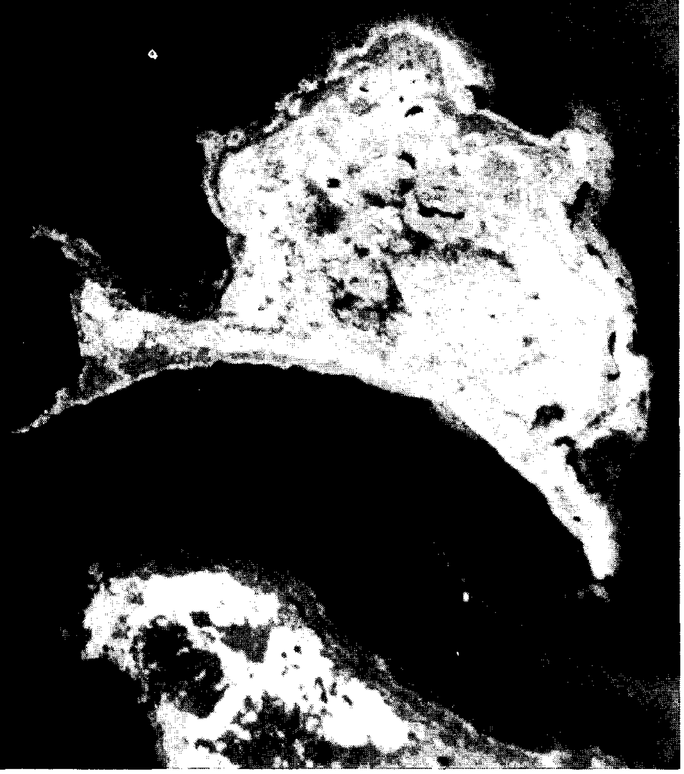
ANALYSIS AND DELINEATION OF THE SUBMERGED VEGETATION OF COASTAL NEW JERSEY:

A Case Study of Little Egg Harbor



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EXECUTIVE SUMMARY

The submerged vegetation of a portion of New Jersey's coastal waters was investigated by personnel from the Center for Coastal and Environmental Studies at Rutgers - The State University of New Jersey during the period Spetember 1977 - January 1978. The project, designed in cooperation with the New Jersey Office of Coastal Zone Management, N.J. Department of Environmental Protection, had as its goals the identification and delineation of submerged vegetation in the Little Egg Harbor estuary of New Jersey. Remote sensing was to be utilized in attempting to delimit the important submerged macrophytes. In addition, the functions these species play in the estuarine ecosystem were to be described.

Field sampling revealed that the study area had extensive beds of eelgrass (Zostera marina) and lesser amounts of widgeon grass (Ruppia maritima). Significant amounts of algal species important in other New Jersey coastal bays (sea lettuce, Ulva lactuca; spaghetti grass, Codium fragile; and a red alga, Gracilaria) were absent from Little Egg Harbor.

This study demonstrated that the distribution of submerged vegetation in Little Egg Harbor could be determined through remote sensing. After some experimentation, the film/filter combination of Kodak Ektachrome with a Wratten No. 4 or No. 8 filter is recommended along with certain environmental constraints. Results of the delineation from the aerial photographs are shown on Figure 11.

A survey of the literature revealed that major functions of eelgrass beds include: their role in grazing and detrital food chains; creation of habitat for epiphytes, epifauna, finfish and shellfish; participation in nutrient cycles; and stabilization of sediments. Although eelgrass beds are viewed as an important contributor to the normal functioning and health of estuarine ecosystems, such beds have not been stable in the past due to disease episodes and environmental factors.

It is anticipated that a variety of human activities associated with coastal development are potentially harmful to submerged vegetation. These include thermal discharge, sewage pollution, and dredging. Suitable habitat for the dominant vegetation, eelgrass, is largely confined to shallow waters which might be especially vulnerable to human influence. The interaction of all these factors should be carefully considered in dealing with this valuable coastal resource.

1.0 INTRODUCTION

1.1 Purpose

The estuarine waters of New Jersey, together with their associated salt marshes, constitute a highly productive ecosystem of considerable importance to coastal fisheries, wildlife, shore protection and recreation. The relationships between the estuarine waters and the adjacent terrestrial systems with which they may exchange materials are only understood in gross terms. Considerable effort has already been expended in determining the role of portions of the salt marshes along the New Jersey coast. Aspects studied have included mapping major community types, determination of aboveground and belowground production, determination of caloric content and chemical composition and some studies on decomposition. Complementary studies on the beds of submerged vegetation of the adjacent shallow coastal waters are lacking although these beds have been cited as functioning as sediment traps, as absorbing wave energy, supplying forage for waterfowl and shelter for fishes and crustaceans, and as contributing to fishery resources primarily via detrital food webs. It is the purpose of this project to initiate a study of the submerged vegetation to begin to fill a serious gap in knowledge of the estuarine system so that the functioning of the system can be better understood and managed.

The major objectives of this project are:

1. to develop methods for an accurate and efficient aerial survey of submerged vegetation;

2. to provide a 1:24000 scale map depicting areas of submerged vegetation equal to or greater than 2 hectares in a pilot study area;

3. to discuss the ecological and economic values of the submerged vegetation of coastal New Jersey.

Development of an aerial survey method was particularly desirable since the high turbidity of New Jersey coastal waters makes visual location of much of the submerged vegetation from direct surface observation very time consuming and therefore costly. The feasibility of delimiting submerged vegetation through the application of remote sensing methods, as verified with ground truth information, has been well documented (Orth and Gordon, 1975; Seher and Tueller, 1973). For purposes of this study, experimentation was conducted with aerial photographic techniques. The procedure consisted of conducting tests on film/filter combinations and on different exposure levels so as to enhance the resultant photographic images. Aerial photography has several distinct advantages that are applicable to this mapping problem.

1. Film/filter combinations can reduce the photographic recording of scatter in the short wavelength region of the visible spectrum and thus enhance image definition.

2. Information is gathered on an areal data base and is in a mapping mode; point data from field measurements can be extended through the areal matrix.

3. Aerial observation provides increased water penetration and improved resolution of submerged vegetation details as compared to that which is possible from the water surface.

4. The photographic image is a permanent record of the areal distribution of surface phenomena.

5. The film/filter appraoch is also favored because of economic considerations and the limited study period.

The aerial photography will yield data on submerged vegetation which will be useful to a number of offices within NJDEP including the Division of Marine Services, the Division of Fish, Game and Shellfisheries, Office of Coastal Zone Management, Office of Wetlands Management and Office of Riparian Lands Management, as well as county and federal agencies.

The data from the photograph will be mapped at a scale of 1:24000 so as to be compatible with U.S. Geological Survey (U.S.G.S.) 7½ minute topographic quadrangles and other map resources which are available to the regulatory agencies.

1.2 Study Area

Little Egg Harbor (Fig. 1) was chosen as a study site for submerged vegetation because of its proximity to the intensively studied Manahawkin salt marsh ecosystem and the existence of some data on the distribution of submerged vegetation from previous studies of NJDEP (W. Shoemaker, personal communication). A second study area (Fig. 1), Lakes Bay, was chosen to include more species in the pilot study because submerged vegetation at Little Egg Harbor is dominated by *Zostera marina*. Lakes Bay was reported to support considerable quantities of *Ulva lactuca* (sea lettuce), common at other locations along the New Jersey coast, but virtually absent in Little Egg Harbor.

Little Egg Harbor, located at 39^{o} 15' north latitude, is midway between Sandy Hook to the north and Cape May Point to the south. It is part of the extensive bay ecosystem along this part of the New Jersey coast. These coastal bays are similar in that they lie just east of the mainland with its fringe of swamp forest grading into brackish and saltwater marshes and are bordered on the east by barrier islands. Little Egg Harbor encompasses an area of $\approx 75\ km^2$ of water surface.

The harbor supports important sport fishing and clamming industries. Pleasure boating, swimming, water skiing, and hunting occur in the area.

Little Egg Harbor is bordered by *Spartina alterniflora* dominated marshes to the west and by the residentially developed Long Beach Island to the east. Several freshwater

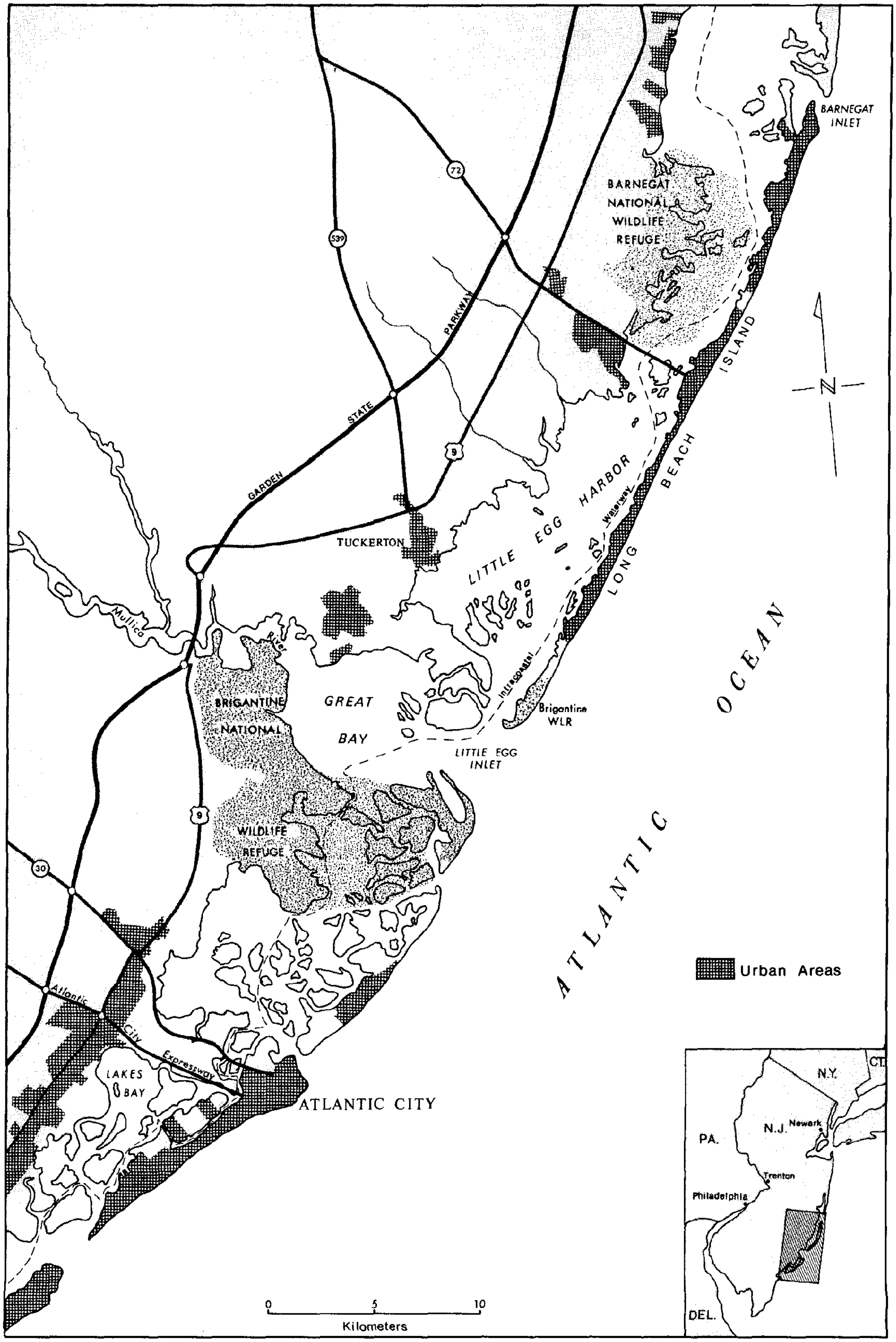


Fig. 1. Coastal New Jersey: Little Egg Harbor and Lakes Bay Areas.

creeks including Westecunk and Tuckerton Creeks drain into this bay along the western shore. Access to the ocean is provided through Barnegat Inlet to the north and Little Egg Inlet to the south. Tidal currents run in a north-south direction with tidal amplitudes ranging from 0.66 to 0.81 m (Thomas, et al., 1972). The mean depth of non-channel areas is 0.7 m (Nordstrom, et al., 1974). Depths are the greatest in the southwestern portion of the harbor and decrease northward. A dredged channel, the Intracoastal Waterway, traverses the eastern side of Little Egg Harbor.

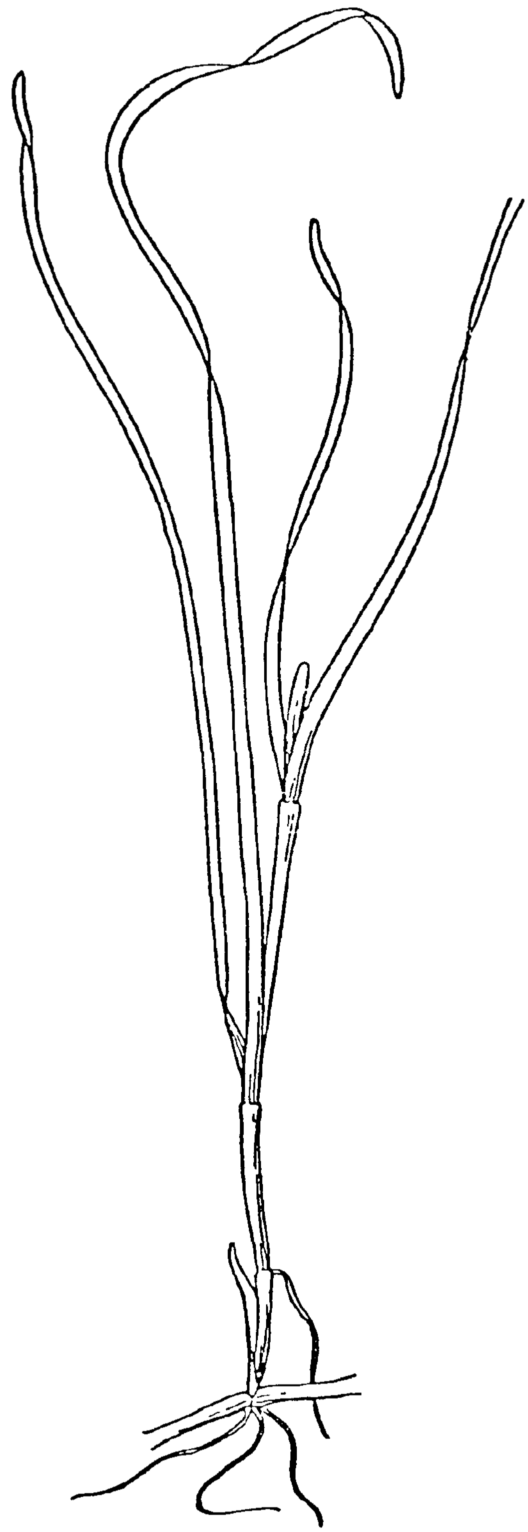
1.3 Submerged vegetation

Shallow marine waters throughout much of the world support beds of submerged vegetation often dominated by seagrasses which include about 50 species of monocots in two families, the Hydrocharitaceae and Potamogetonaceae. None of the seagrasses are true grasses. Most of the seagrasses are tropical, including all of the Hydrocharitaceae (Dawson, 1966). The most widely distributed seagrass in America, and the one of prime importance in New Jersey, is eelgrass, *Zostera marina*. Other species of submerged vegetation of importance in New Jersey waters include *Ruppia maritima* (widgeon grass) and macroscopic algae such as *Ulva lactuca*, *Codium fragile*, and *Gracilaria* sp.

