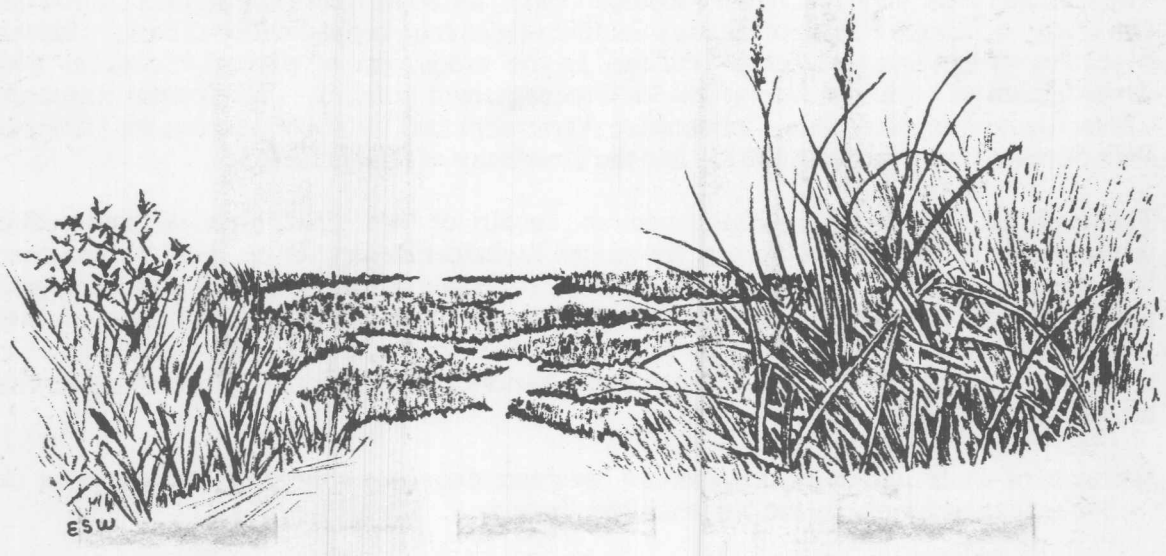
A Proposal for

CAPE COD NATIONAL SEASHORE

To Serve as a Prototype Monitoring Program for the Atlantic/Gulf Coast Biogeographic Region

-- October 1993 --



U.S. Department of the Interior • National Park Service • North Atlantic Region

Coastal Research Center • Cooperative Park Studies Unit
at the University of Rhode Island

PREFACE

This proposal was prepared in response to a call from the National Park Service's Associate Director for Natural Resources to submit proposals to the NPS Servicewide Inventory and Monitoring Program. The intent of the Program (phase I) is to establish a network of "experimental" or prototype monitoring programs that will determine how to effectively design and implement park-wide ecosystem monitoring in a manner which supports park planning and management. The knowledge and experiences gained through these prototype efforts will be shared with other park units located in similar ecological settings. To insure that selected prototype programs represent the full range of NPS ecological conditions, each park unit was assigned to one of ten biogeographic associations. Cape Cod National Seashore is within the Atlantic/Gulf Coast Association.

Primary authors of the this proposal were Charles T. Roman (Director, Cooperative Park Studies Unit at Univ. of Rhode Island) and David Manski (Resource Management Specialist, Cape Cod National Seashore). Numerous scientists, resource managers and administrators familiar with the natural resources of Cape Cod National Seashore contributed much time and information to this effort. Special acknowledgement goes to the the following; Andy Ringgold (Superintendent, Cape Cod National Seashore), Mary Foley (Regional Chief Scientist, North Atlantic Region), John Portnoy (Office of Scientific Studies, North Atlantic Region), James Allen (Office of Scientific Studies, North Atlantic Region), Kyle Jones (Cape Cod National Seashore), David Crary (Cape Cod National Seashore), Howard Ginsberg (CPSU at Univ. of Rhode Island), Charles LaBash (GIS specialist, Univ. of Rhode Island), and Nigel Shaw (Office of Scientific Studies, North Atlantic Region).

INTRODUCTION

Cape Cod National Seashore (CACO; Fig.1) comprises 44,600 acres of diverse ecosystems including coastal (barrier islands, eroding cliffs, dunes, spits), estuarine (salt marshes, seagrass beds, intertidal flats, beaches), freshwater (kettle ponds, streams, vernal ponds, marshes, swamps) and terrestrial (pine/oak forests, heathlands) components. Like other Seashores, Parks, and Recreation Areas of the Atlantic and Gulf Coast Biogeographic Region, Cape Cod National Seashore is experiencing intense pressure from expanding urban centers and recreational demands. With over 5 million people visiting CACO annually and with residential and commercial development abutting the Seashore boundaries, natural resources are continually threatened. These pressures provide a compelling justification for establishing a comprehensive ecosystem-based natural resource monitoring program for CACO.

This proposal will demonstrate that Cape Cod National Seashore is best qualified to serve as a prototype monitoring program for the Atlantic and Gulf Coast Biogeographic Area. The Seashore 1) contains the diverse array of coastal zone habitats found along the Atlantic/Gulf region, 2) is exposed to common threats (i.e., sea level rise and storms, external development pressure, ecosystem fragmentation), 3) provides the necessary human and physical resources to implement a scientifically credible plan, and most important, 4) contains an extraordinary multidisciplinary inventory data base. This last factor will be emphasized throughout the proposal, clearly showing that Cape Cod National Seashore resource management personnel, NPS scientists, and cooperating scientists have published inventory and monitoring findings in the professional literature and peer-reviewed technical outlets. This demonstrates the scientific integrity of databases that will serve as a foundation for design of an effective prototype monitoring plan at Cape Cod National Seashore.

1. RECOGNIZED MANAGEMENT NEED

The Resource Management Plan (RMP) for CACO was approved in 1992 and recognized by the Water Resources Division-WASO as being one of the Service's more comprehensive and well-developed Plans. Almost all the RMP project statements propose a monitoring or resource inventory component; however, about 25% of the statements specifically highlight long-term monitoring needs. As noted from Table 1 (and Appendix 1), these selected statements encompass the diverse range of ecosystem types occurring throughout the Seashore, and moreover, they address the ten key program areas identified in the RMP (not listed in priority order);

Baseline Inventories and Monitoring
Groundwater and Estuarine Water Quality
Federal and\or State listed Rare Species

TABLE OF CONTENTS

Executive Summary iii

Introduction 1

1. Recognized Management Need 1

2. Status of Inventory 5
   A. Park-wide 5
   B. Habitat-specific 8

3. Program Readiness 10
   A. Existing Monitoring Protocols 10
   B. Existing Cooperative Relationships 14
   C. Funding Opportunities 18

4. Monitoring Program Design 18
   A. Shoreline Margins 19
   B. Barrier Islands, Spits, and Dunes 24
   C. Estuaries 28
   D. Kettle Ponds and Freshwater Habitats 34
   E. Maritime Forests and Heathlands 43
   F. Periodic Atmosphere, Water & Veg Monitoring 45

5. Scientific Credibility and Capability 47

6. Budget and Cost Effectiveness 48
   A. Protocol Design and Testing 48
   B. Implementation (Start-up and Base Funding) 54
   C. Implementation Strategy 58
   D. Budget Summary 65

7. Servicewide and Multipark Applicability 65

8. Park Infrastructure and Organization 67
   A. Infrastructure 67
   B. Organization and Approved Reorganization 69

9. Data Management Plan 69

10. GIS Support and Integration 71

11. Linkage and Leveraging 73

12. Reporting System 75

13. Threats to Park Resources 76

References Cited 81

Appendix 1 -- RMP Project Statements ..... A 1
Appendix 2 -- Vegetation Monitoring Protocol ..... A 53
Appendix 3 -- GIS Date Themes at CACO ..... A 71

EXECUTIVE SUMMARY

Cape Cod National Seashore (CACO), within the Atlantic and Gulf Coast Region, is ready to serve as a prototype monitoring park in the National Park Service's Inventory and Monitoring Program. This proposal clearly demonstrates the existence of an extraordinary multidisciplinary data base that can form the scientific foundation for development of a comprehensive long-term ecosystem monitoring program. Moreover, the park has already designed and initiated testing and implementation of several monitoring protocols.

In addition to highlighting CACO's past successes in completing resource inventories, establishing productive cooperative relationships, and creating a professional Division of Natural Resource Programs, this proposal presents a prototype monitoring program. The proposal addresses five major ecosystem components, each representative of the Atlantic and Gulf Coast region -- Shoreline Margins, Barrier Islands/Spits/Dunes, Estuaries, Kettle Ponds and Freshwater Habitats, and Maritime Forests. Each monitoring task is designed to specifically address current management questions that are relevant to CACO and other coastal parks, while also monitoring more general ecosystem components and controlling processes that will serve to enhance our knowledge of the ecosystem. Specific objectives, testable hypotheses, and simplicity without jeopardizing scientific integrity, are the cornerstones of the proposed plan.

CACO has made excellent progress in design and testing of monitoring protocols, particularly for estuaries and coastal pond water quality. However, this aspect of the proposed budget remains considerable to insure that adequate research and testing are conducted before a scientifically-credible program is fully implemented. In addition to a design and testing budget (assumed to be performed by the National Biological Survey), the proposal provides itemized budgets for implementation start-up costs and annual base costs.

CACO, located in the urban northeast, is exposed to increasingly complex and challenging issues, similar to other coastal park units within the coastal zone. A long-term ecosystem monitoring program is necessary to inform park management of ecosystem changes, to provide a scientifically-based evaluations and interpretations of observed changes, and to support development of appropriate solutions to protect ecosystems and to implement appropriate restoration or mitigation actions. Cape Cod National Seashore is ready to serve the role as prototype monitoring park for the coastal region.

Table 1. RMP project statements that specifically highlight long-term natural resource monitoring needs. See Appendix 1 for complete project statements.

Coastal-Estuarine Ecosystems

CACO-N-001 Manage Nesting Shorebirds
1. Protect, manage and monitor nesting shorebirds
2. Develop GIS based habitat suitability index

CACO-N-022 Revegetate Landscapes Affected by Human Activities
1. Evaluate vigor and survival of dune plantings

CACO-N-030 Protect Migratory Alewives and Herring
1. Monitor Herring River dissolved oxygen

CACO-N-031 Monitor Eutrophication of Coastal Bays and Estuaries
1. Monitor nutrient loading of coastal embayments

CACO-N-032 Salt Marsh Restoration at Hatches Harbor
1. Monitor ecological changes resulting from improved tidal flushing

CACO-N-033 Salt Marsh Restoration at Herring River
1. Monitor ecological changes resulting from improved tidal flushing

CACO-N-036 Monitor Nauset Marsh
1. Implement long-term monitoring

CACO-N-039 Preserve Estuarine Natural Resources
1. Design protocols for long-term monitoring of estuarine resources
2. Implement esturine natural resource monitoring

CACO-N-041 Monitor Shoreline Retreat, Accretion, and Ecological Processes
1. Design and implement coastal proceses monitoring effort

CACO-N-045 Monitor Marine Debris
1. Continue ongoing debris monitoring

Freshwater Wetlands and Pond Ecosystems

CACO-N-008 Monitor Spotted Salamandar Fecundity
1. Continue annual breeding monitoring

CACO-N-025 Monitor Wetland Plant Species
1. Implement monitoring program based on results of existing studies

Kettle Ponds
Consumptive Use
Geomorphic Processes
Vegetation Processes
Air Quality
Non-native Species
Human-altered Systems

These program areas, while specifically developed for CACO, are all directly relevant to the other Atlantic and Gulf coast park units. The prototype monitoring, proposed herein, will meet these monitoring needs as identified in the CACO RMP.

2. STATUS OF INVENTORY

The Seashore's active research and resource management programs, coupled with activities by other federal agencies (principally USGS), state agencies (MA Coastal Zone Management, MA Dept. Marine Fisheries, etc.), regional entities (Cape Cod Commission), and private organizations (MA Audubon Society, Nature Conservancy, Provincetown Center for Coastal Studies, Assoc. for Preservation of Cape Cod), have resulted in a fairly extensive inventory of park natural resources. The discussion that follows will identify the status of park-wide inventories and habitat or site-specific inventories. An exhaustive bibliographic search of scientific research at Cape Cod National Seashore was conducted in 1984 (Claxon and Renwick 1992). Much of the information regarding the status of CACO inventories was derived from this bibliography, with updates as appropriate.

A. PARK-WIDE INVENTORIES

1. Flora -- The flora of the Cape Cod region was first published in 1922 (Setchell 1922) and recently updated (Svenson and Pyle (1979). A Seashore-specific flora is lacking, but given the abovecited references, one is probably not needed. In a literature search, Crary (1991) found that over 800 vascular plant species have been recorded within Seashore boundaries, with many represented in the park's 1000 specimen herbarium.

   Presently, no federally-listed rare plants have been identified in CACO, but the park-wide distribution of 32 state-listed rare, threatened or endangered species is documented (Jones 1991a; LeBlond 1983a, 1983b, 1986, 1990). It is interesting to note that the convergence of Atlantic coastal plain, maritime, and boreal influences on outer Cape Cod is clearly reflected in the ranges of rare plant species found at CACO. Eight rare species of a northern maritime-boreal distribution are at their southernmost limit within CACO, while fourteen plant species are at their northern limit.

Table 2. Cover types for CACO's 1962, 1977 and 1991 vegetation maps, prepared by NPS-Denver Service Center

pitch pine
black oak-white oak
black locust
beech
red maple
Atlantic white cedar
bearberry
bear oak
huckleberry
bayberry-beachplum-black cherry
meadowsweet-goldenrod
highbush blueberry-swamp azalea
beach grass
hair grass
mixed grass
cattail (including phragmites)
cordgrass
barren
developed

Table 3. Parkwide faunal inventories of CACO. Asterisk (*) denotes a field survey was conducted in compilation of the inventory.

Taxonomic Group	References
Mammals	Jones 1990a Spitzer 1977*
Saltwater Fish	Jones 1990b
Freshwater Fish	Jones 1991a
Birds	Jones 1991b Nikula 1976* Hill 1965
Reptiles and Amphibians	Higgins 1990 Lazell 1974
Four-toed Salamander	Seipt 1987*
Spotted Salamander	Portnoy 1990*
Invertebrates	
Mosquitoes	Portnoy 1984*
Dragonflies	Carpenter 1990
Lepidoptera	Mello 1986*
Tiger Beetles	Nothnagle 1989*
Threatened and Endangered	Mello 1990* Jones 1991c Smith 1990

Table 4. Habitat-specific inventories conducted at CACO

Habitat Type	References
Estuaries and Salt Marshes	
Nauset Marsh	
- primary production	Roman et al. 1990; Roman and Able 1988; Kaiser 1990
- fish and macroinvetebrates	Heck et al. 1989; Roman and Able 1989; Able et al. 1988; Fahay and Able 1989; Lazzari et al. 1989; Roman and Able 1989
- shorebirds	Roman and Able 1989
- reference collection/species lists	Roman and Able 1988
- water quality/nutrient loading	Teal 1983; Roman and Able 1989; Giblin and Gaines 1990; Portnoy 1993
Wellfleet Harbor	Curley et al. 1972; EPA Mass Bay Program 1993
Pleasant Bay	Fiske et al. 1967
Herring River	Roman 1987; Portnoy et al. 1987; Portnoy 1991
Inlets and Barrier Beaches	
Inlet dynamics (Nauset Inlet)	Aubrey and Speer 1984; Leatherman and Zaremba 1986
Inlet dynamics (Wood End)	Ashley 1987
Overwash processes (Nauset system)	Zaremba and Leatherman 1984
Vegetation processes and plots (Nauset system)	Zaremba and Leatherman 1984, 1986; Godfrey et al. 1979
Shoreline profiles	
Herring Cove	Ekwurzel 1989
Race Point	Allen 1988

Table. 5. Existing monitoring protocols for CACO

Habitat type	Reference	Status
Estuaries and Marshes		
Parkwide	Burroughs and Lee 1991 Beatty et al. 1993	- seeking implementation funds
Nauset Marsh	Roman and Able 1989	- partially implemented by CACO staff (Jones et al. 1990) and regional science program
Herring River and Hatches Harbor	Roman 1987, RMP 1990	- partially implemented with WRD-WASO funds (92-93)
Kettle Ponds (water quality)	Martin et al. 1993	- fully implemented by CACO staff
Heathlands (vegetation plots)	Carlson et al. 1992	- seeking implementation funds
Provincelands Dunes (vegetation monitoring)	Ehrenfeld et al. 1987	- fully implemented (Godfrey et at. 1991; Koske and Gemma 1992)
Freshwater Wetlands (vegetation transects)	Bachand and Patterson 1993	- seeking implementation funds
Vernal Ponds (Salamander fecundity)	Portnoy 1986	- implemented by CACO staff
Nesting Terns and Plovers	RMP 1990	- implemented by CACO staff

Table 6. Recently completed and ongoing Cape Cod National Seashore projects conducted through the University of Rhode Island CPSU and other University Cooperators

Project Title	Project Cost	Completion Date
University of Rhode Island		
Species composition, migration chronology, and habitat use of birds on Cape Cod National Seashore	$ 34,000	May 1993
Evaluating the response of salt marshes to accelerated sea level rise: a preliminary assessment	$ 38,719	December 1993
Anthropod-borne diseases in and near National park areas of the continental United States	$ 25,000	December 1993
Assessment of ground and surface water impacts from the Provincetown landfill and septic disposal site	$ 69,460	April 1993
Monitoring program for Cape Cod National Seashore estuaries	$ 20,000	August 1991
Restoration of early and late successional dune communities at Province Lands, Cape Cod National Seashore	$ 25,000	October 1992
A feasibility study for vibracoring at the Nauset Light Archeological Site	$ 8,000	December 1991
Development of a protocol for the inventory and long-term monitoring of submerged marine-estuarine resources at Cape Cod National Seashore	$ 50,151	June 1993
An evaluation of hydrologic aspects of groundwater discharge to a Cape Cod National Seashore Estuary	$ 35,000	October 1992
Establishing data management and analysis strategies using a Geographic Information System (GIS) for coastal parks	$ 93,648	December 1994

Table 6. (continued)

Inventory of submerged marine-estuarine resources at National Park Service coastal parks in the northeast: regionwide information compilation and initial monitoring	$113,960	September 1994
Denitrification in a Cape Cod National Seashore Estuary	$ 82,063	May 1995
Restoration of the Herring River and Hatches Harbor estuaries: Cape Cod National Seashore	$ 14,875	March 1994
Nutrient analyses for Cape Cod National Seashore kettle pond monitoring	$ 7,313	December 1993
Paleoenvironments of the Nauset Marsh lagoon and adjacent area, Cape Cod National Seashore	$ 28,270	December 1994
Development of water quality inventory protocols for the National Park Service	$ 18,050	April 1994
<u>University of Massachusetts</u>		
Evaluate relationship between long-term fire history and vegetation dynamics	$90,000	December 1993
<u>Univeristy of Wisconsin-Madison</u>		
Paleolimnological development of the Gull Pond Chain of Ponds and Provincetown Ponds	$93,200	September 1993
Development of Ryder Pond and determination of causes ofpondwater chemistry changes	$16,600	March 1994
<u>Nature Conservancy</u>		
Investigate kettle pond hydrogeology	$50,000	December 1994

performed for each ecosystem component and identify the rationale for selecting each task. Items such as proposed spatial and temporal sampling frequency and data analyses techniques are also presented. However, it should be clearly noted that most aspects of the proposed monitoring program will require rigorous field testing and statistical interpretation prior to implementation.

The overall framework of the CACO Prototype Monitoring Plan is shown in Fig. 2. As noted, a multidisciplinary Technical Advisory Board will be critical to the success of the proposed monitoring plan. The purpose of the Advisory Board will be to insure quality of the data collected, to assist with data interpretation, and to provide a sufficiently broad scientific scope. More details on the composition and function of the Technical Advisory Board are presented in Item #12 (Reporting System) of this proposal.

Throughout the various components of the proposed plan, the guild approach to monitoring is applied. A guild is defined as a group of species that exploit the same class of environmental resources in a similar way (Root 1967). Examples include the foliage-gleaner guild (animals that glean insects from the surface of foliage), the leaf-chewer guild, and the pollen-forager guild. The theoretical advantage of interpreting the dynamics of a natural community in terms of its guild structure is that the guild is the unit of direct interaction, especially competition, among organisms. This approach has value for monitoring natural communities because it provides a framework for analyzing the functional groupings within a community. The guild approach can be applied by analyzing the guild structure of community types of interest (e.g., estuaries, forests, ponds) and then selecting indicator species in such a way that all major guilds are represented. This would avoid excessive redundancy in the monitoring program and assure that all important elements of the community are monitored. For example, by applying the guild approach, superfluous monitoring of individual species is avoided (e.g., monitoring five different species, all of which subsist on acorns).

Several aspects of this proposed program have benefitted from a workshop of coastal park resource managers and scientists held at the University of Virginia, 10-12 August 1992. Representatives of parks, regions and universities from Maine to Texas attended. A draft document of protocol statements was produced from this effort (edited by T. Simons, formerly CPSU at Univ. Virginia, now NBS at NC State Univ.).

A. SHORELINE MARGINS

The shoreline margins of CACO are very dynamic, as with all Seashore units of the NPS and comprise several distinct types associated with the following: a barrier spit/island complex fronting the Nauset and Pleasant Bay estuaries, an unconsolidated cliff, the Provinelands dune complex and associated barrier spit at Long Point, and the margin along Cape Cod Bay that contains both

cliff and barrier forms. Whereas the entire shoreline is retreating under the influence of a relative rise in sea level, waves (especially during storms) are most important in reshaping the shore. Inlets migrate and reform, thus drastically altering the form of the barriers and the functions resident within estuaries; the function of inlets has been modelled (Aubrey and Speer 1984, 1985; Speer and Aubrey 1985) but need revision through time as their geometry changes. Although some general aspects of change in shoreline position are slow and predictable, many are variable in both space and time. These dramatic changes affect the vistas and landscape in many ways: by altering the recreational experience of the visitor, by threatening cultural resources and recreational support facilities, by the loss or change in habitat function, and by replacement of existing species. Monitoring the shoreline is necessary to understand the rates, timing, causes, sensitive locations, and dimensions of change.

Routine shoreline position monitoring will be accomplished by beach profile monitoring, aerial photographic analysis, and global positioning system (GPS) surveys.

Shoreline Profile Monitoring

As previously noted, CACO offers an outstanding opportunity to understand both short and long-term patterns of shoreline change. Historic shoreline profiles have been maintained since 1889 (see item #2 of this proposal). Field techniques for resurveying profiles are labor- and time-intensive, but the data generated provide accurate information on shoreline position, elevation change during horizontal shoreline migration, and volumetric changes.

a. Field Method -- Existing benchmarks will serve to reference the profiles. Locations of all Coast and Geodetic Survey benchmarks and CACO boundary markers (with elevations) are known. All profiles must be located by permanent markers (steel pipes), with known elevations relative to a benchmark. On barrier beaches and spits, profiles should be cross-island and extend to the maximum seaward (or bayward) limit possible. For cliffs, profiles are from the baseline permanent marker to the seaward limit. The spacing of elevation data points along the profile line is variable, but as a minimum the following points should always be included; dune crest, dune toe, berm crest, top and bottom of shore step, high and low water lines, bar crest, cliff base, cliff top etc. Ideally, the protocol will specify these points, plus a routine point interval of perhaps 5m.

b. Spatial Frequency -- Ideally, profiles should be located at 1 km intervals along the ocean and bay coastlines of CACO. Even closer spatial frequency should be considered along very geomorphically active areas (Fig. 3), such as in the vicinity of inlets (i.e., Nauset Inlet, new inlet at Chatham, Ballston

Beach overwash). Further, profiles should be located in association with all recreational, support, and cultural facilities (e.g., Coast Guard Beach, Nauset Light, Highland Light, etc.). Because of time and labor intensive factors, it is recommended that shoreline profile establishment be implemented in two phases: 1) Locate and re-establish historic profiles (Marindin) and locate a high density of profiles in association with critical cultural, recreational and long-term research sites. In particular, Nauset Spit-Coast Guard Beach, Nauset Light, Highland Light, Long Point-Wood End, Herrring Cove, Race Point, Ballston Beach, and NorthBeach - Chatham. 2) Establish profiles at a minimum of 1 km intervals along the entire ocean and bay shoreline.

c. Temporal Frequency -- The morphology of the Cape Cod beach, as with shorelines of other Atlantic coast park units, differs dramatically from summer to winter, due primarily to seasonal differences in storm intensity and storm frequency (Hayes and Boothroyd 1969). Generally storm erosion is followed by redeposition of sand within a few weeks; this cyclic process is completed in the summer but the more frequent storms of winter interrupt the cycle and lead to depleted beach volumes. Ideally, winter and summer profiles should be conducted annually; however, the labor-intensive nature of collecting profile data may preclude this. Instead, it is recommended that a subset of profiles be identified for winter-summer annual surveys and that the remaining profile lines be monitored at 3-yr winter-summer intervals. Criteria will be developed for selection of the subset to be certain that critical resources are adequately monitored. Further, it is recommended that pre- and post-storm profile monitoring be accomplished. If major storms are not predicted to allow adequate time for a pre-storm survey, then a post-storm survey should still be performed. Storm monitoring is extremely valuable as most pronounced changes in shoreline geomorphology occur as the direct result of major storms.

Aerial Photographic Analysis

Aerial photography offers much information beyond shoreline position. It is recommended that low altitude photography (color, scale 1:5,000 or larger) of the entire ocean and bay shoreline be obtained at 3 year intervals, and in addition, following major storm events. Shoreline position and features (overwash, offshore bars, tidal deltas, etc.) will be photointerpreted and entered into the park GIS database. The aerial imagery will be referenced to an orthophoto base map (see item #10). Accurately located ground control points (GPS-located) will be used to rectify image destortion that is inherent to aerial photography.

paramount goal of a coastal vegetation monitoring program. Monitoring should enable scientists and managers to predict the effects of natural events, human impacts, or planned management activities on vegetation patterns and processes. Barrier and spit vegetation monitoring will follow the methods presented by Roman, Gibson and Art in the previously mentioned draft document of protocol statements for coastal parks (Simons, editor). Appendix 2 contains the entire draft protocol. This protocol is supported throughout by technical literature and similar protocols have been successfully implemented at CACO (Zaremba and Leatherman 1984, 1986) and other barrier island parks (Fire Island NS -- Art 1976; Gulf Islands NS -- Gibson and Looney 1992).

1. Vegetation Map -- Using the color aerial photography identified in the previous section on SHORELINE MARGINS, a detailed vegetation map should be prepared at 3-yr intervals, and following major disturbances. Ideally, the aerial photographs should be obtained between June 15 and September 15 -- the period of maximum foliage and definition of distinct community types.

2. Permanent Sampling -- Several permanent cross-island vegetation transects will be established at each of the barrier island/spit sites identified in Fig. 3. As with the vegetation map, a 3-yr sample frequency is suggested, and following disturbances.

a. Spatial Frequency -- The transects should be located a 1-km intervals, corresponding to the shoreline profiles. Some areas that have high geomorphic activity may require a greater frequency. If re-location is possible, permanent transects should correspond to transects sampled throughout the 1970's at Nauset Spit, North Beach, and Race Point (Godfrey et al. 1979; Zaremba and Leatherman 1984; Godfrey, personal communication).

b. Temporal Frequency -- It was recommended above that barrier island vegetation transects be monitored at 3-yr intervals, and during the growing season that follows a major disturbance. This frequency should clearly be tested in preliminary studies. Perhaps studies using historic aerial photography, can be performed to evaluate the relative degree of vegetation change over 1, 3, 5, and 10-yr intervals.

c. Field Methods -- Field methods are detailed in Appendix 2. In brief, transects will be oriented perpendicular to the long axis of the barrier/spit and will extend from mean high water on the ocean to mean high water on the estuary or bay. Ten by ten meter (10x10m) permanent plots will be arranged along the transect at an interval to be determined via preliminary studies. These studies should follow Ekblad (1991) and are outlined in Appendix 2. As noted in Fig. 2 of Appendix 2, the plots will be used to monitor the tree layers (10x10m), shrub layer (5x5m) and herbaceous layer (0.5 x 0.5m). Definitions of these layers and data collection

Intensive shorebird and waterfowl counts for all seasons are documented in Roman and Able (1989), in which the effects of tidal stage on foraging flock size in Nauset Marsh were studied.

