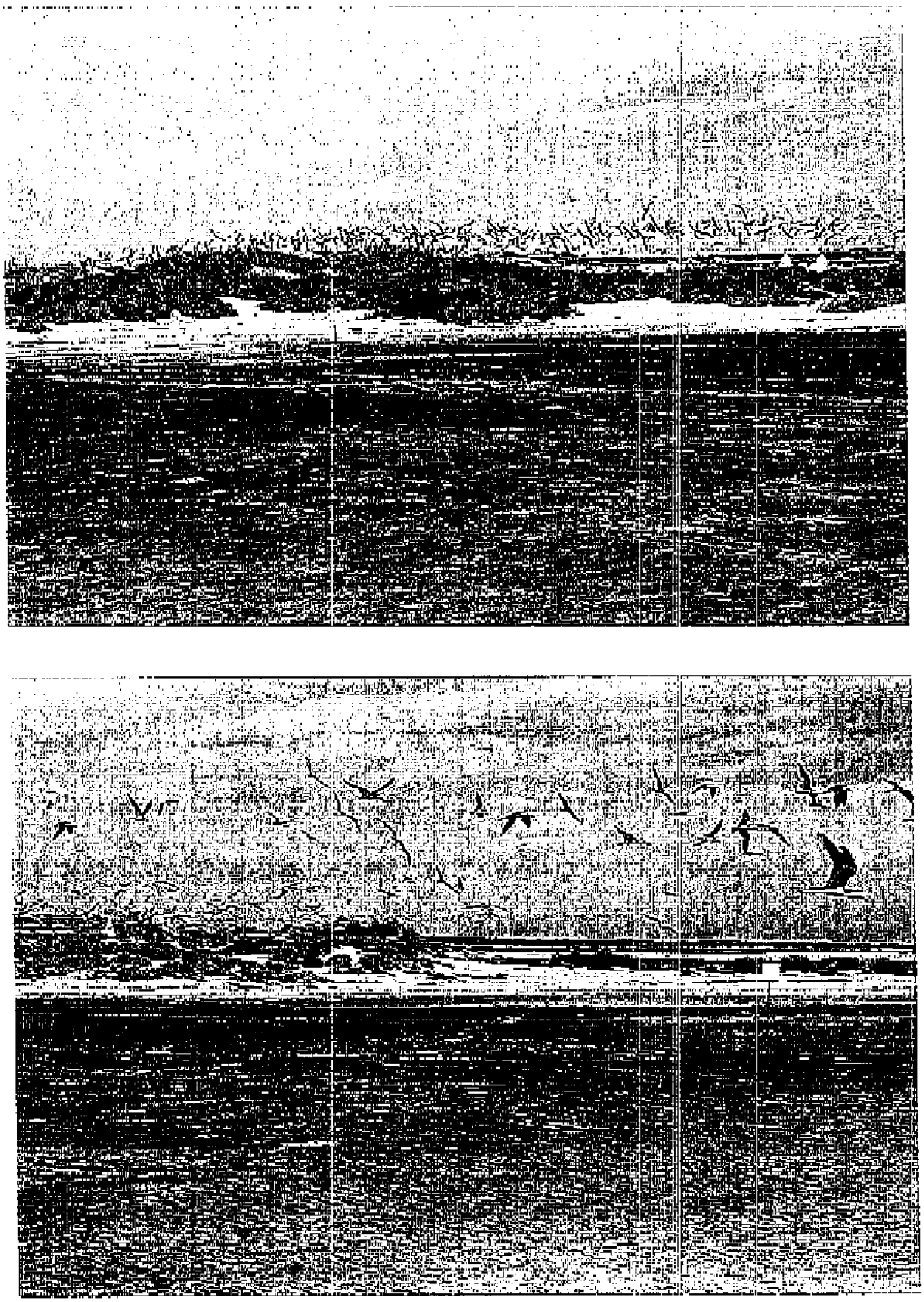


Figure 7

Islands 1 & 2: Signs of Predation

Raccoon tracks

Disturbed terrapin nests

Figure 8

Island 4

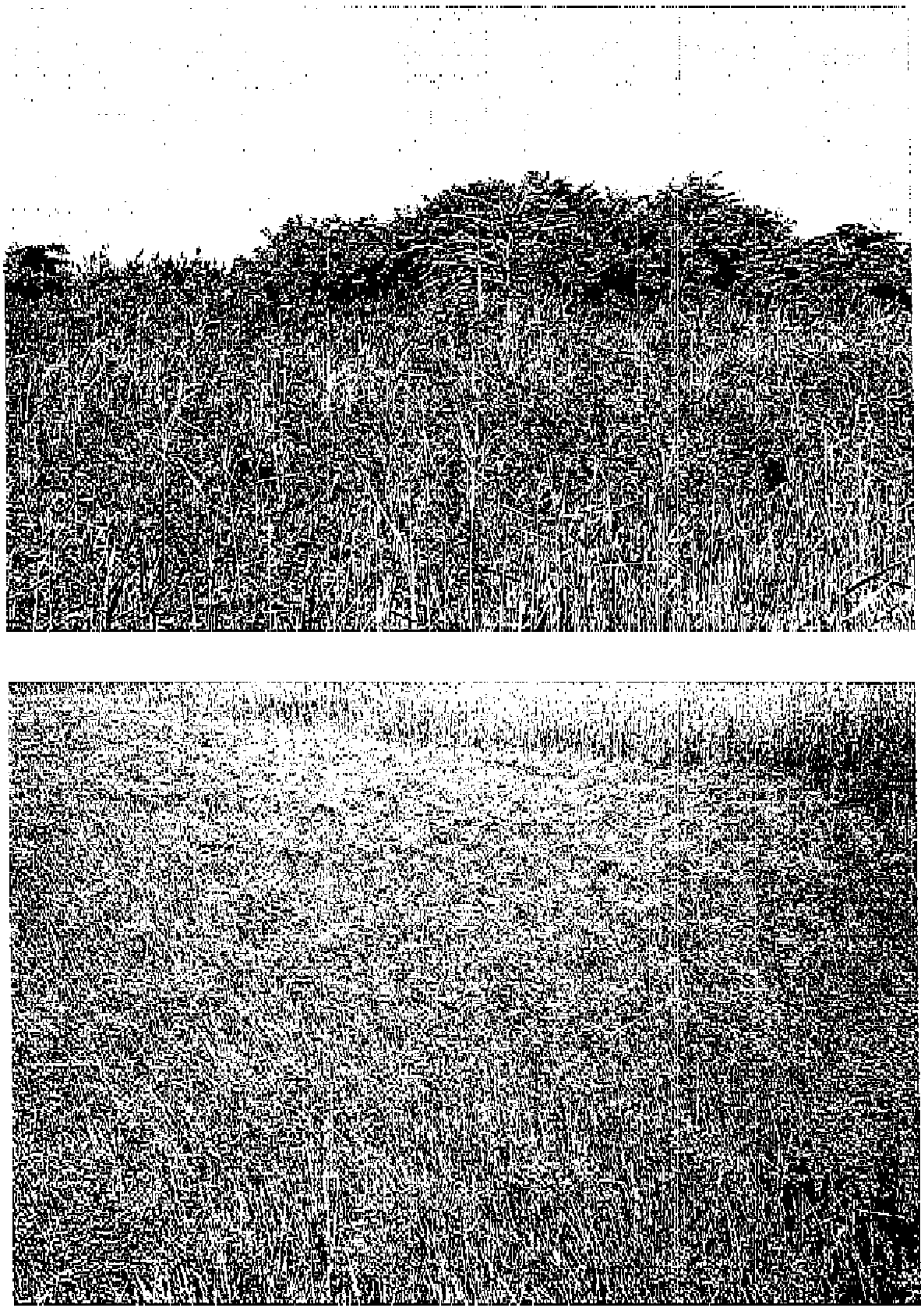


Figure 9

Island 4

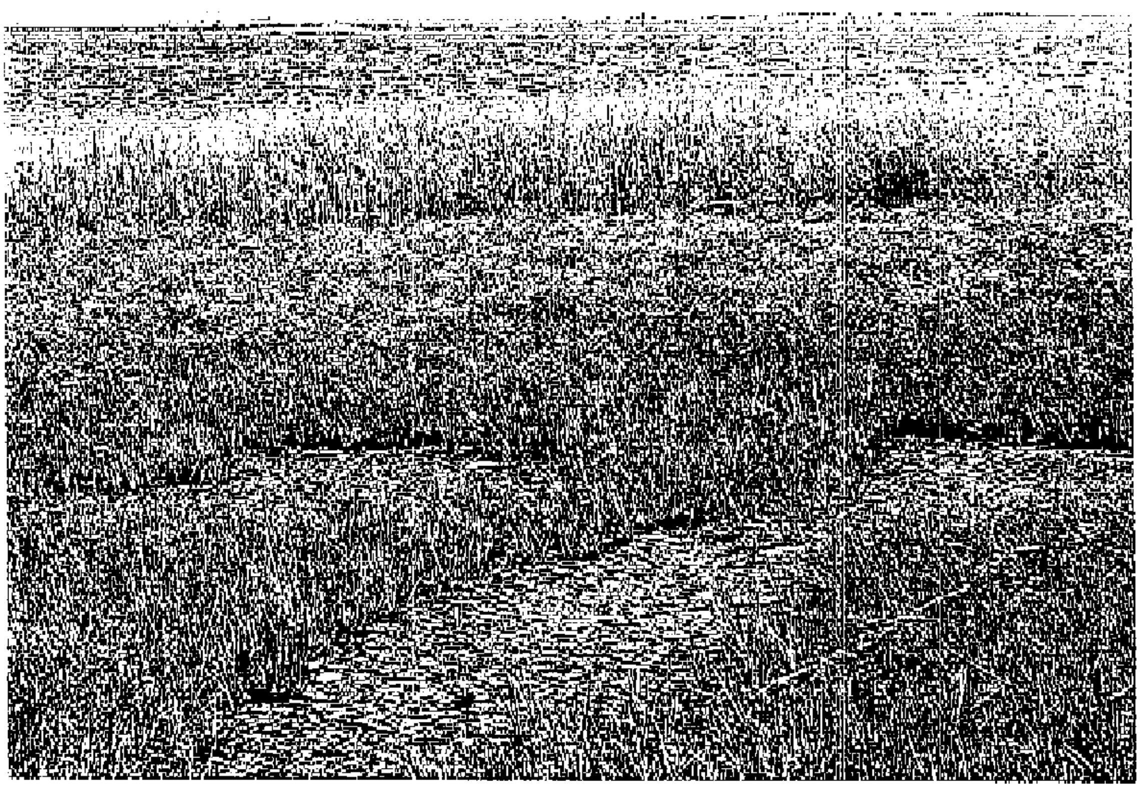


Figure 10

Sample of a Posted Island

Figure 11

Illustration of the Target Species

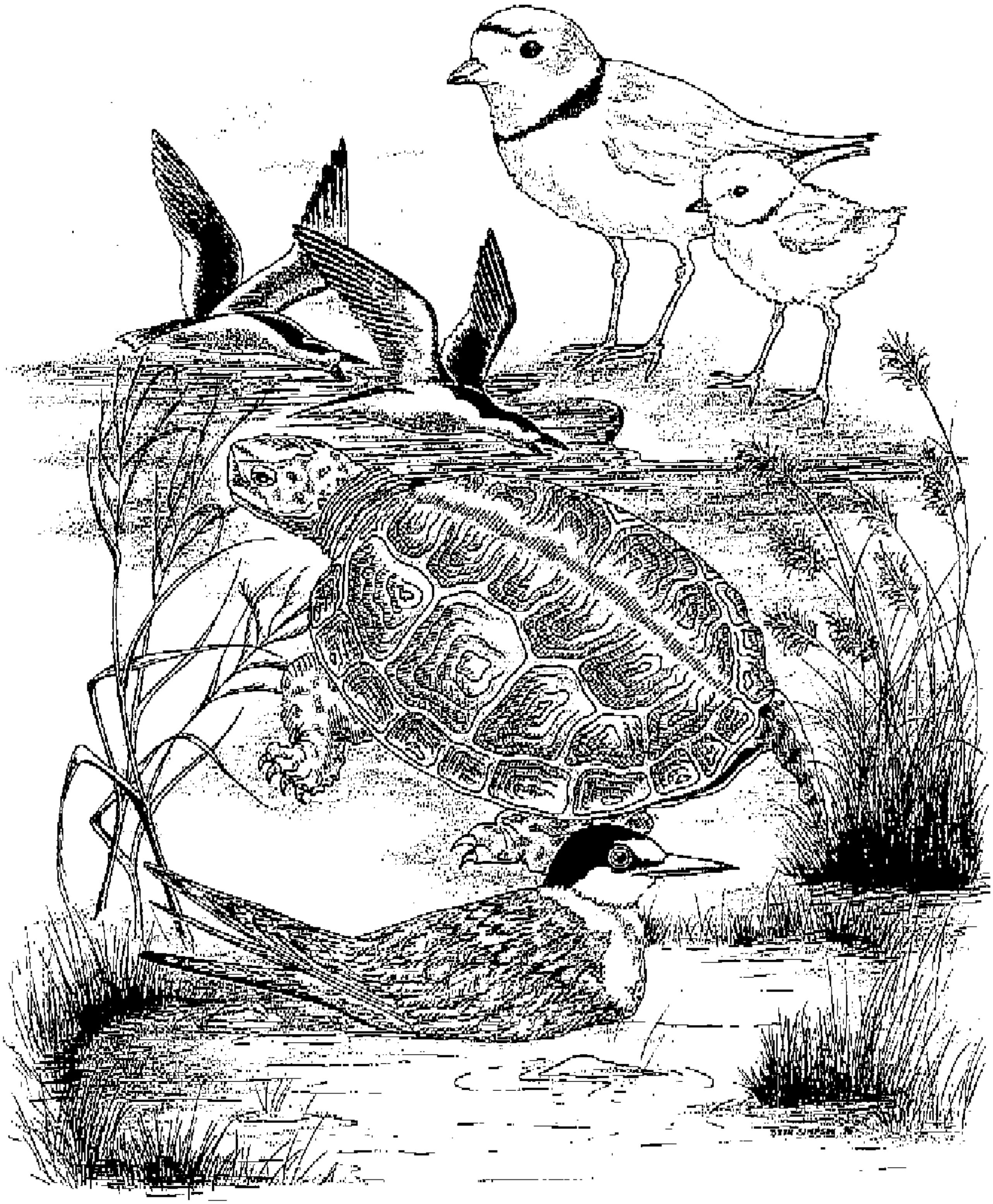


Table 1

Colonial Waterbird Species found Nesting on Dredged Material Islands in Seven Regions of the Corps-Maintained Waterways

Species	Regions[2]					
	TX	FL	NC	NJ	GL	PNW
White pelican	X					
Brown pelican	X	X	X			
Double-crested cormorant		X	X			
Olivaceous cormorant	X					
Anhinga		X				
Great blue heron	X	X	X	X		X
Green heron	X	X	X	X		
Little blue heron	X	X	X	X		
Cattle egret	X	X	X	X	X	