1.3.1 *Zostera marina* (Fig. 2) eelgrass, occurs on the Pacific coast from Alaska to Mexico and on the Atlantic coast from Greenland to North Carolina. *Zostera marina* also occurs along the coasts of Europe, Asia Minor, and eastern Asia. Other *Zostera* species are found in South Africa, Australia, Tasmania, New Zealand, Japan, and Korea (Burkholder and Doheny, 1968). Although eelgrass survives a fairly wide range of water temperatures, a range of 5^{o} - $27^{o}C$ would include most of the areas where the plant is established and the optimum temperature range for growth is between 10^{o} - $20^{o}C$, (Phillips, 1974). Growth may be limited by heat rigor in summer and cold rigor in winter. Eelgrass in considered euryhaline and has been grown in the laboratory for considerable periods without obvious harm at salinity ranges of 10-40 o/oo (Tutin, 1938). Its natural depth of occurrence is associated with turbidity and the resultant effect on light penetration. For example, Ostenfeld (1908) found the maximum depth of eelgrass in Denmark to be 11 m in clear water and 5.4 m in turbid water whereas Cottam and Munro (1954) found dense eelgrass in 12-15 m in La Jolla Bay, California and patches to at least 30 m on the slopes of the La Jolla submarine canyon. In the turbid waters of South Oyster Bay, Long Island, eelgrass is not found below a depth of 1.8 to 2.4 m (Burkholder and Doheny, 1968). Upper limits on growth are determined by tidal exposure and desiccation (Tutin, 1942). The mean lower low water level is a typical upper limit in Puget Sound (Phillips, 1974).

Eelgrass has been reported from a wide variety of substrates from soft mud to gravel and coarse sand mixtures in

Ruppia maritima



Zostera marina

Fig. 2 . Representative seagrasses reproduced by permission of the Cooperative Extension Service , Cook College, Rutgers-The State University of New Jersey.

England (Tutin, 1938) and to sandy clay in the Black Sea (Caspers, 1957). Moderate currents appear to enhance eelgrass growth but the plants can not persist where wave shock is regular (Phillips, 1974).

Eelgrass extends its cover principally by vegetative rhizome growth rather than by seedlings (McRoy, 1968). In a denundation experiment in Puget Sound, Phillips (1974) found a littoral 1 square meter plot to contain 50 plants from rhizome growth and 5 seedlings while an identical sublittoral plot contained 5 plants from rhizome growth and no seedlings after 7 months of observation. Zostera meadows are perennial although the individual leafy shoot or turion is reported to be biennial (Setchell, 1929), breaking off after flowering the second year. In Puget Sound minimum biomass occurs in January and February with maximum biomass developing in June through September (Phillips, 1974). In Massachusetts, Conover (1958) reported the peak standing crop to occur in July with minimum in January and February.

Eelgrass beds have been cited as being of considerable significance to fish (Peterson, 1891) and other organisms. The beds may be important in at least several ways; as a direct food source via the grazing chain, indirectly as food via the detritus chain, as a substrate for epiphytes, and as providing cover and a protected habitat. Zostera is not utilized in fresh form by many organisms although some waterfowl are known to feed on it (Table 1). The detritus food chain is not well known and more difficult to assess. Zobell and Feltham (1942) stressed the importance of mud bacteria associated with eelgrass beds as the food source for marine invertebrates. The plant surface is also a substrate for bacteria, anemones, bryozoa, hydroids, isopods, protozoa, and small crabs. The larval stage of the bay scallop Pecten irradians attaches to the leaves for about a month (Davenport, 1903). Large numbers of fish are also typically associated with eelgrass beds although most do not feed directly on the plants.

Economic uses of eelgrass date back to early times (Burkholder and Doheny, 1968). Ancient village sites in Denmark give evidence of the burning of eelgrass in the production of salt and soda. Eelgrass has been used as a filling for mattresses and as a bedding for domestic animals. The plant also has been used as a packing and upholstering material and as a soil additive and mulch for gardens. Perhaps the most common use for eelgrass in modern times has been as an insulating material.

Much interest in eelgrass beds has been associated with the wasting disease which caused a very severe decline in Zostera vegetation along the North Atlantic coasts of the United States and Europe. A very sharp decline observed in the 1930's is the best documented but other declines in the North Atlantic were noted ln 1854, 1889, 1894, 1913, 1914, 1917, and 1920-1922 (Rasmussen, 1977). Diseased

Table 1. Waterfowl Known To Feed On Aquatic Plants (Bellrose, 1976)

	Eel-grass	Widgeon Grass	Sea Lettuce
Whistling swan (*Cygnus columbianus*)	-	+	-
Atlantic brant (*Branta bernicla hrota*)	x	x	x
American widgeon (*Anas americana*)	+	+	-
Gadwall (*Anas strepera*)	+	+	-
American green-winged teal (*Anas crecca carolinensis*)	-	+	-
Mallard (*Anas platyrhynchos platyrhynchos*)	+	+	-
Black duck (*Anas rubripes*)	x	x	-
Pintail (*Anas acuta acuta*)	-	+	-
Blue-winged teal (*Anas discors*)	-	+	-
Canvasback (*Aythya valisineria*)	+	+	-
Redhead (*Aythya americana*)	-	+	-
Greater scaup (*Aythya marila mariloides*)	+	-	+
Lesser scaup (*Aythya affinis*)	-	+	+
Black scoter (*Melanitta nigra americana*)	+	+	-
Surf scoter (*Melanitta perspicillata*)	+	+	-
Bufflehead (*Bucephala albeola*)	-	+	-
Ruddy duck (*Oxyura jamaicensis rubida*)	-	+	-

- \- Does not utilize
- \+ Does utilize
- x Utilizes extensively

plants yielded mycelia of *Ophiobolus halimus* and also contained a slime mold, *Labyrinthula macrocystis*. The role of these organisms in the disease and the possible contribution of other factors, especially unusually warm winter and summer temperatures, is discussed by Rasmussen (1977). Observed ecological consequences of this natural catastrophe serve to illustrate the significance of eelgrass beds. Following the wasting disease dramatic declines of waterfowl species directly dependent on eelgrass as a food source occurred in Europe (Bruijns and Tanis, 1955; Ranwell and Downing, 1959) and the United States (Moffitt and Cottam, 1941). Brant counts at a location along the New Jersey coast dropped from about 29,000 in the winter of 1927-28 to about 2300 in the winter of 1932-33 (Stone, 1937). Dexter (1944) reported declines in soft-shelled and razor clams, lobsters, and mud crabs whereas Milne and Milne (1951) reported reductions in cod, flounder, shellfish, scallops, and crabs. Stauffer (1937) reported a loss of one-third of the species characteristic of the eelgrass system in the Wood Hole, Massachusetts area. Interest in ecological consequences of *Zostera* decline in Scandanavia was lost when predicted catastrophic effects on coastal fisheries did not occur (Rasmussen, 1977). Comparisons of Danish invertebrates in eelgrass areas before and after the wasting disease show the disappearance of a number of species and the present day dominance by species not listed earlier (Rasmussen, 1977). Mechanical effects of eelgrass removal may also be very important. Eelgrass effectively stabilizes the bottom and reduces turbidity by reducing currents. Erosion may increase with eelgrass decline but effects are not always immediate because the dead rhizomes bind the sediments for a time (Rasmussen, 1977). Clearly, any assessment of the effects of eelgrass removal should include mechanical as well as biological effects. By 1944, widespread recovery of eelgrass populations had occurred in the United States (Cottam, 1945) and by 1968 populations were of sufficient density to be considered a nuisance (Burkholder and Doheny, 1968). In contrast the Danish eelgrass populations described by Rasmussen (1977) have not recovered to any great extent.

1.3.2 *Ruppia maritima* (Fig. 2), widgeon grass, is an essentially cosmopolitan species occurring in marine, brackish, or inland alkaline waters (Dawson, 1966), and is the only other seagrass in the study area. *Ruppia* is sometimes not included with the seagrasses because of its frequent occurrence in brackish water (den Hartog, 1970), *R. maritima* is usually found in very shallow areas of reduced salinity along the Atlantic and Pacific coasts (Phillips, 1974) and occurs from Newfoundland to Florida along the eastern coast of North America as well as in the West Indies and along the Mexican coast (Moul, 1973). *Ruppia* is the only Texas seagrass tolerating nonsaline conditions (McRoy and McMillan, 1977). Phillips (1960) showed that

R. maritima is very sensitive to increases in turbidity but no information is available on its light requirements. Sensitivity to high temperatures is indicated by lethal effects noted in the Maryland estuary when Ruppia beds were exposed to elevated temperatures resulting from the operation of an electrical generating station (Anderson 1969). Setchell (1924) noted cessation of pollen production at temperatures over 25°C. Germination and seedling development occurred in the range 15° - 20°C whereas vegetative growth and reproduction occurred in the range 20° - 25°C. Ruppia is considered to be one of the most valuable of the submerged aquatics, providing excellent food and cover for fish. Waterfowl eat all parts of the plant (see Table 1) whereas marshbirds and shorebirds eat only its fruit and foliage (Correll and Correll, 1972).

The non-vascular submerged vegetation of New Jersey estuarine waters includes approximately 147 species and varieties of macroscopic algae (Taylor, 1970). Benthic algae were estimated to contribute 33% of the July standing crop at nearby Barnegat Bay with Zostera contributing the remaining 67% (Moeller, 1964). Four nonvascular submerged species occur in New Jersey coastal waters in sufficient quantities to be potentially important. They are Ulva lactuca (sea lettuce, Codium fragile (spaghetti grass), Gracilaria verrucosa, and G. folifera.

1.3.3 Ulva lactuca, sea lettuce, accounts for 10% of the standing crop of submerged aquatic vegetation in Barnegat Bay (Moeller, 1964) where it occurs over 12 of the 47 square miles of bay. This species forms large bright green sheets of irregular outline and is common in quiet waters and salt marsh pools. It grows attached to a solid substrate by means of a holdfast or as drifting sheets which can attain a size of 1-3 m in length, being nearly as broad (Taylor, 1937). In Great Bay, it is common from June to January and extensive beds were observed at Barnegat Beach bordering Barnegat Bay (Moeller, 1964). Sea lettuce proliferates under eutrophic conditions and can form thick deposits on shallow areas, suffocating underlying stands of eelgrass (den Hartog and Polderman, 1975). The species has no present economic value although it is sometimes used as food in Asian countries. However, Penkala (1975) found that sea lettuce was the most important food of Atlantic brant sampled in New Jersey during 1972-1974. Sea lettuce frequently occurs as pure stands of considerable size and has a characteristic green appearance. This species should be readily identifiable on aerial photographs.

1.3.4 Codium fragile ssp. tomentosoides, spaghetti grass, is a green algae composed of numerous intertwined coenocytic filaments compacted to form a macroscopic spongy plant body, resembling bunches of thick green spaghetti. It is typically found attached to a solid substrate by means of a holdfast, although it can grow as unattached fragments within a Zostera bed. Fragments can produce a holdfast and become attached (Taylor, 1967).

Codium is found in every latitude from the equator to the coldest parts of the temperate zone, reaching nearly to the Polar Basin (Bouck and Morgan, 1957). It is not native to the northeastern North American coast. Its appearance and spread along this coast can be traced in the literature from its appearance at Long Island, New York (Bouck and Morgan, 1957) to Cape Cod, Massachusetts (Wood, 1962), Maine (Coffin and Stickney, 1966), New Jersey (Taylor, 1967), Connecticut (Malinowski and Ramus, 1973), and to Virginia (Hillson, 1976). Silva (1955) gives a brief chronology of its spread through Europe beginning in about 1900.

Codium is highly competitive and is able to withstand cold northern winters. It also initiates new growth early in the spring before other algae begin to develop. Moeller (1969) reports a maximum lifespan of 30 months, but the longevity of the algae varies with location and environmental conditions. It grows within salinity ranges of 17.5 to 40 o/oo and temperatures of -2.0^{o} to $34.0^{o}C$. Periods of active growth in Long Island extend from April to late October, corresponding to a period when water temperatures remain about 10^{o} - $13^{o}C$. Taylor (1970) suggests that elevated temperatures, especially during the colder months, may favor the proliferation of Codium to the detriment of other algae. In Long Island waters, the plant grows from extreme low water spring tide level to a depth of 10 m.

Spaghetti grass provides a substrate for 19 species of algae and numerous invertebrates (Moeller, 1969). Due to its great competitive abilities it crowds out other algae and can cause damage to oyster and scallop fisheries. For example, it has caused considerable damage to the Long Island Sound shellfish industry by blanketing shellfish beds with a heavy growth (Wood, 1962; Malinowski and Ramus, 1973).

