Applications of Remote Sensing and Geographical Information Systems for Marine Resources Management in Penobscot Bay, Maine:

Intertidal Habitat Definition and Mapping in Penobscot Bay

FINAL PROJECT REPORT

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Introduction

The Gulf of Maine is characterized by an unparalleled geologic, climatic and oceanographic complexity which has resulted in remarkably diverse and productive biotic systems. These systems have provided abundant utilizable marine resources which have sustained human culture on the Gulf of Maine's shore from the retreat of the last glacier to the present day. The Gulf of Maine has always been a dynamic system. Marked changes in the physical environment have occurred continuously at varying rates over the past 10,000 years. These natural changes in tidal range, surface water temperature, estuarine flushing rates, etc. produced ecosystem responses and sequential replacement of the dominant exploited natural resource species. Since the European settlement of New England, human activities, intensive land use practices, modification of rivers, chemical contamination, exotic species introductions and over-fishing, have greatly accelerated the rate of ecosystem change.

Despite the ecological and economic importance of the coastal zone, the details and consequences of humankind's impacts are poorly documented and understood. In many coastal regions, human influence is so great that the underlying natural signals are completely masked. In many eastern Maine estuaries and embayments, however, the principal human influence remains natural resource harvesting and they are less impacted by the more insidious forms of degradation. These estuaries are, therefore, excellent laboratories in which to demonstrate and study natural biological functioning and the effects of natural and human abiotic focing on the development and maintenance of biotic systems. Nevertheless, these important estuaries, such as Penobscot Bay, remain some of the most poorly studied in the United States.

The Island Institute, with its parteners, the Environmental Research Institute of Michigan and The National Oceanic and Atmospheric Administration's National Environmental Satellite, Data, and Information Service, has embarked on a landmark program to describe and delineate the basic ecological character of Penobscot Bay. The goal of this effort is to provide an accessible information base to guide enlightened marine resource use and management decisions. The primary focus is on restoration and sustainability of wild resources species and aquaculture siting. In addition, however, the results will provide a context to encourage ecosystem level management and will have applications well beyond the confines of Penobscot Bay.

The foundation of a meaningful ecological characterization is based upon knowledge of: 1) the identity of the principal system components; and 2) their distribution in space and time. Such knowledge is not always easily attainable. In fact, in the coastal zone, with multiple sources of primary production, complex geology and steep environmental gradients, gaining sufficiently rigorous information on the contributions of ecosystem components can be time-consuming and costly. Only a decade ago, attempting to characterize a region on any significant scale at a resolution adequate to contribute to resource management would have been impractical. Recent technological developments in remote sensing of the environment and in storing and manipulating diverse environmental data in a spatial framework have greatly advanced the comprehension of heretofore unaccessible and/or incompatible data sets. The use of satellite and aircraft-derived imagery allows the synoptic examination of relatively large areas and greatly expands the inferences that can be derived from site specific field studies. Furthermore, by examining time series images, environmental trends can be identified and the results of temporally limited studies can be projected over seasons, years and even decades. With the addition of GIS technology, satellite images and field studies can be liniked to several other existing data bases to produce a comprehensive matrix of environmental information accessible to scientists and managers alike. For management purposes, the whole becomes greater than the individual parts because subtle relationships and trends in the complex data sets may become obvious when put into common context. In addition, marine and terrestrial information on the environment, which are usually considered in isolation from one another, become linked and can then be treated as the inter-related components that they actually are.

In Penobscot Bay, as in most macrotidal estuaries, the intertidal/nearshore region is a very significant component of the system. The resident fucoid beds, kelp forests and SAV meadows contibute substantially to the primary productivity budget of the Bay while providing habitat for ecologically and commercially important species. The productivity contribution is temporally distinct from the spring phytoplankton bloom and, hence, is important in smoothing the carbon input curve. In many macrotidal embayments (Bristol Channel, Cobscook Bay) the productivity of benthic diatoms of mud and sand flats far exceeds that of the phytoplankton. The intertidal region provides habitat for comercially and recreationally inportant invertebrates, marine mammals and birds. It is a feeding ground for several species of fish, being especially important to certain age classes. The intertidal is a major interface between the terrestrial and marine environment. Human activity is concentrated at the shore and the intertidal is a conduit of materials from the land to the sea.

This report summarizes our efforts to use the spatial coverage and analytical power of ariborne remote imagery and GIS technology to define, classify and map the intertidal and nearshore habitats of two large subregions of Penobscot Bay. We see this activity as providing the foundation upon which a rational ecological characterization of Penobscot Bay may be built. The resulting GIS layer(s) will feed directly into other project components and will provide accessible linkages to the larger user communities which include researchers, managers, fishermen and aquaculturists.

The Study Areas of Penobscot Bay:

For the purposes of this study, the shoreline of Penobscot Bay was divided into two study areas. The first is the Islesboro region, which includes Islesboro Island and several smaller islands that surround the main island (Ram Island, Seal Island, Flat Island, Seven Hundred Acre Island, Spruce Island, Warren Island, Minot Island, Job Island, Lime Island, Lasell Island, Saddle Island, and Mark Island). The second is the Owl's Head region, which stretches from Rockland Harbor in the North to Wheeler Bay in the South, including several offshore islands (Monroe Island, Sheep Island, Fisherman Island, Ash Island, Spaulding Island, Tommy Island, Garden Island, Sprucehead Island, Burnt Island, Rackliff Island, Elwell Island, Calf Island, Norton Island, Whithead Island, and the Muscle Ridge Islands).

Project Activities:

Year 1 activities of the project began on July 1, 1997. Year 1 activities included:

- visited the Washington Department of Natural Resources (WDNR) to learn techniques for characterizing intertidal habitats using CASI
- reviewed habitat classification systems and developed a working system for use in the marine intertidal of the northern Gulf of Maine
- developed field protocols for characterizing training and accuracy assessment sites
- collected and reviewed reference data
- completed an extensive field data collection program

- prepared for receipt and processing of the multispectral CASI data
- observing the successful acquisition of the multispectral CASI data

Our Year 2 activities of the project began on September 15, 1997. The following activities were completed in Year 2:

- prepared the CASI data for image processing by subsetting the data and creating a land mask
- processed all 5 CASI images to completion
- wrote a combination model to combine the output images from the classifications into composite images
- completed accuracy assessment of the classified data
- converted raster layers to vector format
- created a data library that includes all of the processed and final images
- prepared metadata information for the Maine Office of Geographic Information Systems (MOGIS)

Summary of Activities and Presentation of Results

<u>Visit to Washington Department of Natural Resources (WDNR)</u>:

The Nearshore Habitat Program of the WDNR is engaged in a long-term program of mapping and monitoring the intertidal habitats and resources of Puget Sound. Airborne multispectral imagery is their data collection method of choice. Since 1988, they have completed several surveys using two airborne remote sensing systems. After getting disappointing results in their earlier surveys, they have switched to the exclusive use of the CASI system. Over the years, they have gained vast experience with the efficient collection of ground data and the processing of multispectral intertidal imagery. WDNR staff provided advice on many aspects of this task during the planning and proposal stages and, ultimately, offered to walk us through their latest techniques. Accordingly, Cyndy Erickson and Peter Larsen traveled to WDNR headquarters in Olympia, Washington from July 12-16 and received intensive firsthand experience. Cyndy worked primarily with the image processor and Peter with the ecologists of the field crew. We are extremely grateful to the staff that contributed eight days to sharing their knowledge with us.