Reddish egret	X	X				
Great egret	X	X	X	X		
Snowy egret	X	X	X	X		
Louisana heron	X	X	X	X		
Black-crowned night heron	X	X	X	X	X	
Yellow-crowned night heron	X	X	X	X		
White-faced ibis	X					
Glossy ibis	X	X	X	X		
White ibis	X	X	X			
Roseate spoonbill	X	X				
Glaucous-winged gull						X
Great black-backed gull			X	X		
Herring gull			X	X	X	
Western gull					X	
Ring-billed gull					X	X
Laughing gull	X	X	X	X		
Gull-billed tern	X	X	X	X		
Forster's tern	X		X	X	X	
Common tern		X	X	X	X	X
Roseate tern		X	X	X		
Least tern	X	X	X	X		
Royal tern	X	X	X			
Sandwich tern	X	X	X			
Caspian tern	X	X	X		X	X
Black tern					X	X
Black skimmer	X	X	X	X		

Soots, R. F. & Landin, M., 1978

Table 2

List of Species Which Are Year-round Residents of the Hereford Inlet System

Conger oceanicus	conger eel
Anguilla rostrata	American eel
Brevoortia tyrannus	Atlantic menhaden
Anchoa mitchilli	bay anchovy
Opsanus tau	oyster toadfish
Urophycis regius	spotted hake
Cyprinodon variegatus	sheepshead minnow
Fundulus heteroclitus	mummichog
Fundulus majalis	striped killifish
Lucania parva	rainwater killifish
Menidia menidia	Atlantic silverside
Menidia beryllina	tidewater silverside
Tautoga onitus	tautog
Tautogolabrus adspersus	cunner
Gobiosoma ginsbergi	seaboard goby
Gobiosoma bosci	naked goby
Myoxocephalus aeneus	grubby
Ammodytes americanus	sand lance
Scophthalmus aquosus	windowpane
Pseudopleuronectes americanus	winter flounder
Gasterosteus aculeatus	threespine stickleback
Apeltes quadracus	fourspine stickleback
Syngnathus fuscus	northern pipefish