Areas of Codium infestation can be expected to be identifiable as vegetated areas in aerial photographs. However, when occurrence coincides with Zostera it is unlikely that the presence of Codium will be discernable. Pure stands of this species have not been reported for Barnegat Bay, Little Egg Harbor, or Great Bay.

1.3.5 Gracilaria, a red alga, accounts for 11% of the standing crop and occurs over 17 of the 47 square miles of Barnegat Bay (Moeller, 1964). Gracilaria verrucosa and G. folifera both grow unattached among Zostera beds. In Great Bay, Gracilaria is found from June to January, being rare or absent in the spring (Moeller, 1964). Gracilaria is used as a source of agar although the economics of its harvest from New Jersey waters is doubtful.

The ability to identify _Gracilaria_ in aerial photographs is questionable. Its association with eelgrass in Barnegat Bay would be expected to mask its presence in aerial photographs. In Lakes Bay, where eelgrass is much less plentiful, identification may be possible.

2.0 METHODS

2.1 Field Sampling

The field sampling program was conducted to provide interpretive "ground truth" data for the analysis of the aerial photographs and to identify and delimit species distributions, abundances, and environmental parameters within portions of the study areas.

Sites for field sampling (Figs. 3-6) were chosen from visual observations made during the aerial flights and from the photographic images obtained from the flights. Areas of distinctive coloration and patterning were selected for the initial field sampling. Later sites were chosen to encompass a variety of water depths and habitat types. Particular emphasis during the later sampling period was directed toward areas yielding difficult to interpret photographic images or containing unusual or distinctive features. A total of 166 stations were sampled.

Access to sampling locations was provided by a shallow draft Boston Whaler powered by a 40 h.p. outboard motor. Data sheets included location, date, time, water depth, secchi readings, wind speed, sediment character, vegetation type, percent bottom cover, and comments. Observations of the bottom were made by a person standing in the water and viewing the bottom through a partially submerged styrofoam box with a glass bottom (Aquascope). Observations in water deeper than the 0.75 m length of the Aquascope were based on samples obtained with a scissors-type clam rake with 3 m handles. When used with care on a soft bottom, a virtually undisturbed 0.015 m^3 sample was obtained. Multiple samples were taken at most sites where this method was employed. Several direct visual observations were made in deep water with the aid of a mask and snorkle to check for the accuracy of the clam rake sampling procedure. Attempts were made to sample the parameters which are listed below at least once during a collection trip, but not all parameters were sampled at each site.

Depth - Water depth was measured at the time of sampling and was not corrected for tidal effects. Depths were obtained with a weighted rope marked in decimeters or by a scale painted on the clam rake handle marked at quarter meter intervals.

Secchi depth - Turbidity measurements were performed with a plexiglass secchi disk, 25 cm in diameter, painted with alternating black and white quadrants. The depth at which the black and white pattern could no longer be distinguished was recorded as the secchi depth. This depth corresponds to light levels which are 18% to 24% of the surface value. (Holmes, 1970; Idso and Gilbert, 1974).

Wind - Wind velocity measurements were made with a hand held anemometer or with a pith ball type wind gauge. Measurements were taken from the boat at the sampling locations or at the

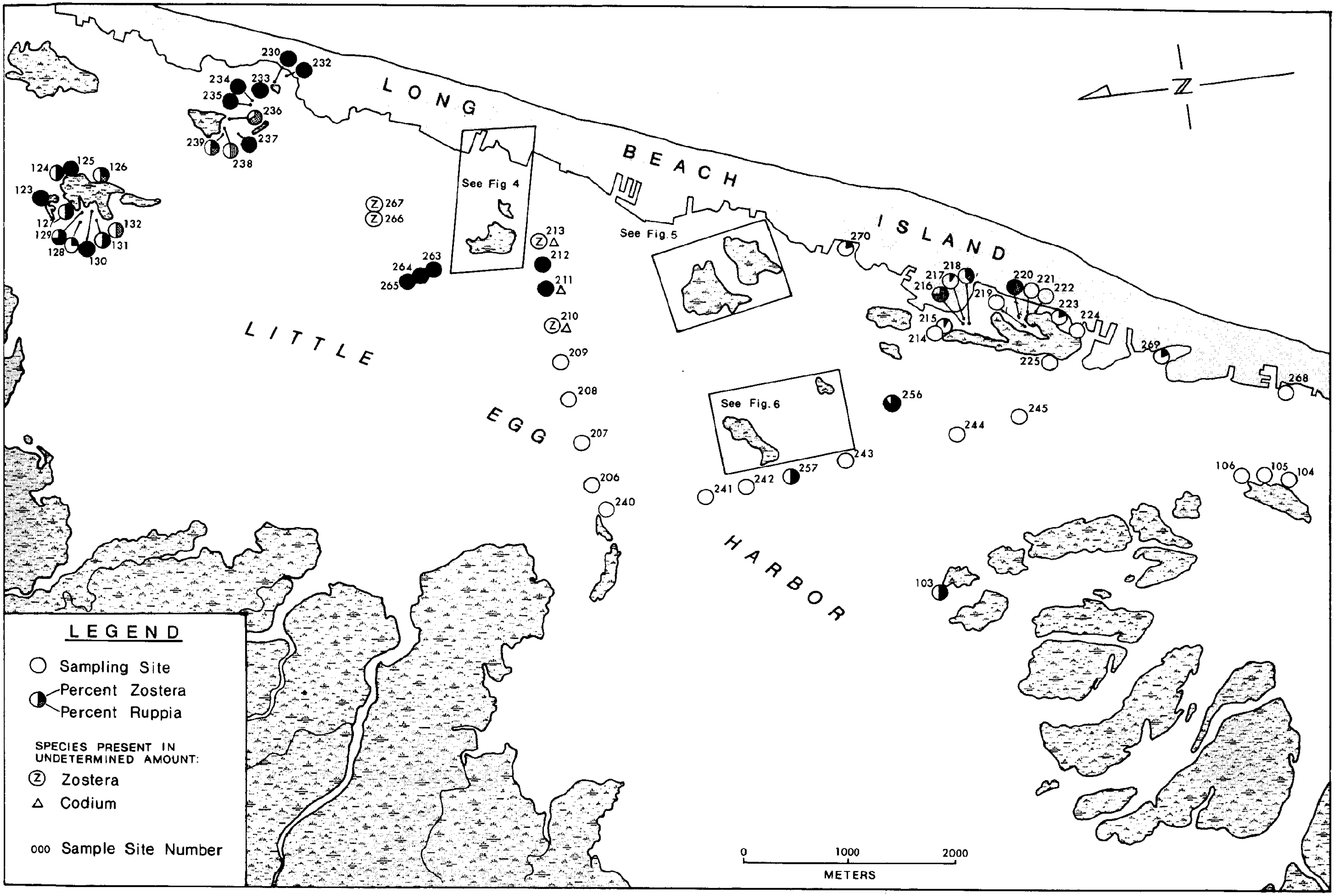


Fig. 3. Field Sampling Sites: Little Egg Harbor.

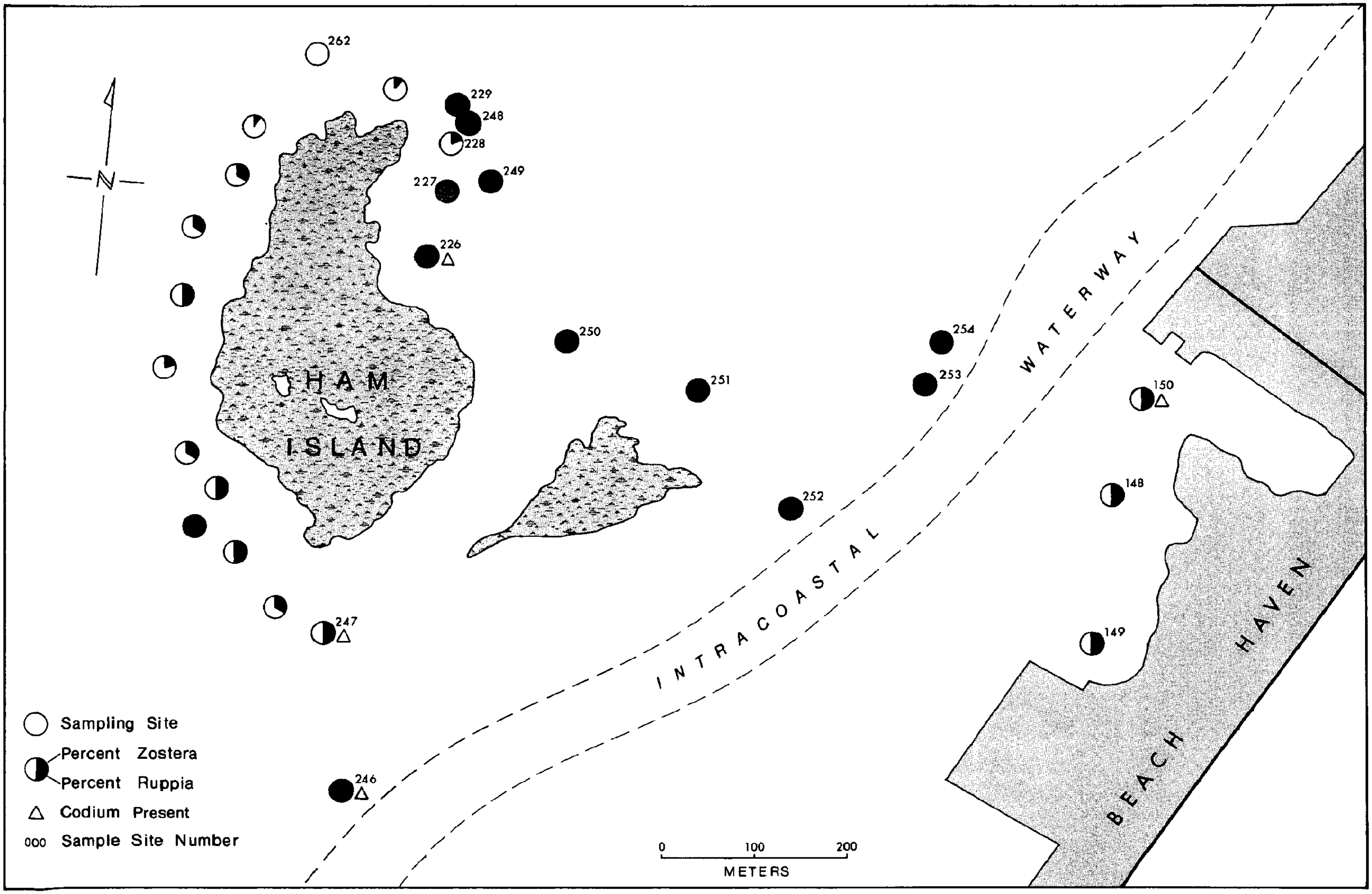


Fig. 4. Field Sampling Sites: Ham Island – Long Beach.

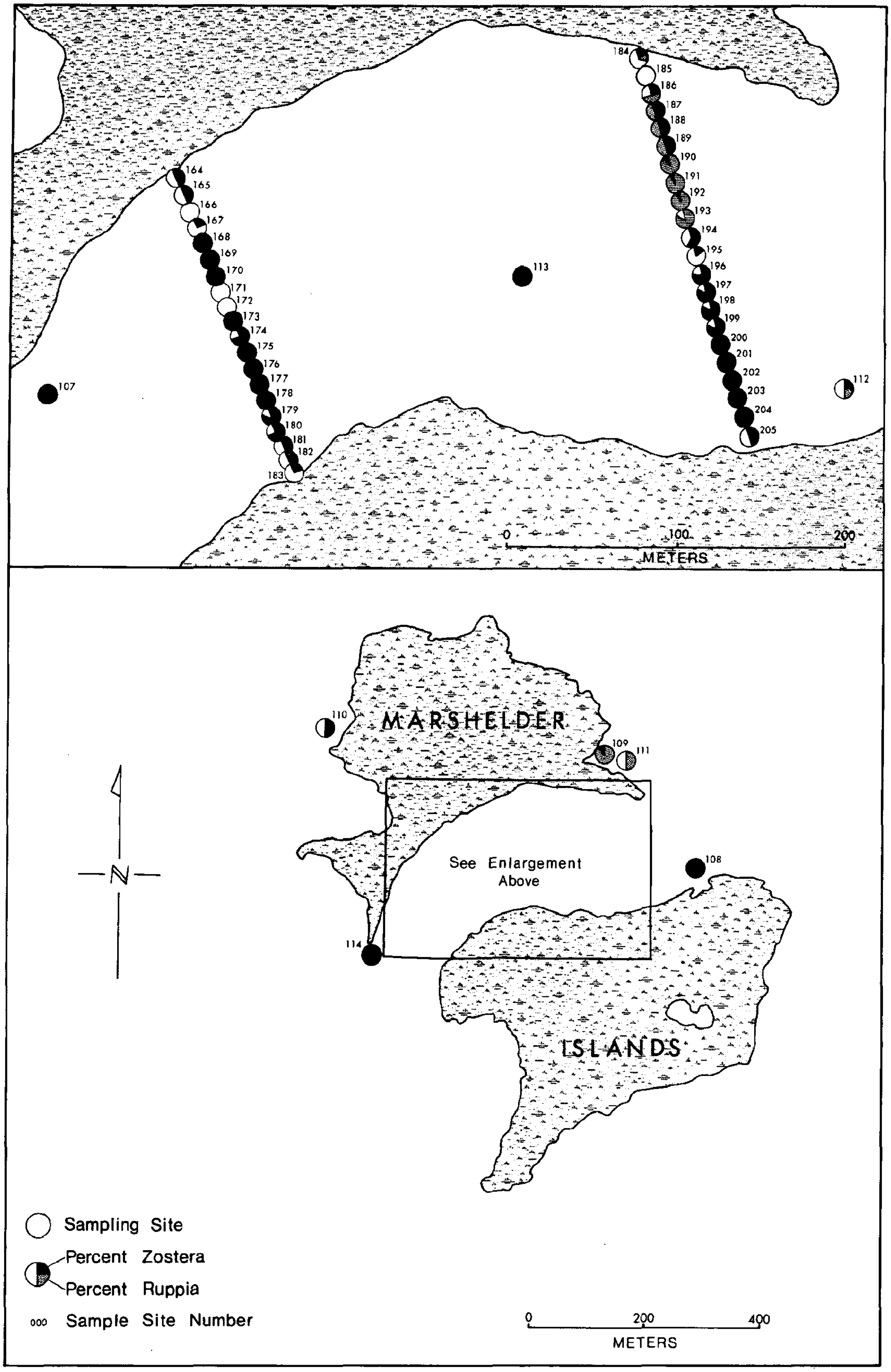


Fig. 5. Field Sampling Sites: Marshelder Islands.