<u>Development of Habitat Classification Scheme</u>:

As with any systematic treatment of a knowledge base, the quantitative description of the intertidal region of Penobscot Bay requires a comprehensive and unambiguous vocabulary, i.e., a classification scheme. The scheme must include every piece of ground covered and each piece must classify to one, and only one, category. The scheme must account for the range of environmental variability to be encountered, the relative size, abundance and importance of habitat types, the discrimination of the sensing system and the practicality of dealing with continuous environmental data.

Many marine and estuarine habitat classification systems were collected. Those having appropriate levels of detail and relevance to the biogeographic and geomorphologic conditions encountered in the Gulf of Maine were reviewed. The principal classification schemes among these fall into two categories. The group including The Coastal Maine

Geologic Environments (known as CMGE and based on Timson's work in The Geology of Maine's Coastline, 1983) and Maine's Intertidal Habitats (Larsen and Doggett, 1985), were developed for specific inventory work on the Maine coast sponsored by the Maine State Planning Office. The second group consists of the National Wetland Inventory (NWI) (Cowardin, Carter, Golet and LaRoe, 1979), A Marine and Estuarine Habitat Classification System for Washington State (Dethier, 1990), A Classification System of Marine and Estuarine Habitats in Maine: An Ecosystem Approach to Habitats (Brown, 1993) and A Field Guide for Characterizing Habitats Using a Marine and Estuarine Habitat Classification System for Washington State (Bailey, Ward and Manning, 1993). The second group are intellectually related in that Dethier (1990) takes the basic form of the NWI and greatly expands its detail and usefulness in the marine and estuarine environments, while Brown (1993) largely adapts the Dethier (1990) format to Maine's nearshore benthic environments. All of these are too complex for practical use in a remote sensing project. Bailey, *et al* (1993) is a simplification of Dethier for use in the WDNR Puget Sound surveys.

We have developed a hierarchical classification scheme based on the existing classification systems, our experience with Gulf of Maine intertidal systems, the goals of the project and the attributes of the remote sensor. Care was taken to be consistent, to the extent possible, with other classifications in use in Maine, especially that of Brown (1993). Consideration was given to the applicability of the scheme to regions outside of Penobscot Bay.

In brief, the oceanic environment is divided into two Systems: Marine and Estuarine. Each System consists of two Subsystems based on the tidal regime: Intertidal and Subtidal. In deference to the abilities of the CASI system, and in departure from Brown (1993), we include a Superclass level into the hierarchy. The Superclasses are Vegetation and Substrate and their purpose is to group those habitat attributes which CASI discriminates well and those which it does not. Brown (1993) includes only inorganic substrate categories at the class level and uses the biota, including vegetation, as descriptors of diagnostic and common species of specific habitats at the lowest level of the hierarchy. Within the Vegetation Superclass are the Classes of Brown Algae, Green Algae, Kelp, Red Algae, Mixed Algae, Submerged Aquatic Vegetation, Marsh and Spit/Berm. In the Substrate Superclass are the Classes of Bedrock, Boulder, Cobble, Mixed Coarse, Gravel, Mixed Coarse and Fine, Sand, Mixed Fine, Mud and Artificial. These Classes are defined below. A Subclass level is included to partition, where necessary, each Class based on wind wave or current energy. For the Marine Intertidal the four energy descriptors at the Subclass level are; Exposed, Partially Exposed, Semi-Protected and Protected. Individual classes will not contain all the subclasses. Several modifiers related to salinity, temperature, depth, etc. can be attached to the above scheme. Definitions of energy levels and modifiers can be found in Brown (1993). A diagram of the Marine Intertidal Habitat Classification Scheme as used in the present project is presented in Figure 1.

A working version of the scheme, similar to Bailey, *et al* (1993) was prepared and discussed with colleagues including Seth Barker, John Kenney, Steve Dickson and Bob Vadas. The result is as follows:

WORKING CLASSIFICATION SYSTEM FOR THE INVENTORY OF INTERTIDAL VEGETATION AND SUBSTRATES IN PENOBSCOT BAY

Nearshore Vegetation Classes

An area is assigned to a vegetation class if 25% or more of the surface is covered by vegetation. When the dominant plant type exceeds 75% of the cover surface, the site is assigned to one of the 'pure' vegetation classes described below; otherwise it is assigned to mixed algae. Vegetation classes will be mapped principally by multispectral imaging. The pixel size will be 4m and the final minimum mapping unit will probably be four pixels.

Brown Algae - Algae belonging to the Division Phaeophyta excepting the kelps (see below). The principal members of this class are the rockweeds *Ascophyllum* and *Fucus*.

Green Algae - Algae belonging to the Division Chlorophyta. *Enteromorpha* and *Ulva* are the most common species.

Red Algae - Algae belonging to the Division Rhodophyta. Red algae occur most abundantly in a narrow band along the sublittoral fringe. It is not expected that this class will be encountered frequently.

Kelp - Algae belonging to the Division Phaeophyta, Order Laminariales, i.e. a brown algal group. They are separated from the rockweeds because they occur in a different ecological context and have distinct management considerations. It is uncertain how effectively kelp beds will be resolved by multispectral imaging.

Mixed Algae - Areas where several plant groups co-exist, but no one type contributes 75% surface cover.

Submerged Aquatic Vegetation - SAV. Operationally, SAV beds consist of the rooted, vascular plants. *Zostera marina*, commonly called eelgrass, and Widgeon grass, *Ruppia maritima*, are the species encountered in Maine.

Salt Marsh - Salt-tolerant, emergent wetland plants; principally *Spartina alterniflora* and *Spartina patens*. Several subdominant species occur especially at higher marsh levels. Freshwater marshes are excluded from this study.

Spits and Berms - Supratidal plant communities influenced by salt spray. In the study area, this class is uncommon and usually will not be of sufficient size to meet the minimum mapping unit.