Allen et al., 1978

Table 3

List of Species Which Reproduce Within the Hereford Inlet System

Mustelus canis	smooth dogfish
Brevoortia tyrannus	Atlantic menhaden
Anchoa hepsetus	striped anchovy
Anchoa mitchilli	bay anchovy
Opsanus tau	oyster toadfish
Rissola marginata	striped cusk-eel
Cyprinodon variegatus	sheepshead minnow
Fundulus heteroclitus	mummichog
Fundulus majalis	striped killifish
Lucania parva	rainwater killifish
Menidia menidia	Atlantic silverside
Menidia beryllina	tidewater silverside
Gasterosteus aculeatus	threespine stickleback
Apeltes quadracus	fourspine stickleback
Sygnathus fuscus	northern pipefish
Hippocampus erectus	lined seahorse
Bairdiella chrysura	silver perch
Cynoscion regalis	weakfish
Menticirrhus saxatilis	northern kingfish
Tautoga onitus	tautog
Tautogolabrus adspersus	cunner
Gobiosoma ginsbergi	seaboard goby
Gobiosoma bosci	naked goby
Prionotus carolinus	northern searobin
Prionotus evolans	striped searobin
Etropus microstomus	smallmouth flounder
Scophthalmus aquosus	windowpane
Pseudopleuronectes americanus	winter flounder

Allen et al., 1978

Table 4

Summary of Ecological Data for Species Collected in the Hereford Inlet Estuary

Common name	Seasonal Occurrence: Spring	Summer	Fall	Winter	Annual Occurrence: 73	74	75	76	77	Geographic Distribution: Boreal	Temp.	Tropical	Occurrence in Sampling Gear: Seine	Trawl	Trap	G. Net	Sled	Plk. Net	Hk & line
smooth dogfish	x	x	x		x	x	x	x	x		x	x	x	x		x			x
roughtail stingray		x				x			x		x	x		x					x
bluntnose stingray		x	x		x	x	x		x		x	x	x	x					x
spiny butterfly ray		x			x						x	x		x					x
smooth butterfly ray		x							x		x	x		x					x
bullnose ray		x			x							x		x					
winter skate	x					x	x			x	x			x					x
little skate	x								x	x	x			x					x
clearnose skate		x							x		x	x		x		x			
conger eel	x	x	x	x		x	x	x			x			x			x		x
American eel	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
American shad	x			x			x	x	x	x	x	x		x					
blueback herring	x	x		x				x	x		x	x	x	x					
alewife	x	x		x		x	x	x	x	x	x		x	x		x			
Atlantic herring	x	x				x	x		x	x	x		x			x			
Atlantic menhaden	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	
striped anchovy		x	x		x	x	x	x	x		x	x	x	x				x	
bay anchovy	x	x	x	x	x	x	x	x	x		x	x	x	x			x	x	
inshore lizardfish		x	x		x	x	x	x	x		x	x	x	x					
oyster toadfish	x	x	x	x	x	x	x	x	x		x	x	x	x	x				x
pollack	x	x		x		x	x	x		x	x		x	x					
spotted hake	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x
red hake		x	x	x	x			x	x	x	x			x			x	x	x
white hake		x	x			x		x		x	x		x	x					
Atlantic cod	x				x					x	x							x	
silver hake			x	x					x	x	x			x			x		
striped cuskeel	x	x	x		x		x	x	x		x	x	x	x			x	x	
Atlantic needlefish		x	x		x	x	x	x	x		x	x	x						

Allen et al., 1978

Frequency of Occurrence in Collections	Habitat Type: Shore	Channels	Marsh	Obstructions	Shallow coastal	Life Stage Present: Egg	Larvae	Juvenile	Adult	Spawning Activity: Yes	No	Nursery Ground: Yes	No	Major Foods: Plant	Polychaetes	Mollusks	Crustacea	Fishes
3%	X	X			X			X	X	X		X				X	X	
<1%	X	X			X			X	X		X	X				X		
1%	X	X			X				X		X					X	X	
<1%	X				X				X		X		X				X	
<1%	X				X				X		X		X				X	
<1%		X							X		X		X					
<1%		X			X				X		X		X		X	X	X	
<1%		X			X				X		X		X		X	X	X	
<1%		X			X				X		X		X					
<1%		X		X	X		X	X			X	X				X	X	X
3%	X	X	X	X	X			X	X		X	X				X	X	
<1%		X			X			X			X	X				X		
<1%	X	X			X			X			X	X				X		
1%	X	X			X			X	X		X	X				X		
1%	X	X			X			X	X		X	X				X		
6%	X	X	X		X	X	X	X	X	X		X		X		X		
3%	X	X			X	X	X	X	X	X		X				X		
19%	X	X	X		X	X	X	X	X	X		X				X		
3%	X	X			X		X	X	X		X	X				X	X	X
6%	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X
1%	X	X		X	X			X			X	X					X	
.5%	X	X		X	X	X	X	X	X	X		X					X	
1%		X		X	X		X	X			X	X			X		X	X
1%	X	X			X			X			X	X			X		X	X
<1%		X			X		X				X		X					
<1%		X			X			X			X	X					X	X
2%	X	X			X		X	X	X	X		X					X	
1%	X							X	X	X		X						X

cont.