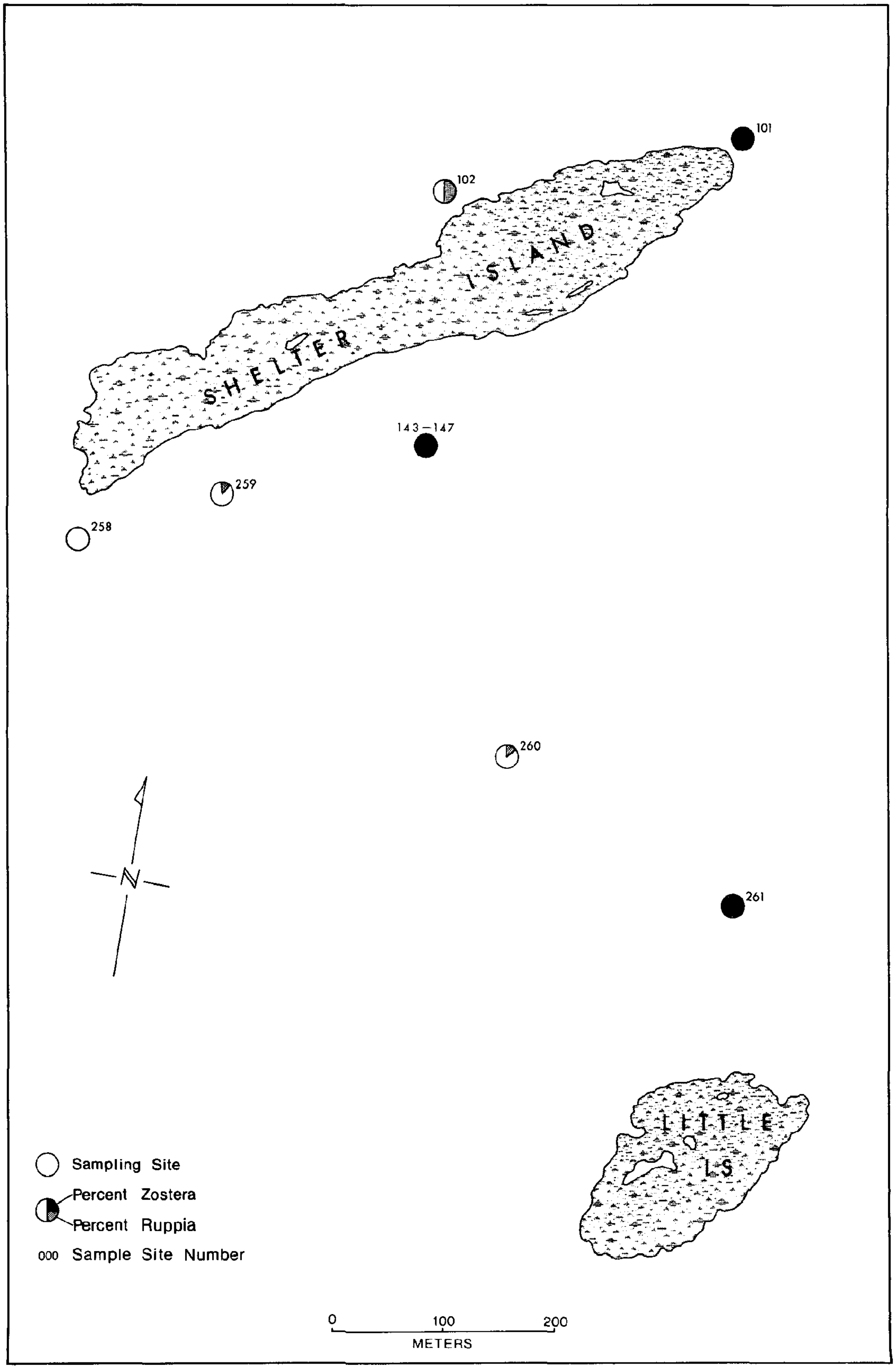


Fig. 6. Field Sampling Sites: Shelter Island - Little Island.

Little Egg Inlet Marine Field Station away from buildings and other obstructions.

Vegetation type - Plants viewed through the Aquascope or brought aboard the boat with the clam rake were identified to species. Plant specimens were collected in several locations and examined and preserved for later, more detailed examination.

Percent bottom cover - The percentage of bottom area covered by vegetation was estimated visually through the use of the Aquascope or by snorkling in several of the deeper sites. When using the clam rake in deep water, undisturbed samples were used to estimate the percent bottom cover. In areas yielding poor samples, no estimates were attempted.

Sediments - Sediments were categorized by the color exhibited at the water-sediment interface and by the type of materials present; both visual and tactile observations were made. The presence of debris or detritus on the sediment surface was noted. General observations at sampling sites were noted in many cases.

Locations of the field sampling sites were plotted at the time of sampling on plastic coated maps drawn from aerial photographs or traced from U.S.G.S. topographic maps. Sites in close proximity to islands or to the shoreline presented no problems for position plotting. However, open water sites were positioned on transects directed toward fixed landmarks. Occasionally, sampling sites were distinguishable during aerial surveys as lightly colored paths created by the passage of the propeller on the sediment interface.

2.2 Aerial Photography

A number of factors had to be calculated to permit the photographic recording of the submerged vegetation of Little Egg Harbor. These factors included the film/filter combination, exposure, sun angle, camera, tide level, coordination with the ground truth team, and other photographic procedures. Selection of a film/filter combination was complicated by the unavailability of the experimental Kodak water penetration film (SO-224) utilized in the study of submerged vegetation of Chesapeake Bay (Orth and Gordon, 1975). Therefore, it was necessary to experiment to identify that film/filter combination which provided the best contrast between the submerged vegetation and the surrounding submerged area (especially on sand and mud bottoms).

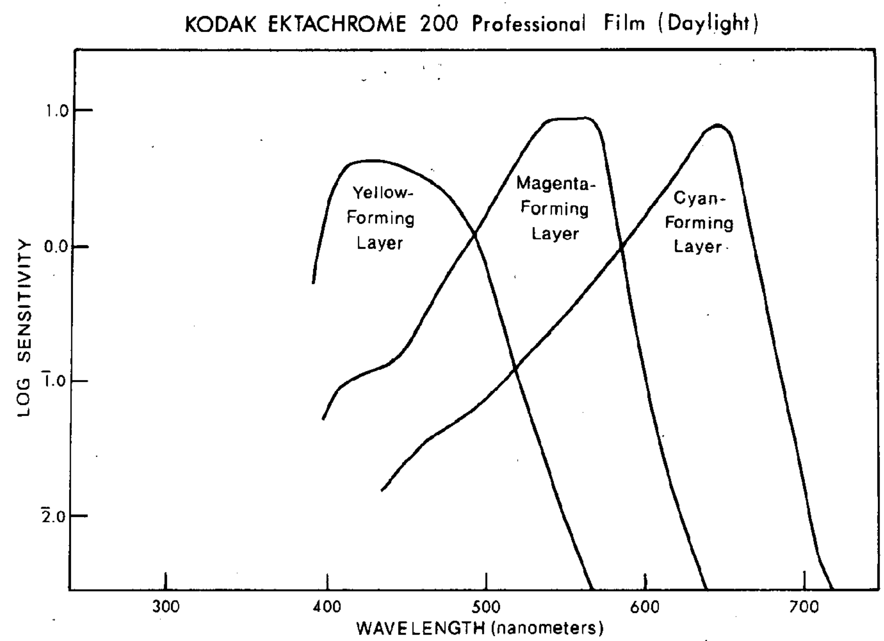
Because the maximum light transmittance in turbid coastal waters is estimated to occur at a wavelength of about 550 nm (green portion of the electromagnetic spectrum), the spectral sensitivity of the film to the green portion of the spectrum is significant in determining contrast (Specht, et al., 1973). The contrast attained also is dependent on the spectral reflectance signatures of the targets in the scene and on the spectral distribution of the energy reaching the targets. For marine waters, the transmission peaks in the blue-green spectral region at approximately 450 nm to 580 nm (Specht, et al., 1973). It is impossible to alter the reflectance properties of the targets being photographed, but it is possible to control the relative amount of blue and green light recorded through the use of yellow filters. Yellow filters absorb light in the short wavelength end of the visible portion of the spectrum (blue light). The darker the yellow filter, the greater the amount of short wavelength energy that is absorbed. Because the film is sensitive to the blue band (Fig. 7), altering the amount of blue light reaching the film affects the contrast of the elements in a scene. The filters which were selected cut off short wavelength radiation as demonstrated in Fig. 8.

A Kodak representative (personal communication) indicated that results comparable to that achieved with the experimental water penetration film could be obtained with Kodak Ektachrome 200 color reversal film and proper filtration. A Wratten No. 4 (light yellow) filter was used in our tests based on a recommendation by the Kodak representative. A Wratten No. 12 (deep yellow) filter also was used based on previous scientific investigations (Orth and Gordon, 1975). In order to make the tests more complete, a Wratten No. 8 (medium yellow) filter also was utilized. This filter absorbs an intermediate amount of short wavelength light (blue) compared with the Wratten Nos. 4 and 12 filters. Additionally, Kodak Ektachrome Infrared film with a Wratten No. 12 filter was used. The other test film/filter combination was Kodak Plus-X black and white panchromatic film with a Wratten No. 25 (red) filter.

Photographs were taken using hand-held 35 mm Pentax Spotmatics with 55 mm Super-Takumar lenses, or an Olympus OM-1 with a 50 mm Zuiko lens. Supplementary photos were taken with a Hasselblad 500 C. A Gossen Super Pilot exposure meter was used in exposure calculations. Both a helicopter and a Cessna 172 were used in conducting the flights.

Four photographic missions were conducted over the study area: 15 September, 7 and 21 October, and 17 December, 1977. Following an initial aerial reconnaissance a number of test sites were selected. These included Marshelder Islands, Shelter Island, Ham Island, the eastern portion of Long Beach Island, and a transect from Long Point on the west to Ham Island on the east. The last site had the greatest variation in water depth and was selected for this reason.

Exposure readings for all flights except the first were taken with the hand-held meter. A ground reading of a mixed sky/landscape scene and an aerial reading of the bay were taken. The appropriate filter was placed in front of the meter for both readings. An average of both readings provided the base exposure upon which over and underexposure were calculated. A shutter speed of 1/500 of a second was used for



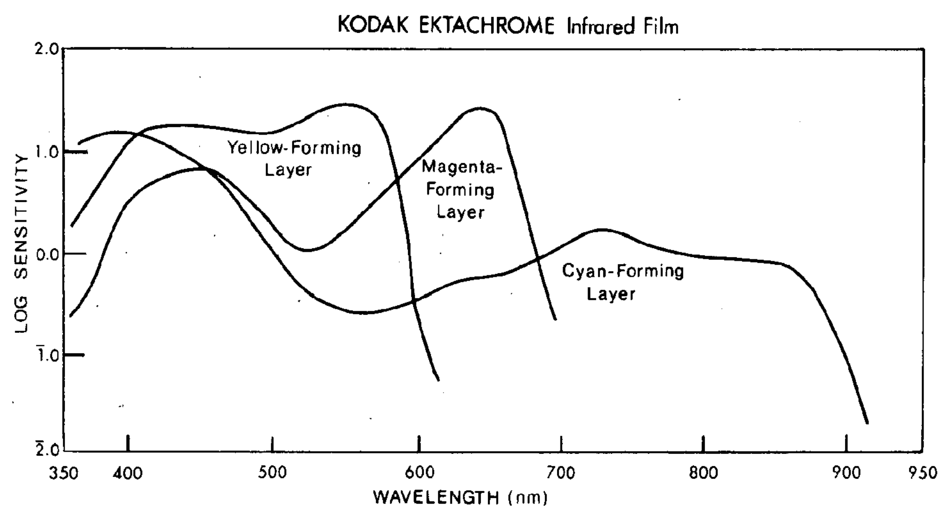


Fig. 7 Film Sensitivity Curves.