From this earlier work, it was noted that daily maximum counts for a given species are fairly stable during the several hours of the tidal cycle when a species is most abundantly feeding. Further, it was determined that most stable counts can be acquired during low-ebb tidal periods. [Enumeration of the total of each species which uses each habitat is impossible because of the dynamic nature of individual migratory movement; i.e. most species move through the Seashore as overlapping waves of individuals rather than as cohesive flocks.]

Monitoring can be further simplified by lumping species into guilds with respect to feeding habits. For example, it may be possible to represent the abundance of all deeply-probing scolopacid shorebirds by monitoring the abundance of one dominant species utilizing this mode of feeding, e.g dunlin. Charadriidae, feeding largely from the sediment surface, are probably adequately represented by counting only semipalmated sandpipers, the most abundant species. As for other community types throughout this monitoring plan, analysis of the guild structure and selection of indicator species to represent all major guilds assures maximum efficiency and the inclusion of all important community elements. Feeding intensity by dominants is assumed to be dependent on, and will be tested as a surrogate measurement of, secondary production.

It is therefore proposed that waterbird monitoring employ four species, semipalmated sandpiper, short-billed dowitcher, ring-billed gull and American black duck as dominants representative of four major feeding guilds in the Cape Cod coastal zone.

1. Study sites -- In consideration of the availability of earlier studies and the extent of suitable habitat, coastal waterbird monitoring will be centered at Nauset Marsh. All four representative species feed for part of the tidal cycle on exposed or flooded intertidal sand and mud flats which comprise 23 percent of the marsh system (Roman and Able 1989). Extensive data on foraging by these species are available for Nauset Bay, Nauset Harbor, the Skiff Hill marsh and Salt Pond Bay (Roman and Able 1989).

2. Sampling periods and frequency -- Because spring and fall migrations and the timing of peak Nauset habitat use can vary by several weeks, counts will be conducted at least weekly during the seasonal "window" of maximum use predicted from previous years. Periods of weekly counts for each species are tentatively set as follows:

Semipalm. sandpiper	15 July - 30 Aug.
Dunlin	1 Oct. - 1 Dec.
Ring-billed gull	1 Sept. - 15 Oct.
Amer. black duck	15 Dec. - 15 Jan.

Table 7. Questions to be addressed by the proposed Estuarine Monitoring Program (after Beatty et al. 1993).

1.	Is the relative distribution of submerged habitats at CACO changing?
2.	How do natural disturbances like storms, inlet migration and sea level rise affect park estuaries?
3.	How are estuarine ecosystems at CACO responding to human-induced changes, specifically, to increasing nutrient loads?
4.	What are the primary sources of nutrients to CACO estuaries and are nutrient loads increasing over time?
5.	How do interactions at the sediment/water interface and hydrographical features such as tidal flow and bathymetry modify nutrient inputs to CACO estuaries?
6.	What is the impact of commercial and recreational shellfishing on submerged habitats?
7.	What changes occur to populations of selected species after restoring tidal flow to diked estuaries?

Table 8. (continued)

WATER QUALITY Temperature Salinity Light Dissolved oxygen Nutrients Chlorophyll a	Daily to 1x/week[1]
NUTRIENT LOADING	Seasonally
Groundwater nitrogen input	
Stream nitrogen input	
Benthic nutrient flux and turnover	
BIOTIC	
Total System Metabolism	Continuous
Macroalgal Biomass	Summer (monthly)
Eelgrass Wasting Disease Index	Summer (bimonthly)
Eelgrass Epiphyte Biomass	Winter (monthly)
Benthic Infauna	Seasonal
Finfish	April-November (monthly)

[1] A University of Rhode Island graduate student, under the direction of a CPSU scientist, is currently evaluating relationships among water quality parameters and testing various scenarios to design an optimum sample frequency (NRPP-funded, FY92-94).

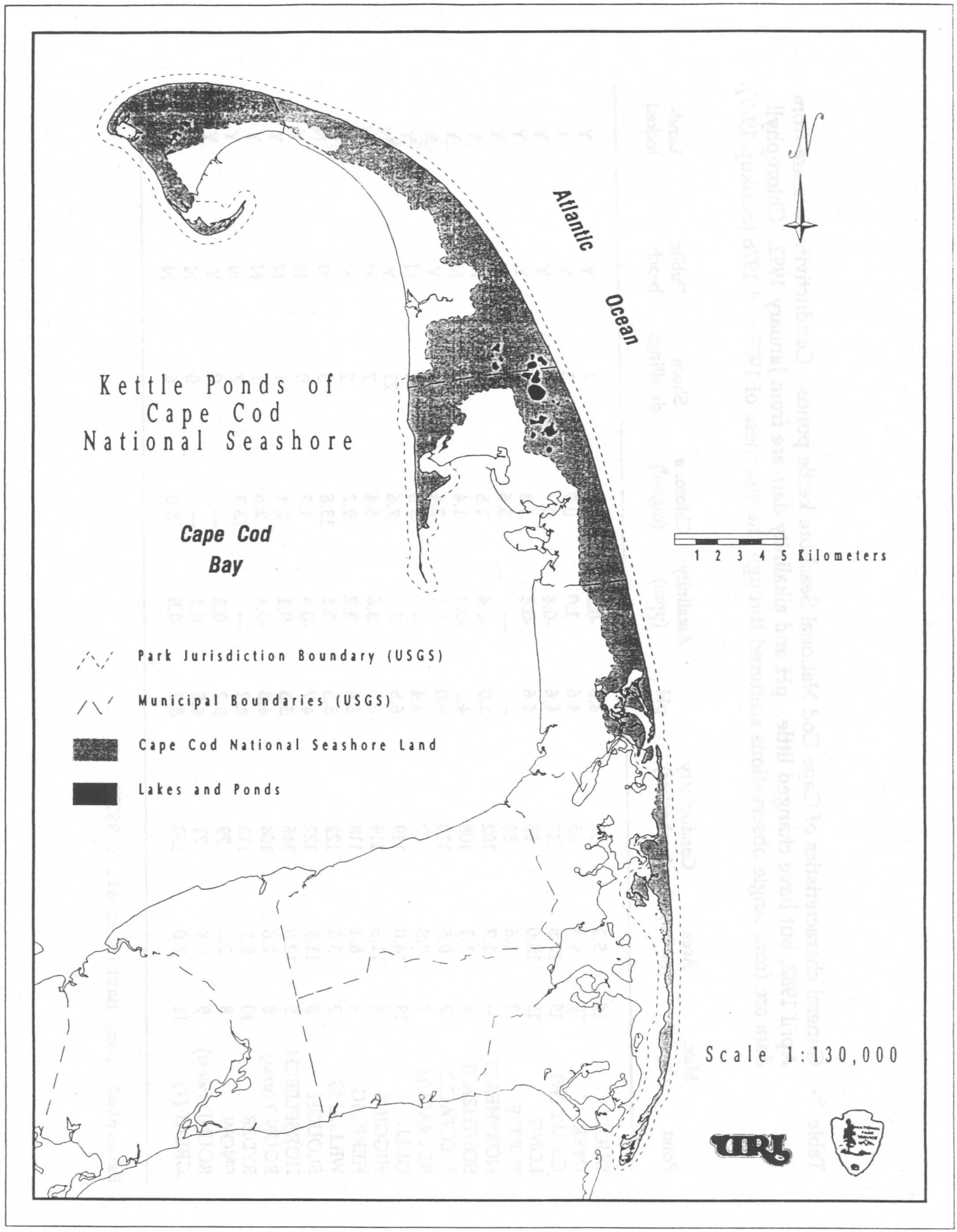


Figure 5. Kettle ponds of Cape Cod National Seashore.

3. Liming ponds to increase pH (decrease acidity) for enhanced recreational fishing.

Phosphorus (P) is the nutrient most likely limiting primary production and controlling water clarity in CACO's kettle ponds (Soukup 1977). Local glacial outwash soils are low in P, probably explaining the native clarity of most ponds. A primary management concern, and the working hypothesis of this monitoring program, is that kettle pond water quality deteriorates when "extra-watershed" P is imported into the pond basin by humans. With increasing shoreline development, human wastes from septic systems are assumed to be a major source of P.

Acid rain can have a strong potential to alter pond water quality, through acidification or disturbance to sedimentary sulfur, iron and phosphorus chemistry (Caraco et al. 1989). Besides continuing to monitor pH and alkalinity of kettle ponds on a quarterly basis, in cooperation with the state-wide Acid Rain Monitoring Project, no specific research or monitoring programs for acid rain effects have been undertaken.

Pond liming, conducted in the past by State fisheries managers at several outer Cape Cod ponds and proposed for others, is opposed by NPS as inappropriate for the preservation of these naturally acidic and oligotrophic aquatic systems. There is also concern that additions of $CaCO_3$ could alter the species composition of both phyto- and zooplankton, increase water column production and reduce hypolimnetic aeration during periods of stratification.

Past limnological monitoring has produced a twenty-year baseline on water quality. It is proposed that current limnological monitoring be augmented with surveillance of specific biotic components. In particular, an important deficiency in present monitoring is the lack of species-specific quantification of plankton. Although net production is monitored with chlorophyll measurements, the significance of particular species assemblages indicative of very specific environmental conditions is ignored. For example, though chlorophyll concentrations may be similar from communities dominated by either diatoms or blue-green algae, water column conditions (pH, nutrients) indicated by these two assemblages will be quite different. Further, the amount (biomass) and quality (species dominance) of secondary production within the water column (i.e., zooplankton) has only been studied for brief periods in a few ponds (MacCoy 1958, Shortelle and Colburn 1987). Finally, little quantitative work has been done on the macrophyte assemblage typical of the ponds' shorelines. This omission is particularly important in view of the location of these plants' roots in a geochemically and hydrologically active littoral zone.

The monitoring and research program presented here defines monitoring objectives, identifies field sampling protocols (frequency and variables), and identifies suitable laboratory methods and field instrumentation. The water quality aspects of the program have been excerpted from Martin et al. (1993).

Table 10. Proposed annual survey of CACO kettle pond water quality during spring and autumn mixing (from Martin et al. 1993).

PONDS: All twenty.

SEASON: April.

DEPTH STATIONS FOR FIELD VARIABLES: 1-m intervals.

DEPTH STATIONS FOR LABORATORY VARIABLES: 0.5 m from surface and bottom.

FIELD VARIABLES:

- Temperature, conductivity, dissolved oxygen by Hydrolab
- Chlorophyll fluorescence by field fluorometer
- Light by Licor meter with deck cell
- Secchi depth

LABORATORY VARIABLES:

- Dissolved oxygen by Winkler titration for low DO bottom waters
- Fe^{++} by Ferrozine method
- Total sulfides using DPDH indicator
- Total P by acid persulfate digestion and ascorbic acid method for PO_4
- Total N by alkaline persulfate digestion and cadmium reduction for NO_3-NO_2
- Ammonium-N by the phenolate method
- Nitrate-nitrite-N by cadmium reduction
- Phosphate by the molybdate blue method
- Anions by ion chromatography
- Cations by inductively-coupled plasma emission spectroscopy

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Fe, SiO_2, SO_4, NO_3, PO_4, NH_4, HCO_3 and Cl).

The summer intensive, multiple-depth monitoring of five ponds will include laboratory analyses of TN, NO_3, NH_4, TP, total sulfides, and ferrous iron. The measurement of pH, alkalinity and the major ions will be limited to the quarterly ARM program of surface grab samples for all ponds. Dissolved oxygen readings will be made with a Hydrolab, supplemented with titrations using the Azide Method. Light readings will be made using a LiCor meter with deck cell. Fluorescing chlorophyll concentrations will be determined with a Turner Designs fluorometer, standardized daily with chlorophyll standards. Secchi depth readings will also be made and recorded.

c. Data Analysis -- Summary plots and descriptive statistics will annually be interpreted by a technical oversight group, chaired by Dr. Harold Hemond. As the data set accumulates, trend analysis will be performed and sampling protocols revised as appropriate.

Plankton monitoring

During limnological surveys, samples will also be collected for analyses of phytoplankton and zooplankton communities. Phytoplankton collections will consist of one 60-ml grab from 0.5 m below the surface and one from the depth of maximum fluorescence. Zooplankton samples will be obtained from vertical hauls through the entire vertical profile with a zooplankton net. Both plankton groups will be sampled at all ponds during the spring survey, and biweekly at the five ponds intensively monitored throughout the summer. Comparative analyses of species composition of the phytoplankton and zooplankton samples will be conducted by cooperating researchers with data periodicaly integrated with water quality results and interpretations.

Observed relationships between water chemistry and dominant phytoplankton and zooplankton species will identify assemblages indicative of pH and nutrient status (Winkler 1985b). Guilds of zooplankton, consisting of species exploiting a common resource, will emerge from which representative dominants, i.e. "indicators", can be selected to economize on future enumeration efforts.

Littoral and Transition Zone Vegetation Monitoring

The CACO kettle ponds are generally fringed with a zone of littoral vegetation, including emergents (e.g., Arrowhead, Sagittaria latifolia), floating attached plants (e.g., Water Lilies, Nymphaea sp.), floating unattached plants (e.g., Duckweek, Lemna minor), and submerged plants (e.g., Bladderworts, Utricularia sp.). The transition zone, between the pond shoreline and upland, can range

Weather stations already established at three Seashore locations will provide needed meteorologic data for water budgets.

Further, staff gauges, now in place at five regularly sampled ponds, will be installed at the remaining 15 ponds to monitor water level on a monthly basis. All staff gauges will be related to a known Mean Sea Level elevation.

Past and current hydrogeologic research around Duck and Gull Ponds has established monitoring well networks suitable for following both water level and quality (i.e. nutrients). It is proposed that these measurement points be sampled monthly over the long term for water level to calibrate and improve current modeling efforts, and for pH, conductivity, nitrate, ammonium, orthophosphate and dissolved oxygen to continually monitor ground-water chemistry around the ponds.

E. MARITIME FORESTS AND HEATHLANDS

Pine/oak dominated maritime forests are abundant throughout CACO, exhibiting a diversity of habitats, including forests associated with remnant dune ridges (Province Lands) and extensive glacial deposits. Patterson et al. (1983) provide a detailed review of the vegetation and edaphic factors of pine/oak forests and other forested community types of CACO. Heathlands, dominated by plants of the Ericaceae family, have been mapped and quantiatatively evaluated (Carlson et al. 1992).

Monitoring of these upland ecosystems will be conducted to evaluate 1) the effect of sea salt and atmospheric deposition on terrestrial vegetation dynamics and nutrient cycling, 2) the role of fire management in vegetation dynamics, and 3) the relationships among vegetation processes and management activities, pest outbreaks, forest patch size, and adjacent development activities.

Monitor Atmospheric Deposition and Nutrient Cycling

Proximity to the sea strongly affects the species composition, growth form, biogeochemistry and primary production of maritime forests. Vegetation of the narrow (generally 6 km) outer Cape Cod peninsula is clearly affected by distance to the shore, though processes affecting plant architecture and production have not been studied. Because of its extreme exposure to the North Atlantic, the Cape can serve as an important research and monitoring site to follow, and evaluate over wider spatial and temporal contexts, both natural and anthropogenic affects on nutrient deposition and cycling in forests of the land-sea margin. It is proposed that two hypothesized major influences be investigated with long-term monitoring and associated ecological research: 1) sea salt deposition, and 2) atmospheric deposition with emphasis on coastal fog (i.e., cloud water). This program will be particularly relevant to CACO and the other coastal parks of the Atlantic and Gulf coast

at intervals (perhaps 100 m) along several transects (replicates) running perpendicular to the Atlantic shore. Evaluation of the importance of atmospheric deposition in general to the nutrient status of coastal forests, as well as to adjacent estuaries, requires knowledge of soil carbon and nitrogen cycling. Soils at each station will be characterized to describe soil nitrogen and carbon pools and to account for principal in situ factors affecting N mobility.

New monitoring will include continuous cloud water collection lysimeters for soil leachate at all stations, a collection system for both wet and dry deposition at selected sites, and the establishment of permanent vegetation plots (see below) to follow forest structure and growth rates. Lysimeters will be sampled monthly for one year to determine temporal variability among all major ions, with time-intensive monitoring of selected parameters after storms and high salt deposition. Long-term sampling frequency will be determined after analysis of the first year's data.

Forest and Heathland Vegetation Monitoring

Vegetation monitoring will follow the proposed protocol presented in the BARRIER ISLANDS/SPITS/DUNES aspect of this proposal, with some modification, and as presented in Appendix 2. With regard to heathlands, a series of permanent plots were recently established and a monitoring protocol set forth (Carlson et al. 1992). Careful efforts will be made to integrate these permanent plots into the proposed sampling protocol without jeopardizing statistical integrity of the program.

As noted above it will be important to monitor growth rates of selected species in the tree, shrub and herbaceous strata to evaluate the role of salt spray and deposition in controlling vegetation processes. Numerous techniques are available that must be tested in preliminary studies (e.g., tree ring analysis, tagging, biomass, ground-based remote sensing, others).

F. PERIODIC MONITORING OF ATMOSPHERE, WATER BALANCE, & VEGETATION

Several routine monitoring tasks are necessary to assist in interpreting trends that may be observed in the ecosystem monitoring components. These include meteorological, groundwater (water table level), and sea level monitoring. In addition, parkwide vegetation mapping is included as a periodic monitoring need.

Meteorological Monitoring

The National Weather Service maintains daily weather stations in

permanently mark the wrack line for a later elevation survey.

Vegetation Mapping

Parkwide vegetation maps (scale 1:24,000) are available in the CACO GIS for 1962, 1977, and 1991. It is proposed that the frequency of parkwide vegetation mapping be increased to 8-10 year intervals. Spatial vegetation trend analysis of the Herring River basin using these vegetation maps has revealed that dramatic changes occurred between the vegetation mapping intervals. A greater frequency of mapping would enable a more refined interpretation of vegetation dynamics and analysis of agents of change.

5. SCIENTIFIC CREDIBILITY AND CAPABILITY

Cape Cod National Seashore has the appropriate resource management personnel and research support to adequately execute the initial phases of a prototype monitoring program. At the park level, the Division of Natural Resource Programs serves several important functions, including formulation of natural resource program objectives and action plans; monitoring and data collection activities in support of natural resource programs; coordination of natural science research activities; technical review of proposals/reports from other agencies (including local or regional municipalities) that could impact the park's natural resources; environmental compliance of park natural resource activities, and; liaison with NPS and other federal, state, local and private natural resource professionals. The Division is currently staffed by a Chief (GS-12) with a Master's degree in Wildlife Biology and over 10 years experience as a resource management specialist, including the NPS Resource Management Trainee Program. The Division's GS-11 Biologist has a BS in Natural Resources, is currently pursuing a Master's degree and also completed the Trainee Program. This core professionalized staff, augmented by a cadre of seasonal bio-technicians meets the Division's functions. The park's Fire Management Officer, a professional with a Master's degree in forest ecology, is associated with another CACO Division but also interacts closely with the Division of Natural Resource Programs, particularly on issues related to vegetation processes.

The park's resource managers have always enjoyed close interaction with research grade scientists associated with the CPSU at Rhode Island and the Region's Office of Scientific Studies. A GS-13 wetlands ecologist, affiliated with the CPSU, is duty-station at CACO. He has been at the Seashore for over twelve years and has been engaged in a diversity of research topic areas including, mosquito ecology (Portnoy 1984), marsh restoration (Portnoy et al. 1987), marsh sediment chemistry (Soukup and Portnoy 1986), estuarine chemistry (Portnoy 1991), nutrient loading (Portnoy 1993), wetland hydrology and sea level rise (Nuttle and Portnoy 1992), amphibian biology (Portnoy 1990), and shorebird ecology

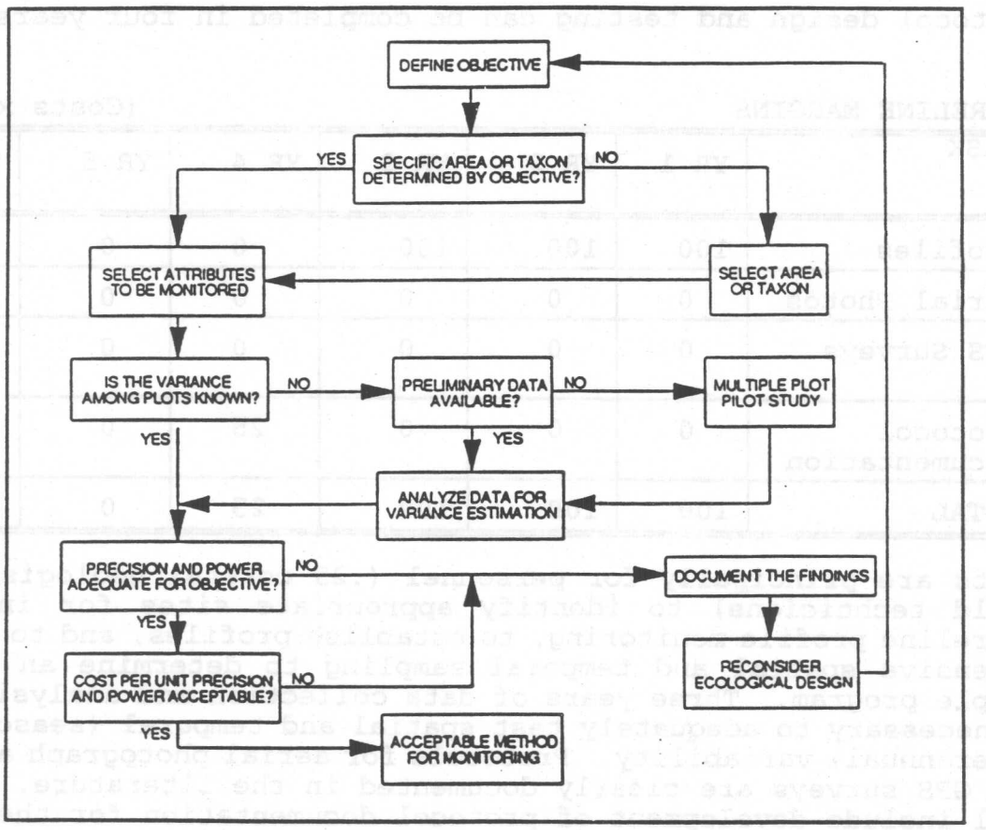


Fig. 6. Conceptual procedure for designing and testing an ecosystem monitoring program (excerpted from, Silisbee and Peterson 1991).

Vegetation Monitoring B. Permanent Sampling	120	120	120	0	0	
Migratory Waterbird Monitoring	0	0	0	0	0	
Protocol Documentation	0	0	0	25	0	
TOTAL	120	120	120	25	0	385

The vegetation monitoring programs have been designed, as noted in Appendix 2. Costs are for personnel to test the program by evaluating spatial variability and appropriate plot dimensions. Previous research is appropriate to prepare and justify a protocol document for vegetation mapping and migratory waterbirds. The vegetation monitoring component will also develop and test protocols for the Forest and Heathland Component discussed below. Year 4 will focus on completing protocol documents.

ESTUARIES (Costs x1000)

TASK	YR 1	YR 2	YR 3	YR 4	YR 5	TOTAL
Comprehensive Ecosystem Analysis	50	50	50	0	0	
Routine Ecosystem Monitoring	100	100	100	0	0	
Protocol Documentation	0	0	0	40	0	
TOTAL	150	150	150	40	0	490

The estuary monitoring program is designed (Beatty et al. 1993) and some aspects are currently being tested. The costs are for additional testing of the comprehensive and routine aspects of the proposed program. An estuarine ecologist (0.25 time) and estuarine chemist (0.25 time) will lead the testing effort with a team of field and laboratory technicians. Testing includes assessing spatial variability, temporal frequency and methods analysis. Year 4 will include protocol documentation.

Kettle Ponds	28	100
Maritime Forests and Heathlands	5	52
Periodic Monitoring of Atmosphere, Water Balance and Vegetation	5	8
Data Management	8	87
Administrative Support	108	93
TOTAL	268	683

SHORELINE MARGINS (Costs x1000)

CATEGORY	Start-Up Costs	Annual Costs
Vehicle	13	
Computer/Printer/Software	5	
Personnel ($/FTE)		83/2.0
Equipment/Supplies	15	3
Travel		2
Publication/Education		2
Other (aerial photos, cooperators, etc)		5
TOTAL	33	95

BARRIER ISLANDS, SPITS, DUNES (Costs x1000)

CATEGORY	Start-Up Costs	Annual Costs
Vehicle	13	
Computer/Printer/Software	10	
Personnel ($/FTE)		71/1.5
Equipment/Supplies	15	4
Travel		4
Publication/Education		3
Other (cooperators, etc)		5
TOTAL	38	87

MARITIME FORESTS AND HEATHLANDS (Costs x1000)

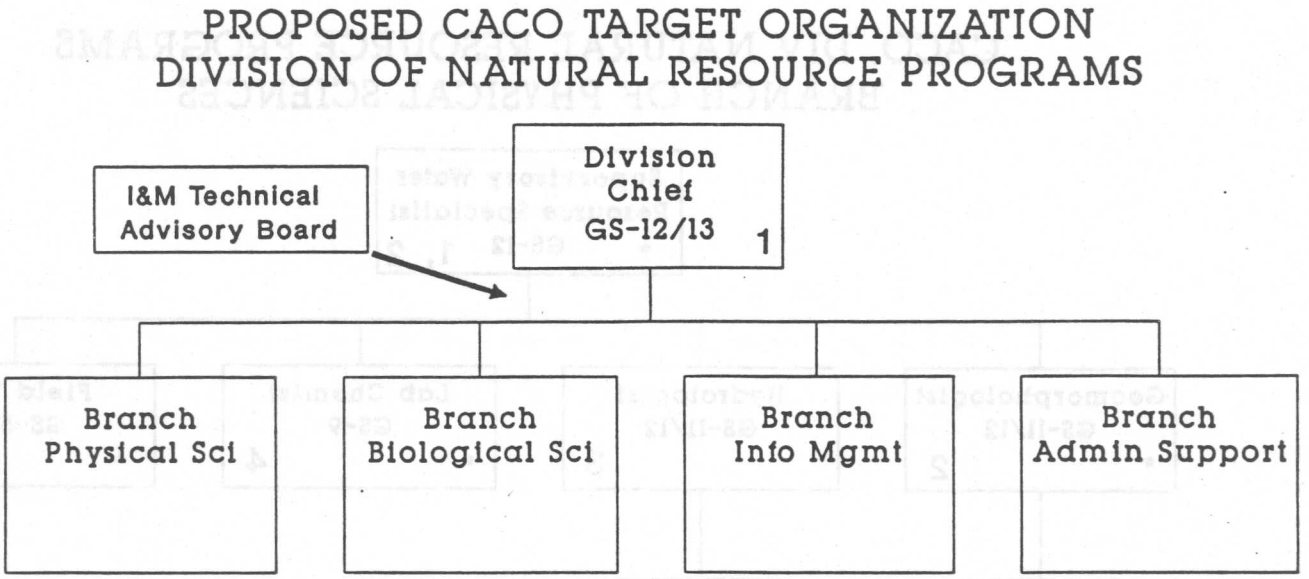
CATEGORY	Start-Up Costs	Annual Costs
Personnel ($/FTE)		40/1.0
Equipment/Supplies	5	3
Travel		2
Publication/Education		2
Other (cooperators, etc.)		5
TOTAL	5	52

PERIODIC MONITORING OF ATMOSPHERE, WATER AND VEGETATION

CATEGORY	Start-Up Costs	Annual Costs
Equipment/Supplies	5	3
Other (aerial photos, cooperators, etc.)		5
TOTAL	5	8

DATA MANAGEMENT (Costs x1000)

CATEGORY	Start-Up Costs	Annual Costs
Computer/Printer/Software	8	
Personnel ($/FTE)		75/1.5
Equipment/Supplies		10
Travel		2
TOTAL	8	87

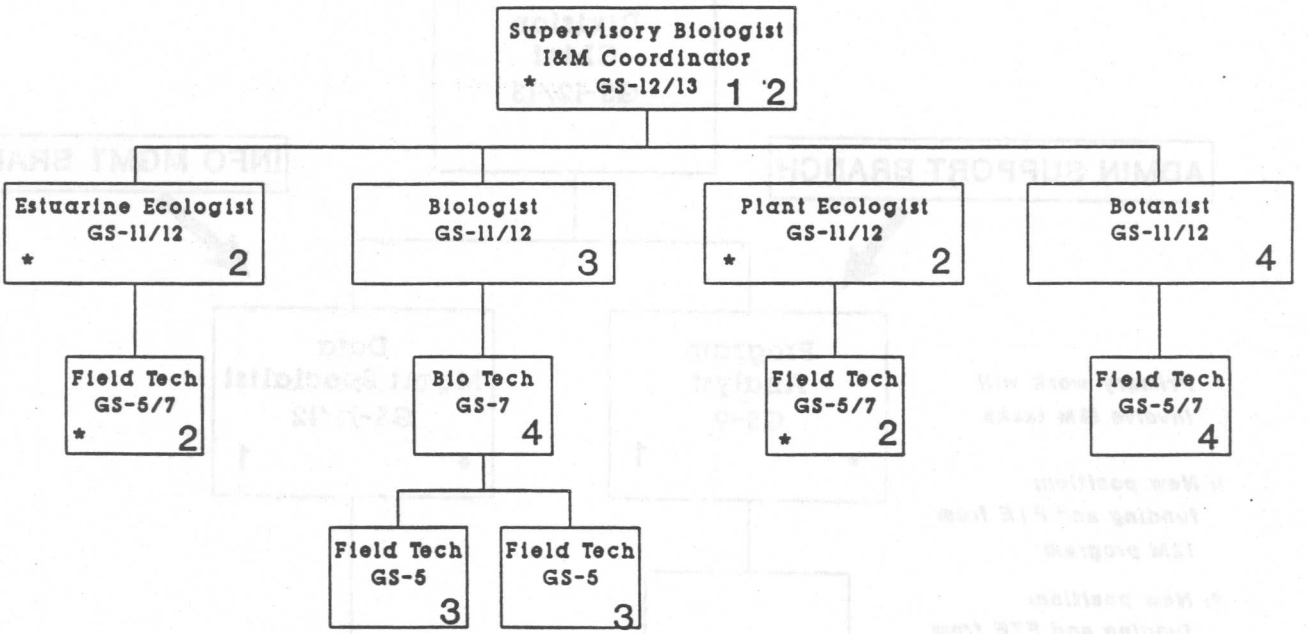


1: Existing base funded position

Fig. 7a. Proposed target organization for Division of Natural Resource Programs, with integration of Long-term Monitoring Tasks. The following figures present the structure of each Branch.