Summary of ecological data for species collected in the Hereford Inlet Estuary

Common name	Seasonal Occurrence: Spring	Summer	Fall	Winter	Annual Occurrence: 73	74	75	76	77	Geographic Distribution: Boreal	Temp.	Tropical	Occurrence in Sampling Gear: Seine	Trawl	Trap	G. Net	Sled	Plk. Net	Hk & line
sheepshead minnow	x	x	x	x	x	x	x	x	x		x	x	x	x	x				
mummichog	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	
striped killifish	x	x	x	x	x	x	x	x	x		x	x	x	x	x				
rainwater killifish	x	x	x	x	x	x	x	x	x		x	x	x						
spotfin killifish		x					x				x		x						
halfbeak		x							x		x	x	x						
Atlantic silverside	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	
tidewater silverside	x	x	x	x	x	x	x	x	x		x		x	x					
rough silverside			x						x		x	x	x						
threespine stickleback	x	x		x	x	x	x	x	x	x	x		x	x			x	x	
fourspine stickleback	x	x		x	x	x		x	x		x		x	x			x		
bluespotted cornetfish		x	x		x	x	x	x	x			x	x	x					
northern pipefish	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	
lined seahorse	x	x	x		x	x	x	x			x		x	x			x	x	
white perch	x		x		x				x	x	x		x	x	x			x	
striped bass		x							x	x	x	x	x					x	
gag		x				x						x	x	x	x				
black sea bass	x	x	x		x	x	x	x	x		x		x	x	x		x	x	x
snowy grouper		x					x					x							x
cobia		x					x				x	x	x	x					
bluefish	x	x	x		x	x	x	x	x		x	x	x	x		x			x
short bigeye		x	x			x		x				x	x	x					
Atlantic moonfish		x			x	x						x		x					
Florida pompano		x						x				x	x						
crevalle jack		x	x				x	x				x	x						x
horseeye jack		x					x					x	x						
bigeye scad		x						x				x	x						
rough scad		x			x							x	x						

(next group is continuous with the last one)

Frequency of Occurrence in Collections	Habitat Type: Shore	Channels	Marsh	Obstructions	Shallow coastal	Life Stage Present: Egg	Larvae	Juvenile	Adult	Spawning Activity: Yes	No	Nursery Ground: Yes	No	Major Foods: Plant	Polychaetes	Mollusks	Crustacea	Fishes
28%	x	x	x			x	x	x	x	x		x		x			x	
35%	x	x	x			x	x	x	x	x		x		x	x	x	x	x
30%	x	x	x			x	x	x	x	x		x			x	x	x	
9%	x	x	x			x	x	x	x	x		x					x	
<1%	x		x						x									
<1%	x							x	x		x		x					
47%	x	x	x			x	x	x	x	x		x			x		x	
14%	x		x			x	x	x	x	x		x		x			x	
<1%	x								x		x		x					
3%	x	x	x				x	x	x	x		x					x	
2%	x	x	x				x	x	x	x		x					x	
1%	x	x						x	x		x		x				x	x
13%	x	x	x	x	x		x	x	x	x		x					x	
4%		x			x		x	x	x	x		x					x	
< 1%	x	x						x	x		x	x					x	x
< 1%	x	x		x	x			x	x		x	x			x		x	x
< 1%	x	x		x				x			x		x					
15%	x	x		x	x		x	x	x		x	x			x	x	x	x
<1%		x						x			x		x					
<1%	x	x						x			x		x				x	x
14%	x	x	x		x		x	x	x		x	x					x	x
<1%	x	x		x				x			x		x					
<1%		x						x			x		x					
<1%	x							x			x		x					
<1%	x			x	x			x			x		x					
<1%	x							x			x		x					
<1%	x				x			x			x		x					
<1%	x							x			x		x					

cont.

Summary of ecological data for species collected in the Hereford Inlet Estuary

Common name	Seasonal Occurrence: Spring	Summer	Fall	Winter	Annual Occurrence: 73	74	75	76	77	Geographic Distribution: Boreal	Temp.	Tropical	Occurrence in Sampling Gear: Seine	Trawl	Trap	G. Net	Sled	Plk. Net	Hk & line
pilot fish		x					x				x	x	x						
blue runner		x			x				x			x	x						
banded rudderfish		x	x			x	x	x				x	x	x					x
permit		x				x	x					x	x						
lookdown		x	x			x	x	x	x			x	x	x					
African pompano		x							x			x	x						
dolphin		x			x							x	x						
pinfish		x	x		x	x	x	x				x	x	x					
scup		x	x		x	x	x	x		x	x		x	x					x
spotted seatrout			x			x	x	x	x			x							x
Atlantic croaker			x					x	x		x	x	x	x		x			x
silver perch		x	x		x	x		x	x		x	x	x	x				x	
weakfish	x	x	x		x	x	x	x	x		x	x	x	x		x	x	x	x
spot	x	x	x		x	x	x	x	x		x	x	x	x	x	x	x	x	x
northern kingfish		x	x		x	x	x	x	x		x		x	x			x	x	x
gray snapper		x	x				x					x	x		x				
tautog	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x
cunner	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x
striped mullet	x	x	x		x	x	x	x	x		x	x	x					x	
white mullet	x	x	x		x	x	x	x	x		x	x	x						
northern sennet		x	x		x	x	x	x	x		x	x	x	x					
seaboard goby	x	x	x	x	x	x	x	x	x		x		x	x			x	x	
naked goby	x	x	x	x	x	x	x	x	x		x	x	x	x	x		x	x	
grubby	x	x	x			x		x		x	x		x	x				x	
spotfin butterflyfish		x	x				x	x				x	x	x					
northern stargazer	x	x	x		x	x			x		x		x	x					x