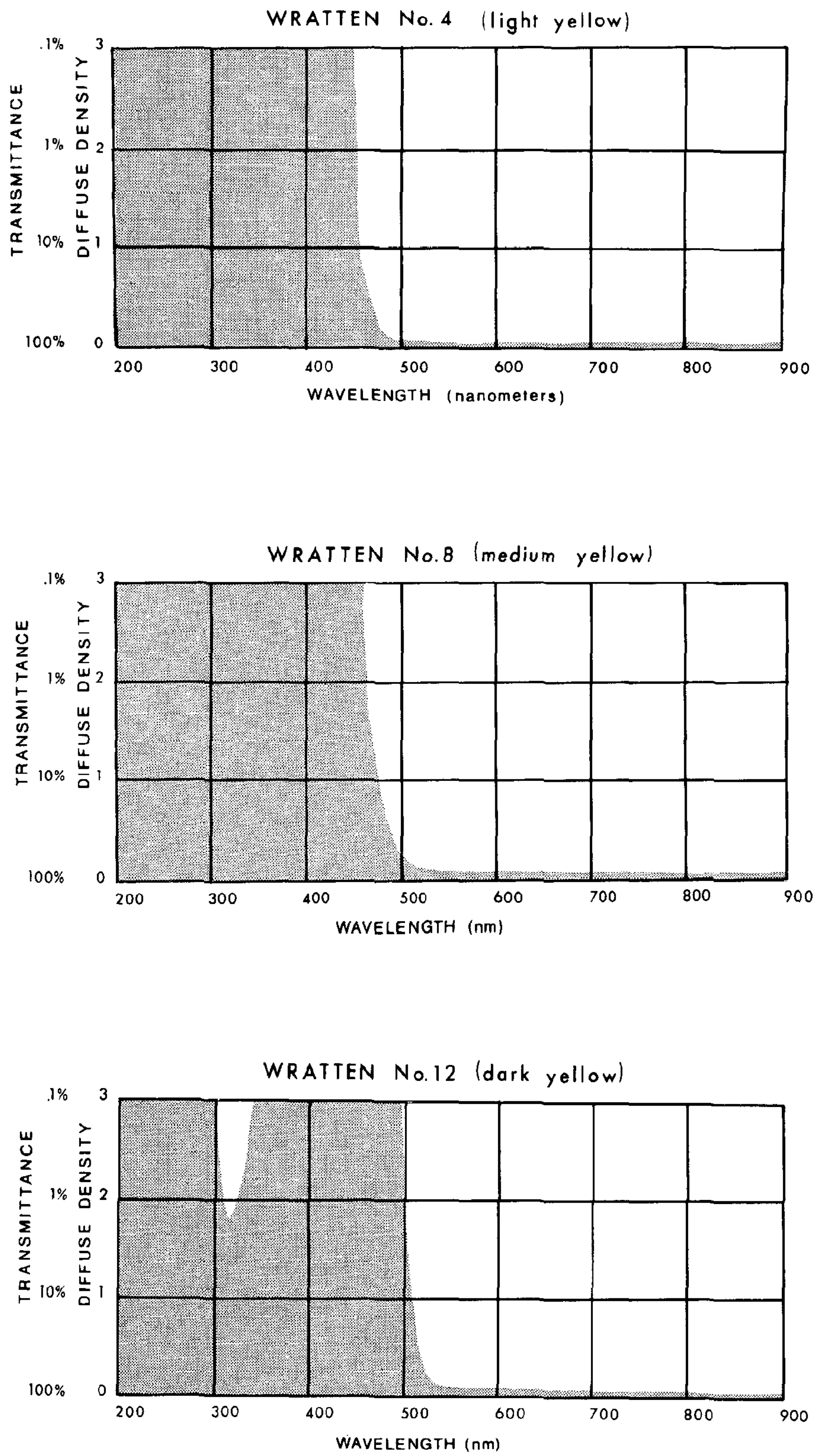


Fig. 8. Filter Absorption Curves.

most exposures.

Flights usually were confined to days with little or no surface wind in order to minimize water surface glitter and to avoid excessively turbid waters. When possible, the day following prolonged precipitation (with resulting turbidity) also was avoided. Photographs were taken with the sun at the photographer's back and during a period with solar elevation of between 20° and 36° from the horizontal. Vertical or nearly vertical shots under these conditions minimized reflections and surface glitter. The flights were scheduled to begin approximately one-half hour before low tide so as to reduce the column of water above the submerged vegetation.

3.0 RESULTS AND DISCUSSION

3.1 Vegetation Field Studies

Submerged vegetation in the Little Egg Harbor area is strongly dominated by eelgrass. Almost half the field stations supported *Zostera* while *Ruppia* dominance accounted for 11% of the stations and mixed *Ruppia-Zostera* occurred at 7% of the stations. Approximately 30% of the stations did not support submerged vegetation. Since the stations were not located at random, these percentages can not be considered as necessarily representative of Little Egg Harbor as a whole.

Although only limited environmental data were taken (Appendix 1), some trends are apparent. Water depth appears to be a prime factor in determining areas suitable for submerged vegetation in the Little Egg Harbor area. Additionally, turbidity decreases the depth to which light penetration is adequate to support growth. Widgeon grass characteristically inhabits sheltered, shallow locations which restricts it to island perimeters and coves as on Long Beach Island. Depths of *Ruppia*-dominated stations are the smallest, averaging 4.1 dm. Eelgrass commonly occurs in dense beds in somewhat deeper water (average 9.3 dm) away from emergent features but may also be found near shore. Mixed *Zostera-Ruppia* vegetation does occur but is not very extensive. These stations were largely of intermediate depths averaging 5.6 dm. At depths greater than 1.5 m submerged vegetation was rarely found. Only a few secchi disc readings exceeded 1 m and submerged vegetation in the area may be limited by the high turbidity generally present. The lack of submerged vegetation on the western side of Little Egg Harbor is probably due to greater water depths coupled with increased turbidity (Makai, 1974; J.B. Durand, personal communication).

Substrate type probably also plays a role in determining vegetation type. *Ruppia* seems to occur largely on sand whereas *Zostera* was found on a variety of muds and sands.

Dredged areas may be unsuitable for recolonization if the bottom is below the light compensation depth or because of siltation. Several areas of Little Egg Harbor have been cited by Murawski (1969) as being practically anoxic and almost totally devoid of living organisms due to previous dredging. The largest of these areas is 14 hectares with 4 other sites totalling an additional 13.1 hectares. Many of these areas are near shore where submerged vegetation may have been abundant.

At the southern end of Little Egg Harbor tidal currents and sand deposition may be important factors excluding submerged vegetation. Island configurations and U.S.G.S. topographic maps indicate large areas of recent sand deposition, especially at the southern end of Long Beach Island. Sheltered sites in coves and islands support patchy vegetation.

None of the algae included in the study were abundant at many stations. *Gracilaria* was found at 7 stations, all in Lakes Bay, whereas *Codium* occurred at 9 stations, usually as a minor component (in terms of cover) of *Zostera* beds. *Ulva* occurred as an associate of *Gracilaria* at 4 stations in Lakes Bay but was not seen in Little Egg Harbor.

The distribution and abundance of *Zostera*, *Ruppia*, and the algal species are shown for Ham Island, Marshelder Islands, Shelter Island-Little Island, and the remainder of Little Egg Harbor (Figs. 3-6). These test site maps are based solely on the field data with no input from aerial photography. The following discussions of these areas illustrate some of the typical patterns of submerged vegetation in the area.

3.1.1 Ham Island

The distribution of vegetation in the vicinity of Ham Island (Fig. 4) gives evidence of a large die-back of eelgrass within the previous year. Sampling around the perimeter of the island yielded a dense, continuous bed of eelgrass rhizomes. These samples were not assigned site numbers in the data log (Appendix 1) since they represent a continuous series of observations rather than being discrete data points. However, samples from the northwest corner of the island produced rhizomes in obvious stages of decay with only a scattering of specimens with green leaves attached. This area of recent die-back extended over an area roughly the same size as Ham Island. An aerial inspection of the area revealed a noticeable line separating the surrounding deeper water areas of healthy eelgrass beds from this depauperate area. This line may represent the extent to which freezing or ice scouring occurred during the severe winter of 1976-77. The scattered live eelgrass specimens in this area may serve as sources for vegetative recolonization.

A large mass of decaying eelgrass and *Codium* fragments was encountered in the cove on the northern end of Ham Island. This mass was first observed as a dark crescent in the aerial photographs of 7 October and was still a prominent feature during the flight of 17 December. Masses of this type are common in sheltered areas of Little Egg Harbor. In addition, a blanket of decaying macrophytes often was encountered over widespread areas of the harbor. The deeper northern end of the cove on Long Beach Island east of Ham Island contains an abundance of eelgrass and several large attached plants of *Codium*. The sediments in this portion of the cove are primarily soft muds. Widgeon grass begins to occur near the midpoint of the cove and forms a pure stand on the shallow southern end of the cove. Sediments in this area tend to be firmer and composed primarily of sand. As in other portions of the harbor, the area of mixed cover of widgeon grass and eelgrass is not extensive.

3.1.2 Marshelder Islands

The channel between the two Marshelder Islands contains a complex series of intermixed eelgrass and widgeon grass beds (Fig. 5). Data in this area were collected along two transects dividing the channel roughly in thirds. Sampling sites along the transects were separated by approximately 10 m intervals. Other sampling sites were located along the perimeter of the islands. Currents passing through the channel may be partially responsible for the patterns observed. Noticeable features of this area include a central, non-vegetated channel approximately 1 m deep at low tide and a tendency toward soft, muddy sediments in the middle of the channel with the sides tending to be composed of firmer silts and sands. Eelgrass tends to grow in the muddy areas. This may be a reflection of the increased deposition of fine sediments over eelgrass beds due to current reductions than to a preference of eelgrass for muddy bottoms. Widgeon grass tends to be found in the shallower areas of firm sediment composition. Unlike Ham Island, no evidence of a die-back of eelgrass was noted in this area.

3.1.3 Shelter Island - Little Island

The Shelter Island - Little Island area (Fig. 6) is the southern boundary of a large eelgrass bed occurring in the northern portion of Little Egg Harbor. Southwest of this area, depths increase, and bottom sediments are characterized by well-worked sands. Sediments to the northeast are finer grained and are muddy in places.

The southwestern portion of the area between Shelter and Little Islands presently is being covered by a layer of clean sand. A bed of widgeon grass at this site exhibits elongate growth, perhaps as compensation for burial by the sand. Thus, the widgeon grass may stabilize the newly transported sands, and the bottom may become elevated in this area. The invading sand blanket is being deposited over a dark, silty-mud bottom inhabited by a dense eelgrass bed off the northern shore of Little Island. Continued monitoring of this interface between the vegetated and non-vegetated portions of Little Egg Harbor may provide valuable insight into the depositional and erosional forces active in the area.

3.1.4 Lakes Bay

Lakes Bay is very different from Little Egg Harbor. The entire bay is characterized by a soft, muddy bottom which was devoid of any significant amounts of attached vegetation when sampled in December. One large area of unattached *Gracilaria* was sampled at the northern end of the bay, but all specimens appeared to be resting on the bottom without permanent attachment. Only isolated specimens of sea lettuce (*Ulva lactuca*) were obtained.

However, December is not a likely period to obtain an accurate distribution of Ulva.

Lakes Bay is characterized by a restricted connection to the sea and a higher degree of eutrophication. Although clams are abundant, clamming in the area is prohibited for health reasons.

3.2 Aerial Photography

3.2.1 Aerial Flights

The flight on 15 September was largely observational with the remaining flights photographic. The 15 September, 1977 flight utilized a helicopter and recorded with unfiltered Ektachrome and filtered (No. 25) black and white panchromatic film at altitudes of 150 m and 300 m. Much of the flight time was spent locating potential vegetated sites for ground truth acquisition. Several sites previously located by boat were seen easily from the air, suggesting that aerial direction could aid the ground-based team in locating patches of submerged vegetation.

The flight of 7 October was made with a Cessena 172, as were the subsequent flights. The main objective of this flight was the selection of the proper exposure level for optimal water penetration. Photographs from the flight were taken with Ektachrome 200 film with a No. 8 filter at altitudes of 300 m, 750 m, and 1500 m. The weather was clear and haze-free with winds of 10-11 kmph. Most of the images were exposed at 1 f-stop under the calculated exposure, with some overexposures for comparative purposes. Results clearly indicated that underexposure produced photographs which were too dark for interpretation. An overexposure of 1 f-stop, on the other hand, provided sufficient contrast for the location of submerged vegetation. Delineation was possible at all flight altitudes, but species identification and/or differentiation proved to be impractical.

The flight of 21 October utilized the information on exposure determined during the previous flight to allow testing of the following film/filter combinations at the calculated (averaged) exposure as well as at 1 and 2 f-stops overexposed:

Kodak Ektachrome 200/Wratten No. 4 filter

Kodak Ektachrome 200/Wratten No. 8 filter

Kodak Ektachrome 200/Wratten No. 12 filter

Kodak Ektachrome Infrared/Wratten No. 12 filter

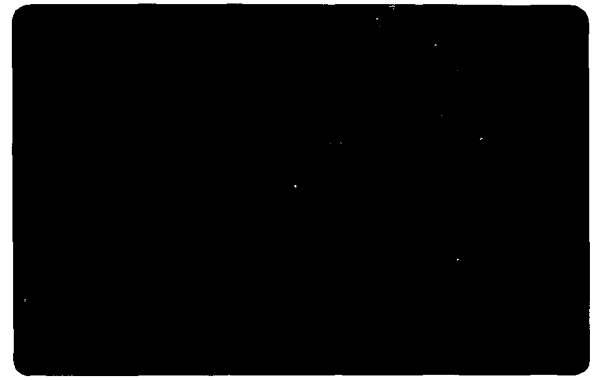
Additionally, the color infrared film was exposed at 1 f-stop below the calculated exposure. Photographs were taken at altitudes of 750 m, 1500 m, and 2300 m on a clear, slightly hazy day with a moderate wind speed of 16 kmph. Due to the time needed to expose the array of film/filter/exposure combinations at the three altitudes, only the Marshelder Islands and Long Point to Ham Island transect sites could be photographed. Whereas vegetation could be delineated at all flight altitudes, it was easier to distinguish percent bottom cover variations within the submerged vegetation on the larger scale images which were taken at the lower elevations.

The aerial photography proved to offer a measure of detail that was considerably greater than that which could be observed by the field team in the boat. Whereas secchi disc depth measurements were on the order of 1 m, the water penetration observed on the photo images was up to 3 m. Thus, the areal data were enhanced considerably through aerial photography.

All of the film/filter combinations produced useable results of an overexposure of 1 f-stop, including the infrared film as shown in Figure 9. However, differentiation of vegetation of the Ektachrome Infrared film seemed not to be as distinct as on the Ektachrome 200 film although the blue color of the water appeared more "natural". The Ektachrome 200/No. 12 filter combination provided good differentiation, but the more extreme color shift made long-term interpretation fatiguing and potentially more error-prone. Both the No. 4 and No. 8 filters provided images in which the vegetation could be discerned readily. It was decided that any additional photography of the harbor should utilize the Ektachrome 200 film/No. 8 filter combination because the No. 8 filter is more widely available and yields acceptable results. Infrared film was not used because of the greater difficulty in calculating exposures. A paper print enlargement was made of one of the Ektachrome 200 slides to see if interpretation was enhanced. However, there was no apparent advantage of this procedure over projecting the slides for visual analysis.