7b. Branch of Physical Science
7c. Branch of Biological Science
7d. Branch of Information Management and Branch of Administrative Support

CACO, DIV NATURAL RESOURCE PROGRAMS
BRANCH OF BIOLOGICAL SCIENCES



** Primary work will involve I&M tasks*

1: Series either ecology or biology

2: New position; funding and FTE from I&M program

3: Existing base funded position

4: New position; funding and FTE from park base program

Fig. 7c. Branch of Biological Sciences

data acquisition, analysis, interpretation and synthesis skills, technical writing ability, and leadership qualities. This team of professionals will be supported by field and laboratory technicians, administrative personnel, seasonal assistants, and at times, university cooperators. As noted in several of the component budgets, annual costs are included for cooperators to assist with highly specialized tasks, such as taxonomic sorting, species identifications, selected laboratory analyses, and others.

Schedule

Three schedules for full implementation of the proposed prototype monitoring program are presented; 1) complete design/testing and initiate full implementation in five years, 2) and 3) two alternatives for completing design/testing and initiating full implementation in nine years. Each schedule is explained and presented below.

5-yr Implementation Schedule -- An extremely ambitious 5-yr schedule is presented, assuming that complete funding and NBS support is provided.

Years 1-3
- Design and test all protocols
- Hire I&M Coordinator (Yr 3)
- Hire Supervisory Water Resource Specialist (Yr 3)
- Hire Program Analyst (Yr 3)

Year 4
- Finalize protocol documents
- Hire remaining professionals, technicians, other personnel
- Train staff and conduct "dry runs" (training to be accomplished by NBS and Supervisory staff)

Year 5
- Continue hiring staff
- Continue training sessions
- Implement full program

9-yr Implementation Schedule (alternative 1) -- If full funding or a complete personnel commitment from NBS is not available to accomplish the neccessary tasks in five years, then an alternative schedule is presented. The initial focus will be on kettle ponds and estuaries -- ecosystems of the park that are under immediate threat and ecosystems with a substantial data base and existing protocols. The alternative schedule can be fully implemented in 9 years.

Estuaries program, then the entire Kettle Pond program, and so on. For example, in five years it may be appropriate to design and implement Kettle Pond water quality, Estuarine water quality, Estuarine and Barrier Island migratory birds, Shoreline GPS surveys, and Heathland vegetation protocols. These aspects of the program are of immediate relevance to addressing resource management issues, and moreover, extensive data bases and oftentimes draft protocols exist to form an immediate basis for the design and testing phase. Design, testing and implementation of the remaining program components could be completed during years 4-9.

The budgets for design and testing, start-up, and implementation are itemized so annual costs from years 1-9 can be determined for the three implementation schedules presented here, or for other scenarios of implementation.

D. BUDGET SUMMARY

The CACO Long-term Ecosystem Monitoring Program budget has been carefully developed and leveraged to take full advantage of existing and anticipated activities of the CACO Division of Natural Resource Programs. Moreover, the budget realistically identifies the costs associated with design, testing, and implementation of a comprehensive program. Estimated costs are summarized as follows;

Design and Testing Protocols.....	$1,780,000
Implementation	
- Start-up Costs.....	$ 268,000
- Annual Base.....	$ 683,000

7. SERVICEWIDE AND MULTIPARK APPLICABILITY

The ten (10) Seashore and Recreation Area park units from Cape Cod to Padre Island National Seashore, as well as several other parks within the Atlantic/Gulf Biogeographic Unit, have similar ecosystem types, common resource management issues, and common monitoring and research needs. In fact, a systematic analysis of park resource management plans (Cape Cod to Gulf Islands) strongly supported the concept that coastal reserves share a common vulnerability to dramatic change since they are all influenced by the same kinds of natural and human-induced forces (Roman et al. 1987).

The ecosystem components of the CACO prototype monitoring plan were selected because they are relevant to CACO, but also because of their similarity to other Seashore/coastal parks. Table 12 identifies some of the common ecosystem types and resource management issues or threats at the Seashore and National Recreation Area parks. It should also be noted that a prototype

monitoring program at CACO will not only be directly applicable to these NPS units, but also to other federal holdings [e.g., Parker River (MA), Forsythe (NJ), Chincoteague (VA), Pea Island (NC), Merritt Island (AL), Aransas (TX), and other National Wildlife Refuges], private reserves (e.g., Nature Conservancy's Virginia Coast Reserve), and numerous state holdings.

8. PARK INFRASTRUCTURE AND ORGANIZATIONAL STRUCTURE

A. INFRASTRUCTURE

Office Space

Existing staff are housed at three locations within the park (headquarters, Race Point Ranger Station and the research lab complex). Additional space is presently available in a 10X50' mobile office trailer (room for 4 people) and a number of park acquired houses that could easily be converted to offices. In addition, during 1993 a total of 6 "use and occupancy" homes reverted back to the NPS. At least half are not being used and could be utilized as offices to support this inventory and monitoring initiative. As noted in the budget (see Administrative start-up costs), funds will be necessary to convert these existing facilities to office space.

Laboratory

The present Atlantic Coastal Laboratory and Warehouse buildings have supported a wide range of park natural resource management and research programs for the past 15 years. Many crucial issues, from off-road vehicle impacts, to wetlands and pond preservation, to forest ecology and wildlife and endangered species management have been resolved by lab-based field studies by NPS scientists and cooperators of many disciplines. In recent years, the work at the lab has focused on a number of important issues relating to protection of fresh and marine water quality, and thus, presently houses fairly complete instrumentation for wet chemistry analysis.

It also provides very useful space for sorting biological materials and sediment, and storing and maintaining the diverse equipment associated with the following ongoing monitoring and research projects:

> Monitoring: National Atmospheric Deposition Project, Acid Rain Monitoring Project, kettle pond monitoring, atmospheric ozone monitoring, browntail moth survey, Nauset Marsh water quality and macroalgae, vernal pond water chemistry, Herring River dissolved oxygen, Truro burn plots (effects of mowing and burning on forest understory vegetation), marine debris monitoring, benthic invertebrate sorting, fisheries surveys, native plant propagation.

B. ORGANIZATIONAL STRUCTURE AND APPROVED REORGANIZATION

The Division of Natural Resource Programs has the lead role at CACO for developing, coordinating and implementing actions to understand the park's natural resources, identify threats to them and mitigating any potential or realized effects. Natural resource staff at CACO have professional expertise in wildlife, forest and wetland ecology, forestry and fire management, and acquired knowledge of CACO hydrology and coastal geomorphic processes. As noted in item #5 of this proposal, the Division is staffed by a Chief (GS-12) and a biologist (GS-11). Seasonal biotechnicians are annually associated with kettle pond monitoring, pond shoreline revegetation, estuarine water quality monitoring, marsh restoration, and other activities. The CACO Fire Management Officer, a plant community ecologist, works closely with the Division of Natural Resource Programs.

The Superintendent has been very supportive of the need for a professional staff directing natural resource activities at CACO. He was responsible this past year for a major reorganization at the park which resulted in a new and separate Division of Natural Resource Programs. He also oversaw the reclassification and promotion of the two permanent employees in the Division; both individuals were in the 025 (park ranger) series and now are GS-12 and GS-11 biologists (401 series). He also approved a greatly expanded target organization for the Division which includes a GS-12 supervisory biologist, four GS-11 professionals (general biologist, botanist, hydrologist and aquatic ecologist), a GS-9 laboratory chemist, a GS-9 GIS specialist and numerous GS-5 technicians. The Superintendent has also provided significant base funding increases to support the Division functions. In FY89, the approximate level of funding for full-time CACO natural resource management activities was $100,000. In FY93, this amount has increased to approximately $158,000.

In association with the budget and justification (see item #6), a proposed target organization for the Division of Natural Resources Programs that will incorporate monitoring needs is presented (Fig. 7).

9. DATA MANAGEMENT PLAN

By definition, ecosystem monitoring is an exercise in measuring temporal changes in quality and quantity of environmental features. A baseline dataset that describes the condition of an ecological unit at time T_0 is developed and changes in condition are measured at times T_1 and into the future. For the analyses between time periods to be reliable, the T_0 and T_n datasets must be comparable. Therefore, it is exceedingly important to develop a well-designed and carefully crafted T_0 database at the onset of the monitoring

invitation to establishing a data volume rich in redundancy, inaccuracy and incompatibility. The monitoring program must be designed so that all necessary data are collected at a level of accuracy and replication that is appropriate for the targeted change detection. Statisticians and biometricians must be an integral part of the CACO monitoring program design phase. Also, the Data Manager must be certain that the data management plan is designed to effectively accommodate the necessary statistical analyses to be performed.

10. GIS SUPPORT AND INTEGRATION

CACO has an active GIS program as evidenced by the recent development of a draft GIS plan (expected final approval by October 1993). The Plan reviews the current status of GIS at CACO and provides implementation strategies regarding data base design and collection (e.g., data acquisition, scale and resolution, GPS, metadata, archiving, etc.), system and facility design (e.g., hardware, software), system support (e.g., staffing), and an implementation schedule. A summary of the GIS Plan is presented here, with a focus on existing GIS databases, current and planned facilities, and recent CACO GIS applications.

GIS DATA

The data base for the CACO GIS includes the outer Cape Cod area covered by eight USGS 7.5 minute quadrangles. Appendix 3 identifies the data themes currently available for use. This Appendix is not all inclusive, but does list those themes most appropriate for sustaining a park-wide inventory and monitoring program. The CACO GIS and Cape Cod Commission contain the bulk of data themes, but other agencies, such as Mass GIS also have relevant data. It was previously noted that the Seashore and the Cape Cod Commission have a cooperative agreement to facilitate data exchange. It is further noted that the Environmental Data Center at the University of Rhode Island has thirteen key CACO data themes on their GIS. This facilitates utilization of GIS technology by university researchers and CPSU-based researchers involved with two NRPP-funded studies of estuarine habitat ecology and nutrient loading.

Perhaps the most exciting development for the CACO GIS will be a 1:5000 digital orthophoto map series to use as a CACO base map. The USGS 7.5 minute topographic maps are the *de facto* standard cartographic base for the CACO GIS. They have many of the characteristics required of an acceptable map base: they are of known age and accuracy (i.e., they meet National Map Accuracy Standards); they are planimetrically correct; they are georeferenced; and they are readily available. However, the Cape Cod shoreline is an exceptionally dynamic landscape. Major changes in landform pattern and process occur over very short time periods.

CACO GIS. It is also noted that the Environmental Data Center at the University of Rhode Island is ARC/INFO based, thereby enhancing versatility available to CACO and CPSU researchers and resource managers.

GIS APPLICATIONS

Over the past several years the Seashore has developed some useful GIS applications. This list is not all inclusive, but is merely presented to demonstrate that CACO staff have the ability to apply GIS to inventory and monitoring efforts.

- Habitat boundary changes at Nauset Marsh (1985 to 1990)
- Evaluate efforts of fire suppression on CACO landscape
- Evaluate tern and piping plover habitat suitability (Shaw 1990)
- Support General Management Plan development
- Facilitate salt marsh restoration efforts. Display restoration scenarios and predicted responses.

11. LINKAGE AND LEVERAGING

Over the past several decades, CACO resource management staff, CPSU scientists, and regional scientists have maintained excellent interactions with other agencies and programs. This cooperation will continue toward development and implementation of an effective CACO ecosystem monitoring program. The following lists the cooperating entities that are expected to participate in the program, with some specific examples to follow.

Local
Provincetown, Truro, Wellfleet, Eastham, Orleans, Chatham (natural resource/conservation officers, health agents, planners)

Regional
Cape Cod Commission
Barnstable County Health and Environmental Board

State
MA Coastal Zone Management Office
MA Dept. of Environmental Management
MA Dept. of Environmental Protection
Water Supply
Wetlands and Waterways

researchers maintain almost daily contact with researchers associated with the nearby Waquoit Bay National Estuarine Research Reserve (also an NSF LMER site). Opportunities for shared expertise have already benefitted both programs. As protocols are designed, refined, and/or implemented, knowledge of these ongoing programs will be essential and when appropriate, identical protocols should be adopted.

With regard to groundwater resources and the proposed monitoring efforts (e.g., kettle ponds and water table mapping), the Seashore has recently spearheaded creation of the "Outer Cape Regional Groundwater Management Committee," represented by CACO, the Cape Cod Commission, USGS, 4 towns, and MA Dept. of Environmental Management. This multi-agency committee will be instrumental in identifying research, monitoring and management needs and in seeking appropriate funding opportunities.

Numerous other examples can be identified where mutually beneficial linkages and leveraging will be established toward effective implementation of the CACO plan.

12. REPORTING SYSTEM

Reporting is planned to satisfy both the information needs of park management and the quality assurance demands of the monitoring program itself. CACO I&M staff will produce *annual reports* for park management and interpretation staff in both written and oral form. It is envisioned that the findings of each major subject-area component (e.g. Estuaries) will be annually presented to the I&M Technical Advisory Board, park staff, interested local and visiting public and to other agencies and institutions with similar management responsibilities and interests. Presentations and discussions will be conducted during an *annual symposium* updating Cape Cod environmental research. With the rich scientific and resource management network in the region, it is anticipated that these symposia will become important annual events for the exchange of regional information.

Presentations to the public will include exhibits depicting both site-specific park monitoring and the dynamic ecosystems described by the monitoring effort. It is proposed that resource management staff and associated scientists collaborate with Seashore interpretation staff in designing lectures, walks, slide presentations and exhibits that offer a regularly updated story of how CACO natural systems function.

Technical review will be provided at the Park level by collaborating I&M staff and by the *Technical Advisory Board*, with both assessing results of each component in the context of the multidisciplinary monitoring program. The Technical Advisory Board will be selected to represent a wide range of scientific and resource management expertise in coastal issues, and specifically

of post-European settlement. Residential and commercial development in the six Outer Cape communities abutting CACO's boundaries, plus the mix of private (there are over 600 inholding within the park), federal, state and municipal ownership within CACO itself, further impact both resource conditions and the ability to manage them effectively. Moreover, the blend of state, local and federal jurisdictions, often with conflicting management objectives, makes protection of CACO values and resources complex.

CACO's natural resources face a number of increasingly complex and challenging issues. These include: 1) impacts of adjacent development on groundwater quantity and quality; 2) accelerated rates of freshwater and coastal marine eutrophication; 3) impacts of recreation on natural resources; 4) effects of landscape changes since European settlement; 5) protection and restoration of rare species and communities; 6) consumptive uses of resources, and; 7) sea level rise. While some of these issues are being addressed by park staff (i.e., potential changes in kettle pond water quality), the lack of a systematic approach to ecosystem monitoring and assessment has prevented a full understanding of the these threats and implementation of actions to resolve them.

This proposed monitoring plan has been developed to address known and suspected threats in the coastal zone. Specifically, this plan intends to 1) inform park management of the changes in resource condition over time; 2) provide a scientifically based evaluation and interpretation of the causes for any observed changes, and; 3) support the development of appropriate solutions to maintain native ecosystems and to implement appropriate restoration and/or mitigation actions.

The following are examples of how the proposed monitoring program will address several natural resource issues and threats -- most notably, resource consumption, urban encroachment, altered water quality, altered air quality, and diminished ecosystem integrity. Although not specifically highlighted, threats posed by over 5 million visitors annually are directly related to the abovecited threats.

RESOURCE CONSUMPTION (Fisheries and Municipal Water Withdrawal)

Outer Cape Cod supports an intense recreational fishery, including some of the best bluefish and striped bass fishing on the Atlantic coast. Commercial and recreational shellfishing are legislatively authorized within CACO and recently local towns have begun issuing aquaculture permits on lands administered by the NPS. Little information exists about harvest levels or impacts on harvested and non-target species. In addition, little is known about the effects of harvest techniques (dragging and hydraulic dredging) on bottom sediments and other key habitat features. The strategies outlined in the Monitoring Design section on Estuaries focus specifically on these concerns (also see Table 7). Results from long-term monitoring will be useful in preparing cooperative management plans

sources and environmental impacts of contaminants on park resources, it will be possible for park managers to provide informed input related to local land use decisions, regulatory programs, and other environmental and planning programs.

DIMINISHED ECOSYSTEM INTEGRITY

CACO is a landscape mosaic of natural areas, park recreation areas, and residential development, much like the other parks of the Atlantic and Gulf Coast Region. In addition to the increasing development demands adjacent to park boundaries, CACO has experienced over three centuries of human intervention. These past, present and future activities have dramatically altered the integrity of CACO ecosystems. Some examples related to estuarine impacts, fire management and shoreline processes follow.

Natural tidal water flow to several estuaries of CACO (Herring River, Hatches Harbor, Pilgram Lake) has been altered by dikes and roadways for nearly 100 yrs. This has resulted in well-documented impacts on estuarine-salt marsh water quality, ecology, and hydrology (Soukup and Portnoy 1986, Roman 1987, Portnoy et al. 1987, Portnoy 1991). Moreover, this issue of tidal restriction and detrimental ecological responses is widespread along the Atlantic and Gulf coast (Daiber 1986). The Estuaries component of the plan addresses monitoring of tidally restricted estuaries. This monitoring, when coupled with ongoing efforts to restore these ecosystems (WRD FY92/93 funding), will be instrumental in defining impacts and developing habitat restoration alternatives.

The policy of fire suppression due to public safety concerns has had a dramatic influence on ecosystem integrity at CACO. The dominance of pitch pine forests and the perpetuation of heathland communities may be dependent on fires which predominated during times of native American occupation, European settlement and until recent times. The Forest and Heathland vegetation monitoring will be essential to determining appropriate fire management alternatives to pursue for preservation of these characteristic CACO communities.

Barrier islands, spits, dunes, and shorelines of CACO are constantly changing in response to sea level rise and storms. This dynamic nature is expected, yet human interests often attempt to protect shorelines, build dunes, or stabilize inlet migrations. With climate change, as sea level rise accelerates, as predicted, and as major storms become more frequent and severe (also predicted), efforts to interfere with the natural shoreline processes of barrier islands, spits, and estuaries may be enhanced, especially on lands adjacent to CACO. The potential for altering ecosystem integrity is substantial. Obviously the Shoreline Margin and Barrier Islands/Dunes components of the plan directly address this issue. It is expected that the long-term monitoring efforts will assemble a data base that can be used to develop effective, consistent, and environmentally appropriate policies and guidelines

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APPENDIX 1 -- List of all project statements in the approved CACO Resource Management Plan and as requested in the proposal format guidelines, complete copies of select statements that specifically focus on long-term monitoring needs (see Table 1 in text) are included.

GEOLOGY

CACO-N-041: MONITOR SHORELINE RETREAT AND ACCRETION
CACO-N-042: STUDY CURRENTS IN COASTAL WATERS
CACO-N-043: PRODUCE REFINED SOILS MAP
CACO-N-044: INVENTORY PEDESTRIAN IMPACTS TO DUNES

OTHER

CACO-N-045: MONITOR MARINE DEBRIS
CACO-N-046: MITIGATE OIL SPILL IMPACTS ON RESOURCES
CACO-N-047: ACQUIRE LONG-TERM WEATHER DATABASE
CACO-I-048: ENHANCE GEOGRAPHIC INFORMATION SYSTEM
CACO-N-049: MANAGE OFF-ROAD VEHICLES
CACO-N-050: MITIGATE AND DETER ILLEGAL DUMPING
CACO-N-051: MANAGE HAZARDOUS WASTES

		Budget	FTE
COSTS:	CY:	.2	.1
	OY1:	.2	.1
	OY2:	.2	.1
	OY3:	.2	.1

2. Survey breeding bird populations in other CACO habitats and use an accepted terrestrial landbird monitoring program. Cornell University and the Association of Field Ornithologists' administer a nation-wide program of spot-mapping breeding bird territories and publish the results in the Journal of Field Ornithology. Surveys require 12-15 days of field work each and are completed at least every two years. Minimum plot size for woodland habitats is 10 hectares, surrounded by similar vegetation to avoid edge bias. This type of survey may be used to monitor population levels of breeding birds with small woodland territories. Costs include the initial administration and design of woodland breeding bird survey methodology by the NPS Coastal Research Center at the University of Rhode Island and subsequent monitoring by qualified individuals.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	25.0	
	OY2:	12.5	
	OY3:	12.5	

3. Monitor migratory bird populations where geography and habitat concentrate migrants. The Beech Forest in Provincetown is a widely known migratory landbird spot that attracts hundreds of birdwatchers in late May of every year. A decline in bird populations in the Beech Forest has been observed by amateur ornithologists but not quantified. Freshwater marshes may contain state-listed species that are not detected without focused surveys. Hunting of several bird species is permitted with a complete lack of knowledge of those populations (American woodcock, common snipe, Virginia rail, sora).

		Budget	FTE
COSTS:	CY:	-	
	OY1:	12.5	
	OY2:	12.5	
	OY3:	12.5	

COMPLIANCE: These proposed projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

CACO-N-009: MANAGE FEDERAL AND/OR STATE LISTED RARE INVERTEBRATES

SYSTEMWIDE ISSUE: N02, Impacts on Threatened, Endangered, and other Sensitive Animals.

PROBLEM STATEMENT:

One federally listed species of threatened invertebrate (northeastern beach tiger beetle) has been reported historically from CACO (Nothnagle, 1989), and six other state-listed species of dragonflies and *Lepidoptera* are known to occur (Carpenter, 1990; Mello, 1990). Without a focused monitoring effort to evaluate continuously the status of many of these organisms, large scale impacts to their populations are likely to go unchecked, as happened with the northeastern beach tiger beetle (Knisley et. al., 1987). Because of the variable nature of invertebrate populations, many Federal and/or State listed rare species may be present that have not been located in previous studies.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Develop a monitoring plan for Federal and/or State listed rare invertebrates. A plan will be required to address this difficult and taxonomically broad range of species. The plan will outline future monitoring needs that may be accomplished in the absence of long-term funding support.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	5.0	
	OY2:	-	
	OY3:		

2. Evaluate northeastern beach tiger beetle reintroduction potential. Currently, populations of this species on high-energy beaches occur only at one site in the species former range within the northeastern United States. This project will determine the feasibility of reintroducing this tiger beetle within CACO by working with the USFWS recovery team and biologists familiar with this species. Management techniques will have to be developed specific to CACO, in the absence of previous reintroduction attempts for this species.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	4.0	
	OY2:	-	
	OY3:	-	

CACO-N-010: MANAGE BROWNTAIL MOTHS

SYSTEMWIDE ISSUE:

N04, Degradation of Park Resources Due to Non-Native Animals

N20, Lack of Basic Data: Insufficient Understanding of Park Ecosystems and Threats to Them

PROBLEM STATEMENT:

The browntail moth was introduced into the United States sometime in the 1890's. By 1914, damaging infestations occurred in seven northeastern states. Presently, browntail populations can only be found easily in the Casco Bay area of Maine and in CACO. Although many browntail surveys and control efforts have been conducted within CACO over the last 30 years (see for example, Snowden, 1986; Leonard, 1986; Samora and Whatley, 1987; Anderson, 1989), virtually no quantitative data exist to indicate trends in their distribution or abundance on Outer Cape Cod. Only qualitative descriptions about the perimeter of the past infestation are available and associated census data are fragmentary and methods poorly documented. Survey tools and methodology remain inadequate and expensive for estimating density and distribution of this non-native insect.

The browntail moth causes an allergic reaction in people who come into contact with adults, larvae, webs or just the molted body hairs that are carried by the wind. Humans may suffer a long-lasting itchy rash similar to poison ivy. In addition, the browntail moth has the potential to cause a major perturbation to the dune ecosystem. Preferred plant foods of the browntail moth are beach plum, shadbush, oak and rugosa rose, species that comprise a large part of the dune flora. Because these plants play an important role in stabilizing dune ecosystems and supporting State listed rare *Lepidoptera* (at least 28 rare species have been collected in this dune environment by Mello (1986)), browntail moth feeding habits pose a potential threat to this sensitive ecological community. Observations of feeding by larvae indicate that some host plants may become defoliated. The effects of defoliation on plant growth, vigor and long-term survival are unknown. Leonard's (1986) study of browntail moths within CACO lacked adequate data to support statements regarding mortality of major host plants.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Develop methods to survey browntail moths. Basic survey methods are immediately needed to determine the status of browntail populations within CACO. Over the past two years, the USDA Agricultural Plant and Health Inspection Service (APHIS) and Agricultural Research Service (ARS) have successfully isolated and described the chemical nature of a female browntail moth pheromone.

A brochure explaining the biology and hazards of the moth that would be available at visitor centers would decrease the potential for visitor contracted dermatitus.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	2.0	.1
	OY2:	-	
	OY3:	-	

COMPLIANCE: These ongoing and proposed projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

CACO-N-018: PLAN AND IMPLEMENT FIRE MANAGEMENT PROGRAM

SYSTEMWIDE ISSUE:

N07, Disruption of Natural Fire Regimes

PROBLEM STATEMENT:

Fire management is an important component of the overall resource management program at CACO. Forest fuels, climate and visitor-use factors combine to produce potentially hazardous wildfire behavior in CACO's primary vegetation types. An average of 10 to 15 ignitions occur each year, all the result of human carelessness or mischief (Dosmann and Patterson, 1990). Fires probably contributed to the spatial heterogeneity of upland cover types. Currently, the potential exists for destructive wildfires. Black huckleberry is a highly flammable understory species common in the oak-pine forests of the Cape. Huckleberry foliage contains volatile oils or waxes that burn explosively when ignited. Fire behavior in fuel types, including huckleberry, can be estimated using Forest Fire Fuel models; however, no specific models have been developed for application in fuels of the Northeast.