Substrate Classes

Substrate classes describe the non-living substrata of the environments surveyed. Substrate classes are poorly resolved by multispectral imaging. They are mapped by field work, aerial photography and use of reference data. The recommended minimum mapping unit is 0.5 acres.

Bedrock - Bedrock > 3 m diameter, can be various types of consolidated rock. Rock often has other materials overlying it or is found in conjunction with other types of substrata, therefore, one can classify an area as rock if it has at least 50% cover of bedrock. This definition encompasses the Ledge (M) and Veneered Ramp (F6) classes of Timson and the High-energy Rocky Shore and Low-energy Rocky Shore habitats of Larsen & Doggett. This class accounts for over 24% of Maine's intertidal habitat area.

Boulder - Rocks > 256 mm to 3 m in diameter, i.e. those large enough not to be rolled by moderate wave action. Boulders are also associated with a variety of types of substrata from bedrock to mud. Any site with at least 75% boulders can be classified as boulder. In addition, a site with at least 50% cover of boulders is classified as boulder if at least 6% bedrock is also present. This definition encompasses the Boulder Beach (B4) and Boulder Ramp (Br) classes of Timson and the Boulder Beach habitat of Larsen & Doggett. This class accounts for about 2.5% of Maine's intertidal habitat area.

Cobble - Rocks < 256 mm, but > 64 mm diameter; unstable. Cobble beaches are > 75% particles of this size. This definition encompasses the Gravel Beach (B3) class of Timson and the Cobble Beach habitat of Larsen and Doggett. This class accounts for about 3% of Maine's intertidal habitat area.

Mixed Coarse - Substrata consisting of rock, boulders, cobbles, gravel, shell and/or sand. No one substratum type exceeds 75% surface cover, less than 50% cover by rock and boulders. Brown equates this class, at least in part, with Timson's Mixed Sand & Gravel Beach (B2), Coarse Grained Flat (F1), Washover Fans (Bw), Dunes & Vegetated Beach Ridges (Sd) and Veneered Ramp (B6).

Gravel - Small rocks or pebbles 2 to 64 mm in diameter. Habitats are deemed to have gravel substratum if 75% or more of the surface is gravel. This definition combines the granule (2-4 mm) and pebble (4-64 mm) size classes of Folk (1974). This definition encompasses the Low Energy Beach (B5) and Mussel Bar (F3, in part) classes of Timson and the Gravel Beach habitat of Larsen & Doggett. This class accounts for about 4% of Maine's intertidal habitat area.

Mixed Coarse and Fines - Consists of rocks, boulders and coarse and fine particles. No one substratum type exceeding 75% surface cover and less than 50% cover by rocks and boulders. Neither Timson nor Larsen & Doggett describe an analogous class.

Sand - Sediment particles ranging between 0.0625 and 2 mm in diameter. A habitat is defined as sand if 75% or mare of the surface cover is sand. This definition encompasses the Sand Beach (B1), Spits (Bs), Mixed Sand and Gravel Beaches (B2, in part), Coarse-grained Flat (F1), Flood Tide Delta (M1), Fan Delta (Mb), Channel Levee (F4), Seaweed-covered Coarse-grained Flats (F2), Ebb-tidal Delta (Me) and Vegetated Point or Lateral Bars (My) classes of Timson and the Sand Beach and Sand Flat habitats of Larsen & Doggett. This class accounts for approximately 8.25% of Maine's intertidal habitat area.

Mixed Fines - Mixture of sand and mud, with little gravel; likely to change seasonally. If site has <75% of a single grain size, and less than 6% boulder or cobble, and boulder , cobble and gravel cover classes add up to 7% or less, then it is classified as mixed fine. Neither Timson nor Larsen & Doggett describe an analogous class.

Mud - Fine substrata <0.0625 mm, usually mixed with organic matter. If a site has at least 75% surface cover of mud, it is classified as mud. Mud includes both silt and clay. This definition encompasses the Mud Flat (F), Algal Flat (F5) and Mussel Bar (F3, in part) classes of Timson and the Mud Flat habitat of Larsen & Doggett. This class accounts for about 27% of Maine's intertidal habitat area.

Artificial - Concrete Blocks, tires, riprap, log booms, pilings, oyster culture and others. A site with at least 75% artificial materials is classified as artificial. We add quarry tailings and roadways to this class. This definition encompasses the Man-Made Land (Sz) class of Timson. Larsen & Doggett do not describe an analogous class. This class accounts for a very small, but noticeable, percentage of Maine's intertidal habitat area.

Development of Field Protocols:

The WDNR field protocols were adapted and modified to meet our needs. Each selected site was located on an aerial photograph. The site was outlined and labeled on an acetate overlay. At least one color 35mm slide was taken of the site. Data were tabulated relative to the physical description of the site, substrate type, shore slope, water content, plant cover, tide height, etc. At certain sites, the feature of interest was recorded as a GPS polygon or line for comparison of shape or length with the output of the classified images.

Minimum site size for vegetative classes was 25 pixels, preferably a block five pixels on a side. Substrate classes were considered in 0.5 acre units.

Reference Data:

Several types of reference data were acquired and utilized in the planning and execution of the field work. NOAA navigational charts and USGS topographic maps not already available at the Bigelow Laboratory were purchased. An extensive search for suitable aerial photographs of the study area revealed three surveys of use in the present instance. The National Park Service did an aerial survey of the environs of Acadia National Park in May 1997. The flight lines over Islesboro Island occurred near low tide and the Park Service provided a set of these 1:16,000 color infrared photos to the project at no cost. The Maine Department of Transportation (MDOT) funded a 1992 aerial survey of most of Penobscot Bay for the purpose of mapping eelgrass distribution. With the permission of MDOT, we purchased coverage of Islesboro Island and the eastern Owls Head region from the Sewall Company. These are 1:12,000 true color photographs. Finally, Seth Barker of the Maine Department of Marine Resources has loaned the project 1:12,000 true color photography of the western Owls Head region. This 1995 aerial survey, flown by the Sewall Company, was also undertaken to support the mapping of eelgrass distribution.

GIS files of the Coastal Maine Geographic Environments (CMGE) and National Wetland Inventory have been provided to the project by John Kenney of MIFW. In addition, John has provided large scale maps of the study areas highlighting grouped CMGE categories which correspond with the vegetation classes of the project's Habitat Classification Scheme. Habitat polygons are ranked by size. These projections help prioritize and locate field sites selected for ground-truthing. Seth Barker has also been very cooperative in the effort to obtain and use GIS files in support the field work.