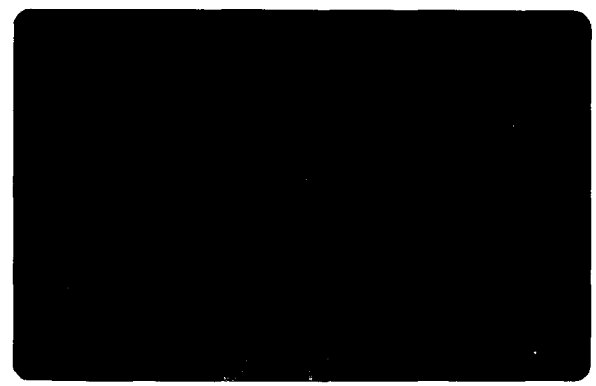
The flight of 17 December was conducted to obtain photo imagery of the portions of Little Egg Harbor which had not been covered during the earlier flights. The flight was made utilizing a preliminary flight plan for an area extending north from Marshelder Channel to the northern end of Egg Island. Eighteen north-south flight lines would be needed to cover Little Egg Harbor at an altitude of 1,500 meters using a 35 mm camera with a 55 mm lens. The four most easterly flight lines were found to cover the vegetation which was apparent from the air except for a small amount of vegetation that exists along the western margin of Little Egg Harbor.

Ektachrome Infrared/No.12 Filter



Ektachrome 200/No.4 Filter

Ektachrome 200/No.8 Filter



Ektachrome 200/No.12 Filter

Fig. 9. Film/Filter Combinations.

The latter vegetation was recorded on one additional flight line. The water penetration on the photos was inferior to that which had been obtained during the October flights because of low solar elevation and cloud cover. However, the quality was sufficient to interpret the submerged vegetation.

3.2.2 Comparison and Analysis of Film-Filter Combinations

The relative differences in contrast among the various scene elements, as described under the 21 October flight description, are shown in Figure 9. These aerial views of the Marshelder Islands, taken at an altitude of 1,500 m, demonstrate the results obtained with each of the film/filter combinations. The photographs suggest that the more extreme color shift which results from the Ektachrome 200/No. 12 filter combination might fatigue the interpreter during prolonged viewing. The greater density range on the Ektachrome 200/No. 4 and No. 8 combinations, as opposed to the Ektachrome Infrared/ No. 12 combination, facilitates the differentiation of vegetated from non-vegetated areas.

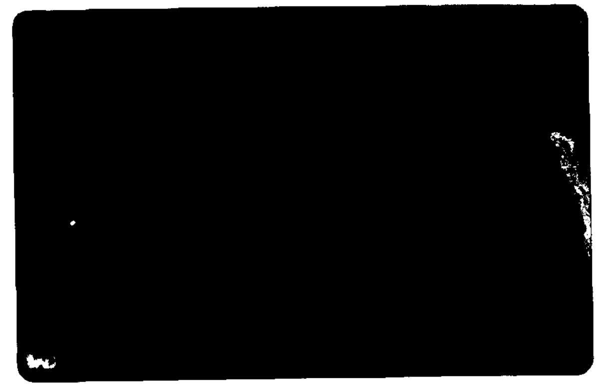
Fig. 9 also illustrates the increased water penetration possible from the air as opposed to surface-based observations. In the four views of the Marshelder Islands, the white object in the channel between the islands is the 6 m Boston Whaler anchored in water 1 m deep. Although good detail is provided of this area in the photographs, secchi depth readings taken at this location were only 6 dm.

The light, crescent shaped linear feature at the lower left of the photograph was created by the destruction of vegetation by the passage of a boat propeller. The dark circular object at the lower right of the photograph is a portion of the aircraft's landing gear.

Figure 10 further documents the usefulness of the Ektachrome 200/No. 8 filter combination at 4 locations in Little Egg Harbor. The photograph of Egg Island was taken on December 17, the remaining 3 photos being taken on October 21.

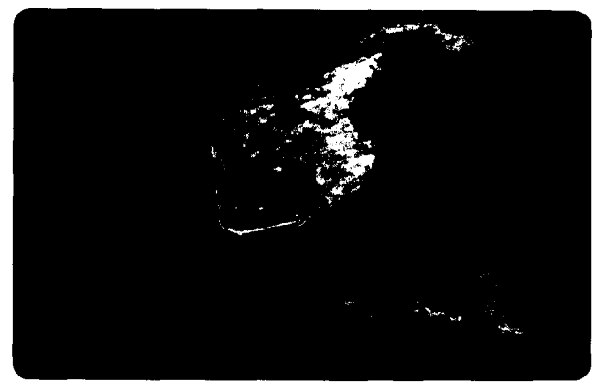
Ham Island - The photograph of Ham Island illustrates the dark green mottling which characterizes vegetated areas. The light green areas between the two islands and at the top center of the photograph represent shallow sandy areas with sparse or non-existant vegetation. The dark, linear features at the island's perimeter are masses of detrital materials deposited in locations where strong currents are absent. This photograph clearly demonstrates the ability to delineate submerged vegetation using aerial photography.

Daniel Island



Shelter Island - Little Island

Egg Island



Ham Island

Fig. 10. Aerial Photographs - Ektachrome 200/No. 8 Filter.

Egg Island - This island is surrounded by shallow, sandy areas which appear light green in the photograph. The dark areas in the coves and along the shore are a combination of dense eelgrass beds and detrital deposits. The white areas at the water's edge are breaking waves and foam accumulations.

Shelter Island - Little Island - This photograph clearly demonstrates the dark green mottling characteristic of the vegetated areas. Mottling is evident at the right center of the photograph and extends horizontally as a broken undulating band across the lower third of the scene. Additionally, a dark green triangular patch of vegetation can be seen to extend from Shelter Island at the right side of the photograph. Field sampling has shown that this feature is a dense eelgrass bed. The light green area next to the aircraft's wheel is a deep (8 m) non-vegetated channel, the edge of which is defined by a thin, dark green horizontal line.

Daniel Island - A portion of the intracoastal waterway can be seen in the photograph of Daniel Island. It appears as a light 0.5 cm wide band along the shore of Long Beach Island and passes below Daniel Island. Depths in the channel are approximately 2.5 m while the adjoining areas are 0.3 to 0.7 m in depth. The light green feature of irregular outline immediately to the left of Daniel Island is believed to be a dredged area with connections to the intracoastal waterway. Field observations would be necessary to positively identify this feature.

The dark coloration of this print makes the delineation of vegetation difficult although careful examination reveals varying concentrations of vegetation throughout the image, especially above the intracoastal waterway on the left side of the photograph and around Daniel Island.

3.2.3 Distribution of Submerged Vegetation of Little Egg Harbor

The results of the aerial surveys of the entire study area are shown in Fig. 11. The vegetation distribution is based on interpretation of the aerial photographs and visual corroboration from the aircraft. The major concentration of vegetation appears in the shallow northeastern portion of the harbor near Ham Island. Other patches are found scattered throughout the harbor, especially in shallow, sheltered locations.

3.3 Photographic and Environmental Guidelines

A major objective of this study was to determine if the use of a relatively inexpensive mode of remote sensing, aerial photography with a single film/filter combination, could be used to delineate submerged vegetation. Based on this pilot study, it is felt that such an approach can be used to reduce significantly the costs of inventorying submerged vegetation along the New Jersey coast. An additional advantage is the historical record this method provides. This information should prove valuable in recording the encroachment upon the vegetation from both onshore and offshore development.

The conditions necessary to produce optimal results, with Ektachrome 200 film and a 35 mm camera are shown in Table 2. Interpretation of the images was complicated by a color variation in the vegetation from a light to a dark green. The variation could be a function of several factors; water depth, site bottom characteristics, species, density, and conditions of the vegetation. Mottled areas showing a mixture of dark and light green shades proved to be the clue to interpretation. Field checking revealed that this mottling indicated sparse vegetation coverage, often near the margins of a large submerged vegetation bed. Other mottled areas merely indicated limited expanses of sparse vegetational coverage. There were some instances in which it was difficult to positively identify a mottled area (from the image) as a separate patch or as the thinning edge of a large patch. Most problem areas could be positively identified in a visual aerial survey. Finally, it should be stressed that there is difficulty in relating vegetation boundaries in open water to mappable reference points with 35 mm photography. This will be far less of a problem with commercially flown 9 x 9 inch photography at a scale of 1:24000 made under controlled flight conditions because some land usually will appear in the image.

3.4 Statewide Estuarine Survey

The success of the present study strongly recommends the initiation of a comprehensive statewide estuarine survey of submerged vegetation. This study should include three distinct phases; 1) obtainment of aerial images; 2) obtainment of ground truth information, and 3) interpretation and presentation of results. The study, conducted using commercial photographic techniques, will provide a working framework for coastal planning and management by identifying areas of high ecological value. By pinpointing these sensitive areas, non-compatible uses may be relocated to less sensitive areas or rescheduled for winter months when the submerged vegetation and associated organisms may be less susceptible to damage. Efficient and effective coastal planning demands a comprehensive data base upon which decisions can be made. The proposed statewide inventory of submerged vegetation will provide this needed information.

The photographic and environmental guidelines listed in Table 2 should be used to plan the overflight. The desirability of conducting the photography at low tide may necessitate the use of several flights over a period of a few days. A logical approach would seem to be to divide the state into 3 or more latitudinal bands. The requisite number of north-south flight lines could then be flown for a given latitudinal band during one photographic mission.

Table 2. Guidelines for Photographic Specifications and Environmental Constraints (35 mm camera format)

Photographic	Guidelines
Film	Ektachrome 200. Sensitivity curve shown in Figure 7.
Filter	Wratten No. 4 or No. 8. Transmission curves shown in Figure 8.
Exposure	Average of a ground and aerial reading taken with a hand-held meter; overexposure by 1 f-stop from this calculated exposure.
Shutter speed	Speeds of 1/250 to 1/1000 sec. are sufficient to eliminate motion encountered from the airplane.
Altitude	An altitude of 1500 m was selected for the camera-lens format which was used because it offers the best compromise between detail and the amount of flight time utilized. The representative fraction of the imagery which was taken at 1500 m was about 1:27,000.
Image overlap	A forward overlap of 50% and a lateral overlap of 25% are desirable.

Environmental	Guidelines
Lighting	A solar altitude of 50^{o} maximum to avoid glare, 30^{o} minimum to provide sufficient lighting (Smith, 1968; Reeves, 1975). A cloud-free sky for easiest interpretation of the images is desirable.
Wind	Wind speeds under 16 kmph are necessary to prevent excessive surface glitter and minimize water turbidity.
Tide	Flights should be planned to minimize the depth of water which must be penetrated to view submerged vegetation. Lag times between inlet and bay tidal cycles complicate this when extensive areas are to be surveyed.
Visibility	As haze-free and clear as possible
Precipitation	No photographs were taken the day of or the day after any measureable precipitation due to the increased water turbidity encountered at these times.

Since the vegetative growth in the cooler northern bays lags several weeks behind that of the warmer southern bays (R. Good, personal observation), a survey of vegetation in comparable stages of growth could be accomplished by photographing the northern portions of the state a few weeks after the southern section has been photographed.

The recommended periods for the overflights are April-May, when vigorous growth of the submerged vegetation commences, June to early July, when standing crop is high and the plants are in prime condition, and in September when the amount of vegetation available to resident and migratory waterfowl populations can be assessed. The period from December through March is not recommended for photography due to the removal of submerged vegetation by feeding waterfowl (Table 1) and the poor weather conditions encountered at this time.

The second phase of this study, the obtainment of ground truth information, is vital for the interpretation of the aerial photographs. Information is especially desirable for areas containing plant species such as sea lettuce which have not been sampled in Little Egg Harbor. It may be possible, with adequate ground truth information, to differentiate species composition in some areas from the aerial images. Additionally, ground truth information will provide a much more detailed description of the environmental factors operating at given locations. Ground truth data should be collected on a monthly or a seasonal basis.

Results of a statewide survey should be presented in a form similar to Fig. 11. At this scale, the data portrayed are compatible with a number of information sources readily available to municipal, county, state, and federal agencies and is appropriate for decision-making purposes.

Estimated costs (1978 dollars) for a statewide estuarine survey are listed below:

Direct Costs		
photography of entire N.J. coastal zone		$13,000
personnel		$15,000
cartography		$ 4,000
preparation of final report		$ 1,500
travel, field work		$ 2,500
field supplies		$ 1,000
office support, secretary, telephone, supplies		$ 3,000
	TOTAL	$40,000

It should be emphasized that this statewide survey is limited to the identification and delineation of areas of submerged vegetation along the New Jersey coast. Additional research concerning the life history, ecology, and function of the species involved is highly desirable for proper management of the coastal zone and its resources.

4.0 FUNCTIONS OF SUBMERGED VEGETATION

Most of the functions which can be attributed to the submerged vegetation in Little Egg Harbor can be directly related to the dominant form, Zostera marina. For convenience, major functions can be discussed under several headings although perfect separation of these functions may not exist in nature. The role of submerged vegetation may be: as a contributor to the food chains of the ecosystem including the grazing and detrital food chains; as a component in the nutrient dynamics of the estuarine system; in the creation of habitat for juvenile fish and invertebrates (nursery and shelter); as a substrate for epiphytic algae and associated fauna; and as a sediment stabilizer and contributor to coastal stability.

Seagrass beds are very productive systems, typically producing between 500 and 1000 $gC/m^2/yr$. (Fenchel, 1977). They are often the dominant bottom community and hence important contributors to primary production (Burkholder and Doheny, 1968; Mann, 1972; McRoy, 1970). Most work in marine system food chains has centered on the role of phytoplankton with the contribution of macrophytes being less well known. The importance to several species of local waterfowl is well known and has already been mentioned. The grazing food chain accounts for the consumption of only a minor fraction of the total productivity of eelgrass.