Frequency of Occurrence in Collections	Habitat Type: Shore	Habitat Type: Channels	Habitat Type: Marsh	Habitat Type: Obstructions	Habitat Type: Shallow coastal	Life Stage Present: Egg	Life Stage Present: Larvae	Life Stage Present: Juvenile	Life Stage Present: Adult	Spawning Activity: Yes	Spawning Activity: No	Nursery Ground: Yes	Nursery Ground: No	Major Foods: Plant	Major Foods: Polychaetes	Major Foods: Mollusks	Major Foods: Crustacea	Major Foods: Fishes
<1%	x				x			x			x		x					
<1%	x				x			x			x		x					
<1%	x			x	x			x			x		x					
<1%	x							x			x		x					
<1%	x							x			x		x					
<1%	x							x			x		x					
<1%	x						x				x		x					
1%	x	x									x	x		x	x		x	
3%	x	x		x	x						x	x			x	x	x	x
<1%	x				x				x		x		x				x	x
<1%	x	x			x			x	x	x		x			x	x	x	
2%	x	x			x	x	x	x	x	x		x					x	
5%	x	x			x	x	x	x	x	x		x					x	x
25%	x	x	x		x			x	x		x	x		x	x	x	x	
5%	x	x			x	x	x	x	x	x		x			x		x	
<1%	x							x			x		x				x	
5%	x	x		x	x	x	x	x	x	x		x			x	x	x	
4%	x	x		x	x	x	x	x	x	x		x			x		x	
5%	x		x					x	x		x	x		x				
11%	x		x					x	x		x	x		x				
3%	x		x					x			x	x					x	x
<1%	x	x	x			x	x	x	x	x		x					x	
1%	x	x	x			x	x	x	x	x		x			x		x	x
1%	x	x		x				x		x		x			x		x	x
<1%	x	x		x				x			x		x				x	
<1%	x	x			x			x			x		x				x	x

cont.

Summary of ecological data for species collected in the Hereford Inlet Estuary

Common name	Seasonal Occurrence Spring	Summer	Fall	Winter	Annual Occurrence 73	74	75	76	77	Geographic Distribution Boreal	Temp.	Tropical	Occurrence in Sampling Gear Seine	Trawl	Trap	G. Net	Sled	Plk. Net	Hk & line
butterfish		x	x		x	x	x	x	x	x	x	x	x	x		x	x	x	
northern searobin	x	x	x		x	x	x	x	x	x	x		x	x			x	x	x
striped searobin	x	x	x		x	x	x	x	x	x	x		x	x		x	x	x	x
flying gurnard		x	x		x		x		x			x	x	x					
American sand lance	x	x	x	x	x	x	x	x	x	x	x		x	x			x	x	
smallmouth flounder	x	x	x		x	x	x	x	x		x		x	x			x	x	
summer flounder	x	x	x		x	x	x	x	x		x		x	x		x	x	x	x
windowpane	x	x	x	x	x	x	x	x	x		x		x	x			x	x	x
winter flounder	x	x	x	x	x	x	x	x	x	x	x		x	x			x	x	x
hogchoker		x			x	x					x	x						x	
blackcheek tonguefish		x	x				x	x			x	x					x		
gray triggerfish		x						x				x							x
orange filefish		x	x		x		x	x	x		x	x	x	x					
planehead filefish		x	x		x	x	x	x			x	x	x	x			x		
striped burrfish		x	x		x							x	x	x					
smooth puffer		x	x			x	x	x				x		x					
northern puffer		x	x		x	x	x	x	x		x		x	x					x
smooth trunkfish		x	x			x	x					x	x	x					
crested blenny		x				x						x		x					
feather blenny		x	x		x	x	x	x				x	x	x			x		
barbfish			x			x						x		x					
scorpionfish			x			x						x		x					

Frequency of Occurrence in Collections	Habitat Type: Shore	Channels	Marsh	Obstructions	Shallow coastal	Life Stage Present: Egg	Larvae	Juvenile	Adult	Spawning Activity: Yes	No	Nursery Ground: Yes	No	Major Foods: Plant	Polychaetes	Mollusks	Crustacea	Fishes
2%	x	x			x		x	x	x		x	x					x	
8%	x	x			x	x	x	x	x	x		x					x	x
4%	x	x			x	x	x	x	x	x		x					x	x
<1%	x	x						x	x		x		x					
2%	x	x			x		x	x	x		x	x					x	
14%	x	x			x	x	x	x	x	x		x					x	
12%	x	x			x		x	x	x		x	x					x	x
12%	x	x			x	x	x	x	x	x		x					x	
12%	x	x			x	x	x	x	x	x		x			x	x		
<1%	x	x				x	x				x		x					
<1%		x			x		x				x		x					
<1%	x	x		x	x				x		x		x					
<1%	x	x		x	x			x	x		x	x		x			x	
2%	x	x		x	x			x	x		x	x			x		x	
<1%	x	x			x			x	x		x		x					
<1%	x	x						x					x					
1%	x	x			x		x	x	x	x		x			x		x	x
<1%	x	x					x				x		x					
<1%		x						x										
1%	x	x					x	x	x			x					x	
<1%		x						x			x		x					
<1%		x						x			x		x					

Table 5

Summary of Atlantic Coast Piping Plover Population Estimate
1986 to 1994

STATE/REGION	PAIRS								
	1986	1987	1988	1989	1990	1991	1992	1993	1994
Maine	15	12	20	16	17	18	24	32	35
Massachusetts	139	126	134	137	139	160	213	289	352
Rhode Island	10	17	19	19	28	26	20	31	32
Connecticut	20	24	27	34	43	36	40	24	30
NEW ENGLAND	184	179	200	206	227	240	297	376	449
New York	106[1]	135[1]	168[1]	191	186	191	187	192	209
New Jersey	102[2]	93[2]	105[2]	128	126	126	134	127	124
NY-NJ REGION	208	228	273	319	312	317	321	319	333
Delaware	8	7	3	3	6	5	2	2	4
Maryland	17	23	25	20	14	17	24	19	32
Virginia	100	100	103	121	125	131	97	106	96
North Carolina	30[3]	30[3]	40[3]	55	55	40	49	53	54
South Carolina	3	-	-	-	-	1	-	-	-
SOUTHERN REGION	158	160	171	199	200	194	172	180	186
U.S. TOTAL	550	567	644	724	739	751	790	875	968
ATLANTIC CANADA	240	223	238	233	229	236	236[4]	236[4]	182
ATLANTIC COAST	790	790	882	957	968	987	1026	1111	1150

1 The recovery team believes that this estimate reflects incomplete survey effort. See discussion on page 22.

2 The New Jersey plover coordinator conjectures that one quarter to one third of the apparent population increase between 1986 and 1989 is due to increased survey effort.