Historically, fires have burned the vegetation of New England and Cape Cod for thousands of years. Fire frequently burned certain areas of Cape Cod before European settlement (Backman, 1984; Day, 1953; Patterson and Sassaman, 1988). CACO's staff has suppressed all wildfires aggressively since its establishment in 1961, limiting total burned acres to less than 40 hectares in 30 years. The effect of the full-suppression policy on forest fuels and vegetative communities is not known. Hypothetical ecological consequences of this policy include: 1) Forest cover will become more uniform, 2) Fire dependent communities such as grasslands and heathlands will diminish and eventually disappear, 3) Organic matter will accumulate leading to unprecedented fuel loadings that may, at some future time, ignite and burn with extreme intensity, and 4) Surface water acidity will increase. Organic matter may accumulate to levels that limit control efforts in some areas regardless of the resources committed to the fire. These fires may destroy improved properties and vegetation structure within CACO. Education of visitors and Cape Cod residents relating to fire prevention, fire ecology, fire protection, fire suppression and prescribed burning is minimal.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Update and re-write Fire Management Plan: An update of the approved draft fire management plan is required for operations and planning of fire management activities (National Park Service, 1990b). Revisions are necessary to reflect changes in dedicated staff (full-time Fire Management Officer and Clerk, three seasonal fire protection positions), vegetation management goals and hazardous fuel/prescribed burning opportunities.

Fire-safe landscaping techniques will be used to improve wildfire safety around improved properties. Techniques include: mechanical removal of dead trees, limbs and branches within 100 feet of structures, elimination of brush that can serve as ladder fuels and relocating firewood piles away from government structures.

		Budget	FTE
COSTS:	CY:	30.0	2.6
	OY1:	30.0	2.6
	OY2:	30.0	2.6
	OY3:	30.0	2.6

6. Fire Road Management: Cyclic fire maintenance during the last five years has cleared brush and trees from fire road corridors. Heavy fire road brushing, defined as clearing that requires removal and chipping of trees and brush, is expected to be completed within two years. After heavy maintenance is accomplished, continued clearing of sprouting vegetation is necessary to keep fire roads open. CACO will continue fire road maintenance using base funds and Dosmann and Patterson (1990) as a guideline.

		Budget	FTE
COSTS:	CY:	5.0	.3
	OY1:	5.0	.3
	OY2:	5.0	.3
	OY3:	5.0	.3

COMPLIANCE: The proposed research, monitoring and maintenance projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities." Any use of prescribed fire in these projects will follow NPS and DOI guidelines and policies, including preparation of environmental assessments for smoke management. The CACO Fire Management Plan will require an environmental assessment.

COMPLIANCE: These monitoring and planning projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities." Management and protection of many of these listed species are required by the Massachusetts Endangered Species Act.

DESCRIPTION OF RECOMMENDED PROJECT:

1. Study the ecology of broom crowberry: CACO heathlands are classified as rare communities by Massachusetts due to the occurrence of broom crowberry. This species has been considered for listing as federally endangered because of its globally restricted range. Outer Cape Cod is one of the few areas in its entire range where it is abundant. Work by Dunwiddie (1990) has focused on broom crowberry communities on Nantucket, however Nantucket heathlands are primarily grasslands and not under immediate threat of woody species invasion as are the CACO heathlands. A study will determine the life history, reproduction, recruitment and maintenance requirements of this species at CACO. This research project will provide baseline information about this species.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	15.0	
	OY2:	15.0	
	OY3:	15.0	

2. Re-survey monitoring plots: In 1988, Carlson and Godfrey established and quantitatively surveyed twelve long-term monitoring plots in the three types of heathland found on CACO. Re-surveying these plots will greatly add to our understanding of heathland community dynamics and should help determine why some heaths are overgrown more rapidly than others. This information will also be valuable in evaluating the results of experimental treatments aimed at maintaining selected heathland areas.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	4.0	.2
	OY2:	4.0	.2
	OY3:	-	

3. Develop and experimentally test heathland management techniques: Limited work has been conducted to test the four available management strategies (burning, mowing, hand clipping followed by herbicide treatment and grazing) to maintain heathland communities. The use of individual treatments and in different combinations needs to be investigated for the site specific conditions at CACO. This project would select several different heathland sites dominated by broom crowberry and bearberry and implement small to moderate scale experiments to investigate which management strategies (and during which seasons) provide the best protection for these communities. Without basic research on various treatments and their effects, long-term protection of heathlands can not be accomplished.

CACO-N-022: REVEGETATE LANDSCAPES AFFECTED BY HUMAN ACTIVITIES

SYSTEMWIDE ISSUE:

N06, Disruption of Native Plant Communities and Accelerated Erosion Due to Past Land Practices

N22, Overuse/Impacts to Recreation and/or Landscaped Zones

PROBLEM STATEMENT:

CACO has been continuously inhabited by European settlers since the mid 1600's. Historical impacts included deforestation, agriculture practices that depleted soil nutrients, human-caused wildfire and sand mining. Current revegetation needs at CACO are to stabilized dunes, mitigate vegetation and soil loss at kettle ponds and on social trails. The migrating sand dunes in Provincetown are partly the result of human deforestation, probably exacerbated by pedestrian social trails. Dune stabilization, primarily with plantings of beachgrass, has been attempted for many years and appears to be successful. However, beachgrass is a primary successional species, and long term stabilization of dunes will require succession to woody plant species. Eroded slopes at kettle ponds result from heavy summer visitor use by anglers and bathers. Human impacts usually are recognized only after erosion has started, the result of disturbed or destroyed vegetation and soil compaction.

DESCRIPTION OF RECOMMENDED PROJECT:

1. Evaluate Dune Planting Program. Historically, dune stabilization efforts have been conducted by various municipal and private organizations using both herbaceous and woody plantings. Over 900 acres of previously forested and currently barren dune area in Provincetown were identified in need of revegetation by Leatherman (1981). Planting of open dunes began in 1985 to stabilize the dunes and 110 acres have been planted with beachgrass to date. Justification for planting was based on the premise that human deforestation of the land initiated dune migration. However, Winkler (1990) argues that the Little Ice Age with its corresponding cooler temperatures and drier winds probably was a contributory cause of dune advancement and not human disturbance. A review of the dune planting program is necessary to determine: 1) if planting all remaining 800 acres is necessary, 2) if woody species can be introduced and survive and 3) if human disturbance or climate change (or both) was the driving force that initiated dune migration.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	20.0	
	OY2:	20.0	
	OY3:	20.0	

5. Establish Native Plant Nursery: Anthropogenic influences have resulted in the loss of vegetation on heavily impacted sites leading to erosion and site degradation. Efforts to revegetate impacted areas must conform with NPS guidelines specifically requiring the exclusive use of native vegetation and local genotypes. Development of a plant nursery and seed bank will allow CACO to revegetate impacted areas properly with native plant species. A synthesis of CACO managers' needs for revegetation and plantings for restoration will be made. Plans for nursery, greenhouse and seed storage area will be developed and funding for construction of the nursery will be pursued.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	10.0	.3
	OY2:	30.0	1.5
	OY3:	20.0	1.0

COMPLIANCE: These proposed projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2)&(4): "Day-to-day resource management and research activities" and "stabilization by planting native species in disturbed areas." Prior to the implementation of any large scale restoration or revegetation action, a NEPA review will be conducted.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	8.0	
	OY2:	5.0	
	OY3:	-	

COMPLIANCE: These proposed projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

2. Monitor Septic Leachate Entering Ponds: Nutrient loading from failing septic systems or cesspools of adjacent pondshore cottages and homes is of major management concern. At present, potential impacts from these systems are not linked to their sources. Implementation of a monitoring program will allow CACO staff to define the sources of septic effluent and evaluate the effectiveness of future modifications or upgrading of private and NPS septic disposal systems. Long-term monitoring will entail sampling groundwater along permanent transects at the pond shoreline and evaluating nitrate, phosphorous or sodium levels (sampling techniques were tested during the summer of 1990).

	Budget	FTE
COSTS: CY:	-	
OY1:	3.0	
OY2:	3.0	
OY3:	3.0	

3. Inventory Aquatic Macrophytes: Increased nutrient loading from septic systems and other sources can greatly increase pond algal and aquatic macrophyte production. While good historical information exists on the presence of pond shoreline plants (Soukup, 1977; Hinds and Hathaway, 1968), there is limited quantitative data on the abundance of these species. This project proposes to inventory existing emergent vegetation in the kettle ponds and to design a monitoring program to be implemented in the future so that changes in plant species abundance and composition can be detected and evaluated.

	Budget	FTE
COSTS: CY:	-	
OY1:	-	
OY2:	15.0	
OY3:	15.0	

4. Inventory Kettle Pond Benthic Invertebrates: Baseline data on these taxa are critically needed in order to understand the impacts of any water quality changes associated with visitor use and adjacent residential development. A complete survey of each pond for benthic invertebrates is also necessary before we can fully evaluate the effects of the State's active fishery enhancement program (stocking and pond liming). Metals concentrations in invertebrates are useful parameters to use in monitoring water quality changes, especially acid balance, presently of concern with acid deposition. At present, no information exists on kettle pond benthic invertebrates.

	Budget	FTE
COSTS: CY:	-	
OY1:	-	
OY2:	25.0	
OY3:	25.0	

In addition, some CACO areas appear to be annually enlarging and in many areas, trampling and subsequent loss of ground vegetation, shrubs and tree seedlings continue to be unquantified. A standardized monitoring program is needed to provide for the detection and evaluation of human impacts to pond shorelines and adjacent slopes. Monitoring data would provide an objective record of site conditions over time and allow an evaluation of impacts. Deteriorating conditions could be detected and appropriate management actions implemented before severe or irreversible impacts (especially to water quality) occurred. In addition, monitoring use patterns and impacts would provide a mechanism for developing management strategies and for evaluating the success or failure of resource protection measures following their implementation.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	12.0	
	OY2:	12.0	
	OY3:	-	

8. Implement Kettle Pond Interpretive Program: Except for an informational brochure available at only three ponds or through the Wellfleet town office, and infrequent ranger guided pond walks, CACO does not conduct specific public education activities about pond management concerns. None of the ponds have any permanent signs to convey natural history messages, information about appropriate visitor behavior while at the ponds, the location of designated beach access sites or regulations that directly relate to preserving pond water quality. Moreover, there is relatively little formal contact between CACO staff and the public about pond management issues. Interpretive talks are infrequently conducted at the ponds and have been poorly attended. Increased education and public communication are two of the most important resource management actions that can be implemented to help facilitate effective long-term management of the kettle ponds.

This project would develop a permanent signs/display for kettle ponds and provide for a roving and dedicated "pond ranger" to talk with visitors about pond management issues. This seasonal employee would host on-site formal talks and demonstrations using water sampling equipment and encourage spontaneous discussions with the public about kettle pond management issues. Topics for signs and direct public contact would include, origins and ages of the kettle ponds, pond ecological characteristics, why ponds are susceptible to change and how people can protect pond water quality.

		Budget	FTE
COSTS:	CY:	54.0	3.5
	OY1:	18.0	1.5
	OY2:	18.0	1.5
	OY3:	18.0	1.5

COMPLIANCE: These proposed projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities." NEPA review will be required before implementation of any pond specific management plan.

CACO-N-031: MONITOR EUTROPHICATION OF COASTAL BAYS AND ESTUARIES

SYSTEMWIDE ISSUE:

N11, Degradation of Water Quality Due to External Activities

N20, Visual and Biological Impacts of Urbanization and Other Near-Park Development on Park Resources

PROBLEM STATEMENT:

Primary production in marine systems is usually limited by the element nitrogen. Throughout the world, anthropogenic nitrogen loading is degrading coastal embayments by stimulating massive micro- and macroalgal blooms. Unlike more river-dominated areas, most nitrogen pollution on the Cape enters coastal waters with groundwater from the highly permeable aquifer. Nitrate-nitrogen, primarily from septic wastes, is carried with little attenuation to the shoreline. Although cultural eutrophication of CACO embayments has yet to be demonstrated, groundwater nitrogen values downgradient of developed areas, and immediately upgradient of sensitive surface waters, are often much above background unpolluted conditions. Upgradient development and sewage disposal continue with effects which may not reach a critical threshold for some time. Already, massive macroalgal blooms occur sporadically in Nauset Marsh, though their actual cause has not been determined. In addition, thick epiphytic algal growth occurs on eelgrass in less well-mixed portions of the Nauset system, suggesting nutrient excesses.

DESCRIPTION OF RECOMMENDED PROJECT:

Monitoring is proposed to determine the extent and degree of nitrogen and phosphorus loading into CACO coastal systems via surface runoff and groundwater discharge. Ongoing surveys of NO_3-N will be expanded in scope to include ammonium and phosphate once the CACO laboratory has obtained autoanalytical capabilities. Shoreline surveys will continue to control for high spatial variation, to document seasonal differences and to extend the sampled area. In this way, we hope to establish, and periodically monitor the pattern of nutrient loading to coastal embayments. Concurrent studies of macroalgal (*Cladophora*) production and eelgrass health will be used to expose likely indicators of eutrophication (CACO-N-WATR-10). These data should be critical for local land management decisions.

		Budget	FTE
COSTS:	CY:-		
	OY1:	95.0	1.8
	OY2:	95.0	1.8
	OY3:	95.0	1.8

COMPLIANCE: This proposed project is categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

2. Monitor ecological changes resulting from tidal restoration. CACO staff have been amassing physical, biological and water quality data on the Hatches Harbor system since 1987 in preparation for restoration management. This should of course continue after reconstruction provides increased tidal flow. If the current conceptual plan is finally approved, a likely strategy for the reintroduction of tide will be to begin with the culverts closed and to open in small increments. This will allow the system to slowly equilibrate to the restored tidal regime, minimizing biogeochemical disturbance and allowing management staff to fine-tune the culvert's operation for both marsh restoration and airport flood protection.

		Budget	FTE
COSTS:	CY:	10.0	.3
	OY1:	7.0	.2
	OY2:	-	
	OY3:	45.0	1.5

3. Implement an interpretive program about restoration. A major gap in CACO restoration programs at both Herring River and Hatches Harbor has been the lack of public outreach, i.e. communication of the preservation message to the local and visiting public. This project should include regular public meetings to describe goals and management strategies and to respond to questions and concerns. A small exhibit for the Province Lands Visitor Center will be developed to inform visitors about the restoration project. CACO resource management staff most familiar with the resource and political background should provide this outreach, with technical help from trained interpretation staff.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	9.0	.4
	OY2:	4.0	.1
	OY3:	4.0	.1

COMPLIANCE: Wetlands permits will be required for reconstruction of the dike at Hatches Harbor. Because the dike valve is currently controlled by the Massachusetts Department of Environmental Protection (DEP), its readjustment may not require filing under the Wetlands Protection Act. The proposed research, monitoring and education projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2)&(6): "Day-to-day resource management and research activities" and "Restoration of noncontroversial native species into suitable habitats within their historic range...". NEPA review will also be required prior to construction of alterations to the existing dike.

One of the two dwellings is subject to acquisition by the NPS; the other dwelling is not subject to acquisition and could persist as an obstacle to restoration unless a mutually agreeable compromise can be reached. Acquiring and/or moving both houses will require funding. A third socio-economic impact of restoration management is salt water intrusion. However, work by the USGS has shown that there will be no effects on the quality of adjacent water supply wells.

Restoration will involve a number of government and private entities, including the Town of Wellfleet which holds title to the dike, the state DEP which has control of the valves within the structure and has regulatory authority over adjacent wetlands, the Chequesset Yacht and Country Club (the golf course), the two homeowners within the flood plain, and CACO. Restoration will additionally involve extensive public outreach and interpretation and continued ecological monitoring.

DESCRIPTION OF RECOMMENDED PROJECTS

1. Coordinate planning and construction of a Mill Creek dike. CACO and others have produced a report describing expected freshwater discharge from the Mill Creek watershed and (thus) the pumping requirements should this tributary be diked to protect the golf course. Topographically, the dike would most effectively be built on golf course land. Since it obviously is intended to benefit the course, negotiations are needed to agree upon funding, construction and operation responsibilities. An action plan or prospectus will be developed to guide future restoration activities.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	10.0	
	OY2:	60.0	
	OY3:	-	

2. Complete study of salt/fresh groundwater relations. This work will be completed with a final report expected in May 1991. In brief, the USGS has definitively shown that salt water intrusion with restoration management will not affect residential wells.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	-	
	OY2:	-	
	OY3:	-	

COMPLIANCE: Wetlands permits and NEPA review will be required for construction of a dike at Mill Creek and for removal of the dwellings within the floodplain. Because the dike valve is currently controlled by the DEP, its readjustment may not require filing under the Wetlands Protection Act. The proposed education and monitoring projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

2. Design a detailed protocol for inventorying CACO's submerged resources. Based on criteria established at the workshop and augmented by the investigator and CACO, the protocol will select and prioritize species and/or habitats to be studied. For each species and habitat the protocol must identify data collection methods, seasonality, and indicators. The protocol must serve as the overall plan for CACO to follow as funds become available to perform the inventory. Further, it will be a synthesis of most relevant CACO specific and regional knowledge of particular species, habitats and processes.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	15.0	
	OY2:	-	
	OY3:	-	

3. Continue design of field monitoring plan and then begin a prototype submerged resource inventory. Based on the plan, the actual inventory program will begin by focusing on a particular species and / or habitat type. Interpretive materials will be developed to help the public understand more about the submerged resources of Cape Cod. These materials will include slides and video taken underwater, and may include travelling exhibits for outreach programs. The prototype inventory will include CACO staff as data collectors and logistics support, to simplify the transition from prototype to institutionalized inventory.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	-	
	OY2:	30.0	
	OY3:	-	

COMPLIANCE: These proposed projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

GIS technology can also be adapted for modeling purposes to predict future shoreline retreat and dune movement based on monitoring data.
These efforts and capabilities should be incorporated into the monitoring plan. Regional staff are available to assist in the preparation and implementation of the plan.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	5.0	
	OY2:	-	
	OY3:	-	

2. Implement the coastal geomorphology monitoring plan. This funding will be required for effective incorporation of the plan into CACO monitoring programs.

		Budget	FTE
COSTS:	CY:	5.0	.1
	OY1:	5.0	.1
	OY2:	5.0	.1
	OY3:	5.0	.1

COMPLIANCE: These proposed projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

Procedures follow those established by the NMFS and the WASO Division of Wildlife and Vegetation. This monitoring effort is expected to continue for at least five years.

		Budget	FTE
COSTS:	CY:	7.8	.4
	OY1:	7.8	.4
	OY2:	8.0	.4
	OY3:	8.0	.4

COMPLIANCE: This ongoing project is categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

3. Develop Weather Observation Retrieval Procedure for AANDREA Weather Station: An AANDREA automatic weather station, (obtained via a five-year memorandum of agreement) will be operational in fall 1991. A procedure to collect and archive weather observation will be developed.

		Budget	FTE
COSTS:	CY:	.5	
	OY1:	.5	
	OY2:	.5	
	OY3:	.5	

4. Summarize and Archive NADP and Provincetown Precipitation Data: Daily precipitation event and quantity data are collected through NADP sample collecting. These data, specific to CACO, are summarized on a monthly basis and will offer staff local rainfall duration and amounts.

		Budget	FTE
COSTS:	CY:	1.0	.1
	OY1:	1.0	.1
	OY2:	1.0	.1
	OY3:	1.0	.1

5. Subscribe to New England NOAA Monthly Precipitation and Climatological Data: NOAA monthly publications will be maintained at CACO headquarters.

		Budget	FTE
COSTS:	CY:	.3	
	OY1:	.3	
	OY2:	.3	
	OY3:	.3	

COMPLIANCE: These ongoing and proposed projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

APPENDIX 2 -- Vegetation Monitoring Protocol for Barrier Islands/Spits/Dunes, Forests, and Heathlands.

This vegetation monitoring protocol was prepared for implementation on all barrier island parks of the Atlantic and Gulf coasts. As noted in the text of this proposal (see item #4) it is intended that this multipark protocol be adapted for application at Cape Cod.

INTRODUCTION

The vegetation of barrier island parks along the Atlantic and Gulf Coasts is constantly changing in response to both natural and human-induced factors (e.g., storms, sea level rise, fire, ORV/pedestrian trampling, grazing, fire, among others). Effective management and protection of barrier island vegetation patterns and habitat function is contingent upon recognizing changes in community composition and structure and moreover, understanding the factors or environmental processes contributing to observed changes. Ideally, scientists and resource managers should have the ability to predict the effects of natural events, human induced impacts, or planned management actions (e.g., controlled burns, grazer control).

The program outlined below presents the minimum data acquisition necessary to implement a multipark, and geographically widespread vegetation inventory and monitoring program for barrier island parks of the Atlantic and Gulf of Mexico coast [Fig. 1; Cape Cod National Seashore (CACO), Fire Island National Seashore (FIIS), Gateway National Recreation Area (GATE), Assateague Island National Seashore (ASIS), Cape Hatteras National Seashore (CAHA), Cape Lookout National Seashore (CALO), Cumberland Island National Seashore (CUIS), Canaveral National Seashore (CANA), Gulf Islands National Seashore (GUIS), Padre Island National Seashore (PAIS)]. This recommended program is consistent with the National Park Service's Natural Resources Inventory and Monitoring Guideline (NPS-75) -- a plan intended to maintain consistency and technical rigor in data acquisition Servicewide. By employing a consistent methodology among coastal parks, some exciting interpretations of latitudinal differences in barrier island vegetation dynamics will be possible. At the park or regional level, issues related to special status plant occurrence and habitat requirements, exotic plants, grazing, fire, flora updates, storm responses, pest impacts, and visitor impacts, can all be addressed.

This *draft* document includes a proposed methodology for barrier island vegetation mapping, permanent transect establishment, data analyses, and program implementation.

METHODS

General Approach

The barrier island vegetation inventory and monitoring program proposes mapping of vegetation at 3 year intervals to assess large scale changes in vegetation patterns. Coincident with the mapping, permanently established cross-island transects will be monitored to evaluate finer scale changes in community composition and structure, as well as enabling an assessment of the factors and processes effectuating vegetation change. Permanent plots will be evenly spaced along the transects for collection of vegetation, environmental, and physical data.

Establishing cross-island transects provides uniformity of sampling across entire islands and between the many islands from Massachusetts to Texas. Cross-island transects, with permanent plots, will also enable a relatively unbiased evaluation of the vegetation. Alternatively, permanent plots could be established within major vegetation cover-types and monitored, yet this selection of sample sites is dependent on our preconceived ideas of the character of the vegetation (Greig-Smith 1983). On a statistical basis, introduction of this bias would be inappropriate.

Permanent Sampling

Transects and Plots[1]

Criteria. A minimum of one transect per 10 ± 2 km of barrier island in each of the ecological-geographical units will be established. The transects will be located to provide sampling of as many of the following eco-physiographic features as is possible within each of the units:

1. Distal end of the barrier island (accreting via longshore deposition).
2. Proximal end of the barrier island (erosion via inlet migration).
3. Maritime forest communities.
4. Overwash zone communities.
5. Salt marsh communities.
6. Interior freshwater wetlands.
7. Maximal cross-island community diversity.

It is presumed that typical dune, swale, thicket, and woodland communities will be sampled in the process and that a transect intersecting the maximum community diversity (#7) might also intersect maritime forest, significant salt marsh, and/or interior freshwater wetlands, thereby satisfying several of the eco-physiographic feature criteria simultaneously. The exact placement of the transects in each of the ecological-geographic units will be done with the aid of 1) preliminary vegetation maps, 2) using the elevation profile transect system established by the geomorphological team, and 3) consultation with scientists/resource managers at, and familiar with, the unit in question. It is expected that along the 800 km of Atlantic Ocean-Gulf of Mexico coastline under NPS jurisdiction, a total of 100-120 transects will be established.

Sampling Frequency. Sampling will be conducted once every 3 years by the coastal vegetation inventory team (see later definition), each team rotating annually among 3-4 adjacent ecological-geographical units along the barrier island network. The sampling would occur between 15 June and 15 September each year in order to consistently monitor vegetation in mid-growing season condition. In the event of major disturbance (e.g., hurricane, oil spill, etc.), the inventory team will assemble for an immediate assessment to be followed by a complete and detailed monitoring the next season (June 15 to Sept. 15).

Layout. Transects will be oriented perpendicular to the long axis of the island, extending from mean high tide on the ocean side to mean low tide on the bay side (Fig. 2a). The sampling scheme will consist of a series of 10x10 meter plots arranged at intervals along the transect. As shown in Fig. 2b, the permanent plots consist of a 10 x 10 meter tree layer plot, with a single 5x5 meter shrub layer plot and nine (9) 0.5x0.5 meter herbaceous layer plots nested inside. Corners of each tree layer plot will be permanently marked with reinforcing rod, or some other long-term product. Shrub and herb plots will also be marked consistently (see Fig. 2b). Each transects concrete marker(s) should be referenced with the aid of a Global Positioning System.

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[1]The sampling program presented here should be subjected to a preliminary study to enable justification and refinement of the design. See later section of this document.

12. Cover of live tree stems.
13. Cover of debris of human origin.
14. Cover of standing water.

The shrub layer will be sampled in a 5 x 5 meter plot ($25m^2$) located in the lower right hand quadrant as the viewer faces the bay. The following data will be collected in each shrub layer plot:

1. Density of stems emerging from the ground inside the plot by species.
2. Maximum height of each species to the nearest 0.1m.
3. A sketch map of the shrub canopy distribution and fallen logs-branches on the ground.

The tree layer will be sampled in the entire 10 x 10 meter plot [$100m^2$]. Trees are defined by the US Forest Service (Forest Survey Field Manual) criteria as any stem greater than a minimum diameter emerging from the ground within the plot and intersecting a plane at breast height. Each stem that arises from a fork of a trunk below breast height will be measured as an individual, while only a single measurement would be made for a trunk forking above breast height. All trees in the plot will be permanetly tagged and assigned a unique identification number.

The following data will be collected in each tree layer plot:

1. Diameter (by cm size class) of each stem by species (both live and standing dead).
2. Location on 1x1m grid map of each stem by identification number.
3. Maximum height of tree in canopy (with identification number).
4. A 1x1m grid map of fallen logs, gaps, canopy irregularities, stumps, trails, etc.

Environmental Data Requirements

To effectively interpret the vegetation data in terms of understanding why the species composition or community structure may be changing over-time, it is imperative that environmental and other data be collected coincident with the vegetation data sets. The following identifies minimum requirements.

For each ecological-geographical unit

Weather Data
- Precipitation (daily)
- Temperature (daily max, min, mean)
- Wind (speed and direction, mean, max)
- Relative humidity

Shoreline-Geomorphic Data
- Shoreline change rates for ocean and bay shorelines
- Cross-island elevation profile (at least annual and after events)

Other
- Significant herbivore populations
- Location of human disturbance (trails, dwellings, groundwater wells, etc)

What short and long term changes in barrier island flora and community patterns can be identified?

The need to accurately identify temporal changes in plant communities is central to the monitoring program. As with the classification procedures outlined above, this question can be addressed at several spatial scales.

Simple patterns of species abundance, richness and diversity can be identified through the construction of simple x - y plots of the descriptor variables against time. However, these plots will not be feasible until several intervals of data are available. Students t-tests comparing abundances between pairs of plots or sites, or Analysis of Variance (ANOVA) to compare abundances between several sets of plots over shorter time intervals will be used. Appropriate levels of significance can be determined from the preliminary studies (see next section).