Any menaingful assessment of the total contribution of eelgrass must consider the decomposition process and the utilization of detritus. This topic is summarized by Fenchel (1977). Soluble constituents in senescent and dead plant material are usually leached out in a short time, entering the pool of dissolved organics of the system. Some of this is adsorbed to particles and is probably utilized by sediment bacteria. Zostera is reported to contain about 20% water soluble organics in fresh leaves and 12% in senescent leaves (Mann, 1972). Particle size of the detritus is continually reduced by organisms and also mechanically by wave and surf action. Detailed studies indicate that detritus, as such, is not a good nutrituve source but that the associated microflora is. Fenchel (1970, 1972) studied the gastropod Hydrobia ventrosa, the bivalve Macoma balthica, and the amphipods Parhyallella whelpleyi and Corophium volutator, all of which ingest quantities of seagrass detritus. Assimilation efficiency for the bacterial and protozoan component was over 90%, for the microalgae 50-80%, and negligible for the detritus proper. Kristensen (1972) studied the enzyme systems of 22 shallow water, mostly detrital feeding invertebrates and found they did not have enzyme systems capable of utilizing the structural carbohydrates found in detritus. The bulk of the plant material must pass through the bacterial or fungal portions of the food chain before becoming useable to animals. Bacterial counts on detrital particles of Zostera, Thalassia, and other vascular plants are in the range 10^9-10^{10} bacteria per gram dry weight of detritus. Approximately 2-10% of the detrital surface is covered by bacteria. Total bacterial counts and oxygen uptake from Thalassia-derived detritus were nearly inversely proportional to particle size (Fenchel, 1970), indicating the importance of size and the related surface-volume ratio. Zooflagellates and ciliates are important consumers of detritus bacteria. Other invertebrates near the base of the food chain include rotifers, turbellarians, nematodes, and small crustaceans. The biomass of the microfauna associated with detritus is of approximately the same magnitude as the bacteria so they also form an important part of the food for detrital feeders. Animal activity on detritus results in a positive feedback on bacterial activity by reducing particle size, increasing oxygen availability, and regenerating mineral nutrients (Fenchel, 1977).

The dynamics of the detritus food chain is closely related to the role of submerged vegetation in mineral cycling. Decomposer bacteria enrich nutrient-poor detritus particles by assimilating inorganics, especially nitrogen and phosphorus, from the water (Fenchel, 1977). Availability of these nutrients may limit decomposition rates and utilization of detritus by higher trophic levels. Mineral nutrients may cycle largely between bacteria and animals in detritus systems. Protein content in Zostera detritus increases with time in much the same way as observed in salt marsh Spartina detritus by Odum and de la Cruz (1967) and Squiers and Good (1974).

Anaerobic decomposition is probably quantitatively more important than aerobic decomposition because anaerobic conditions are promoted by burial of organic material by sediments and the high oxygen demand of associated bacteria. Murawski (1969) has cited anaerobic conditions in New Jersey dredge holes which act as traps for organic debris and limit mixing of water. Ruppia maritima was identified as an important contributor of detrital material. The sulfur cycle is important and quantitatively dominant under such conditions. Hydrogen sulfide provides a sink for heavy metals, especially iron which precipitates as ferrous sulfide. Burrell and Schubel (1977) have suggested that seagrass beds may also act to remobilize and transport heavy metal pollutants. Phosphates are liberated from iron in the presence of sulfides and this mechanism may be of some significance in maintaining phosphate availability in eelgrass beds (Wood, 1965). Fenchel (1969) has described the matter and energy dynamics of Danish shallow water areas inside Zostera beds dominated by the sulfur cycle.

In addition to the complex trophic and nutrient relationships briefly outlined above, seagrass beds form an important habitat based on their physical structure. Kikuchi and Pérès (1977) have characterized animal communities from a variety of Zostera and other types of seagrass beds from around the world. Seagrasses are a suitable substrate for small algae which form the base of a grazing food chain structurally dependent on the presence of seagrass but trophically distinct. Many invertebrates including small gastropods, amphipods, and isopods feed on the epiphytic algae (Kikuchi and Pérès, 1977). Algae, mostly epiphytes, had a greater biomass than eelgrass leaves in two beds off Rhode Island studied by Nixon and Oviatt (1972). Hard clams (Mercenaria mercenaria) and mud snails (Nassa obsoleta) were dominant in terms of biomass whereas the Atlantic silverside (Menidia menidia) was the most common fish present. The results of Thayer et al. (1975) in North Carolina indicate that the fauna inside and outside of areas of eelgrass beds are taxonomically similar but a greater number of individuals of a somewhat smaller size occur within the eelgrass beds. The epifauna of the beds is distinct and not found outside the beds. Fish biomass also is typically much larger inside the beds and composed of a greater proportion of juveniles.

Seagrass systems perform another, perhaps less appreciated function, sediment binding and stabilization. Underground portions are most important in binding the sediments whereas aboveground portions are important in slowing water movement, thus promoting settling of suspended particles. The observation that eelgrass is often associated with more or less muddy sediments may be more related to sedimentation than to habitat preference. Sediment trapping and stabilization usually results in some substrate buildup compared to non-vegetated areas (Burrell and Schubel, 1977). Because most of the information on the magnitude of sediment build-up is from the tropics and subtropics where other seagrass species occur, this function for local Zostera beds is speculative. Changes in sediment morphology and composition have been noted after elimination of Zostera by Cottam and Munro (1954). They found that denudation was followed by replacement of well-anchored, organic rich sediments by shifting sand. Wilson (1949) observed a 2 foot reduction in sand banks in Salcombe Harbor (Great Britain) following the disappearance of eelgrass.

Not all of the functions performed by submerged vegetation are viewed as being beneficial. Eelgrass is sometimes viewed as an undesirable weed, accumulating in large windrows on beaches after storms and fouling boat propellers in the water (Burkholder and Doheny, 1968). Dense decaying masses of vegetation may smother benthic organisms and produce foul odors as a result of anaerobic fermentation. Insects, such as deerflies and stableflies are reported to breed in decaying eelgrass deposits (E.G. Rockel, personal communication). Interference with waterskiing, bathing, and fishing by hook and line are other activities which may be adversely affected by dense beds of submerged vegetation (Burkholder and Doheny, 1968). The harvest of shellfish also may be hampered by the presence of eelgrass (T. McLoy and W. Figley, personal communication).

In summary, the eelgrass system performs a variety of biological and physical functions, many of which are interrelated. Transport to other systems such as beaches and deeper offhsore waters also may be of some importance but is little understood at present. Viewed in terms of Odum's (1969) strategy of ecosystem development, seagrass ecosystems are mature in a number of respects such as complexity of food interrelationships, feedback mechanisms between bacteria and their grazers, high diversity and structural complexity (especially of microbes), and relatively closed mineral cycles. Efforts to more fully evaluate these systems must await whole system examination of their structure and function. Burrell and Scubel (1977) state, "no multi-disciplinary coordinated efforts to understand a seagrass ecosystem have been attempted to date and this is a serious omission."

5.0 PRESENT AND POTENTIAL IMPACTS ON SUBMERGED VEGETATION

Maintenance of healthy beds of submerged vegetation is an integral part of preserving the health of the estuarine environment. Many of the functions of the seagrass beds are similar to those of the salt marshes which have been recognized to be of sufficient value to prompt legislation aimed at halting their destruction. Similar to marshes, seagrass beds are areas of high productivity which implies their potential importance in food chains although few data are available on the primarily detritus-based pathways. Seagrasses also form important habitats for many animals, not all of which may be directly related to the beds by food relationships. Effects on sedimentation and mineral cycling are also of significance although largely unknown in detail. Seagrass beds here, as elsewhere, may be expected to decline as a result of human activity.

It is extremely difficult to compare the extent of eelgrass beds in any area of the North Atlantic because of lack of information and natural fluctuations, such as those resulting from the wasting disease and other natural factors. Orth (1976) has documented the destruction of *Zostera* by the feeding activities of cownose rays and possible adverse effects of high summer temperatures which have resulted in marked fluctuations of eelgrass in Chesapeake Bay. den Hartog and Polderman (1975) discuss a variety of possible causes for *Zostera* decline in Holland including wasting disease, cold temperature, and pollution. It is interesting to speculate if human induced stresses such as thermal or other forms of pollution would affect the vitality or distribution of eelgrass. If above average water temperature is an important factor in the wasting disease, as suggested by Rasmussen (1977), thermal pollution might be especially detrimental to *Zostera*, particularly in years of above average temperatures. Other forms of human disturbance are also likely to be detrimental to *Zostera* as documented by Kikuchi and Pérès (1977) in the Seto Inland Sea of Japan where decreasing catches of shrimp, crab, squid, and some reef fishes have accompanied seagrass reduction. Sewage effluents would be expected to have a detrimental effect on *Zostera* by promoting growth of sewage-tolerant *Ulva lactuca* which forms blooms near outfalls (Guist and Humm, 1976). Other activities such as dredging for channel maintenance or for constructing marina facilities will serve to eliminate potential habitat for submerged vegetation. Although not as obvious visually, boat channels and maintained waterways remove habitat in much the same way that building a road across a salt marsh does. Extensive boating in shallow areas of submerged vegetation uproots and cuts plants as evident from repeated photography in this study. Small damaged areas can be repaired by vegetative propagation but repeated or larger disturbance can exceed this capacity. Attempts to reestablish or initiate new seagrass beds by transplantation have yielded poor results in most cases (Phillips, 1974).

The construction of bulkheads and navigation channels associated with residential development adjacent to the wetlands may produce negative impacts on the submerged vegetation system. The depths of water off the bulkheads and in the channels may be too great for the necessary light levels to support vegetation growth. Further, many structures or construction which alter currents will also influence submerged vegetation. Currents in the vicinity of 3.5 knots are considered the upper limit for successful Zostera growth (Phillips, 1969). Presumably, any human activities reducing currents might create new favorable habitats wherever water and substrate conditions are otherwise suitable.

Although still in early stages of development for the Middle Atlantic coast, exploration for oil and gas could have major impacts on submerged vegetation through oil spills, dreding for pipeline corridors, and onshore support bases and associated activities. Proper safety measures coupled with lack of major accidents may allow for this additional activity without serious impact.

Although present data are relatively incomplete, it is clear that seagrass beds in New Jersey, as elsewhere, are an important part of the estuarine ecosystem. Their significance extends far beyond the variety of waterfowl which use them as a major food source and even beyond the many organisms which use them via the detritus food chains. Basic knowledge of the total role of submerged vegetation is very incomplete but available evidence indicates it may be of considerable significance in the functioning of the estuary.

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Appendix I   Field Data At Sampling Sites In Little Egg Harbor

Site	Location	Date	Time	Depth (dm)	Secchi (dm)	Wind kmph	Sediment	Vegetation Type	% Bottom Cover	Comments
101	Shelter Is.	9-15	1455	14	4	8-12	Sandy, detritus	Z	100	Large bed of Z
102	Shelter Is.	9-15	1505	4	3		Soft sand	U	1	
								R	50	No Z
103	Sedge Is.	9-15	1525	7	3		Sand, detritus	Z	50	Patchy
104	Goosebar Sedge	9-27	1130	10	9	Mod.	Sand	N	0	Z debris, some C, U debris
105	Goosebar Sedge	9-27	-	7	-	-	Sand	N	0	Sparse floating Z, U
106	Goosebar Sedge	9-27	-	6	-	-	Sand	N	0	Sparse floating Z, U
										Soft sediments near plants.
107	Marshelder Is.	9-27	1350	10	10	High	Silty-clay, muck	Z	100	Firm sand in bare spots.
108	Marshelder Is.	9-27	-	9	6	High	Silty muck	Z	100	Long leaves
109	Marshelder Is.	9-27	-	7	6	-	-	R	90	-
								Z	10	
110	Marshelder Is.	9-27	-	9	-	-	Sand	Z	50	No R
111	Marshelder Is.	10- 7	0910	4	>4	14	Sand	R	50	Z detritus
112	Marshelder Is.	10- 7	0930	5	>5	10	Sand	R	25	Mixed vegetation, Patchy
								Z	25	
113	Marshelder Is.	10- 7	0945	6	>6	14	Mud	Z	100	
114	Marshelder Is.	10- 7	1005	5.5	>5.5	11	Mud	Z	100	-
123	Egg Is.	10- 4	-	-	10	-	-	Z	100	Long leaves
124	Egg Is.	10- 4	-	-	-	-	-	Z	50	-
125	Egg Is.	10- 4	-	-	-	-		Z	100	Long leaves
126	Egg Is.	10- 4	-	-	-	-	-	Z	25	Some mixed vegetation, Patchy
								R	25	
127	Egg Is.	10- 4	-	-	-	-	-	Z	50	-
128	Egg Is.	10- 4	-	-	-	-	-	Z	25	Z detritus
129	Egg Is.	10- 4	-	-	-	-	-	Z	75	-
130	Egg Is.	10- 4	-	-	-	-	-	Z	100	Long leaves

* Z = Zostera   C = Codium   N = None
R = Ruppia   U = Ulva   G = Gracilaria

Appendix I Continued

Site	Location	Date	Time	Depth (dm)	Secchi (dm)	Wind kmph	Sediment	Vegetation Type	% Bottom Cover	Comments
131	Egg Is.	10- 4	-	-	-	-	-	Z	50	-
132	Egg Is.	10- 4	-	-	-	-	-	R	50	Dense Z detritus
133	Egg Is.	10- 4	-	-	-	-	-	Z	50	
143	Shelter Is.	10-11		10	9	Calm	-	Z	100	Some dark epiphytes
144	Shelter Is.	10-11	-	7	7		Sand	Z	<25	Z small leaves
						-		R	25	
145	Shelter Is.	10-11	-	10	-	-	-	Z	100	Long leaves, epiphytes
146	Shelter Is.	10-11	-	10	-	-	-	Z	100	Long leaves, epiphytes
147	Shelter Is.	10-11	-	-	-	-	-	Z	100	Long leaves
148	Cove Long Beach Is.	10-11	-	4	-	-	-	R	25	R detritus
								Z	25	
149	Cove Long Beach Is.	10-11	-	4	-	-	-	R	50	Short R 7-10 cm
150	Cove Long Beach Is.	10-11	-	9	-	-	-	C	<25	
								Z	50	
164	Marshelder Is.	10-21	1020	-	-	-	-	Z	50	Z detritus
165	Marshelder Is.	10-21	-	3	-	-	Med-brown silt	Z	50	
166	Marshelder Is.	10-21	-	-	-	-	Med-brown silt	N	0	Z detritus
167	Marshelder Is.	10-21	-	-	-	-	Med-brown silt	Z	25	
168	Marshelder Is.	10-21	-	-	-	-	Med-brown silt	Z	100	Z detritus
169	Marshelder Is.	10-21	-	-	-	-	Soft brown mud	Z	100	Long leaves
170	Marshelder Is.	10-21	-	10	6	-	Soft brown mud	Z	100	Mid-point of transect Long leaves
171	Marshelder Is.	10-21	-	10	-	-	Soft brown mud	N	0	
172	Marshelder Is.	10-21	-		-	-	Soft brown mud	N	0	
173	Marshelder Is.	10-21	-	-	-	-	Med-brown mud	Z	100	Long leaves
174	Marshelder Is.	10-21	-	-	-	-	Med-brown mud	Z	75	Z detritus
175	Marshelder Is.	10-21	-	-	-	-	Soft brown mud	Z	100	Z detritus
176	Marshelder Is.	10-21	-	-	-	-	Soft brown mud	Z	100	No detritus
177	Marshelder Is.	10-21	-	-	-	-	Soft brown mud	Z	100	No detritus
178	Marshelder Is.	10-21	-	4	-	-	Soft brown mud	Z	100	No detritus
179	Marshelder Is.	10-21	-	-	-	-	Soft brown mud	Z	90	No detritus