Note: The CMGEs represent a major and useful data base with which to generally characterize the coast in support of nearshore research and management. We have found several instances, however, where the CMGE files did not describe accurately the habitat classes at specific locations. Some of these discrepancies can be attributed to changes in the vegetation in the 20 plus years since the CMGEs were completed.

Collection of Field Data:

Candidate sites for processing were selected based on reference data and preliminary field trips. Criteria for selection included size and homogeneity of the feature, its location relative to other examples of the class, and accessibility. An effort was made to choose sites over as broad a geographic distribution as possible to spread the training sites among as many flight lines as possible. Further candidate sites were identified during the field work. The goal was to have six, at a minimum, suitable training/accuracy assessments sites for each class in each of the two regions.

The acquisition of field data using highly advanced systems such as CASI invariably involves practical compromises. From an ecological viewpoint, CASI overflights would ideally be scheduled for the lowest possible tides to maximize, spatially and temporally, the exposure of intertidal habitat. In the Gulf of Maine these tides occur in the early morning or late afternoon. The best CASI images are obtained, however, close to solar noon when illumination conditions are most consistent. These contrasting preferences necessitated a compromise whereby the overflights were scheduled as close to solar noon as possible at tide levels below +2.0 feet. The minimum tidal elevation during the selected windows for flying is 0.0. This compromise should result in good imagery but will limit the evaluation of habitat classes such as kelp and red algae which are exposed only at extreme low tidal levels.

Dates and times for field work were determined as follows. All tidal minimums of +1.0 feet or less during daylight hours from early August to mid October were tabulated. For each of these tides, the time window during which the water level was below +2.0 feet was determined (plus two feet being the projected maximum water level during the CASI overflights). Work effort was scheduled into these tidal windows based on several practical considerations. For instance, boat days are scheduled for tidal windows early in the day before onshore winds develop, and foot sampling on Islesboro was scheduled around mid-day tidal windows to fit the ferry schedule.

Candidate sites were visited on foot or by a boat provided by the Maine Department of Inland Fisheries and Wildlife. At each site that met the minimum requirements necessary for selection as a training/accuracy assessment site, the documentation process described in the field protocols above was instituted. The entire shore line of the study areas was observed from the DIFW boat.

The distribution of the processed sites by class and region is presented in Table 1. The geographic distribution of the sites is represented in Figs. 2 and 3. (Note: The sites are not more specifically identified in these figures because up to one third of them will be accuracy assessment sites and, hence, pertinent information is kept from the image processors). These 167 sites are those which fit the defined criteria for training/accuracy assessment sites. They were culled from close to 1,000 sites visited. Several points are reflected in Table 1. First, certain classes are simply not extant in the study areas or occur in patches too small to be used for training or accuracy assessment. The latter is especially true in high energy regions such as the southern shores of Islesboro and the Muscle Ridge Islands where the fractured geology and high wave action result in very patchy vegetative communities. Red algae sites are too deep, too sparse or too narrow to be annotated. Likewise, although we observe occasional kelp plants, we have encountered only one bed that is marginally suitable as a training site. Many subtidal and intertidal macroalgae beds indicated in the CMGE simply are no longer present. Many of the substrate classes are covered by macroalgae and, hence, are classed as vegetation in the present scheme. Whether due to higher energy, simpler geomorphology or a lack of large sediment deposits, the habitat diversity on Islesboro seems to be lower than in the Owls Head region.

Field data sheets, photo logs and GPS data sheets are contained in our Year 1 project report and will not be duplicated here.

<u>Airborne Multispectral Data Acquisition</u>:

The following two paragraphs describing the acquisition of airborne multispectral data are paraphased from the project summary of Borstad Associates previously submitted to the Island Institute (Borstad Associates, 1998).

Multispectral overflights were planned for the tidal window encompassing August 24-28, 1997. Borstad Associates field team were able to obtain images of the two selected study areas on August 24, 25 and 26. During this period the ground truthing team sampled in both areas on foot and by boat. Forty sites were characterized on the flight days and a total of 66 sites were annotated in the six days from August 22-27.

The bands of the CASI were configured with an eleven channel bandset used specifically for intertidal habitat mapping(See Table 2). (Borstad, Project Plan, July 14, 1997) Band 1 was selected for clear water penetration and shows a reflectance maxima for Carotene and an absorption maxima for Chlorophyll b and Fucoxanthin. Band 2 was selected for turbid water penetration and to show the green vegetation reflectance peak. Band 2 shows a reflectance maxima for Chlorophyll a and an absorption maxima for

Table 1. The distribution of vegetation and substrate classes between the study areas.

Habitat Class	**Owls Head**	**Islesboro**	**Total Sites in Class**
Brown Algae	12	13	25
Green Algae	6	1	7
Kelp		1	1
Red Algae	1		1
Mixed Algae	1	3	4
Submerged Aquatic Vegetation	11	8	19
Marsh	6	11	17
Spit/Berm	5	4	9
(Mussel Bed)*	2		2
Bedrock	5		5
Boulder	2	2	4
Cobble	4	3	7
Mixed Coarse	9	3	12
Gravel	1	3	4
Mixed Coarse & Fine	6	13	19
Sand	12	3	15
Mixed Fine	2		2
Mud	6	2	8
Artificial	3	3	6
Totals	94	73	167

*not a defined habitat

Phycoerythrin. Band 3 was selected to show the absorption well for brown algae. Band 4 was selected to show the first reflectance peak of brown algae. Band 4 has a reflectance maxima for Chlorophyll c, Fucoxanthinm and Phycoerythrin. Band 5 was selected to show the well between the two reflectance peaks of brown algae and has a reflectance peak for Carotene and an absorption maxima for Chlorophyll c and Phycocyanin. Band 6 was selected to show the second reflectance peak for brown algae. Band 6 has a reflectance maxima for Fucoxanthin and Phycoerythrin and has an absorption maxima for Chlorophyll b and Chlorophyll c. Band 7 was selected to show strong Chlorophyll absorption and has an absorption maxima for Chlorohpyll a. Band 8 was selected to show the reflectance for shallow submerged and floating vegetation. Band 9 was selected to show the near infrared reflectance for submerged and floating vegetation. Bands 10 and 11 were selected to show the near infrared reflectance for emerged vegetation and for substrate typing.

<u>Pre-processed Remote Sensing Data Received from Contractor</u>:

Flightlines of the CASI data were flown on August 24 - 27, 1997 by Borstad Associates Ltd. Bigelow Laboratory for Ocean Sciences received the following data from Borstad Associates Ltd. on the dates noted:

- Mosaic 4a (Block 4, lines 1-5) on October 31, 1997. This data was not color-matched. Also included was an interim processing report.
- Mosaic 4b (Block 4, lines 6-10) on November 14, 1997. This data was not color-matched. Also included was an interim processing report.