As the long term data set accumulates, the most appropriate approach will be multivariate ordination techniques. For example, Roman and Nordstrom (1988) used Principal Components Analysis (PCA) to investigate temporal changes in plant communities with respect to shoreline processes (erosion rate, overwash penetration distance, dune height, etc.) at Assateague Island National Seashore. These procedures can allow the direct incorporation of other data (i.e., environmental) into the analysis in order to objectivley assess relationships between vegetation composition and other variables (Gauch 1982). Gibson et al. (1992) used Canonical Correlation Analysis (CANOCO) to demostrate the relationship between composition of vegetation on Perdido Key (GUIS) and plot elevation, distance from mean high water, and sand accumulation rate. As the most advanced ordination procedures, CANOCO and DCA (Detrended Correspondence Analysis -- derived from PCA) will be the ordination methods recommended in this program. Ordination provides a very sensitive and powerful tool to monitor long and short term changes. However, it is important to recognize that ordination is designed to reveal treands, rather than "significant" changes (Greg-Smith 1971). Given the proposed sample design, we also have the ability to test the significance of changes in relative aboundance of any species or assemblage of species between time periods using standard statistical methods (e.g., ANOVA), as noted above.

In all the classification and ordination approaches discussed above a multilayered investigative procedure will be followed. As well as the local, regional and latitudinal approaches, sufficient data will exist to allow investigations both spatially and temporally of specific plant communities. For example, the response of only marsh communities to sea level change across all ecological-geographical units could be investigated within a single ordination analysis. Further tree dbh, as well as tree and shrub denisty data, can be particulary useful in interpreting the response of maritime forest communities to the gradient of storm frequencies along the Atlantic and Gulf coasts.

How can these data be synthesized to address predictive needs to assist in vegetation management and park planning?

The analytical procedures outlined above seek to identify patterns within the existing data sets. However, there is a real need, particularly from the management perspective, to address predictive questions. For example, it would be relevant to ask what the effect of continuing sea level rise might have on marsh communities (the previous question asked how the marshes responded during the time frame encompassed by the data set). Ecological models provide a test of our understanding of barrier island systems (as encoded in a model) and actual measurements (Shugart 1989). At the simplest level,

a) At one eco-geographic unit for each of the three regions, sample a contiguous cross-island swath of $100m^2$ plots. Select a transect represented by maximum cover-type diversity.

b) Based on recent aerial photography, construct a vegetation map for each eco-geographic region with a preliminary transect.

c) Within each cover type identified on the map, calculate the variance and optimal sample size necessary to be 90% confident of identifying a 5% change in a variable (cover of an indicator species) between time t_o and t_{o+1} using the procedures outlined in Eckblad (1991).

d) Based on (c) above, determine the minimum number of plots needed per cover type per eco-geographic unit. From this a minimum number of cross-island transects can be determined after incorporating the additional criteria mentioned in this draft pertaining to transect siting.

The question of sampling frequency is best addressed as the monitoring program is underway. If dramatic vegetation changes are documented over the suggested 3 year interval, then perhaps a more frequent sampling is warranted. Alternatively, more stable eco-geographic units may require less frequent sampling.

COASTAL PARKS INVENTORY AND MONITORING MANUAL

The establishment and maintenance of this inventory and monitoring system will rely on the production of a ***Coastal Parks Vegetation Inventory and Monitoring Manual.*** Among other things, the manual will include:

1. A numbering system for all geographic-ecological units / ecophysiographic features / transects / plots / subplots.
2. Species, plant growth form, and debris class codes to be used.
3. Common data encoding forms. and formats.
4. Common plot mapping formats.
5. Common formats for transferring data to a central repository.
6. Common data analysis techniques and description of software needs.

PROGRAM IMPLEMENTATION

Implementation of a long term barrier island vegetation inventory and monitoring program, encompassing 10 park units, 4 NPS regions, and 800 linear kilometers of shoreline, represents a challenging task. It is recommended that three regional teams be assembled as follows:

North Atlantic --	CACO, FIIS, GATE, ASIS
Mid/Southeast Atlantic --	CAHA, CALO, CUIS
Florida Atlantic and Gulf Coast --	CANA, GUIS, PAIS

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Table 1. Recommended ecological-geographical units

PARK Ecological-Geographical Unit	Linear Shoreline (km)
CAPE COD NS	
Coast Guard Beach/Nauset Spit	5
Great Island Spit Complex	10
FIRE ISLAND NS	
1 unit	35
GATEWAY NRA	
Sandy Hook	10
Breezy Point/Fort Tilden	5
ASSATEAGUE ISLAND NS/ CHINCOTEAGUE NWR	
1 unit	60
CAPE HATTERAS NS	
Bodie Island	35
Hatteras Island	95
Ocracoke Island	20
CAPE LOOKOUT NS	
Core Banks	70
Schackelford Banks	15
CUMBERLAND ISLAND NS	
1 unit	30
CANAVERAL NS	
1 unit	xx
GULF ISLANDS NS	
Perdido Key	11
Santa Rosa Island	13
Mississippi Islands	xx
PADRE ISLAND NS	
1 unit	xx

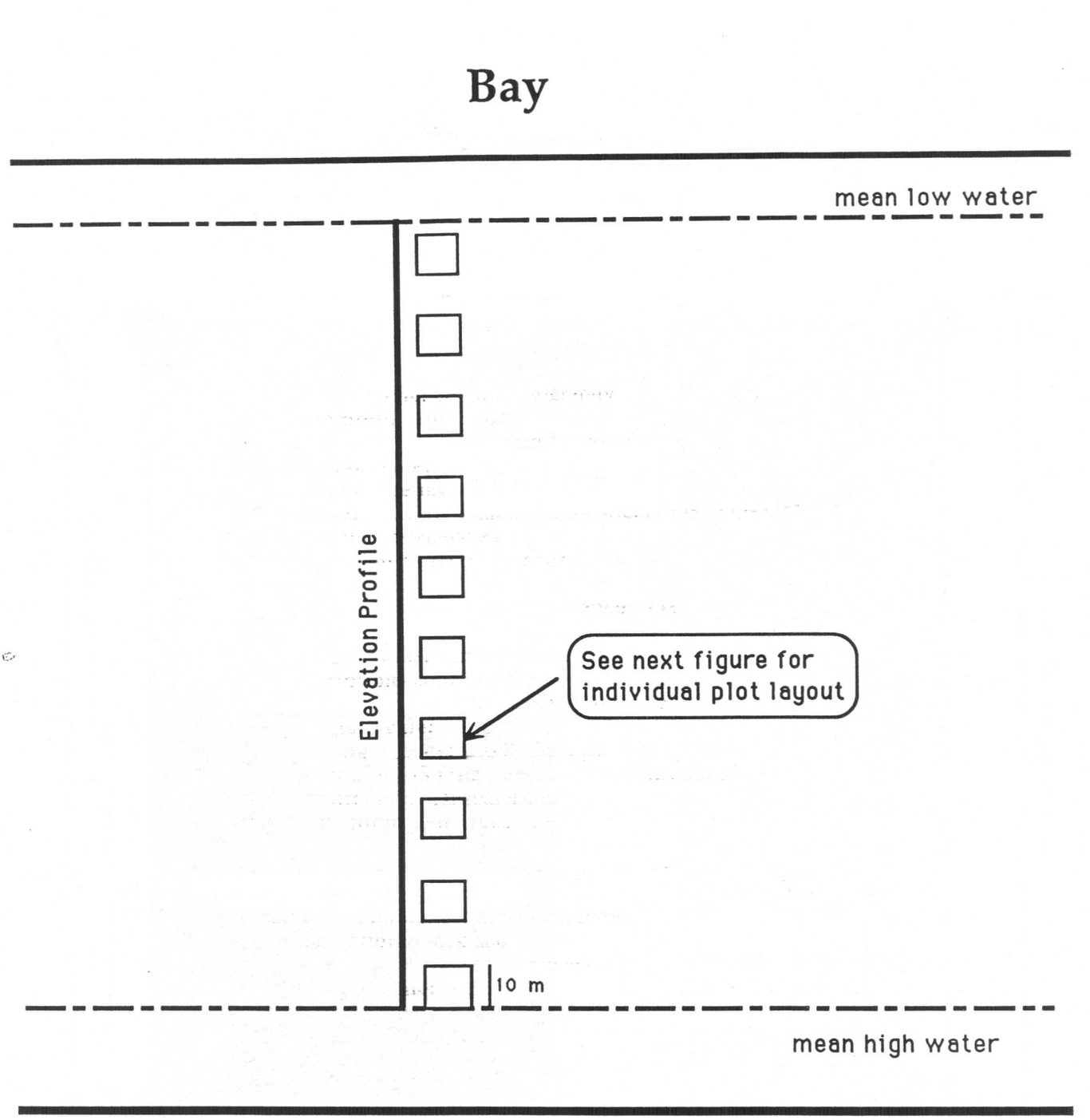


Fig. 2a. Schematic of cross-island transect. Note the permanent plots are off-set from the elevation profile line.

APPENDIX 3 -- Data themes associated with the Cape Cod National Seashore Geographical Information System.

An inventory of digital spatial data that will be applicable to design and implementation of a long-term monitoring program at Cape Cod is included below. Many of these data themes are on the CACO GIS, on the Univ. of Rhode Island CPSU GIS,or associated with cooperating agencies (e.g., Cape Cod Commission).

GIS Inventory Referenced by Data Theme

Data Theme	Reference #
land use	1,2,9
land cover	1,2,3,4,5,19,22
ownership	6,7
salt marsh	1,2,3,4,5,17,19,22
wetlands	1,2,3,4,5,17,19,22
vegetation	1,2,3,4,5,19
roads	1,2,8,9
coastline	1,2,11,12,19,22
hydrography	1,2
submerged aquatic vegetation	19,20
developed land	1,2
elevation	10
bathymetry	14,21
water quality	27
sediments	18
tidal flats	13,19
shorebirds	23,24,25
finfish	26
shellfish	15,16,19

GIS Inventory Referenced by Source Institution

Source	Reference #
Cape Cod National Seashore GIS (CACO GIS)	1,3,4,5,6,8,10,11,13,14,15,17,19
Cape Cod Commission GIS (CCC GIS)	1,7,9,12,15,17,27,28,29,30
Massachusetts GIS (MassGIS)	1,2,9,10,12,21,34
Massachusetts EOEA	33
Massachusetts Division of Marine Fisheries (MA DMF)	16
U.S. Geological Survey (USGS)	18
Massachusetts Department of Environmental Protection (MA DEP)	20,35
U.S. Fish and Wildlife Service, Portland, ME	22,23,24,25,26
EROS Data Center, Sioux Falls, SD	31,32

Reference #5

data set name: veg91
description: 1991 vegetation cover for CACO
25 classes
original scale: 1:7,200
curating agency: CACO GIS
contact: Marconi Station Headquarters (508) 349-3785
format: digital
GRASS raster
production year: 1991

Reference #6

data set name: 1966 parcels
description: 1966 land ownership parcels for CACO
original scale: 1:4,800
curating agency: CACO GIS
contact: Marconi Station Headquarters (508) 349-3785
format: digital
GRASS raster
production year: 1992

Reference #7

data set name: 1980's parcels
description: 1980's land ownership parcels for Cape Cod
original scale: variable - recompiled to 1:7,200
curating agency: Cape Cod Commission
contact: Cape Cod Commission (508) 362-3828
format: digital
ARC/INFO vector
production year: early 1990's

Reference #8

data set name: roads
description: light, medium, and heavy duty roads for CACO
digitized from 1972 USGS 7.5 minute topographic maps
original scale: 1:25,000
curating agency: CACO GIS
contact: Marconi Station Headquarters (508) 349-3785
format: digital
GRASS vector
production year: 1990

Reference #13

data set name: tidal.flats
description: intertidal mud and sand flats for CACO
digitized from 1972 USGS 7.5 minute topographic maps
original scale: 1:25,000
curating agency: CACO GIS
contact: Marconi Station Headquarters (508) 349-3785
format: digital
GRASS vector
production year: 1990

Reference #14

data set name: bathym
description: bathymetry for CACO
digitized from 1972 USGS 7.5 minute topographic maps
original scale: 1:25,000
curating agency: CACO GIS
contact: Marconi Station Headquarters (508) 349-3785
format: digital
GRASS vector
production year: 1990

Reference #15

data set name: shelfish
description: potential shellfish beds based on water depth for Cape Cod
digitized from 1972 USGS 7.5 minute topographic maps
original scale: 1:25,000
curating agency: Cape Cod Commission GIS
contact: Cape Cod Commission (508) 362-3828
format: digital
ARC/INFO vector
production year: 1990

Reference #16

data set name: shellfish habitat
description: shellfish habitat mapping for MA
growing areas, open/closed areas, water quality
original scale: 1:25,000 or 1:5,000
curating agency: MA Dept. of Fisheries, Wildlife, and Environ. Law Enforcement
contact: MA Division of Marine Fisheries (508) 745-3107
format: digital
ARC/INFO vector
production year: 1995 (in system design and pilot stage)

Reference #21

data set name: bathymetry
description: NOAA digital bathymetry for MA
processed by MassGIS
original scale:
curating agency: MassGIS
contact: MassGIS (617) 727-3888
format: digital
ARC/INFO point
production year: 1991

Reference #22

data set name: nwi
description: National Wetlands Inventory
digitized under USFWS Gulf of Maine Coastal Estuary Project
original scale: 1:25,000
curating agency: U.S. Fish and Wildlife Service
contact: USFWS Portland, ME (207) 828-1080
format: digital
ARC/INFO vector
production year: 1993 (undergoing automation)

Reference #23

data set name: breeding birds
description: generalized occurrence of bird nesting areas
digitized under USFWS Gulf of Maine Coastal Estuary Project
from MA Breeding Bird Atlas (1978)
original scale: 1:25,000
curating agency: U.S. Fish and Wildlife Service
contact: USFWS Portland, ME (207) 828-1080
format: digital
ARC/INFO vector
production year: 1993 (undergoing automation)

Reference #24

data set name: colonial coastal water bird nesting areas
description: all known colonial water bird nesting sites on Cape Cod and Islands
from surveys conducted in 1978 and 1984
digitized under USFWS Gulf of Maine Coastal Estuary Project
original scale:
curating agency: U.S. Fish and Wildlife Service
contact: USFWS Portland, ME (207) 828-1080
format: digital
ARC/INFO point
production year: 1993 (undergoing automation)

The National Park Service Coastal Research Center, a Cooperative Park Studies Unit at the University of Rhode Island, conducts scientific research on coastal national parks with the objective of applying research findings to the protection of natural resources and development of effective natural resource management policies. The Coastal Research Center was established under Cooperative Agreement 1600-9-8008 between the National Park Service, North Atlantic Region and the University of Rhode Island.

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Copies of this report are available from the following. To order from the National Park Service Technical Information Center, use the reference number on the bottom of the report's last page.

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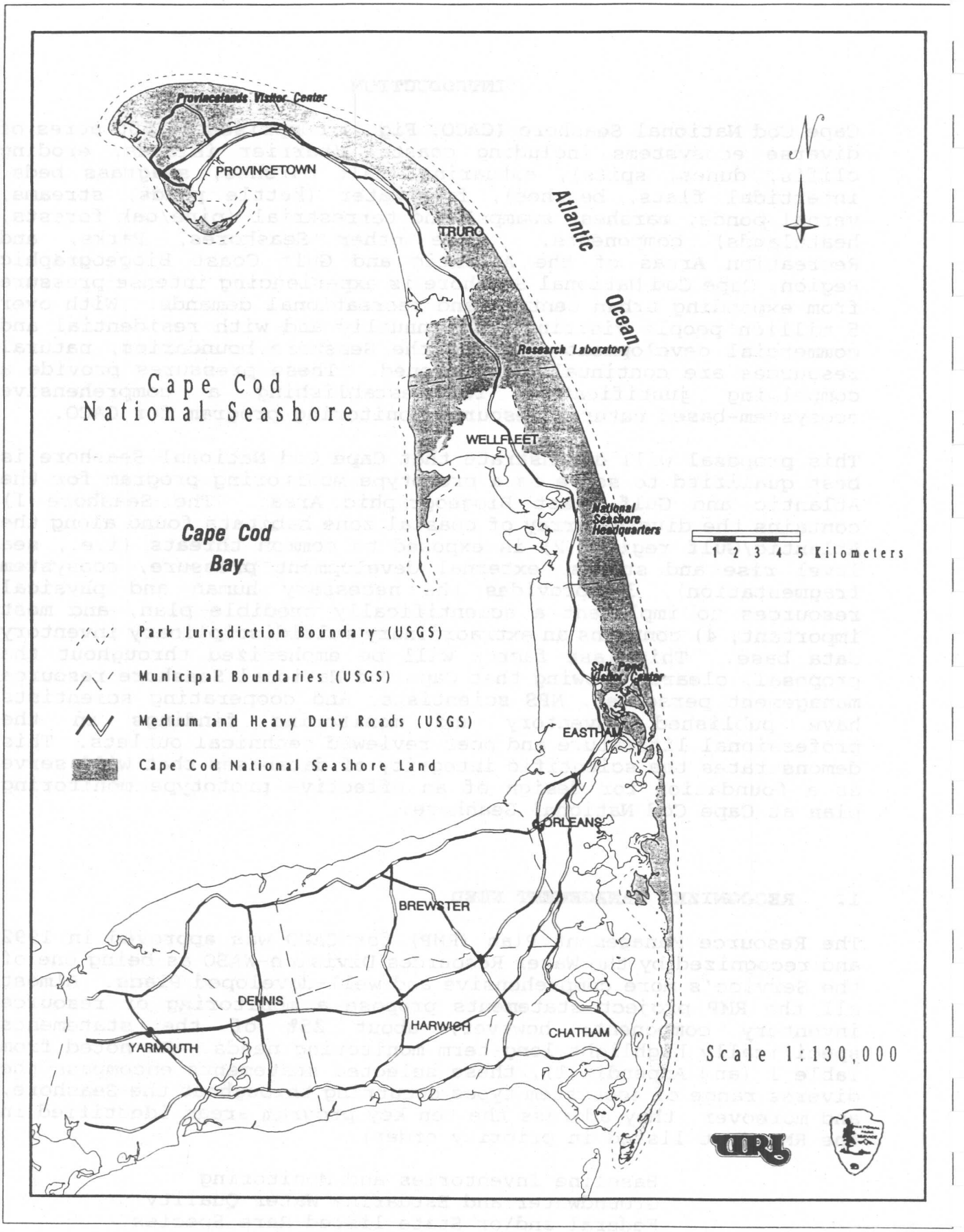


Figure 1. Local setting of Cape Cod National Seashore.

LIST OF FIGURES

1. Local setting of Cape Cod National Seashore 2
2. Schematic of proposed monitoring program 20
3. Critical shoreline areas 22
4. Location of estuaries 29
5. Location of kettle ponds 35
6. Conceptual procedure for monitoring design & testing.. 49
7. Proposed target organization 59

LIST OF TABLES

1. List of Resource Management Plan project statements .. 3
2. Cover types on Cape Cod vegetation maps 7
3. Parkwide faunal inventories 9
4. Habitat-specific inventories 11
5. Existing monitoring protocols 13
6. Recent and ongoing research projects 16
7. Questions/objectives of estuarine monitoring component 31
8. Estuarine monitoring parameters 32
9. Kettle pond characteristics 36
10. Kettle pond annual monitoring parameters 39
11. Kettle pond summertime monitoring parameters 40
12. Common ecosystem types and issues of Atlantic/Gulf ... 66

CACO-N-028 Manage Kettle Ponds
1. Monitor kettle pond water quality

Terrestrial Ecosystems

CACO-N-002 Monitor Terrestrial Birds
1. Continue breeding bird censuses
2. Expand census to other habitats
3. Monitor migratory bird populations

CACO-N-010 Manage Browntail Moths
1. Develop methods for long-term monitoring
2. Monitor browntail distribution and abundance

CACO-N-011 Monitor Gypsy Moths
1. Continue annual monitoring

CACO-N-018 Plan and Implement Fire Management Program
1. Monitor live fuel moisture

CACO-N-020 Manage Heathlands
1. Continue long-term monitoring of permanent plots

Multi-ecosystem

CACO-N-009 Manage Federal and State listed rare invertebrates
1. Develop and implement monitoring plan

CACO-N-019 Manage Rare Plant Communities
1. Initiate rare plant monitoring

CACO-N-047 Acquire Long-Term Weather Database
1. Continue fire weather observations
2. Continue monitoring ambient weather conditions using AANDERRA station

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2. Vegetation Maps -- Vegetation maps (scale 1:24,000) for 1962, 1977, and 1991 are digitized into the Seashore's GIS. Cover-types are listed in Table 2. This mapping time-series has been extremely valuable in recent Seashore studies, most notably, the NRPP-funded interpretation of fire suppression on landscape ecology and a WRD-funded study of restoration in the Herring River floodplain. Further, the vegetation maps are instrumental to development of the park's Fire Management Plan, particularly in relation to hazard fuels analysis, and ongoing preparation of the General Management Plan.

3. Geology and Soils Maps -- About 18,000 yrs ago the glacial ice sheet of the Wisconsonian stage began to retreat leaving the present day landscape of freshwater kettle ponds, plains, estuaries and hills. The glacial history of Cape Cod and descriptions of glacial features and deposits have been richly studied, with a most recent monograph by Oldale (1992). Geologic maps of Cape Cod, including the Seashore, are published by the USGS (scale 1:24,000; Oldale 1976) and are presently included in the Seashore GIS.

   Soils of the Seashore are predominantly mineral, with organic soils restricted to swamps and marshes. Soils maps, published by the Soil Conservation Service (1987), are included in the Seashore GIS.

4. Hydrology -- Conceptually, the hydrology of Cape Cod is relatively simple with the aquifers consisting of sand and gravel deposits. Groundwater flow is generally from the central area of the aquifer, where the water table is highest, toward the discharge area (streams, ponds, ocean, bay). Designated as a sole source aquifer, the groundwater system within the Seashore consists of four basins divided by streams. A USGS hydrologic atlas of Cape Cod (LeBlanc et al. 1986) describes the boundaries of freshwater lenses, including the saltwater interface, the groundwater flow system, groundwater levels, and water use. This atlas, coupled with a 5 ft contour water table map (LeBlanc and Guswa 1977) and digital flow models (Guswa and LeBlanc 1985) all provide an excellent baseline inventory of CACO hydrology.

   In addition to these Cape and park-wide studies, extensive research, modelling, monitoring and inventory of Cape Cod's groundwater resources has been conducted over the past several decades in response to the issues of groundwater withdrawal for municipal supply (Martin 1993; LeBlanc 1981, 1982; Cambareri et al. 1989), seawater intrusion (Fitterman and Dennehy 1992), groundwater contamination from landfills and non-point source inputs (Urish et al. 1993, Frimpter and Gay 1979, LeBlanc 1984, Persky 1986), and sea level rise (Nuttle and Portnoy 1992). These published studies and numerous others not discussed here (see Claxon and Renwick 1992), coupled with ongoing hydrological research (e.g., FY93\94 WRD-funded analysis of groundwater discharge and nutrient loading

to CACO ponds), have generated a comprehensive understanding of Cape Cod hydrology and an excellent appreciation for the relationships and interactions between hydrologic processes and ecosystem responses.

5. Fauna - Park-wide faunal inventories are excellent for some taxonomic groups and poorly established for others. Baseline inventory data, based on literature reviews and personal consultations, are available for many taxa. However, park-wide inventories based on systematic field surveys are limited, except as noted in Table 3. The following section of this proposal on habitat-specific studies will identify some comprehensive faunal inventories of select taxonomic groups. Obviously, many of these inventories can be successfully used to infer park-wide faunal status.

6. Shoreline change -- The 229 beach profiles established by Marindin (1889, 1891) on outer Cape Cod comprise one of the oldest shoreline field surveys in North America and the baseline for several follow-up surveys (Ziegler et al. 1964, Bowman and Rogers 1967, Leatherman et al. 1981, Giese and Aubrey 1987). They will continue to serve as a valuable benchmark for shoreline change monitoring at CACO. Surveys of shoreline change using historic maps and aerial photos have also been quite comprehensive with investigations by the Massachusetts (MA) Coastal Zone Management Office (1976), Gatto (1978, 1979), and US Army Corps of Engineers (1979). Shoreline change analyses dating from 1890 to 1978 are available and the MA Coastal Zone Management Office is planning an update via aerial photography (MA CZM, personal communication) in 1994.

7. Air and Meteorological Datasets -- Air resources are being monitored through participation in several state and national programs. Monitoring of ambient ozone has been conducted in cooperation with the Massachusetts Department of Environmental Protection since 1987 (Massachusetts Department of Environmental Protection, 1989). A National Atmospheric Deposition Program site has been operated by CACO staff since 1981. CACO staff cooperate in the Massachusetts Acid Rain Monitoring program as collectors for many of the outer Cape Cod ponds and as analysts for field chemistry. Weather conditions are monitored daily (fire weather - April 15 through November 15) and at an automated station near the Marconi headquarters. The National Weather Service maintains daily weather monitoring stations in Provincetown and Chatham. CACO is designated as a Class II air quality area under the Clean Air Act.

B. HABITAT-SPECIFIC INVENTORIES

Comprehensive inventories of particular habitats or sites throughout the Seashore have been conducted. These inventories

often represent intensive field efforts in an effort to derive complete species lists, knowledge of seasonal distribution patterns of biota and an appreciation for processes controlling species composition and distribution. Table 4 lists some of the more complete inventories of the biotic and physical features of CACO. This table is not exhaustive, but merely provides a representation of the kinds of published inventories that are available.

When combined with the park-wide inventories and assessments, CACO has an excellent foundation from which to design and implement an effective long-term ecosystem monitoring program.

3. PROGRAM READINESS

Several factors contribute to CACO's readiness to develop and effectively implement a comprehensive long-term ecosystem monitoring program. These include, a) the development, and often times, implementation of monitoring protocols, b) an extensive network of cooperative relationships, and c) funding opportunities.

A. EXISTING MONITORING PROTOCOLS

Table 5 list some of the key monitoring protocols that have been developed for CACO and identifies their implementation status. This table demonstrates that the park's Division of Natural Resource Programs has taken an active role in seeking appropriate funding to develop scientifically-based protocols, and moreover, in implementing monitoring programs. All of the protocols in Table 5 are worthy of mention, but only two (estuaries and kettle ponds) will be highlighted here to demonstrate the successful approach that CACO has taken toward design and implementation of monitoring programs.

For three years the Seashore has been developing park-wide monitoring protocols for estuarine resources (marshes, eelgrass beds, fish, shellfish, water quality, etc.). Initially, Burroughs and Lee (1991) evaluated the controlling ecological and physical processes and assessed the primary ecosystem threats/issues and developed monitoring objectives for the Seashores five major estuarine systems (Hatches Harbor, Pilgrim Lake, Pamet River, Herring River, Nauset Marsh). This was followed by the recent "Plan for Inventory and Monitoring of Estuarine Resources at Cape Cod National Seashore" (Beatty et al. 1993, draft). This Plan, prepared by researchers associated with the Cooperative Park Studies Unit at the Univ. of Rhode Island, provides a detailed critical assessment of existing information, recommends specific sites for inventory and monitoring, presents an inventory plan, and presents a monitoring plan. The inventory and monitoring aspects of the Plan recommend standard methodologies, identify specific parameters, recommend spatial and temporal sampling frequencies,

Table 4. (continued)

Habitat Type	References
Provinceland Dunes	
Dune evolution and migration	Madore and Leatherman 1981; Winkler 1992
Vegetation	Koske and Gemma 1992; Godfrey et al. 1991; Ehrenfeld et al 1987
Kettle Ponds	Martin et al. 1993; Soukup 1977; Winkler 1988
Heathlands	Carlson et al. 1992
Atlantic White Cedar Swamps	Motzkin 1990, 1991
Forested uplands	Patterson et al. 1984

detail a data management program with GIS integration, and identify potential cooperating agencies. More details of the estuarine Inventory and Monitoring Plan will be presented in item #4 (Monitoring Design) of this proposal. Although some aspects of this Plan are currently implemented on a site-specific basis (see Table 5), it is expected that complete testing and implementation of the Plan will commence with designation of CACO as a Prototype Monitoring Program.