Appendix I Continued

Site	Location	Date	Time	Depth (dm)	Secchi (dm)	Wind kmph	Sediment	Vegetation Type	% Bottom Cover	Comments
180	Marshelder Is.	10-21	-	-	-	-	Soft brown mud	Z	75	-
181	Marshelder Is.	10-21	-	-	-	-	Soft brown mud	Z	50	-
182	Marshelder Is.	10-21	-	-	-	-	Med-brown sand	Z	50	Patchy vegetation
183	Marshelder Is.	10-21	-	-	-	-	Med-brown sand	Z	25	End transect
										Patchy vegetation
184	Marshelder Is.	10-21	-	-	-	-	-	R	<25	Begin transect
								Z	<25	Abundant Z detritus
185	Marshelder Is.	10-21	-	-	-	-	-	N	0	Abundant Z detritus
186	Marshelder Is.	10-21	-	-	-	-	-	R	50	Z detritus
								Z	25	
187	Marshelder Is.	10-21	-	-	-	-	Med-brown silt	R	50	-
								Z	50	
188	Marshelder Is.	10-21	-	-	-	-	Med-brown silt	R	50	-
								Z	50	
189	Marshelder Is.	10-21	-	2	-	-	Med-brown silt	R	50	-
								Z	50	
190	Marshelder Is.	10-21	-	2	-	-	-	R	95	-
								Z	5	
191	Marshelder Is.	10-21	-	2	-	-	-	R	99	-
								Z	01	
192	Marshelder Is.	10-21	-	2	-	-	-	R	99	-
								Z	01	
193	Marshelder Is.	10-21	-	-	-	-	-	R	90	-
194	Marshelder Is.	10-21	-	-	-	-	-	Z	60	-
195	Marshelder Is.	10-21	-	-	-	-	-	Z	<25	Mid-point of transect
196	Marshelder Is.	10-21	-	5	-	-	-	Z	80	Z detritus
197	Marshelder Is.	10-21	-	6	-	-	-	Z	90	-
198	Marshelder Is.	10-21	-	6	-	-	-	Z	90	-
199	Marshelder Is.	10-21	-	6	-	-	-	Z	90	-
200	Marshelder Is.	10-21	-	4	-	-	Light brown mud	Z	100	Long leaves, epiphytes

Appendix I Continued

Site	Location	Date	Time	Depth (dm)	Secchi (dm)	Wind kmph	Sediment	Vegetation Type	% Bottom Cover	Comments
201	Marshelder Is.	10-21	-	4	-	-	Light brown mud	Z	100	Long leaves, epiphytes
202	Marshelder Is.	10-21	-	4	-	-	Light brown mud	Z	100	Long leaves, epiphytes
203	Marshelder Is.	10-21	-	4	-	-	Light brown mud	Z	100	Long leaves, epiphytes
204	Marshelder Is.	10-21	-	4	-	-	Light brown mud	Z	100	Long leaves, epiphytes
205	Marshelder Is.	10-21	1150	2	-	-	Med- brown sand	Z	50	-
206	Long Point Transect	10-21	1220	30	3	-	Dark mud	N	0	Near buoy #2
207	Long Point Transect	10-21	1228	>40	-	-	-	-	-	Could not reach bottom
208	Long Point Transect	10-21	1230	20	4	-	Med- brown mud	N	0	Z detritus
209	Long Point Transect	10-21	1235	20	5	-	Med- brown mud	N	0	Z detritus
210	Long Point Transect	10-21	1240	15	4	-	Med-brown sand	C Z	-	C unattached, Z patchy
211	Long Point Transect	10-21	-	5	4	-	Med-brown sand	Z C	100 -	Z detritus
212	Long Point Transect	10-21	-	7	5	-	Med-brown silt	Z	100	Some filamentous brown algae
213	Long Point Transect	10-21	-	6	6	-	Soft-brown-sandy	C Z	- -	-
214	Mordecai Is.	10-25	0950	17	9	0	Dark sand, mud	N	0	Numerous clams
215	Mordecai Is.	10-25	1005	9	9	-	Med-dark sand	Z	05	No detritus
216	Mordecai Is.	10-25	1015	6	6	-	Med-dark sand	R	75	Plants along shore only
217	Mordecai Is.	10-25	1025	10	10	-	Med-brown sand	R	05	Slight Z detritus
218	Mordecai Is.	10-25	1031	10	10	-	Med-brown sand	R	40	-
219	Mordecai Is.	10-25	1045	4	4	-	Med-brown sand	N	0	-
220	Mordecai Is.	10-25	1050	10	8	-	Soft mud	R Z	60 40	Large patch of vegetation
221	Mordecai Is.	10-25	1100	5	5		Med-brown silt	N	0	-

Appendix I Continued

Site	Location	Date	Time	Depth (dm)	Secchi (dm)	Wind kmph	Sediment	Vegetation Type	% Bottom Cover	Comments
222	Mordecai Is.	10-25	-	7	7	-	Med-brown sand	N	0	-
223	Mordecai Is.	10-25	1110	6	6	-	Med-brown sand	R	<25	Sparse patches R
224	Mordecai Is.	10-25	1112	8	8	-	Med-brown sand	N	0	-
225	Mordecai Is.	10-25	-	-	-	-	Med-brown sand	N	0	-
226	Ham Is.	10-25	1230	5	5	-	-	Z	99	-
								C	1	
227	Ham Is.	10-25	-	4	4	-	Med-brown sand	R	100	Z detritus
228	Ham Is.	10-25	1235	3	3	-	Light sand	R	20	Z and R detritus
229	Ham Is.	10-25	1250	7	7	-	-	Z	100	-
230	High Is. Area	10-25	1305	9	9	-	Med-brown sand	Z	100	-
232	High Is. Area	10-25	1320	>40	14	-	-	Z	100	-
233	High Is. Area	10-25	1330	9	9	-	-	Z	100	-
234	High Is. Area	10-25	-	12	12	-	-	Z	100	-
235	High Is. Area	10-25	-	8	8	-	Med-brown sand	Z	100	-
236	High Is.	10-25	-	4	4	-	Med-brown sand	R	70	Z detritus
237	High Is.	10-25	1340	7	7	-	Light sand	R	<25	-
								Z	75	
238	High Is.	10-25	-	3	3	-	Med-brown sand	R	50	Z and C detritus
239	High Is.	10-25	1400	4	4	-	Light sand	R	25	-
								Z	25	
240	Long Point Transect	10-25	1430	30	8	-	Med-brown sand	N	0	-
241	Long Point Transect	10-25	-	30	8	-	Med-brown silt	N	0	-
242	Long Point Transect	10-25	-	30	-	-	Dark mud	N	0	Z detritus
243	Long Point Transect	10-25	-	10	-	-	Med-brown sand	N	0	-
244	Long Point Transect	10-25	-	7	-	-	Light sand	N	0	Ripple marks on sand

Appendix I Continued

Site	Location	Date	Time	Depth (dm)	Secchi (dm)	Wind kmph	Sediment	Vegetation Type	% Bottom Cover	Comments
245	Long Point Transect	10-25		20	-	-	Med-brown sand	N	0	Z and C detritus
246	Ham Island	11- 9	1330	10	>10	0	Firm sand and silt	Z	100	C on clam shell
								C	-	
247	Ham Is.	11- 9	-	10	>10	-	Sand	Z	50	Patchy, C fragments
								C	-	
248	Ham Is.	11- 9	-	10	-	-	Sand	Z	100	-
249	Ham Is.	11- 9	-	10	-	-	Sand	Z	100	-
250	Ham Is.	11- 9	-	10	-	-	Sand	Z	100	-
251	Ham Is.	11- 9	-	10	-	-	Sand	Z	100	-
252	Ham Is.	11- 9	-	10	-	-	Sand	Z	100	-
253	Ham Is.	11- 9	-	10	-	-	Sand	Z	100	-
254	Ham Is.	11- 9	1545	10	-	-	Sand	Z	100	-
256	Shelter Is. Area (south)	11-16	0930	10	6	-	Sand	Z	90	Short Z
								C	-	
257	Shelter Is. Area	11-16	-	15	-	-	Sand	Z	50	Area of sand deposition
258	Shelter Is. Area	11-16	-	10	-	-	Mud	N	0	-
259	Shelter Is. Area	11-16	-	5	-	-	Sand (rippled)	R	10	Area of sand deposition
260	Shelter Is. Area	11-16	-	10	-	-	Sand	R	10	Area of sand deposition
261	Little Is. area	11-16	-	12	-	-	Mud	Z	100	No sand
262	Ham Is.	11-16	-	17	-	-	Med-dark sand	N	0	Numerous dead rhizomes
263	Ham Is. area	11-16	-	14	-	-	Med-dark sand	Z	100	-
264	Ham Is. area	11-16	-	14	-	-	Med-dark sand	Z	100	-
265	Ham Is. area	11-16	-	14	-	-	Med-dark sand	Z	100	-
266	Ham Is. area	11-16	-	16	-	-	Med-dark sand	Z	-	Many dead rhizomes
267	Ham Is. area	11-16	-	16	-	-	Med-dark sand	Z	-	Many dead rhizomes

Appendix I Continued

Site	Location	Date	Time	Depth (dm)	Secchi (dm)	Wind kmph	Sediment	Vegetation Type	% Bottom Cover	Comments
268	Cove, Long Beach Is.	12-2	1200	15	-	-	light sand	N	0	1 fragment U
269	Cove near Mordeccai Is.	12-2	1215	10	-	-	sand & cobbles	Z	<25	-
270	Cove Long Beach Is.	12-2	1240	23	13	-	mud	Z	<25	-

Appendix II Field Data At Sampling Sites In Lakes Bay

Site	Location	Date	Time	Depth (dm)	Secchi (dm)	Wind kmph	Sediment	Vegetation Type	% Bottom Cover	Comments
271	Lakes Bay	12-16	1020	18	12	0-9	soft mud	U	-	-
								G	100	
272	Lakes Bay	12-16	-	18	-	-	soft mud	G	100	-
273	Lakes Bay	12-16	-	20	-	-	soft mud	G	100	-
274	Lakes Bay	12-16	-	20	-	-	soft mud	U	< 25	-
								G	< 25	
275	Lakes Bay	12-16	-	20	-	-	mud	N	0	-
276	Lakes Bay	12-16	-	15	-	-	mud	N	0	-
277	Lakes Bay	12-16	-	13	-	-	mud	N	0	-
278	Lakes Bay	12-16	-	8	-	-	pebbles, black-top debris	N	0	no algae on pebbles
279	Lakes Bav	12-16	-	20	-	-	mud	N	0	-
280	Lakes Bay	12-16	-	20	10	-	mud	N	0	numerous clams
281	Lakes Bay	12-16	-	20	-	-	mud	N	0	numerous clams
282	Lakes Bay	12-16	-	20	-	-	mud	N	0	numerous clams
283	Lakes Bay	12-16	-	20	-	-	mud	N	0	numerous clams
284	Lakes Bay	12-16	-	20	-	-	mud	N	0	-
285	Lakes Bay	12-16	-	13	-	-	mud	N	0	-
286	Lakes Bay	12-16	1155	13	-	-	mud	N	0	-
287	Lakes Bay	12-16	1200	13	-	-	mud	U	< 25	-
								G	< 25	
288	Lakes Bay	12-16		15	-	-	mud	N	0	-
289	Lakes Bay	12-16	-	15	-	-	mud	N	0	-
290	Lakes Bay	12-16	-	13	-	-	mud	N	0	-
291	Lakes Bay	12-16	-	18	-	-	mud	N	0	-
292	Lakes Bay	12-16	-	18	-	-	firm mud	G	20	-
293	Lakes Bay	12-16	-	25	-	-	soft mud	U	< 25	-
								G	50	

* Z = _Zostera_ C = _Codium_ N = None
R = _Ruppia_ U = _Ulva_ G = _Gracilaria_

Appendix II Continued

Site	Location	Date	Time	Depth (dm)	Secchi (dm)	Wind kmph	Sediment	Vegetation Type	% Bottom Cover	Comments
294	Lakes Bay	12-16	-	18	-	-	mud	N	0	-
295	Lakes Bay	12-16	-	18	-	-	mud	N	0	-
296	Lakes Bay	12-16	-	20	-	-	mud, peat	N	0	peat on bottom
297	Lakes Bay	12-16	-	15	-	-	sandy mud	N	0	numerous clams
298	Lakes Bay	12-16	-	23	-	-	sandy mud	N	0	numerous clams

Front Cover: Greatly enlarged portion of a 35 mm color slide of the Marshelder Islands, Little Egg Harbor, New Jersey. The dark areas in the waters around the islands are areas of submerged vegetation. See Figure 9 for more detailed images.