- Mosaics 3a and 3b (Block 3, lines 1-3 and 4-6) on November 27, 1997. This data was not color-matched. Also included was an interim processing report.

Table 2. Bandset for CASI.

Band	Wavelength	Location
1	470-515	Blue Visible
2	540-560	Green Visible
3	575-590	Green/Yellow Visible
4	600-615	Orange/Red Visible
5	625-635	Orange/Red Visible
6	640-655	Red Visible
7	670-685	Red Visible
8	704-714	Near Infrared
9	743-755	Near Infrared
10	775-786	Near Infrared

- Mosaic 3c (Block 3, lines 7-10) on December 4, 1997. This data was not color-matched. Also included was an interim processing report.
- Mosaics 4a and 4b (Block 4, lines 1-5 and 6-10) on January 13, 1998. This data was color-matched. Also included was the final project report.

Each of the mosaics was delivered at second stage rectification and was georeferenced correctly.

Preparation for Image Processing:

Using ERDAS Imagine 8.2 image processing software, the CASI data was subsetted to remove excess deep water and to decrease file size. By removing this excess information from the data, the computer was forced to concentrate on the nearshore area. An AOI (area of interest) was created for each mosaic by manually tracing the upland boundary of the nearshore area. The upland/nearshore boundary was delineated by looking at a combination of nautical charts, true color images, and near-infrared images. Using the CMGE's as an AOI to mask out the uplands was considered, but it was found that manually creating the AOI was preferable. Using the CMGE's did not allow certain areas, such as salt marshes, to be included in the AOI.

Image Processing:

The five CASI images of Penobscot Bay were processed to completion using ERDAS Imagine 8.2 software. An iterative classification scheme was used to force every pixel in each of the five mosaics into one of our 18 predetermined classes or into an "unknown" class. The following is a description of the processing scheme used to classify the images. A flow chart illustration is presented in Appendix 1.

1. Collected signatures for the study area using seed pixels to grow spectrally similar areas.
2. Ran supervised classification and produced a distance file.
3. Recoded land mask from 0 to 39.
4. Computed distance histograms.
5. Thresholded histograms and “processed to file”.
6. Examined each polygon and recoded incorrectly classified pixels to 0.
7. When finished examining polygons “saved as” ed2.img.
   - Recoded mask to 0.
   - Recoded 1-17 to 41-57.
8. Re-opened temp2.img and “saved as” im3.img.
   - Recoded 1-27 to 39.
   - Recoded 0 to 38.
   - Recoded 1-27 and 39 to 0.
9. Ran masking utility using im3.img as the mask and the original data as the input raster file.
10. Ran mask3.img through an unsupervised classification.
11. Using un3.sig, ran a mock supervised classification to produce a distance file.
12. Recoded mask from 0 to 39.
13. Computed distance histograms.
14. Thresholded histograms and “processed to file”.
15. Examined each polygon and recoded incorrectly classified pixels to 0.
16. When finished examining polygons, “saved as” ed3.img.
   - Recoded mask to 0.
   - Recoded 1-27 to 81-107.
17. Re-opened temp3.img and “saved as” im4.img.
   - Recoded 1-27 to 39.
   - Recoded 0 to 38.
   - Recoded 1-27 and 39 to 0.
18. Ran masking utility, using im4.img as the mask and the original data as the input raster file.
19. Ran mask4.img through an unsupervised classification.
20. Using un4.sig, ran a mock supervised classification to produce a distance file.
21. Computed distance histograms.
22. Recoded mask from 0 to 39.
23. Thresholded histograms and “processed to file”.
24. Examined each polygon and recoded misclassified pixels to the appropriate class.
25. When finished examining polygons, “saved as” ed4.img.
   - Recoded mask and unclassified pixels to 0.
   - Recoded 1-27 to 120-147.
26. Checked class values and color assignments in all 3 edited images.
27. Used model to combine 3 output edited images into a composite image.
28. Assigned appropriate colors and class names to classes 41-67, 81-107, and 121-147.
29. Saved combined image as final.img and recoded 41, 81, and 121 to 1; 42, 82, and 122 to 2; etc.
30. Edited any misclassified pixels.

For the supervised classification step in the processing routine, a maximum likelihood decision rule was used. This method assumes that training data statistics for each class in each band are normally distributed. (Jensen, 1996).

For the unsupervised classification step in the processing routine, the minimum distance decision rule was selected so that the computer calculates the distance to each mean vector from each pixel. Each unknown is put into the class that it is closest to. If the minimum distance to the closest mean is greater than 2.0, it is put into the unknown class. (Jensen, 1996).

The process of thresholding identifies the maximum distance between a pixel and the mean of the signature to which it is classified. Higher distance values are spectrally farther from the mean and are more likely to be misclassified. (ERDAS, 1994) To curtail human eror in editing the images, the tails of the histograms are cut off so that higher distance value pixels were put into the unknown class.

Combination Model:

Once the images were processed, a model was written to combine the output classified images into composite images. The following is a graphical representation of the model created.

Edited Image #2 IB3c897ed2.img	Edited Image #3 IB3c897ed3.img	Edited Image #4 IB3c897ed4.img

Combination Model
IB3c.gmd

Composite Image
IB3c897comb.img

By using the combination model, all correctly classified pixels in the edited images are combined into one image with most pixels classified correctly. A final edting of the combined image is done to remove any misclassified pixels.

Accuracy Assessment:

Of the 167 sites documented in the field program, 45 were used as training sites and 116 were used as accuracy assessment sites (Table 3). Sites that were correctly classified according to our field annotations were assigned an accuracy rating of 1. Those that were not classified correctly were assigned an accuracy rating of 0. Not all of the sites fell into one of these two ratings. For example, in some cases, an area in the classified image was a different shape than that of the field site annotated on the aerial photograph or only part of the site was classified correctly. In these cases, the site was given a 0.5 rating.

Table 3. The distribution of trsining (T) and accuracy assessment sites (AA) by class within regions. Accuracy assessment scores are listed in column 6. A 1 indicates an accurate classification of the site; a 0 indicates a misclassification; and a 0.5 a partially correct classification. Also indicated is the incorrect or partially incorrect class assigned.