3 The recovery team believes that the apparent 1986-1989 increase in the North Carolina population is due to intensified survey effort. See discussion on page 22. No actual surveys were made in 1987; estimate is that from 1986.

4 1991 estimate.

U.S. Fish and Wildlife Service, 1995

Chapter Five

SUMMARY AND CONCLUSIONS

Summary

There are four dredged material islands located on Gull Island, in Stone Harbor, New Jersey. No plan exists to establish or maintain habitats on these islands.

This study examined this group of islands, and developed a plan to enhance them for habitat use by black skimmers, diamondback terrapins, least terns, and piping plovers.

A baseline survey was conducted on these sites to establish data concerning composition and inhabitants. Extensive research was done on the habitat needs of the target species, and beneficial uses of dredged material for habitat enhancement and creation.

Conclusions

The author concluded that Gull Island is a feasible site to enhance for habitat use by black skimmers, diamondback terrapins, least terns, and piping plovers. By engineering and maintaining the islands in terms of size, shape, elevation, substrate, and vegetation, desirable habitat can be obtained. This project will simultaneously satisfy the need to dispose of dredged material.

The final plan, which is a compilation of recommendations, is based on the author's judgments after reviewing all collected data and research.

The four small islands should be connected with dredged material to form one gently sloping island, which will be approximately six acres in size. This will allow for construction of some expansive beach areas, as well as higher dune areas.

The overall elevation should be about 3 m, which is high enough to deter rapid vegetation encroachment, but low enough to prevent excessive blowing sands. This elevation will also accommodate the target species' needs to nest above the mean high tide line, under normal conditions.

In comparing and contrasting habitat needs of the target species, two common denominators were a fragmentary substrate and sparse vegetation. The recommendation for substrate in this project is sand with a high percentage of shells, broken shells, and/or pebbles. No vegetation is to be planted; allow for natural colonization to occur. Natural colonization is defined as "the process in which plant materials grow naturally" (Soil Conservation Service, 1992, p. 13-45). This will require the availability of plant propagules, which will be supplied by the dredged material, as well as the wind, which will carry seeds from nearby colonized areas.

The previously established vegetation on the island, which is predominantly common reed, should be eliminated by smothering with dredged material, spraying with Rodeo, and burning.

Altering this island, in terms of vegetation, should, in turn, eliminate predators. If herring gulls continue to pose a threat to the new island, exclusion wires should be erected. When the Norway rats return, they should be trapped off the island immediately.

This project should be monitored for colonization of vegetation and wildlife, predators, and erosion. Maintenance will be necessary for long term success.

Connecting the four islands will require a large amount of dredged material. Creating this habitat will allow for on-going use of this area as a disposal site. Once the four islands are connected, continued additions may be a useful management tool.

In any dredging project, some negative environmental impacts are inevitable. The author concluded that the potential long term positive effects of this project on the target species, outweigh the potential adverse effects on the aquatic benthic organisms.

Recommendations for Further Research

1. Development of a maintenance plan for this project is needed. The plan should include monitoring for vegetation and wildlife species colonization, utilization, abundance, and

diversity. Also, stability of substrates should be monitored, as well as maintenance of elevation. Records should be kept on how much island drift and configuration changes have occurred. Such a maintenance plan is needed to provide justification to public agencies, such as the Army Corps of Engineers, for spending future funds on maintaining such islands.

2. Presently, knowledge of bird utilization of dredged material islands is based primarily on empirical observations of existing islands. More baseline data are needed.

3. The eggs of least terns and piping plovers, in some areas, have been found to have high levels of selenium in them. Selenium, which can be found in marsh mud, so resembles sulfur that it often goes unnoticed. It is essential to healthy growth, but in tiny amounts. By increasing amounts just slightly, it becomes 5 - 10 times more potent than arsenic. Experts who have studied the toxicity of heavy metals and trace elements, say selenium has the narrowest range between safety and danger. It is yet one of the least understood of all toxic elements.

4. The public needs to be educated on the vulnerability of colonial nesting birds. Various public affairs channels can be used to make the public aware of the value of dredged material islands to colonial birds. Positive public opinions

regarding disposal operations may improve public understanding and acceptance of such projects.

It is hoped that this plan will be carried out, and that monitoring efforts are made, and maintenance needs are addressed. The success of this project could not only benefit the target species on Gull Island, but could also have a significant influence on future attempts to create and enhance habitats for various species that are running out of time, as well as space.

REFERENCES

Allen, D. M., Clymer, J. P., & Herman, S. S. (1978). Fishes of the Hereford Inlet Estuary. Southern New Jersey: Lehigh University, Department of Biology and Center for Marine and Environmental Studies; and The Wetlands Institute.

Burger, J. & Gochfeld, M. (1992, June). Terns for the better. Natural History.

Carney, L. (1995, November 16). Terrapins are taking a beating. The Atlantic City Press, XCV.

Carreker, R. G. (1985). Habitat suitability index model: Least tern. (Biological Report 82). Fish and Wildlife Service. Washington, DC: US Department of the Interior.

Clark, J. P. (1980). Proceedings from the 9th vertebrate pest conference. Fresno, CA: University of CA.

Ehrlich, P. R., Dobkin, D. S., & Wheye, D. (1988). A field guide to the natural history of North American birds. New York: Simon and Shuster.

Flexner, S. B. (1993). Random house unabridged dictionary. (2nd edition). New York: Random House.

Fowler, J. & Sprague, C. J. (1993). Coastal zone '93. Proceedings of the 8th Symposium on Coastal and Ocean Management. Vicksburg, MS.

Gochfeld, M. & Burger, J. (1994). Black Skimmer. The Birds of North America. (No. 108). Philadelphia: The Academy of Natural Sciences; the American Ornithologists' Union.