With regard to kettle pond water quality monitoring, the Seashore, Regional Science Program, and the Water Resources Division - WASO, developed a monitoring protocol (Martin et al. 1993) that has now been successfully implemented by Seashore staff for two years. As with the estuarine protocol, study sites are identified, spatial and temporal sampling frequency are specified, methods are detailed, data analyses procedures are noted and a data management plan is recommended. This long-term program for kettle ponds will be instrumental in monitoring the limnological processes and anthropogenic inputs (i.e. phosphorous) that may be responsible for altering kettle pond trophic status.

Both protocols mentioned above were launched by CACO-sponsored workshops. These workshops assembled technical experts from academia, state and federal agencies, regional groups, and others, to insure that the protocols benefit from experiences of others and encourage cooperative relationships.

B. EXISTING COOPERATIVE RELATIONSHIPS

When considering the availability and readiness of scientific expertise to pursue development of Cape Cod's prototype monitoring program, the coastal northeast has the advantage of having the densest agglomeration of scientific researchers in the nation. The North Atlantic Region has taken advantage of this wealth of knowledge by establishing cooperative agreements with 12 academic institutions.

Cooperative Agreements between universities and the North Atlantic Region are as follows,

CPSU at University of Rhode Island
CPSU at University of Maine
CPSU at SUNY-Syracuse
Boston University
College of the Atlantic
Dartmouth College
Harvard University
Rutgers University
University of Massachusetts
University of New Hampshire
University of Vermont
University of Wisconsin-Madison

Table 6. Recently completed and ongoing Cape Cod National Seashore projects conducted through the University of Rhode Island CPSU and other University Cooperators

Project Title	Project Cost	Completion Date
University of Rhode Island		
Species composition, migration chronology, and habitat use of birds on Cape Cod National Seashore	$ 34,000	May 1993
Evaluating the response of salt marshes to accelerated sea level rise: a preliminary assessment	$ 38,719	December 1993
Anthropod-borne diseases in and near National park areas of the continental United States	$ 25,000	December 1993
Assessment of ground and surface water impacts from the Provincetown landfill and septic disposal site	$ 69,460	April 1993
Monitoring program for Cape Cod National Seashore estuaries	$ 20,000	August 1991
Restoration of early and late successional dune communities at Province Lands, Cape Cod National Seashore	$ 25,000	October 1992
A feasibility study for vibracoring at the Nauset Light Archeological Site	$ 8,000	December 1991
Development of a protocol for the inventory and long-term monitoring of submerged marine-estuarine resources at Cape Cod National Seashore	$ 50,151	June 1993
An evaluation of hydrologic aspects of groundwater discharge to a Cape Cod National Seashore Estuary	$ 35,000	October 1992
Establishing data management and analysis strategies using a Geographic Information System (GIS) for coastal parks	$ 93,648	December 1994

C. FUNDING OPPORTUNITIES

Based on past funding success, a well-conceived Resource Management Plan, and reorganization plans for the CACO Division of Natural Resource Programs, it is concluded that CACO will have the funding and support necessary to implement the prototype monitoring program.

As noted from Table 6, the Seashore has always been successful in securing appropriate funds for natural resource inventory, monitoring and research. Park base funds are also regularly committed to resource monitoring activities (see Table 5).

The RMP provides outyear budget requests that will be adequate to support initial stages of the monitoring plan (see Appendix 1).

4. MONITORING PROGRAM DESIGN

CONCEPTUAL DESIGN

In general terms, the proposed Prototype Monitoring Program for CACO is intended to, 1) continuously assess the status of the Seashore's major ecosystem components, and 2) evaluate and monitor many of the natural processes and human-induced factors that may be contributing to changes in ecosystem structure or function. The proposed monitoring program is designed to specifically address current management issues and research questions that are relevant to CACO and other coastal parks, while also monitoring more general ecosystem components and controlling processes that will serve to enhance our knowledge of the ecosystem.

It is also important to mention that the CACO prototype monitoring was designed with field and data analyses techniques that are simple to implement, while maintaining a high degree of scientific integrity. Too often, elaborate monitoring plans are designed and initially implemented, but never sustained. Simplicity will be a cornerstone of the CACO plan.

The CACO prototype monitoring program will address five major components of the ecosystem --

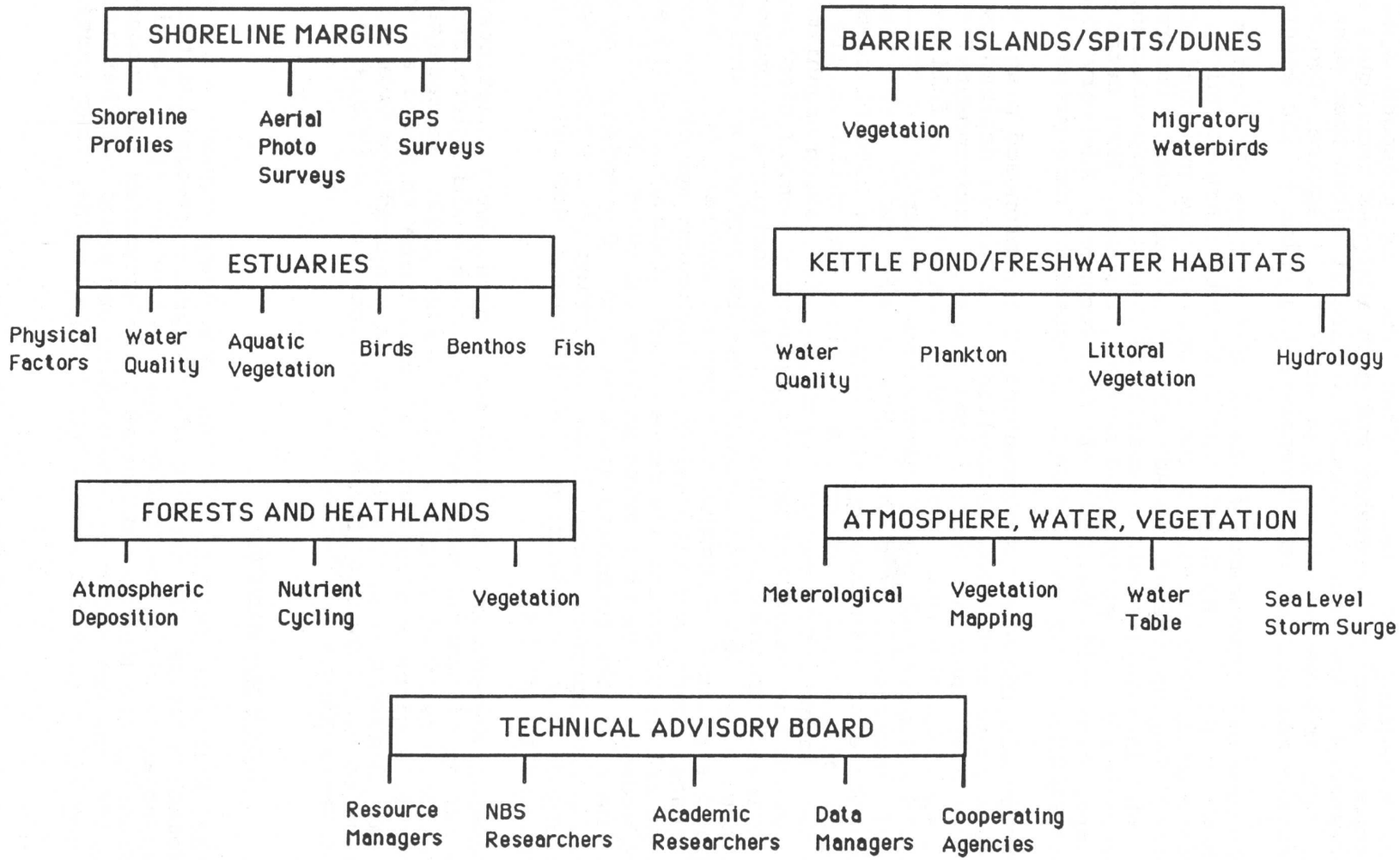
Shoreline Margins
Barrier Islands/Spits/Dunes
Estuaries
Kettle Ponds and Freshwater Habitats
Maritime Forests and Healthlands

In addition, the plan presents several routine or periodic monitoring tasks that are necessary in interpreting causes of trends that may be observed in the monitoring data sets.

The plan proposed herein will outline the monitoring tasks to be

FIGURE 2

Proposed Prototype Monitoring Program for Cape Cod National Seashore



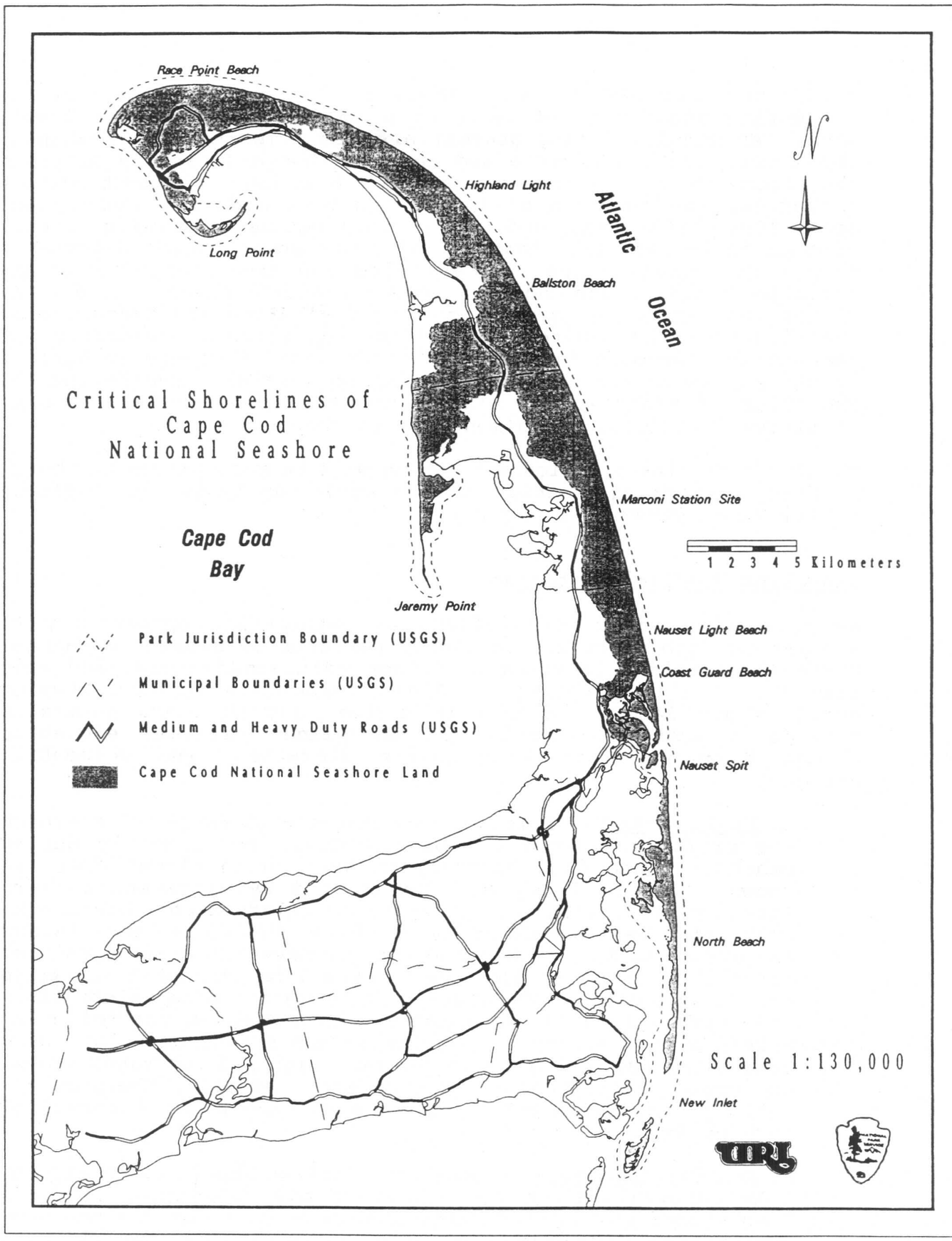


Fig. 3. Critical shoreline areas of Cape Cod National Seashore.

GPS surveys

Global Positioning Systems (GPS) have enabled a new, exciting, and accurate approach to shoreline position monitoring. Most recently GPS technology has been applied in Texas (Morton et al. 1993), at Cumberland Island NS (Byrnes et al. 1993), Fire Island NS (J. Allen, personal communication) and Gateway NRA-Sandy Hook Unit (J. Allen personal communication). This technique provides a rapid (almost real time) and accurate record of shoreline position in the field. Locational accuracy to within 2-5m is now routinely possible. Technological improvements will soon increase the precision in both horizontal and vertical coordinate systems to less than 1m and a few cm, respectively.

Implementation of the GPS monitoring will involve seasonal (as with profiles -- winter and summer) and pre- and post-storm surveys in a kinematic mode from a small vehicle, such as an ATV. The GPS unit can be used to collect shoreline position information (i.e. follow the high tide line -- wetted sand) at one second intervals.

Data Analysis and Interpretation

Digital data on shoreline position obtained from aerial photography and GPS mapping will be stored in the park GIS data base for spatial analysis of change, both for short- and long-term trends. Profile data will be graphically and numerically analyzed to add site-specific vertical change in topography and allow for estimation of sediment budgets and cross-shore exchanges. Models of geomorphic change will be developed to predict future conditions, to identify threats to park resources, and to provide critical parameters for the interpretation of vegetation and habitat change.

B. BARRIER ISLANDS, SPITS, DUNES

The predominant components of barrier islands, spits and dunes to be discussed in this section will be vegetation and migratory waterbirds. Environmental variables, such as hydrology, soils, and nutrients are also addressed here.

Vegetation Monitoring

The vegetation of CACO's barrier islands and spits (Nauset Spit, North Beach, Race Point-Herring Cove, Wood End-Long Point, Great Island - Jeremy Point; see Fig. 3) and major dune system (Province Lands Dunes) is constantly changing in response to both natural and human-induced factors (e.g., storms, sea level rise, ORV/pedestrian use, fire, dune revegetation, and others). Recognizing changes in species composition and vegetation structure, and moreover, understanding the factors contributing to observed changes, is the

techniques are detailed in Appendix 2 (e.g., Art 1976, Bourdeau and Oosting 1959).

Companion environmental data will accompany each transect (and as appropriate, each plot) to assist in interpreting why the species composition or community structure may be changing over time -- elevation profiles, water table level, groundwater and soil chemistry, and photosynthetically active radiation).

d. Data Analyses and Interpretation -- Cross-island transects with permanent plots enable a relatively unbiased evaluation of the vegetation. Alternatively, permanent plots could be established within major vegetation cover-types and monitored, yet this selection of sample sites is dependent on preconceived ideas of the character of the vegetation (Greig-Smith 1983). On a statistical basis, introduction of this bias would be inappropriate.

As detailed in Appendix 2, standard multivariate data analyses coupled with very simple time-series plots of species abundance, richness and diversity will be used to objectively identify long-term changes in barrier island/spit flora and community patterns. Further, the synthesized data can be used as a tool for management and park planning. Models can be developed to predict the response of barrier vegetation to altered water table levels, erosion rates, overwash frequencies, etc.

Migratory Waterbird Monitoring

The coastal barrier beach and estuarine systems of outer Cape Cod are typical of important feeding habitats for migratory birds all along the Atlantic coast. In the Northeast, Cape Cod National Seashore contains some of the least-disturbed habitats for foraging shorebirds, gulls, terns and waterfowl. Monitoring has three long-term goals: 1) to establish CACO as one of a series of coastal field stations involved in assessing the status of migratory species; 2) to identify disturbances to waterbird feeding that could threaten their preservation; and 3) to employ bird use, and especially foraging intensity, as an indicator of secondary production.

Although the role of birds in net nutrient and energy flow within coastal systems is reportedly minimal (Bildstein et al. 1982, Duffy et al. 1981), some studies have shown that shorebirds in particular can deplete local prey populations (Goss-Custard et al. 1977, Schneider 1978). In some habitats shorebirds may have a greater influence on infauna densities than do fish (Quammen 1984).

Previous quantitative work on coastal waterbird foraging in Seashore habitats includes waterfowl work in the 1960's (Grandy 1972) and shorebird counts sporadically since the late 1970's.

To maximize chances of obtaining a "peak" count, each species should be counted repeatedly (at least every 30 min) during the total of maximum habitat usage on the day of the weekly count. For all four species, multiple counts at each observation period will improve accuracy and give an estimate of measurement error.

3. Data Analyses -- The coastal waterbird monitoring data will be analyzed in light of the physical and biological surveys, for both barrier beach and estuarine communities, on an annual basis to elucidate correlations between bird use and habitat changes in this dynamic setting. For example, the physical effects of inlet migration along a barrier beach will be reflected in back-barrier tide heights, mud flat sediment deposition and infaunal production, all of which will be directly monitored under this plan. These data sets will in turn allow interpretation of observed temporal and spatial shifts in waterbird foraging activity.

C. ESTUARIES

Two general estuarine types are associated with CACO -- drowned river valley estuaries and back-barrier estuaries. Herring River and Pamet River (Fig. 4) are river basins that have been slowly "drowned" with sea level rise. Nauset Marsh and Pleasant Bay are examples of estuaries fronted or protected by a barrier beach system. Back-barrier estuaries are the predominant type associated with Seashore parks from Cape Cod to Padre Island.

Estuaries, because of their documented role as nursery areas for fish and shellfish, are an extremely valuable component of coastal parks deserving priority protection and resource monitoring. Moreover, estuaries are a threatened resource, again justifying the need for intensive monitoring aimed at evaluating the status of the resource and better understanding the response of estuaries to impacts. Threats facing Cape Cod National Seashore estuaries are fairly universal among all estuaries of the Atlantic and Gulf coasts. These threats include, (1) pollutant impacts from point and non-point sources which can lead to eutrophication, pathogen contamination, and toxics contamination; (2) fishing and shellfishing activities, such as heavy fishing pressure, fishing gear impacts, and aquaculture; (3) physical anthropogenic alterations (diking, ditching, dredging, etc); (4) recreational uses such as boating and fishing; and (5) episodic events, like oil spills, plankton blooms (i.e., red tides), or invasion of nuisance species.

Given the relative value of estuarine habitats, their dominance in the CACO landscape, and the intensity of threats, CACO has taken the initiative to design a comprehensive estuarine monitoring plan (Beatty et al. 1993). This plan is currently under agency and academic peer review. Major aspects of the plan will be briefly outlined in this proposal.

The estuarine monitoring plan is designed to address seven basic questions (Table 7). As stated by Beatty et al. (1993), the first two questions focus the proposed monitoring effort on whether estuarine habitat boundaries at CACO are changing over time, and whether these changes can be attributed to natural events or human disturbances. This first phase of monitoring effort is intended to take advantage of habitat mapping and inventory work and focuses very simply on whether or not the habitats described for CACO are changing over time with respect to size or location. Accurate maps of habitat boundaries, an ongoing database of physical parameters, and up-to-date descriptions of geomorphological characteristics of the park habitats will be needed in order to begin to distinguish changes due to natural events such as storms or inlet migration from human-induced changes in park ecosystems.

Three questions included in the proposed plan (Table 7) address the problem of nutrient loading to park estuaries by quantifying loading and by examining ecological responses. The parameters of interest in addressing these questions cover a wide range of ecosystem responses from first-order changes in dissolved nutrients or

phytoplankton biomass to more integrated measures of system response such as total system metabolism. The last two questions included in this plan examine the impact of commercial and recreational fishing on estuarine resources, and assess changes occurring to natural populations after tidal flow is restored to diked estuaries.

Outline of Estuarine Plan

A detailed presentation of the estuarine monitoring plan is not justified for this proposal. But in brief, the plan identifies 8 estuaries for monitoring (Fig 4). For each estuary a two part program is proposed. The first part is a comprehensive ecosystem analysis to be completed at each estuary at 5-10 year intervals. It is proposed that at least one estuary be sampled through an annual cycle, then rotate the sampling effort to another system, and so on. Components of the comprehensive monitoring include physical characteristics, water quality, aquatic vegetation, benthic macrofauna, shellfish, finfish, and migratory waterbirds (see previous section on BARRIER BEACHES/SPITS for proposed waterbird monitoring program). Sampling parameters are listed in Table 8. Beatty et. al (1993) provide a rationale for selection of parameters, detailed guidance on field methods, data analysis techniques and sample periodicity.

The second part of the plan includes more routine monitoring (Table 8). This routine sampling will likely be conducted continuously at critical estuarine sites, such as Nauset Marsh and Herring River, and less frequently at other sites -- perhaps for an annual cycle at 3-5 yr intervals. It is important to mention that all aspects of the estuarine plan were designed to collectively address the

Table 8. Parameters for monitoring in the comprehensive Phase One and routine Phase Two estuarine monitoring plan (adapted from Beatty et al. 1993) Guidance on site selection is provided by Beatty et al. (1993).

Parameters	Periodicity
COMPREHENSIVE ECOSYSTEM ANALYSIS	
PHYSICAL/CHEMICAL	
Temp, Salinity, Light Transmission, Chlorophyll a	Summer (bimonthly)[1] Winter (monthly)
Dissolved oxygen	Summer (daily) Winter (monthly)
Bathymetry	Initial only
Sediment Grain Size	Initial only
Tidal Range	Continuous
BIOTIC RESOURCES	
Aquatic Vegetation	
- eelgrass biomass, wasting disease index	Summer (bimonthly) Winter (monthly)
- macroalgae species comp., abundance	Summer (monthly) Winter (every 2 months)
Benthic Macrofauna - species comp., and abundance	Seasonally (4x/yr)
Shellfish - species comp., abundance, size distribution	Summer (monthly) Winter (every 2 months)
Finfish - species comp., abundance, size/weight on target species	Apr - Nov (1-2x/month) Dec - Mar (every other month)
ROUTINE ECOSYSTEM MONITORING	
HABITAT MAPPINGS	Summer (3-5 yr intervals)

questions presented in Table 7.

The final aspect of the estuarine plan presented by Beatty et al. (1993) pertains to data management. Guidance on quality control, data automation standards and GIS integration are provided.

D. KETTLE POND/FRESHWATER HABITATS

The outwash deposits of Cape Cod National Seashore contain a total of twenty permanent ponds, comprising an excellent example of the kettle pond habitat type for the entire western North Atlantic coast (Fig. 5). Water quality has been monitored to some extent since the mid-1950's (MacCoy 1958) in appreciation of these ponds' great value for recreation, for scientific research and as habitat for a distinct group of rare plants and animals (LeBlond 1990). Much is known of the post-glacial vegetation, water quality and ecology of the ponds from intensive sediment analyses conducted over the past two decades (Winkler 1985a, 1985b, 1988, 1989). This work forms an excellent 12,000-yr context for the interpretation of current limnological monitoring results.

Though all within a 5 km radius on the outer Cape Cod peninsula and receiving presumably similar atmospheric and ground water inputs, these ponds present a diverse array of pH's (4.2-7.0), mean depths, and productivities (Table 9), attributes that have be exploited to assess current questions regarding anthropogenic effects.

The NPS has collected water quality data for Seashore kettle ponds since 1975 (Soukup 1977), with at least quarterly measurements of pH, alkalinity and dominant ions since 1983. In 1992, a panel of experts in biological and chemical limnology, ground-water hydrology, biogeochemistry and aquatic ecology was convened to produce a more comprehensive, systematic and intensive protocol to detect important limnological changes associated with human activities (Martin et al. 1993). Since Spring, 1993 a wetlands biogeochemist and limnologist (H. Hemond, Mass. Institute of Technology) has provided regular technical oversight of data collection and reduction through a cooperative agreement with the Park. The current monitoring plan (see below) is dynamic, i.e. subject to methodological updates, but systematic in consistently measuring hypothesized controlling and indicator variables.

Over the past three decades of NPS stewardship, three key issues have emerged, each with a strong potential to alter or degrade the essential character of CACO kettle ponds.

1. Phosphorus loading from development and recreational activities adjacent to the ponds.

2. Acid rain effects on pH, alkalinity and sulfur and phosphorus cycling.

Table 9. General characteristics of Cape Cod National Seashore kettle ponds. Conductivity data are from April 1982, but have changed little. pH and alkalinity data are from January 1992. Chlorophyll data are from single observations scattered through the summers of 1975 and 1976 (Soukup 1977).

Pond	Max. depth	Area (m)(ha)	Conductivity (umhos/cm)	pH	Alkalinity (ppm)	Chloro. *a* (mg/m^3)	Shore dwellings	Public beach	Land-locked
DUCK	18	5.1	97	4.8	-0.5	0.1	1	Y	Y
DYER	10	4.8	85	4.6	-1.0	0.9	3	Y	Y
GREAT (W)	15	17.5	115	4.6	-0.4	0	8	Y	Y
LONG	15	15.0	85	4.6	-0.8	1.8	22	Y	Y
TURTLE	2	1.6	86	---	----	3.6	2	N	Y
NORTHEAST	--	1.7	102	5.0	-0.4	1.5	3	N	Y
SOUTHEAST	4	1.1	108	4.9	-0.3	1.4	1	N	Y
SPECTACLE	7	0.5	110	5.0	0.1	2.4	0	Y	Y
KINNACUM	2	0.8	80	4.4	----	5.3	1	N	Y
GULL	19	44.0	119	6.5	2.9	7.6	21	Y	N
HIGGINS	6	11.3	119	6.5	3.6	6.4	7	N	N
HERRING	4	8.1	118	6.4	3.2	9.2	2	N	N
WILLIAMS	2	3.6	122	5.3	0.4	18.8	3	N	N
SLOUGH	8	11.9	122	4.7	-0.9	1.8	9	N	Y
HORSELEECH	5	10.0	146	5.3	-0.1	2.1	4	N	Y
ROUND (east)	8	2.6	108	4.8	-0.4	2.6	1	N	Y
RYDER	10	8.3	113	4.2	----	13.3	7	N	Y
SNOW	8	2.3	79	5.2	0.3	---	0	Y	Y
ROUND (west)	9	0.8	71	4.8	-0.1	---	0	N	Y
GREAT (T)	11	7.0	130	5.7	0.5	5.0	6	N	Y

Excerpted from, Martin et al. (1993)

Water Quality Monitoring

a. Study sites and frequency (temporal and spatial) -- It is proposed that an annual collection from all ponds for nutrients, cations and anions be conducted during vernal mixing in April. At this time, surface (0.5-m) grab samples are assumed to represent both nutrient status and ionic composition for the entire water column. Bottom water samples (0.5 m from the sediment) will be collected concurrently to test this assumption.

To better characterize seasonal pond processes, five of the twenty ponds have been selected for more intensive biweekly monitoring throughout the period of annual pond stratification, approximately late-May through at least August. Although each pond must be considered a unique system, the above five have been selected to represent the range in morphometry (depth and area), anthropogenic impact, and surface hydrology (isolated or interconnected). Further, the paleolimnology of all but Spectacle Pond has, or will soon be, detailed by sediment core analysis, providing a detailed historic context.

b. Water Quality Methods -- All limnological measurements will be made from a small boat at a marked station at the pond's deepest point. For ponds with two or more distinct basins (Ryder and Great in Truro), it will be necessary to establish stations at the deepest point in each basin. For both the 20-pond spring sampling, and the summer biweekly, five-pond sampling, field-measured variables will be measured at 1-m depth intervals. Laboratory analyses will be conducted for the surface and bottom samples taken in April, and for 7 - 8 specific depth "stations" in each of the five ponds sampled throughout the summer. [See below and Tables 10 and 11 for field and lab variables, Table 11 for pond-specific depth stations.]

Monitoring variables are chosen to document important limnological processes that are closely linked to nutrient status: i.e. water column nutrients, algal production, and hypolimnetic anoxia, reduced iron and sulfides.