	Class	Site #	Date	GPS/Ann.	T/AA	AA Score
Islesboro	Artificial	57S-7-6	8/24/97	Annotated	T	
	Artificial	57S-7-8	9/23/97	Annotated	AA	0-Gravel
	Artificial	57S-3-3	9/24/97	Annotated	AA	1
	Boulder	59S-1-6	8/26/97	Annotated	T	
	Boulder	55S-3-1	9/13/97	Annotated	T	
	Brown Algae	57S-9-2	8/23/97	Annotated	AA	1
	Brown Algae	57S-9-7	8/23/97	Annotated	AA	1
	Brown Algae	57S-7-5	8/24/97	Annotated	AA	1
	Brown Algae	57S-9-14	8/24/97	Annotated	AA	1
	Brown Algae	57S-9-17	8/24/97	Annotated	AA	1
	Brown Algae	56S-9-2	8/24/97	Annotated	AA	1
	Brown Algae	Robinson Rk	8/25/97	Annotated	AA	1
	Brown Algae	59S-1-4	8/26/97	Annotated	T	
	Brown Algae	59S-1-5	8/26/97	Annotated	AA	1
	Brown Algae	58S-4-3	8/26/97	Annotated	AA	1
	Brown Algae	59S-7-1	8/26/97	Annotated	AA	1
	Brown Algae	58S-12-1	8/26/97	Annotated	T	
	Brown Algae	57S-3-2	9/13/97	Annotated		
	Cobble	57S-5-1	9/13/97	Annotated	T	
	Cobble	57S-5-3	9/13/97	GPS	AA	1
	Cobble	58S-4-7	9/24/97	Annotated	T	
	Gravel	57S-9-1	8/23/97	Annotated	AA	0-Mix C & F
	Gravel	58S-4-2	8/26/97	Annotated	AA	0-Mix C & F
	Gravel	56S-11-4	9/24/97	Annotated	T	
	Green Algae	56S-11-2	9/13/97	GPS	T	
	Kelp	59S-1-3	8/26/97	Annotated	T	
	Marsh	57S-7-1	8/23/97	Annotated	AA	1
	Marsh	57S-9-5	8/23/97	Annotated	AA	1
	Marsh	57S-9-8	8/23/97	Annotated	AA	1
	Marsh	57S-9-9	8/23/97	Annotated	AA	1
	Marsh	57S-9-10	8/23/97	Annotated	AA	1
	Marsh	57S-9-11	8/24/97	Annotated	AA	1
	Marsh	57S-9-16	8/24/97	Annotated	AA	0-Up/Sand
	Marsh	56S-9-4	8/24/97	Annotated	AA	1
	Marsh	56S-11-1	8/24/97	Annotated	T	
	Marsh	58S-8-3	9/23/97	Annotated	AA	1
	Marsh	57S-11-4	9/24/97	Annotated	AA	1
	Mixed Algae	57S-7-2	8/23/97	Annotated	T	

	Mixed Algae	58S-8-2	9/23/97	Annotated	T	
	Mixed Algae	57S-11-2	9/23/97	Annotated	AA	1
	Mixed Coarse	59S-1-1	8/26/97	Annotated	T	
	Mixed Coarse	58S-4-1	8/26/97	Annotated	T	
	Mixed Coarse	55S-3-2	9/13/97	Annotated	T	
	Mixed Coarse and Fine	57S-9-3	8/23/97	Annotated	AA	1
	Mixed Coarse and Fine	57S-9-15	8/24/97	Annotated	AA	1
	Mixed Coarse and Fine	58S-2-1	9/13/97	GPS	AA	1
	Mixed Coarse and Fine	57S-3-1	9/13/97	GPS		
	Mixed Coarse and Fine	57S-5-2	9/13/97	GPS	AA	1
	Mixed Coarse and Fine	57S-15-1	9/13/97	GPS	T	
	Mixed Coarse and Fine	56S-11-3	9/13/97	GPS	AA	1
	Mixed Coarse and Fine	55S-3-3	9/13/97	GPS	AA	1
	Mixed Coarse and Fine	57S-7-7	9/23/97	Annotated	AA	1
	Mixed Coarse and Fine	57S-9-19	9/23/97	Annotated	AA	1
	Mixed Coarse and Fine	58S-8-4	9/23/97	Annotated	AA	1
	Mixed Coarse and Fine	57S-11-3	9/24/97	Annotated	AA	1
	Mixed Coarse and Fine	58S-4-6	9/24/97	GPS	T	
	Mud	57S-9-13	8/24/97	Annotated	T	
	Mud	57S-11-1	9/23/97	Annotated	T	
	Sand	57S-7-9	9/23/97	Annotated	AA	1
	Sand	57S-9-20	9/23/97	Annotated	T	
	Sand	58S-4-5	9/24/97	GPS	T	
	Spit/Berm	57S-9-4	8/23/97	Annotated	AA	1
	Spit/Berm	56S-9-3	8/24/97	Annotated	AA	0.5,1-Mix Co
	Spit/Berm	56S-9-5	8/24/97	Annotated	T	
	Spit/Berm	59S-1-2	8/26/97	Annotated	T	
	Sub. Aquatic Veg.	57S-9-6	8/23/97	Annotated	AA	0-Mix C & F
	Sub. Aquatic Veg.	57S-9-12	8/24/97	Annotated	AA	0-Mix Fine
	Sub. Aquatic Veg.	57S-9-18	8/24/97	Annotated	AA	0-Mix C & F
	Sub. Aquatic Veg.	56S-9-1	8/24/97	Annotated	T	
	Sub. Aquatic Veg.	58S-8-1	9/23/97	Annotated	AA	0.5-SAV/Mix
	Sub. Aquatic Veg.	58S-4-4	9/24/97	GPS	AA	1
	Sub. Aquatic Veg.	58S-8-5	10/10/97	Annotated	AA	0-Deep Wate
	Sub. Aquatic Veg.	57S-15-2	10/10/97	GPS	AA	1
Owls Head	Artificial	63S-5-2	8/15/97	Annotated	AA	1
	Artificial	2N-5-2	8/25/97	Annotated	AA	?Boulder
	Artificial	004-4-2	8/27/97	Annotated	AA	1
	Artificial	65-3-5	9/4/97	Annotated	AA	0-Mix C & F
	Bedrock	004-9-2	8/18/97	Annotated	AA	1
	Bedrock	004-4-1	8/27/97	Annotated	AA	1
	Bedrock	004-9-14	9/5/97	Annotated	AA	1
	Bedrock	004-2-2	9/22/97	Annotated	AA	1
	Bedrock	004-4-6	9/22/97	Annotated	AA	1
	Boulder	63S-5-5	8/15/97	Annotated	AA	0-Bedrock
	Boulder	65-1-3	9/15/97	GPS	T	
	Brown Algae	63S-5-6	8/15/97	Annotated	AA	1
	Brown Algae	004-9-1	8/18/97	Annotated	AA	1