Harding, J. J. (1986). Marsh, meadow, mountain: Natural places of the Delaware valley. Philadelphia: Temple University Press.

Harris, T. (1991). Death in the marsh. Washington, D. C.: Island Press.

Hatch, H. J. (1987). Keynote address: Regional conference on the beneficial uses of dredged material. Baltimore, MD.

Hayes, D. F. & Palermo, M. R. (1992). Engineering aspects of wetland design. Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Helmers, D.L. (1992). Shorebird management manual. Manomet, MA.: Wetlands for the Americas.

Hitchcock, S. W. (1972, June). Can we save our salt marshes? National Geographic, pp. 729-765.

Hunt, L. J. & Landin, M. C. (1978). Upland habitat development with dredged material: Engineering and plant propagation. (Technical Report DS-78-17). Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Jesuncosky, B. J. (1987). 4H marine science project. Rutgers University, NJ.

Jones, C. (1993). An evaluation of 11 freshwater wetland creation projects in New Jersey. Unpublished M.A. thesis, Rowan College of New Jersey.

Kane P. F., Rosselet, D. A., & Anderson K. (1992). Bridges to the natural world. Franklin Lakes, NJ: New Jersey Audubon Society.

Klem, D. J. & Master, T. L. (1992). Environmental study of Sturgeon Island. (Final Report). Submitted to the Wetlands Institute for 1992 Summer Research Grant: East Stroudsburg University.

Kotliar, N. B. & Burger, J. (1986). Colony site selection and abandonment by least terns (*Sterna antillarum*) in New Jersey, USA. Department of Biological Sciences, Rutgers University, NJ. Great Britain: Elsevier Applied Science Publishers.

Kress, S. W. (1981). The Audubon Society handbook for birders. New York: Charles Scribner's Sons.

Landin, M. C. (1992a). Achieving success in wetland restoration, protection, and creation projects. Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Landin, M. C. (1987). Beneficial uses of dredged material. Proceedings of the North Atlantic Regional Conference. US Army Corps of Engineers. Baltimore, MD.

Landin, M. C. (1992b). Concept, history, and examples of beneficial uses of dredged material. Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Landin M. C. (1994). Dredged material: A recognized resource. Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Landin, M. C. (1992c). Need, construction, and management of dredged material islands for wildlife. Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Line, L., Garrett, K., & Kaufman, K. (1987). The Audubon Society book of waterbirds. New York: Chanticleer Press, Inc.

Line, L. & Russel, F. (1976). The Audubon Society book of wild birds. New York: Chanticleer Press, Inc.

Martin, A. C. (1987). Golden guide: Weeds. New York: Golden Press.

Master, T. L., Klem, D. J., Sanders, G., & Cooper, T. (1993). Herring gull nest predation investigation: Sturgeon Island. The Wetlands Institute, Stone Harbor NJ: author.

Miller, G. T. (1995). Environmental science: Working with the earth. Belmont, CA: International Thomson Publishing.

Niering, W.A. (1966). The life of the marsh. New York: McGraw Hill Book Co.

Palmer, W.M. & Cordes, C.L. (1988). Habitat suitability index model: Diamondback terrapin. (Biological Report 82). U.S. Fish and Wildlife Service. Washington, DC: U.S. Department of the Interior.

Public Service Electric & Gas Co. (1995). Commercial Township salt hay farm wetland restoration management plan. Cumberland County, NJ. Unpublished manuscript.

Richards, A. (1988). Shorebirds: A complete guide to their behavior and migration. New York: Gallery Books.

Solomon, V. E. (1986). Gulls: Damage prevention and control methods. Ontario, Canada: Thurlow & Associates Environmental Control Consultants.

Soots, R. F. & Landin, M. C. (1978). Development and management of avian habitat on dredged material islands. (Technical Report DS-78-18). Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Soper, T. (1989). Oceans of birds. London: David and Charles Publishers.

Stone, L. M. (1989). Ecozones: Wetlands. Vero Beach: Rourke Enterprises Inc.

Teal, J. & Teal, M. (1969). Life and death of the salt marsh. Boston: Little Brown and Co.

United States Army Corps of Engineers. (1994). Detailed project report and environmental report: Bodkin Island. (Section 204). MD._Unpublished manuscript.

United States Army Corps of Engineers. (1995). Dredging is for the birds. Belvoir, VA.

United States Army Corps of Engineers. (1997). Ecosystem restoration in the civil works program. Washington, DC: Water Resources Policies and Authorities.

United States Department of Agriculture. (1992). Wetland restoration, enhancement, or creation. In Soil Conservation Service (Ed.). Engineering field handbook. Unpublished manuscript.

United States Fish and Wildlife Service. (1995a). Black skimmer facts. Barnegat, NJ: US Department of the Interior.

United States Fish and Wildlife Service. (1990). Piping plover management for the 1990's. Unpublished manuscript.

United States Fish and Wildlife Service. (1995b). Piping plover revised recovery plan. (Atlantic coast population). Hadley, MA: author.

Western Regional Environmental Education Council. (1983). Project wild. Boulder, CO.

Wetlands Institute. (1991). Saltmarsh turtles of the New Jersey coast. Stone harbor, New Jersey. Unpublished manuscript.

Wetlands Institute. (1994). Turtle talk. Stone Harbor, New Jersey. Unpublished manuscript.

Wilson, S. (1981, June). A day in the life of a marsh. National Geographic. Washington, DC: pp. 154-162.

Wood, R. C. (1995a, July). Diamondback terrapin. pp. 299-304. Living Resources of the Delaware Estuary. Delaware Estuary Program.

Wood, R. C. (1995b). Terrapins, tires and traps. New Jersey Outdoors, pp. 16-19.

Wood, R. C. (1994). Turtles and tires: The impact of road kills on northern diamondback terrapin populations on the Cape May peninsula. Southern NJ.