At all pond visits, temperature, conductivity (corrected to a standard 25° C. temperature), dissolved oxygen, light intensity (percent of surface illumination) and chlorophyll concentration (interpreted from measured fluorescence) will be determined in the field at 1-m intervals. The Secchi depth will also be recorded.

The spring sample collection from all twenty ponds will include both surface and bottom water collections (0.5 m from surface and bottom) for laboratory analyses of total nitrogen (TN) and phosphorus (TP), total sulfide, ferrous iron, pH, alkalinity (double end point) and the major ions (Na, Ca, Mg,

from a few meters to much broader areas (depending on topographic slope) and is dominated by wetland shrubs (e.g., Leatherleaf, Chamaedaphne calyculata), occassional trees (e.g., Red Maple, Acer ruburm), and a diversity of herbaceous species. This littoral pond margin and transitional community is in a strategic position to intercept and assimilate nutrients transported from upgradient developments and may serve as a valuable indicator of nutrient loading to ponds. It is strongly documented that the biomass, species composition, and morphology of pond macrophytes varies in response to nutrient loading (Moeller 1985).

It is hypothesized that with nutrient additions to CACO kettle ponds (oligotrophic to eutrophic), 1) the mean biomass will increase, and 2) species with well-developed roots will decrease in abundance favoring more flexuous-stemmed, articulate leaved species. Well-developed root systems are identified as an adaptation in nutrient-poor waters, as is the case in CACO kettle ponds (Bristow and Whitcombe 1971). Further, it is hypothesized that with dramatic increases in nutrient loading, total pond production may shift from phytoplankton- to macrophyte-dominated.

As with the abovecited kettle pond water quality monitoring, the vegetation monitoring will be focussed on the five (5) ponds that represent a range of characteristics.

a. Quantitative Methods -- A protocol will be developed to quantitatively measure biomass and species composition, over a depth gradient at each of the five ponds. Preliminary studies (NPS Water Resources Division FY94-95 funding has been requested) will determine optimum field methods, and spatial and temporal frequency of sampling necessary. Because of the confounding effects of pond bathymetry, wind fetch, water quality, water level, and other factors on the extent and composition of macrophyte communities, a multivariate approach (perhaps principal components analysis) will be undertaken to quantify the importance of specific factors affecting plant density and species composition.

Hydrologic Monitoring

Because groundwater in sediments adjacent to the ponds can freely interchange with pond water, groundwater can be an important source of nutrients for Cape Cod kettle ponds. The hydrogeology of Duck and Gull Ponds is presently under detailed study by WRD-funded research. This work will produce water budgets and residence times in addition to describing the physical hydrologic system. It is proposed that this level of investigation and description be repeated for all ponds or pond complexes. Water table mapping is proposed to define areas of inflow and outflow around pond basins and, together with pond bathymetry, to estimate pond water residence times for the eventual development of nutrient budgets. Water table maps in preparation for Gull and Duck Ponds will be extended to cover the entire 20-pond region.

region.

Sea salt deposition on the outer Cape is expectedly high (20-30 kg Cl ha^{-1} yr^{-1}, National Atmospheric Deposition Program 1991) and vegetation responds with apparently reduced vigor close to the shore. Although inhibited growth is generally attributed to direct toxic salt effects, new research has highlighted both increased electrolyte concentration and osmotic potential as factors inducing a complex of reactions controlling the primary production of shoreline plants (DeLaune et al. 1987). In particular, enhanced NH_4 leaching, through cation exchange with deposited Na, has been documented as a major cause of nitrogen loss from coastal forests following storms (Blood et al. 1991), and may lead to nitrogen deficiency in maritime forests (Duckworth and Cresser 1991).

Proximity to the sea also confers a tendency, in common with mountain tops (Lovett and Linberg, in press), to receive a greater proportion of atmospheric deposition from fogs than at more inland sites. This phenomenon may be very important to generally nutrient-poor coastal forests because fogs often contain much higher inorganic nitrogen concentrations than rain (Lovett and Linberg, in press; Weathers et al. 1988). Further, high inorganic nitrogen can severly limit nitrogen storage in leaf litter and soil organic matter by accelerating mineralization (Duckworth and Cresser 1991).

Questions of forest nutrient status, nitrogen deposition from cloud water, and sea salt-accelerated NH_4 leaching have even wider interest in the coastal zone because of the sensitivity of downgradient marine waters to nitrogen loading (Nixon et al. 1986). Poorly-organic Cape soils presumably have a low heterotrophic nitrogen demand. If N atmospheric inputs, especially from frequent coastal fogs, exceed the demand of the microbial biomass, excess N will be leached as NH_4 from forest soils and nitrified in ground and surface waters, with consequent enrichment of ponds and estuaries.

A monitoring system is therefore proposed to assess the net importance of sea salt and coastal fog effects on the soil nitrogen budget of Cape Cod's pine-oak maritime forests. It is hypothesized that the rate of ammonium leaching from Cape forests will vary inversely with distance from the sea. The proposed monitoring will first test this hypothesis and, over the longer term, assess the significance of ammonium leaching to the nitrogen budget of the system as a whole, and significance to forest primary productivity.

It is also hypothesized that cloud water inputs comprise a large N source compared to either dry or wet deposition. Given the nature of coastal fogs, inputs should be inversely related to elevation, in contrast to the high elevation studies (see Lovett and Linberg, in press). Increased inorganic N deposition from fogs may in fact offset ammonium losses by cation exchange.

a. Sampling protocol -- Sampling stations will be established

Provincetown and Chatham (precipitation, wind speed and direction, barometric pressure, etc.), and the Seashore maintains a station in South Wellfleet. These stations are adequate for collecting routine weather information. With regard to atmospheric deposition, CACO has been the site of a National Atmospheric Deposition Program since 1981. Additional atmospheric deposition monitoring needs are necessary as proposed in the previous section of this proposal (MARITIME FORESTS AND HEATHLANDS).

Water Table Level

High soil permeability and the unconfined nature of the outer Cape aquifer dictate that the height and slope of the water table is crucial to understanding present hydrography and the landscape patterns of vegetation. Further, a water table map is required for predicting the effects of natural and human-induced hydrological changes (e.g., drought conditions, municipal groundwater withdrawal) and the fate of contaminants (e.g., landfill leachate). Present mapping, with the exception of localized study areas, consists of 5-ft contours on 1:25,000 scale maps (LeBlanc et al. 1986). A refined water table map, with enhanced resolution is necessary (2-ft contours). An inventory and assessment of the condition of existing groundwater wells has been completed, representing the first phase toward producing a 2-ft contour water table map for CACO and vicinity. Efforts are also underway by the Cape Cod Commission and local towns to produce more refined water table maps for the Seashore and vicinity.

Upon deployment of an appropriate parkwide array of groundwater wells, it is recommended that a water table map be prepared on a seasonal basis.

Sea Level and Storm Surge Monitoring

Knowledge of sea level, especially during major storms, is important to interpreting observed trends in shoreline and estuarine processes. A NOAA-National Ocean Survey tide gauge is located in Boston and is adequate to monitor long-term trends in sea level for CACO and will be especially useful in evaluating effects of accelerated sea level rise on coastal ecosystems. However, given the often localized nature of coastal storms or the influence of wind direction and shoreline orientation on the severity of storm energy, it is important to have a mechanism for monitoring sea level associated with storm surges.

In addition to the Boston tide gauge, it is proposed that continuous recording tide gauges (e.g., submerged pressure transducers) be deployed in Nauset Marsh (Atlantic side of CACO) and in Wellfleet or Provincetown Harbors (Bay side of CACO). In addition, a simplified method should be devised to monitor storm surge height in estuarine wetland basins following major storms. For example, personnel can walk the perimeter of wetland basins and

(Portnoy 1989). Other research grade scientists associated with the CPSU and who maintain active research programs at Cape Cod include a coastal geomorphogist (GS-14), coastal ecologist (GM-14), colonial waterbird ecologist (GM-15) and entomologist (GS-14). In the Regional Office, a forest ecologist (GM-14) and GIS Specialist (GS-11) actively work with park staff.

This core of resource managers and scientists have the professional expertise necessary to facilitate, coordinate, administer, and implement a prototype monitoring program. It is important to mention that the mechanism is in place to further enhance the CACO Division of Natural Resource Programs. A reorganization plan for the park has been approved, including significant staffing increases for the Division. This reorganization and anticipated staffing is discussed further in item #8 of this proposal.

6. BUDGET AND COST EFFECTIVENESS

The proposed budget for the CACO Long-term Ecosystem Monitoring Program includes two main aspects; 1) Protocol Design and Testing costs, and 2) Implementation costs (initial start-up and annual base funding). It is assumed that the newly created National Biological Survey will be responsible for protocol design and testing and that the NPS (CACO) will implement the program for the long-term, with periodic oversight and input from NBS and other scientists.

This section of the proposal also contains an implementation strategy, addressing staffing needs, organizational structure and implementation schedules.

A. PROTOCOL DESIGN AND TESTING

Designing and testing scientifically defensible protocols is the most important aspect to a successful long-term ecosystem monitoring program. Every detail of the monitoring must be documented, including, articulation of monitoring questions and objectives, definition of meaningful levels of change, identification of field and laboratory procedures given a knowledge of natural variability, procedures for data entry, management and analysis, and data reporting requirements. This is a monumental task especially when considering that a poorly designed program could result in testing of inappropriate questions, inability to separate change due to natural processes from change due to multiple activities, relatively low ability to detect change (i.e., low statistical powers), and poor use of resources due to oversampling or undersampling (National Research Council 1990). Figure 6 provides a conceptual approach to designing an effective monitoring program.

CACO has made excellent progress in the design and/or testing of

monitoring protocols for nearly all the ecosystem components of the proposed plan (especially estuaries and kettle ponds). Moreover, the park's large inventory of past research will greatly assist in monitoring program design. However, a considerable amount of design, research and testing remains before a scientifically-sound program can be fully implemented.

This aspect of the budget itemizes and justifies the Design and Testing aspects of the CACO Monitoring Plan. As previously stated, it is assumed that NBS will take the lead role. If fully funded, protocol design and testing can be completed in four years.

SHORELINE MARGINS (Costs x1000)

TASK	YR 1	YR 2	YR 3	YR 4	YR 5	TOTAL
Profiles	100	100	100	0	0	
Aerial Photos	0	0	0	0	0	
GPS Surveys	0	0	0	0	0	
Protocol Documentation	0	0	0	25	0	
TOTAL	100	100	100	25	0	325

Costs are principally for personnel (.25 coastal geologist and 4 field technicians) to identify appropriate sites for intensive shoreline profile monitoring, to establish profiles, and to conduct intensive spatial and temporal sampling to determine an optimum sample program. Three years of data collection and analysis will be necessary to adequately test spatial and temporal (seasonal and interannual) variability. Protocols for aerial photograph analysis and GPS surveys are clearly documented in the literature. Year 4 will include development of protocol documentation for the entire Shoreline Margin Program (profiles, aerials and GPS).

BARRIER ISLANDS, SPITS, DUNES (Costs x1000)

TASK	YR 1	YR 2	YR 3	YR 4	YR 5	TOTAL
Vegetation Monitoring A. Mapping	0	0	0	0	0	

KETTLE PONDS (Costs x1000)

TASK	YR 1	YR 2	YR 3	YR 4	YR 5	TOTAL
Water Quality	30	30	0	0	0	
Plankton	30	30	30	0	0	
Littoral Vegetation	25	25	0	0	0	
Hydrology	60	60	60	0	0	
Protocol Documentation	0	0	0	25	0	
TOTAL	145	145	90	25	0	405

The kettle pond water quality monitoring protocol is designed and testing is underway (Martin el al. 1993). Costs are for an investigator (0.25 time) and full-time technician to continue testing and refining the protocol (at present the project investigator from Massachusetts Institute of Technology is volunteering his time). Plankton and littoral vegetation monitoring programs require design and testing. Hydrologic monitoring protocol design is ongoing at 2 ponds. Funds are requested to conduct, install and monitor groundwater wells at three additional ponds and to design protocols. Year 4 will include protocol documentation.

MARITIME FORESTS AND HEATHLANDS (Costs x1000)

TASK	YR 1	YR 2	YR 3	YR 4	YR 5	TOTAL
Atmospheric Deposition & Nutrient Cycling	80	0	0	0	0	
Forest & Heathland Veg Monitoring	0	0	0	0	0	
Protocol Documentation	0	10	0	0	0	
TOTAL	80	10	0	0	0	90

A forest biogeochemist (0.25 time) is needed to design the sampling program, supervise instrumentation and data collection, ensure data quality, and design a protocol for long-term monitoring. Funding

Summary -- DESIGN AND TESTING PROTOCOLS (Costs x1000)

TASK	YR 1	YR 2	YR 3	YR 4	YR 5	TOTAL
Shoreline Margins	100	100	100	25		
Barrier Islands	120	120	120	25		
Estuaries	150	150	150	40		
Kettle Ponds	145	145	90	25		
Forests	80	10				
Periodic Monitoring	35					
Data Management				50		
TOTAL	630	525	460	165		1,780

B. IMPLEMENTATION (START-UP AND ANNUAL BASE FUNDING)

The implemenation budget includes initial (one time only) start-up costs and annual base funding needs. A summary budget is presented, followed by individual budgets for each ecosystem component of the monitoring program. Personnel costs are described in the next section of this proposal and Fig. 7. It is noted that the annual base funding requested for the CACO Long-term Ecosystem Monitoring Program is $680,000; however, the actual annual cost of implementing the program will be considerably greater. As detailed in the target organization (Fig. 7), numerous staff will assume shared responsibilities between monitoring and resource protection, but will be funded fully or partially from the park base (e.g., Division Chief, Hydrologist, Botanist, Biologist, GIS Specialist, Lab Chemist, and several technicians). It is estimated that these personnel costs from the park base will exceed $160,000, thereby demonstrating excellent cost effectiveness and leveraging.

SUMMARY -- START-UP AND ANNUAL BASE (Costs x1000)

ECOSYSTEM COMPONENT	Start-Up Costs(x1000)	Annual Costs
Shoreline Margins	33	95
Barrier Island, Spit, Dunes	38	87
Estuaries	43	161

ESTUARIES (Costs x1000)

CATEGORY	Start-Up Costs	Annual Costs
Vehicle	13	
Computer/Printer/Software	15	
Personnel ($/FTE)		142/3.5
Equipment/Supplies	15	7
Travel		4
Publication/Education		3
Other (cooperators, etc.)		5
TOTAL	43	161

KETTLE PONDS (Costs x1000)

CATEGORY	Start-Up Costs	Annual Costs
Vehicle	13	
Computer/Printer/Software	5	
Personnel ($/FTE)		81/2.0
Equipment/Supplies	10	9
Travel		2
Publication/Education		3
Other (cooperators, etc.)		5
TOTAL	28	100

ADMINISTRATIVE SUPPORT (Costs x1000)

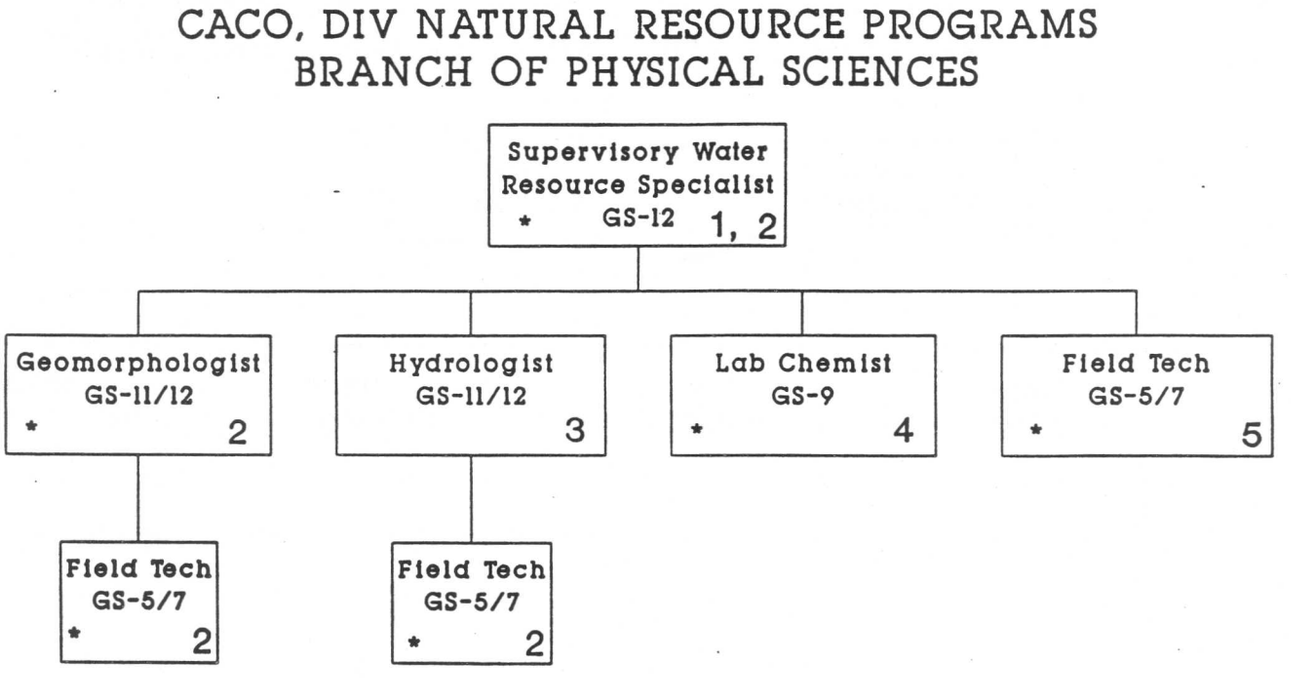
Category	Start-Up Costs	Annual Costs
Computer/Printer/Software	8	
Expand Office Space and Lab Facilities	100	
Division Personnel ($/FTE)		57/2.0
Additional Personnel for Administration Division to handle increased work load of expanded Division of Natural Resource Programs		24/1.0
Office and Lab Utilities, Phone Charges and Gasoline		10
Equipment/Supplies		1
Travel		1
TOTAL	108	93

C. IMPLEMENTATION STRATEGY

Staffing

The CACO Long-term Ecosystem Monitoring Program will be administered through the existing Division of Natural Resource Programs. As noted in Fig. 7, the target organization will include four branches, supervised by a Division Chief. Tasks associated with the monitoring program will be integrated into each Branch, thus being cost effective and taking full advantage of direct collaboration between monitoring and resource protection responsibilities.

For the monitoring program to be effectively implemented, it must be supervised and staffed by highly trained and experienced professionals. The Supervisory Biologist, to also serve as I&M Coordinator, will be a GS 12/13 with a Ph.D. or Master's with several years experience. Likewise, the Supervisory Water Resource Specialist, overseeing the Branch of Physical Sciences, should also have a graduate degree and experience. The Geomorphologist, Hydrologist, Estuarine Ecologist, Data Management Specialist, and other positions, must all have technical and educational experience in their respective disciplines (i.e., Master's degree, or Bachelor's with several years experience). In short, implementation of the proposed program will require individuals with broad research and resource management experience, including



** Primary work will involve I&M tasks*

1: Series to be limnology or other similar discipline

2: New position; funding and FTE from I&M program

3: Funding of position to be shared by park and I&M program

4: Position funded by park

5: Existing base funded position

Fig. 7b. Branch of Physical Sciences.

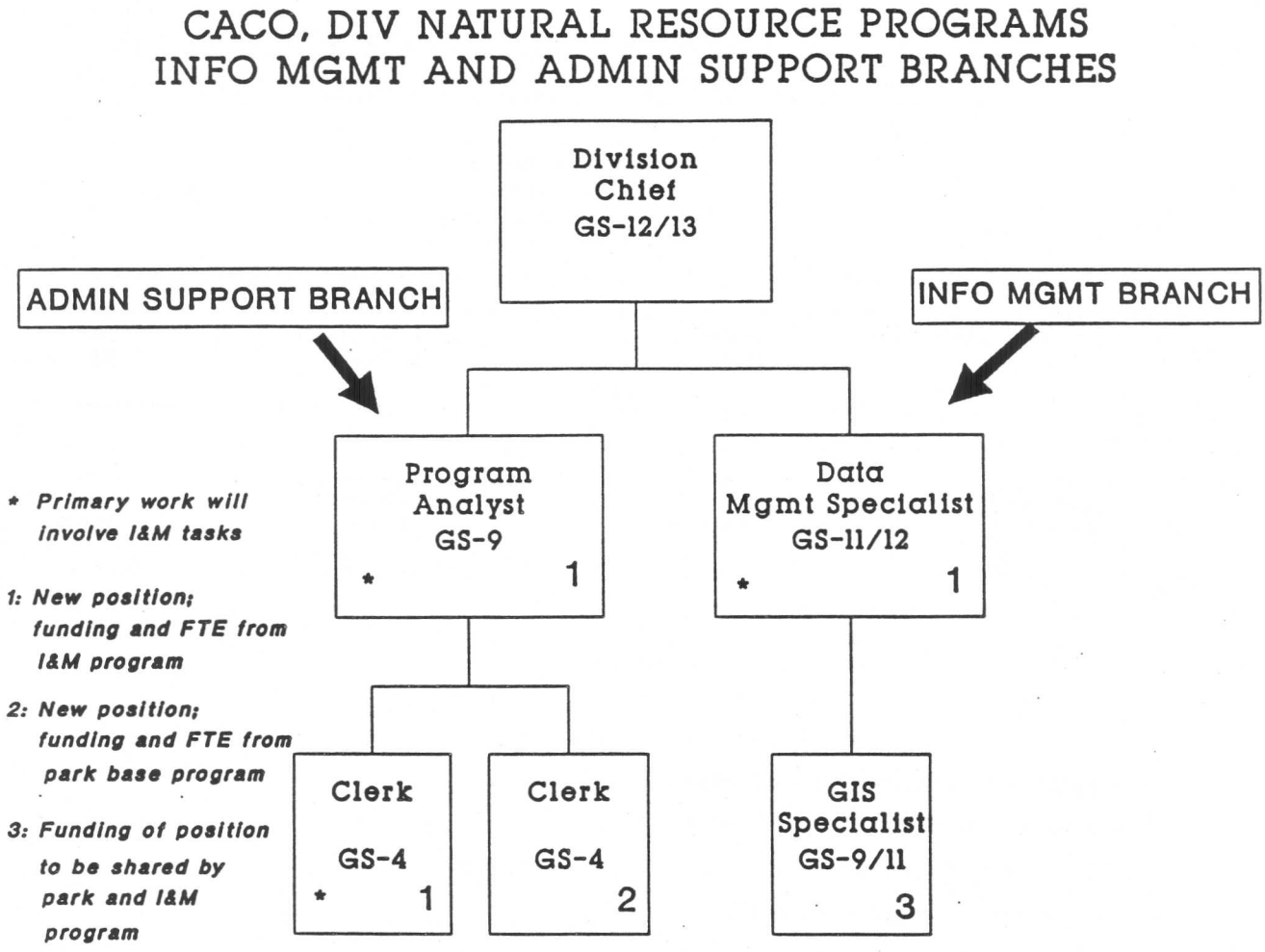


Fig. 7d. Branches of Information Management and Administrative Support

Years 1-3
- Design and test Kettle Pond and Estuaries protocols
- Hire I&M Coordinator (Yr 3)
- Hire Supervisory Water Resource Specialist (Yr 3)
- Hire Program Analyst (Yr 3)

Year 4
- Finalize protocol documents for Kettle Ponds and Estuaries
- Hire professional staff and technicians for Kettle Ponds and Estuaries
- Design Data Management Plan (Kettle Ponds and Estuaries)
- Train staff and conduct "dry runs" for Kettle Ponds and Estuaries
- Begin design and testing of Shoreline Margins and Barrier Islands protocols

Years 5-6
- Implement Kettle Ponds and Estuaries programs
- Continue design and testing of Shoreline Margins and Barrier Islands protocols
- Hire professional staff and technicians for Shoreine Margins and Barrier Islands

Year 7
- Finalize protocol documents for Shoreline Margins and Barrier Islands
- Design data management plan (Shoreline Margins and Barrier Islands)
- Train staff and conduct "dry runs" for Shoreline Margins and Barrier Islands
- Implement Shoreline Margins and Barrier Islands programs
- Begin design and testing of Maritime Forest and Heathlands protocols

Years 8-9
- Continue design and testing of Maritime Forest and Heathlands protocols
- Hire professional staff and technicians for Maritime Forests and Heathlands
- Train staff and conduct "dry runs" for Maritime Forests and Heathlands
- Design data management plan (Maritime Forests and Heathlands)
- Implement Maritime Forests and Heathlands program

9-yr Implementation Schedule (alternative 2) -- Although not presented in detail, another schedule for 9-yr implementation exists. Over the 9-yr period it would be feasible to design and implement various aspects of each ecosystem component, instead of completing the entire

Table 12. Some common ecosystem types and resource management issues at National Seashore and Recreation Area units; CACO, Cape Cod; FIIS, Fire Island; GATE Gateway; ASIS, Assateague; CAHA, Cape Hatteras; CALO, Cape Lookout; CUIS, Cumberland Is.; CANA, Canaveral; GUIS, Gulf Is.; PAIS, Padre Is.

COMMON ECOSYSTEMS	
Barrier Islands/Spits/Dunes	ALL Parks
Estuaries (back-barrier type)	CACO; Nauset, Pleasant Bay FIIS; Great South Bay GATE; Jamaica Bay ASIS; Sinepuxent, Chincoteague CAHA; Pamlico Sound CALO; Core Sound CUIS; Cumberland Sound CANA; Mosquito Lagoon GUIS; Mississippi Sound PAIS; Laguna Madre
Kettle Ponds/Freshwater Habitats	CACO; kettle ponds GATE; Jamaica Bay Wildlife Ref CUIS; Whitney Lake
Maritime Forests	CACO; Province Lands FIIS; Sunken Forest CAHA; Buxton Woods CALO; Shackleford Banks GUIS; Naval Live Daks
COMMON ISSUES	
External Development Impacts	
Estuaries	All Parks
Groundwater/Surface Water	CACO; Truro Wellfleet, Eastham FIIS; Saltaire and others CAHA; Buxton
Shoreline Change	CACO; Lighthouses GATE; Sandy Hook Unit ASIS; Toms Cove Area, North End CAHA; Hatteras Island, Ocracoke GUIS; Pedido Key, Santa Rosa Is.
Artificial Dune Stabilization	CACO, GATE, ASIS, CAHA, GUIS
Salt Marsh Ditching	CACO, FIIS, GATE, ASIS, CAHA

Research: Nauset Marsh nitrogen loading, nutrient cycling in diked salt marshes, greenhead fly biology, marsh sedimentation, and estuarine water quality.

The following equipment are housed at the lab: spectrophotometers (2); autoanalyzer for nutrients (flow injection and computer controlled); photo darkroom with enlarger; compound, dissecting and invert microscopes; analytical balances; titration equipment (including digital titrators); centrifuge; fume hoods; drying ovens; incubator cabinets; muffle furnace; computers (486 desktop and 286 laptop); freezer and refrigerator; pH meters; YSI conductivity/salinity meter; refractometer; conductivity bridge; grinding mill; water still (deionized water; autoclave; 20X15' greenhouse.

Field Equipment

The CACO Atlantic Coastal Laboratory contains all the necessary equipment to conduct routine field surveys, including 16 ft boat with 15hp motor, (2) 12 ft boats, (1) 8 ft boat, several canoes, (2) 4wd trucks (1) 4wd truck at Rhode Island CPSU), field tapes, tools, LiCor light meter, Turner flow-through fluorometer, Hydrolab Surveyor III water quality sampler (T,DO, cond., salinity, pH, depth), (2) Marsh-McBirney electromagnetic current meters, and numerous other items.

Reference collection

Approximately 1300 specimens are within the CACO reference collection. The majority of the collection are vascular plants, but terrestrial and aquatic invertebrates (lepidoptera and macroinvertebrates) and fish are also fairly well represented. A separate reference collection of fish, invertebrates, macroalgae, and angiosperms exists for the Nauset Marsh estuary (Roman and Able 1988). These collections are in a dedicated and secure area for our park collection within the Salt Pond Visitor Center. A full-time permanent GS-9 curator oversees the facility and has two term GS-7 curatorial assistants working on and managing the collection.