Brown Algae	005-8-1	8/22/97	Annotated	AA	1
Brown Algae	2N-1-1	8/25/97	Annotated	AA	1
Brown Algae	2N-5-3	8/25/97	Annotated	AA	1
Brown Algae	005-6-2	8/27/97	Annotated	AA	1
Brown Algae	65-3-3	9/4/97	Annotated	AA	1
Brown Algae	65-6-3	9/5/97	Annotated	AA	1
Brown Algae	66-4-2	9/6/97	GPS	AA	1
Brown Algae	66-4-3	9/6/97	GPS	AA	1
Brown Algae	66-7-3	9/15/97	GPS	AA	1
Cobble	005-6-1	8/27/97	Annotated	T	
Cobble	004-9-13	9/5/97	Annotated	AA	0-Bedrock
Cobble	65-1-4	9/15/97	GPS	T	
Cobble	64S-5-2	9/21/97	GPS	AA	0-Mix Coars
Gravel	65-6-2	9/5/97	Annotated	T	
Green Algae	004-9-3	8/18/97	Annotated	AA	0-Mix C & F
Green Algae	004-9-9	8/18/97	Annotated	T	
Green Algae	6S-12-2	8/27/97	Annotated	AA	0-Mix C & F
Green Algae	65-3-9	9/4/97	Annotated	T	
Green Algae	005-8-3	9/4/97	Annotated	AA	1
Green Algae	66-7-5	9/15/97	Annotated	AA	1
Marsh	004-9-10	8/18/97	Annotated	AA	1
Marsh	6N-3-1	8/27/97	Annotated	AA	1
Marsh	65-3-8	9/4/97	Annotated	AA	1
Marsh	005-10-1	9/4/97	Annotated	AA	1
Marsh	005-8-5	9/21/97	Annotated	AA	1
Marsh	6N-3-2	10/10/97	Annotated	AA	1
Mixed Algae	63S-5-7	9/6/97	Annotated	AA	1
Mixed Coarse	63S-5-1	8/15/97	Annotated	AA	0-Sand
Mixed Coarse	63S-5-4	8/15/97	Annotated	T	
Mixed Coarse	2N-3-1	8/25/97	Annotated	AA	0.5-Mix C &
Mixed Coarse	2N-7-2	8/25/97	Annotated	AA	0.5-Mix C &
Mixed Coarse	65-1-1	8/25/97	Annotated	AA	0.5-Mix C &
Mixed Coarse	004-4-4	8/27/97	Annotated	AA	0-Sand
Mixed Coarse	65-6-1	9/5/97	Annotated	AA	0.5-Mix C &
Mixed Coarse	005-8-7	9/21/97	GPS	T	
Mixed Coarse and Fine	65-3-7	9/4/97	Annotated	T	
Mixed Coarse and Fine	63S-5-8	9/6/97	Annotated	AA	1
Mixed Coarse and Fine	66-4-4	9/6/97	GPS	T	
Mixed Coarse and Fine	66-7-1	9/15/97	GPS	AA	1
Mixed Coarse and Fine	64S-5-1	9/21/97	GPS	AA	1
Mixed Coarse and Fine	63S-5-10	9/22/97	Annotated	AA	1
Mixed Fine	004-4-3	8/27/97	Annotated	T	
Mixed Fine	65-3-10	9/4/97	Annotated	T	
Mud	005-8-2	8/22/97	Annotated	T	
Mud	6S-12-3	8/27/97	Annotated	AA	0.5-Mix C &
Mud	005-4-1	8/27/97	Annotated	AA	1
Mud	005-10-2	9/15/97	Annotated	AA	1
Mud	005-8-4	9/21/97	Annotated	AA	0-Sand
Mud	6N-3-3	10/10/97	Annotated	AA	1

Red Algae	004-2-1	9/22/97	Annotated	T	
Sand	63S-5-3	8/15/97	Annotated	AA	0.5-Mix C &
Sand	004-9-4	8/18/97	Annotated	AA	1
Sand	2N-3-3	8/25/97	Annotated	AA	1
Sand	2N-7-1	8/25/97	Annotated	AA	0-Mix C & F
Sand	65-3-1	9/4/97	Annotated	AA	1
Sand	65-3-4	9/4/97	Annotated	T	
Sand	004-9-12	9/5/97	Annotated	AA	1
Sand	66-4-1	9/6/97	GPS	AA	0-Mix C & F
Sand	66-6-1	9/6/97	GPS	T	
Sand	66-7-2	9/15/97	GPS	AA	1
Sand	66-7-4	9/15/97	GPS	AA	1
Sand	005-8-6	9/21/97	GPS	AA	1
Spit/Berm	004-9-5	8/18/97	Annotated	T	
Spit/Berm	004-4-5	8/27/97	Annotated	AA	1
Spit/Berm	65-3-2	9/4/97	Annotated	T	
Spit/Berm	65-3-6	9/4/97	Annotated	AA	0-Mix C & F
Spit/Berm	63S-5-9	9/6/97	Annotated	AA	1
Sub. Aquatic Veg.	004-9-6	8/18/97	Annotated	T	
Sub. Aquatic Veg.	2N-3-2	8/25/97	Annotated	AA	1
Sub. Aquatic Veg.	2N-3-4	8/25/97	Annotated	AA	0.5-Unclass
Sub. Aquatic Veg.	2N-3-5	8/25/97	Annotated	AA	1
Sub. Aquatic Veg.	2N-5-1	8/25/97	Annotated	AA	1
Sub. Aquatic Veg.	004-9-11	9/5/97	GPS	AA	1
Sub. Aquatic Veg.	65-1-2	9/15/97	GPS	T	
Sub. Aquatic Veg.	004-4-7	9/22/97	Annotated	AA	1
Sub. Aquatic Veg.	004-2-3	9/22/97	GPS	AA	1
Sub. Aquatic Veg.	005-8-8	9/22/97	Annotated	AA	0.5-dif. shap

One way to evaluate the validity of a classification is to calculate an Overall Accuracy. This is done by dividing the total points assigned for correctly identified sites by the total number of points possible if all sites were correctly assigned to the proper classes. In this case, there were 92 points scored (87 correct assignments and 10 sites receiving half points) out of a possible 113 points (three sites were disqualified for various reasons). The resultant Overall Accuracy resulting is 81.4%.

Although an Overall Accuracy of 81% must be considered very good, it only tells part of the story. More insightful information can be garnered by calculating a Producer's Accuracy and a User's Accuracy. A Producer's Accuracy is a measure of how well the accuracy assessment sites were assigned to the correct class. It is calculted by dividing the the number of classified sites assigned to a class by the total number of accuracy assessment sites in that class (Lillesand & Kiefer, 1994). This measure is useful in determining possible methodological and radiometric problems with the data acquisition and analysis protocols or techniques. User's Accuracy is a measure of the liklihood that a site placed in a class on the classified image is that habitat class in the field, i.e. if I take the image in the field to a site identified as salt marsh, what are the chances that it will be a salt marsh. It is calculated by dividing the number of correctly classified pixels by the total number of pixels in a given category. (Lillesand & Kiefer, 1994).

Producer's and User's Accuracy for vegetation classes and substrate classes are presented in Tables 4 and 5, respectively. In general, accuracy is considerably higher for vegetation classes than for substrate classes. This was to be expected because the of the strong signals given by the plant pigments and, of course, the CASI bands were set to identify and discriminate between the plant groups. What is somewhat surprising is the degree to which the classification did differentiate between the substrate classes. As stated in our proposal and based on the previous experience of others, we did not expect any significant success in classifying the substrate classes. In fact, we expected to fill them in using the CMGEs. This degree of success speaks strongly for the classification methods employed. Substrate classes will are discussed further below.

Table 4. Producer's and User's Accuracy for vegetation classes. n/a indicates that no suitable sites were found.

Vegetation Class	**Producer's Accuracy**	**User's Accuracy**
Brown Algae	95%	100%
Green Algae	50%	100%
Mixed Algae	100%	80%
Submerged Aquatic Vegetation	63%	100%
Marsh	94%	100%
Spit/Berm	70%	100%
Red Algae	n/a	n/a
Kelp	n/a	n/a

Table 5. Producer's and User's Accuracy for substrate classes. n/a indicates that no suitable sites were found.

Substrate Class	**Producer's Accuracy**	**User's Accuracy**
Bedrock	100%	71%
Boulder	0%	0%
Cobble	33%	100%
Mixed Coarse	33%	67%
Gravel	n/a	0%
Mixed Coarse and Fines	100%	65%
Sand	77%	74%
Mixed Fines	n/a	n/a
Mud	70%	100%
Artificial	58%	100%

User's Accuracy tended to be higher than Producer's Accuracy especially in the vegetation classes. This indicates that errors of omission are predominant and suggests that training sites were not fully representative of the class population in general. In other words, if a site was classified as Spit/Berm, we can be sure it is a Spit/Berm. Not all Spit/Berms were properly identified, however, indicating that some have characteristics that caused the classification procedure to place them in other groups.

<u>Post-classification Field Evaluations:</u>

We revisited 20 of the 26 sites which did not receive perfect accuracy scores in an effort to determine why the sites were not properly classified. The Producer's Accuracy for Green Algae was only 50% (Table x). None of the Green algae sites was particularly good in terms of size and density. The misclassified Green Algae sites were assigned to the underlying substrate class. The classification was very good at mapping shallow water SAV, however, SAV beds in the intertidal were often assigned to the underlying substrate class. This was true for both of the *Ruppia* beds. Two of the SAV AA sites had disappeared in the year since their initial evaluation so percent cover could not be reassessed. The Spit/Berm class had a Producer's Accuracy of 70%. This accuracy level is higher than we expected because of the variability of the habitat and the location of some sites adjacent to the uplands. One Spit on Islesboro was misclassified as Mixed Coarse and Fine. Having the form of a Spit, the substrate was a mix of sand and gravel with some cobble, but plants were present in very low densities explaining the misclassification.

Most of the misclassifications in the substrate classes were related to overlap in the sedimentary classes, i.e. Gravel, Mixed Coarse and Fine and Mixed Coarse classes being variosly classified as one of the others. This seems to be a definitional problem. In the future perhaps these should be lumped to a single Unconsolidated Sediment class. Alternatively, if it is deemed that differences in the classed are ecologically significant, more indepth field work needs to be done to determine what characteristics the sensors and classification process are keying upon to distinguish one from another. In at least two cases, flats that appeared to be typical mud flats were classified as Sand. Reexamination of these locations failed to suggest a reason for the misclassification. More detailed field work investigating such things as grain size, pore water, slope, color, etc. is needed here too.

<u>File Conversion</u>:

Once accuracy assessment was completed, the raster files were converted to grid files. Several attempts were made to convert the files to vector format, but conflicts between the operating system and ERDAS Imagine 8.2 software prevented the conversion to vector format.

<u>Data Library</u>:

A data library was created that includes all of the processed images in .img format, as well as .gis format (classified images) and .lan format (multispectral images). The data files were written to CD-ROM to become part of this library. A cross-referenced index was also created for easy access to the images. A summary of the classification and the colors assigned to each class is presented in Appendix 2.

<u>Metadata Preparation</u>:

Metadata information was prepared and sent to MOGIS.

<u>GPS Base Station Files</u>:

Fourteen GPS base station files were downloaded from the base station site in Orono, Maine by John Kenney of Maine Department of Inland Fisheries and Wildlife. These sites were used to process our GPS field site locations.

Summary

The intertidal mapping task finished on schedule and has completed the Year 2 activities as indicated in Attachment I of our contract. In Year 2, the pre-processed remote sensing data was received from the contractor, prepared for processing, and processed to completion. Once processed, the classified images were subject to accuracy assessment and field verification.

The conclusions drawn from this two year exercise are straightforward.

° The field and analytical methods and procedures adapted for classifying and mapping intertidal and shallow water habitats were successfully applied.

°The process was unexpectedly successful in classifying inorganic substrate classes.
°Results, as maps of polygons of vegetation and substrate habitats, are available on CD-ROM at the MOGIS.
°User's Accuracy is generally high. Only one vegetative class has a User's Accuracy of less than 100%.
°User's Accuracy among the substrate class is diminished due to misclassifications between very similar habitats.
°Detailed field work and grouping certain similar habitat classes should improve the accuracy levels even more.

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John Kenney and Brad Allen of the Maine Department of Inland Fisheries and Wildlife provided their knowledge of Penobscot Bay and habitat mapping as well as a boat for inspecting the many remote island sites. Seth Barker of the Maine Department of Marine Resources was invaluable with several of the technical aspects and by his knowledge of sea grass distribution.

The project was able to get organized and mobilized quickly because of the the unselfish sharing of knowledge and practical experiences on the part of Dr. Tom Mumford, Helen Berry, Becky Ritter and Betty Bookheim of the Nearshore Habitat Program of the Washington Department of Natural Resources. Their hospitality and continuing collaboration have been a source of pleasure and encouragement.

Finally, Emily Chase has been the workhorse of this project. From preparing for field trips to transferring the results to CDs, she has been an integral part of every aspect of the project. Her cheerful efficiency insured that all tasks went smoothly.

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APPENDIX 1. Image Processing Flow Chart

APPENDIX 2. Penobscot Bay Classification and Color Assignments