Computer support

Each full-time professional staff member with natural resource responsibilities has a desktop computer; all are IBM compatible and are at least 286 configured. Staff have access to two HP laser printers in addition to their own dedicated dot matrix printers. Available software in the park includes: word perfect, quattro pro, dBase, Harvard Graphics, Pagemaker, SPSS PC+, Procite and a variety of utility programs. In addition, the park has a UNIX based SUNSPARK system used for its GIS system. (see item #10 of this proposal).

program. The situation to avoid is when ecological condition between times T_{0-n} are detected and assumed to be true environmental shifts, where in fact they represent statistical aberrations from comparing incompatible data (Clarke 1986). This clearly points to the paramount importance of database management to the success of a long-term ecosystem monitoring program.

Rigid standards must be established when the T_0 baseline dataset is being created. Issues such as units of measurement, data recording convention, species names, digital file formats, and data documentation (metadata) must be addressed at the onset. Consistency, continuity, and uniformity in data gathering/recording methods are fundamental to ecological monitoring. The proposed organization structure for the CACO monitoring program includes a full-time FTE dedicated exclusively to data management. Obviously, the Data Management Specialist must work closely with the full-time GIS Specialist.

The following identifies some of the key issues that must be addressed when designing the CACO data management plan. This discussion is not all inclusive but it does serve to highlight important concerns.

Hardware and Software -- Computers should be standardized, especially with regard to operating systems, structure of the directory, software programs, and software versions. Ideally, a local area network, linking desktop computers, should be established. As discovered by the Shenandoah NP Inventory and Monitoring Program, a local area network will enable sharing of peripheral hardware (e.g., printers, plotters), encourage consistent software usage via site licenses, and enable data access from a central server. Troubleshooting, maintenance, software and data installation, back-up and file duplication procedures are all enhanced with a network configuration. Further, communication with remote users (cooperating universities, other agencies) will be streamlined with a local area network, especially if a high speed data link (accessed via Internet) is installed.

QA/QC and Metadata -- Full written documentation of all field and data entry methods is necessary, and moreover, standardization of data sets must be accomplished. A database dictionary will be useful. Standardizing and normalizing data will be essential to linking of data from various ecosystem components of the plan. For example, relationships between precipitation, water table level, and pond water chemistry will be especially interesting to analyze. Again, it is essential that the Data Manager and GIS Specialist interact to insure that the spatial and non-spatial data sets are compatible.

Data Analysis -- It is imperative that datasets be created in a manner that permits the spatial and statistical analyses required for change detection. To neglect these matters is an

Examples include the recent breachings into Nauset Harbor, Pamet River, and Pleasant Bay. It is obvious that an accurate and up-to-date representation of the CACO coastline is the most fundamental element of the GIS database. The USGS topographic maps do not provide accurate representation of the CACO coastline as it currently exists. CACO and the Regional GIS coordinator are aggressively cooperating with the Massachusetts Executive Office of Environmental Affairs (EOEA) in developing 1:5000 digital orthophotography for CACO. EOEA anticipates project completion by 1995. The 1:5000 digital orthophoto will be an excellent basemap for CACO and long-term monitoring efforts for the following reasons:

- The spatial resolution and positional accuracy (<5 meters) would satisfy most, if not all inventory and monitoring requirements.
- The maps will be a regional standard and will undoubtedly be a key planimetric base for municipal and Cape-wide mapping applications.
- The CACO GIS can receive the digital terrain model (DTM) used to create the orthos. The DTM can used to create contour maps, slope/aspect maps, viewsheds, watersheds, etc.

The 1:5000 ortho mapping project would most likely proceed as a cost-sharing effort with the NPS, EOEA, and perhaps other players. This will almost certainly result in the NPS getting a very high quality data product for a nominal amount of money.

GIS FACILITIES (HARDWARE, SOFTWARE)

The GIS hardware consists of a SUN Sparcstation 1 workstation with an 8 MB internal drive, 200 and 327 Mb external drives, and uses the Solaris operating system version 1.0.1. The workstation also has an external 644 Mb 5 1/4" CD-ROM drive, a 1/4" 150 Mb tape drive and 1.44 Mb 3 1/2" floppy drive. A Hayes 2400 Smartmodem permits telephone communications. Plotting is done on a Tektonix 4696 ink-jet plotter. A Hewlett-Packard 7475A pen plotter and black and white laser printer are available for the printing of small (8.5" x 11") maps. A Panasonic KX-P1595 dot matrix printer is used for text. Local digitizing is done on an Altek digitizing table with a 24" x 36" active area and a power base. The CPU is powered through a Clary Onguard power conditioning and backup system. Funds for a 36" multi-color pen plotter have been requested from GIS-Denver to allow for large format output. Large format plotters at the University of Rhode Island and Cape Cod Commission are currently used. Further, purchase of a one gigabyte external drive is anticipated to allow acquisition of digital orthophoto data.

GRASS version 4.0 and MAPGEN software are currently used for the

Air Quality Control
MA Dept. of Fisheries, Wildlife and Law Enforcement
Div. of Fisheries and Wildlife
Div. of Marine Fisheries

Federal
Environmental Protection Agency
National Estuary Program (Mass Bays Program)
Office of Water
Office of Wetlands
Environmental Research Lab, Narragansett (EMAP-nearshore coastal)
US Geological Survey
Water Resources Division
Coastal Research Laboratory (Woods Hole)
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
National Estuarine Research Reserve Program
US Army Corps of Engineers
National Science Foundation
Waquoit Bay LMER site
US Dept. of Agriculture
Soil Conservation Service, Coop. Ext. Service
Forest Service, Insect Pest Management Group

Private
Nature Conservancy
Mass. Audubon Society
Center for Coastal Studies (Provincetown)
Assoc. for Preservation of Cape Cod
Friends of the Seashore
Local Conservation or Land Trusts

Local Academic Institutions
Marine Biological Laboratory (Woods Hole)
Woods Hole Oceanographic Institution
University of Rhode Island, Graduate School of Oceanography
Boston University Marine Program

Close attention will be made to establishing linkages during design and implementation of the monitoring program in an effort to avoid duplication of effort, to enhance to quality and scope of the program, and moreover, to leverage funds. For example, within the estuarine component, efforts are now underway, 1) to monitor water quality in Provincetown Harbor (Provincetown Center for Coastal Studies), 2) to conduct a comprehensive/multidisciplinary inventory and assessment of Wellfleet Harbor (EPA Mass Bays Program and Barnstable County), 3) to seasonally survey marine finfish and ichthyoplankton in Cape Cod Bay and the nearshore Atlantic Ocean (MA Div. of Marine Fisheries, and NOAA-NMFS), 4) to monitor shellfish stocks and estuarine water quality - coliform (all towns), and 5) to conduct marine mammal surveys (harbor seals) in Nauset Marsh estuary (Mass Audubon Society). In addition, NPS

in coastal ecology and management, maritime forest ecology and wetland biogeochemistry. In addition to coordinating and hosting the annual CACO symposium, the Committee will review progress and make recommendations at technical sessions with monitoring staff held semi-annually and additionally as needed.

To ensure the use of up-to-date sampling and analytical methods and the timely exchange of technical information, publication of monitoring results in *peer-reviewed scientific journals* will be strongly encouraged. CACO research and resource management programs have an excellent record for producing high quality publications of results and methodologies in a timely manner (see References). In addition, CACO *representation at national and regional meetings* will continue to be routine to ensure that the program benefits, and is benefitted by, related work elsewhere.

Actual reports will include a detailed exposition of statistical data treatments and results. In addition, data sets will be periodically revisited to interpret material relevant to issues of regional and wider importance.

To summarize, the CACO Long-term Ecosystem Monitoring Program will include the following approaches for information transfer;

- Written annual report with peer review by the Technical Advisory Board and other reviewers. Published by a CACO technical report series.
- Annual CACO Symposium on Research and Monitoring with local, regional, and national attendance.
- Semi-annual working meeting with Technical Advisory Board to discuss progress, data analyses, interpretation, and goals.
- Collaboration with interpretation staff toward conducting public lectures, leading walks, designing exhibits, and preparing information brochures.
- Publication in peer-reviewed professional journals.
- Publication of selected aspects (i.e., results) in the CACO technical report series.
- Presentations at regional, national and international professional meetings.

13. THREATS TO PARK RESOURCES

Located within a day's driving distance from many large cities of the urban northeast, CACO receives over five million visitors annually. This intense demand for recreation threatens many coastal resources which are already compromised by over 300 years

for shoreline and barrier island management.

ALTERED AIR AND ATMOSPHERIC DEPOSITION

CACO has some of the highest ozone levels recorded in the northeast. Ozone (O_3) is a known human health hazard, and some national parks are now posting health warnings for visitors on days that exceed the Environmental Protection Agency's maximum standard for O_3 (> 0.12 ppm). Studies should be initiated at CACO to evaluate the extent and magnitude of ozone injury to vegetation. This type of data will be essential toward encouraging the state to designate CACO as a Class I area, thus affording the highest level of air quality protection.

The Forest/Heathlands and Kettle Pond components specifically address the issue of atmospheric nutrient deposition. In fact, much of the Forest and Heathland program is designed to evaluate the effects of nutrient inputs from fog on forest nutrient cycling processes, an groundwater nutrient quality (i.e., inputs to ponds), and on vegetation responses. This issue is discussed in more detail in item #4 (Forests and Heathlands).

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B. LIST OF PROJECT STATEMENTS

FAUNA

CACO-N-001: MANAGE NESTING SHOREBIRDS
CACO-N-002: MONITOR TERRESTRIAL BIRDS
CACO-N-003: STUDY WHITE-TAILED DEER ECOLOGY
CACO-N-004: INVENTORY TERRESTRIAL MAMMALS
CACO-N-005: STUDY NORTHERN DIAMONDBACK TERRAPIN
CACO-N-006: INVENTORY AMPHIBIAN AND REPTILE POPULATIONS
CACO-N-007: STUDY CAUSES AND EFFECTS OF BULLFROG RANGE EXPANSION
CACO-N-008: MONITOR SPOTTED SALAMANDER FECUNDITY
CACO-N-009: MANAGE FEDERAL/STATE LISTED RARE INVERTEBRATES
CACO-N-010: MANAGE BROWNTAIL MOTHS
CACO-N-011: MANAGE GYPSY MOTHS
CACO-N-012: MANAGE STRUCTURAL INSECT PESTS
CACO-N-013: INVENTORY FRESHWATER FISH
CACO-N-014: RESPOND TO MARINE MAMMAL/SEA TURTLE STRANDINGS
CACO-N-015: MANAGE HUNTING PROGRAM
CACO-N-016: MITIGATE ADVERSE EFFECTS OF NUISANCE INSECT MGMT
CACO-N-017: INVENTORY MIGRANT SHOREBIRDS

FLORA

CACO-N-018: PLAN AND IMPLEMENT FIRE MANAGEMENT PROGRAM
CACO-N-019: MANAGE STATE LISTED RARE PLANTS
CACO-N-020: MANAGE HEATHLANDS
CACO-N-021: GENERATE A REDEFINED VEGETATION MAP
CACO-N-022: REVEGETATE LANDSCAPES AFFECTED BY HUMAN ACTIVITIES
CACO-N-023: INVENTORY NON-NATIVE PLANT SPECIES
CACO-N-024: INVENTORY NON-VASCULAR PLANTS
CACO-N-025: MONITOR WETLAND PLANT SPECIES
CACO-N-026: DEVELOP VISTA MANAGEMENT PLAN

WATER

CACO-N-027: EVALUATE AND MITIGATE LANDFILL IMPACTS ON GROUNDWATER
CACO-N-028: MANAGE KETTLE PONDS
CACO-N-029: EVALUATE THE IMPACTS OF GROUNDWATER WITHDRAWAL ON RESOURCES
CACO-N-030: MONITOR HERRING RIVER DISSOLVED OXYGEN
CACO-N-031: MONITOR EUTROPHICATION OF COASTAL BAYS AND ESTUARIES
CACO-N-032: SALT MARSH RESTORATION AT HATCHES HARBOR
CACO-N-033: SALT MARSH RESTORATION AT HERRING RIVER
CACO-N-034: PRODUCE COMPREHENSIVE WATER TABLE MAP
CACO-N-035: STUDY SEDIMENTARY INDICATORS OF COASTAL EUTROPHICATION
CACO-N-036: MONITOR NAUSET MARSH
CACO-N-037: MONITOR INTER-DUNE BOGS
CACO-N-038: STUDY ALTERNATIVES FOR PILGRIM LAKE MANAGEMENT
CACO-N-039: INVENTORY SUBMERGED NATURAL RESOURCES

AIR

CACO-N-040: MONITOR AIR QUALITY

CACO-N-001: MANAGE NESTING SHOREBIRDS

SYSTEMWIDE ISSUE:

N02, Impacts on Threatened, Endangered, and Other Sensitive Animals

N18, Visitor Use Impacts on Backcountry Park Resources.

PROBLEM STATEMENT:

The management of nesting shorebirds at CACO has been the subject of off-road vehicle user protests, lawsuits and congressional inquiries. Nesting shorebirds at Cape Cod include the federally endangered roseate tern, federally threatened piping plover and state-listed common, least and arctic terns. These species come into regular contact with visitors to CACO. Breeding success is negatively impacted by off-road vehicles, pets and native and feral predators. Shorebird management requires intensive monitoring and protection, education of beach-users, enforcement of beach closures and wildlife regulations, and involvement with the media, off-road vehicle user groups and conservation organizations. Pre-migratory feeding, essential to meet the energy demands of migration, is interrupted by pedestrians, pets and recreational activities with poorly known consequences.

Data collected to date illustrate that CACO contains the largest least tern colony in New England, the largest common and arctic tern colonies in Massachusetts, and a small but significant population of the endangered roseate tern. In 1990, CACO experienced the highest piping plover productivity rate to have been recorded since the federal listing of the species as threatened.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Protect, manage and monitor nesting shorebirds. Two long-term seasonal positions are required to locate, protect and monitor nesting terns and plovers. In addition, Student Conservation Association volunteers will be used for daily assistance with the shorebird management program. Equipment costs for optical equipment, vehicles, supplies (signs, predator exclosures, string) volunteer stipends and housing is required. Shorebird management standard operating procedures (SOP's) have been developed for CACO. Breeding terns and piping plovers will be censused regularly, but special attention will be given to censusing all areas within CACO boundary on the dates requested by the Massachusetts Division of Fisheries and Wildlife. In addition, census data will be recorded as site information in CACO's GIS to facilitate comparisons of nesting site locations and preferences over time. Predator exclosures will be used on piping plover nests along with posting and stringing.

CACO-N-002: MONITOR TERRESTRIAL BIRDS

SYSTEMWIDE ISSUE:

N17, Loss of Biological Diversity.

N20, Lack of Basic Data: Insufficient Understanding of Park Ecosystems and Threats to Them.

PROBLEM STATEMENT:

There has been no complete inventory of CACO's terrestrial bird populations. Many birds that may nest within CACO are State listed rare species. Construction projects (airport and roadway expansion) within CACO are proposed within areas that have been identified by the state as containing some of these species. The importance of Cape Cod as a breeding and migrating site for neo-tropical migrant landbirds is well-known, but not quantified. In the past, available data on terrestrial birds at CACO has focused on migratory and wintering periods with no qualitative or quantitative database on nesting landbirds. A statewide breeding bird atlas program was conducted in the 1970's (Blodgett, pers. comm.), but the results of that effort have not been published. Management decisions are regularly made with minimal information on, and without consideration of, terrestrial bird populations.

Roger Tory Peterson wrote in the introduction to The Birds of Cape Cod (Hill, 1965) that "...the time is ripe to assess the summer resident birds through breeding bird censuses such as those published by the National Audubon Society in Audubon Field Notes" [now published in the Journal of Field Ornithology]. Hill (1965), referring to the establishment of CACO, noted that "It would appear that teams of biologists working under some higher organizational scheme will make the next advances in the field of ornithology on Cape Cod, and I have therefore chosen the establishment of the Seashore as the end of the period of ornithology covered in this study." To date, no such advances have been made. In an effort to initiate monitoring of terrestrial birds, CACO began a breeding bird survey in 1989 following USFWS breeding bird survey protocol.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Continue breeding bird censuses started in 1989. Until a more detailed monitoring program can be funded and implemented, surveys following the USFWS protocols along selected CACO roads should continue. Current monitoring is limited to one annual survey completed in five hours, and includes 50 stops over a 25 mile stretch of road from Eastham to North Truro. Continuation of this effort will result in the collection of some preliminary baseline data on breeding terrestrial birds within CACO.

CACO-N-008: MONITOR SPOTTED SALAMANDER FECUNDITY

SYSTEMWIDE ISSUE:

N16, Visual and Biological Impacts of Urbanization and Other Near-Park Developments on Park Resources

N20, Lack of Basic Data: Insufficient Understanding of park ecosystems and Threats to Them

PROBLEM STATEMENT:

Mole salamanders (Family *Ambystomidae*) have long been considered vulnerable to acidification impacts due to their near exclusive use of temporary isolated wetlands ("vernal ponds") for breeding. On Cape Cod these habitats are naturally poorly buffered due to their isolation from mineral soils; the presence of sphagnum and pine, oak and maple litter results in highly acidic water of pH 4.5 to 5.5, no reserve alkalinity and high color. Recent work by Portnoy (1990) has demonstrated a high level of acid tolerance among Cape spotted salamanders, but also a clear sensitivity of embryos to the combination of low pH and high concentrations of polyphenolic compounds. It is hypothesized that further reductions in pH, e.g. due to presently acidic rain (pH 4.3), in highly colored sites will substantially reduce embryonic survival and recruitment within isolated demes. Since the common and widely distributed spotted salamander is the only amphibian whose breeding abundance and embryonic survival have been systematically inventoried throughout CACO, a clear opportunity exists to use the existing baseline and methods, and to evaluate the biological effects of potential acidification.

DESCRIPTION OF RECOMMENDED PROJECT:

The basic tool for monitoring spotted salamander populations is by egg mass counts conducted annually at traditional breeding ponds and pond complexes. Although adult salamanders are fossorial and difficult to find, they do assemble to mate and oviposit within a fairly predictable time period in early April, making their reproductive output, if not their adult population size, countable on an annual basis. Work elsewhere indicates that egg mass counts are a good index of breeding female abundance. These counts, coupled with coincident water chemistry (at least pH, alkalinity/acidity, color and tannin-lignin), should over the long term predict biologically important changes in water chemistry.

		Budget	FTE
COSTS:	CY:	1.0	.1
	OY1:	1.0	.1
	OY2:	1.0	.1
	OY3:	1.0	.1

COMPLIANCE: This proposed project is categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

COMPLIANCE: The planning effort toward the development of a monitoring plan is categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities." Section 7 consultation with the USFWS and public involvement will be initiated for any proposed restoration projects.

Initial testing of browntail traps baited with this synthetic lure was completed. These recent developments offer the possibility of developing a pheromone-baited trap and systematic and quantitative approach for surveying browntail moth populations. This project is designed as a cooperative study among CACO, APHIS and ARS to (1) develop a trap design suitable for surveying and monitoring browntails, (2) determine the best loading rate for pheromone baits when placed in traps and (3), investigate browntail behavioral characteristics that affect trap efficiency. Once trap design and dispenser loading studies are completed, data would be collected to determine if relationships exist between the various measures of abundance and damage to host plants.

		Budget	FTE
COSTS:	CY:	17.0	1.1
	OY1:	17.0	1.1
	OY2:	-	
	OY3:	-	

2. Implement survey techniques to monitor browntail moth distribution and abundance on the Outer Cape. Surveys will be designed by U.S. Forest Service personnel with input from CACO and NPS URI staff. CACO resource management staff will annually conduct the monitoring to assess the status of the browntail moth population (is it stable, increasing, decreasing, etc.). In addition, this information will be entered in the CACO GIS so the movement and severity of infestation can be monitored.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	-	
	OY2:	15.0	.6
	OY3:	15.0	.6

3. Study impacts of browntail moths on native plants. Long-term monitoring plots will be established to monitor host plant vigor, growth rates and survival in and outside habitats containing browntail moths. Detailed information about browntail moth abundance within the test and control plots would also be kept to attempt to correlate the degree of defoliation with any associated impacts on plant growth and survival.
Research will be designed and conducted through an NPS contracted scientist.

		Budget	FTE
COSTS:	CY:		
	OY1:	20.0	
	OY2:	15.0	
	OY3:	15.0	

4. Develop educational materials about browntail moths for distribution to CACO visitors. The health and safety issues surrounding the browntail moth are important to CACO visitors, as is the ecological significance of this non-native species.

CACO-N-011: MONITOR GYPSY MOTHS

SYSTEMWIDE ISSUE:

N04, Degradation of Park Resources Due to Non-Native Animals

PROBLEM STATEMENT:

The gypsy moth was accidently introduced into New England by a Massachusetts entomologist around 1870. Since then, gypsy moths have become a serious problem throughout New England resulting in many hundreds of thousands of acres of hardwood forests being defoliated with significant tree mortality. Larvae prefer to feed on oaks, but also feed on other species including gum, maple and Sassafras. In severe infestations, the larvae may also feed on beech, white cedar and pines. Gypsy moth outbreaks at CACO have been cyclical; the last "high" period on Outer Cape Cod was in the mid-1980's. Up until 1965, populations were apparently annually treated with pesticides.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

Current management activity is limited to annual population monitoring. The U.S. Forest Service (USFS), in Durham, NH, is directing the annual monitoring and has used a variety of sampling techniques, including traps, burlap bands, and aerial surveys. Gypsy moth populations are on the rise in Massachusetts (O'Brien, pers. comm.), and continued monitoring using the USFS techniques is planned.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	-	
	OY2:	-	
	OY3:	-	

COMPLIANCE: This proposed project is categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

		Budget	FTE
COSTS:	CY:	8.0	.3
	OY1:	2.0	.1
	OY2:	2.0	.1
	OY3:	2.0	.1

2. Research fire suppression effects on the landscape and plant and animal communities: Complete suppression of all wildfires within CACO could precipitate a decline in habitat heterogeneity. Fuel loadings may build to a point where a major uncontrolled wildfire may destroy extensive natural and cultural features. Research will be conducted to determine present fuel loadings in CACO and the rate of accumulation. Fuel loading transects completed by Patterson et. al. (1984) will be re-surveyed. Long-term monitoring of plant communities and computer modeling of future vegetation trends, using GIS and other techniques, will be initiated.

		Budget	FTE
COSTS:	CY:	30.0	
	OY1:	30.0	
	OY2:	30.0	
	OY3:	30.0	

3. Develop fuel models for communities with huckleberry: Five years of research on huckleberry (Patterson, et. al., 1984) has produced data on vegetation response to fire, fire rate-of-spread and fireline intensity for prescribed burns in the huckleberry understory of oak-pine forests. Synthesis of collected data and field validation trials are necessary for development of CACO specific fuel models with huckleberry components.

		Budget	FTE
COSTS:	CY:		
	OY1:	30.0	
	OY2:	30.0	
	OY3:	30.0	

4. Study live fuel moisture: Moisture contents of live fuels are an important component of the National Forest Fuels Laboratory (NFFL) fuel model calculations. Currently available generic fuel moisture charts were not developed for fuels of the northeast and may not accurately predict CACO fuel moistures. Weekly collection and oven drying of live fuels will be conducted for two years for huckleberry and pine species. Resulting fuel moisture graphs will give CACO managers regionally specific live fuel moisture for fire behavior calculations.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	1.5	
	OY2:	.5	
	OY3:	.5	

5. Hazard fuel reduction: Fuel accumulations, both natural and anthropogenic, are currently at levels which require special management to protect both improved properties and unique natural and cultural resources in the event of wildfire.

CACO-N-019: MANAGE RARE PLANT COMMUNITIES

SYSTEMWIDE ISSUE:

N03, Impacts on Threatened, Endangered and Other Sensitive Plants

N20, Lack of Basic Data: Insufficient Understanding of Park Ecosystems and Threats to Them

PROBLEM STATEMENT:

CACO has over 32 plant species listed as Rare, Threatened or Endangered by the Massachusetts Natural Heritage Program (MNHP). CACO, being one of the largest conservation areas in Massachusetts, protects listed species from many anthropogenic impacts. However, natural and artificial threats (e.g. fire, forest succession, atmospheric pollution, and recreational impacts) still influence rare plant species and communities with unknown consequences. At present, rare plants have been identified and their distribution mapped; however, only sporadic census data on species abundance or density exist (LeBlond, 1990). Based on current information, management actions have been recommended but not implemented. Further monitoring is necessary to collect frequency and density information.

1. Implement Management Actions: LeBlond (1990) recommended specific management recommendations in the *Rare Vascular Plants of Cape Cod National Seashore* report. Few recommendations have been implemented. Recommendations will be reviewed by resource management staff and management actions will be initiated for species and communities determined to require such actions.

		Budget	FTE
COSTS:	CY:	8.0	.4
	OY1:	8.0	.4
	OY2:	8.0	.4
	OY3:	8.0	.4

2. Initiate Rare Plant Monitoring: A total of 101 sites have been reported for 33 listed species by the MNHP. A monitoring plan to visit and collect abundance and density data at least every three years will be implemented. Monitoring will include distribution and site mapping of current and new rare plant sites on the CACO GIS.

		Budget	FTE
COSTS:	CY:	8.0	.4
	OY1:	8.0	.4
	OY2:	8.0	.4
	OY3:	8.0	.4

CACO-N-020: MANAGE HEATHLANDS

SYSTEMWIDE ISSUE:

N03, Impacts on Threatened, Endangered and Other Sensitive Plants

N20, Lack of Basic Data: Insufficient Understanding of Park Ecosystems and Threats to Them

PROBLEM STATEMENT:

Heathlands are one of the more ecologically important communities found within CACO and one that is most commonly associated with Cape Cod. The most extensive coastal heathlands in the United States occur on Nantucket Island, Martha's Vineyard and on Cape Cod, primarily in CACO. Species diversity in heathlands is rivaled by few other CACO plant communities. Several heathland plants are endemic species found in no other habitats, and at least three state listed rare plants occur in CACO heathlands. Other species, though not considered rare due to their occurrence in the arctic-alpine flora, are not found close to sea level anywhere else in Southern New England or New York. Some heathland species have been a component of Cape Cod's vegetation since the last ice age. Heathlands also have great cultural significance at CACO, as the striking views and the unique character of heathland vegetation, described so well by Thoreau and others, typify the historical Cape Cod landscape.

Recent research (Carlson et. al., 1991) indicate that heathlands in CACO are seriously threatened by forest succession. Since CACO's establishment as a unit of the NPS in 1961, over 450 ha of heathland has been lost, representing a reduction of more than 64% during the last 30 years. Moreover, the rate of heathland loss is apparently accelerating. Following the removal of disturbance (both natural and human caused) after CACO's establishment, the species composition, character and appearance of heathlands have dramatically changed. Only nine major areas of heathland remain today in CACO and all are threatened by forest encroachment.

Given their aesthetic appeal, ecological significance, global rarity and rapid disappearance, protection of heathlands at CACO is one of the more important resource management program objectives. While active management of heathlands is occurring elsewhere (e.g., Nantucket), methods to successfully maintain this community and its biological diversity on CACO remains to be investigated. This NRPP proposal requests funding to develop and evaluate specific management techniques for protecting representative heathlands on CACO.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	20.0	
	OY2:	20.0	
	OY3:	20.0	

4. Mitigate forest encroachment on heathlands: Many of the CACO heathlands have already been invaded by pitch pines and other woody material. This project will facilitate the removal of these species from heathland areas that are currently or imminently in danger from encroachment. Manual cutting of stems will be used as an initial means of removing trees and shrubs, with subsequent management treatments to follow once methods have been developed from task #3 above. This strategy would provide a relatively simple and effective short-term solution to mitigating the effects of forest succession on heathlands.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	18.0	1.5
	OY2:	10.0	.8
	OY3:	-	

COMPLIANCE: These research, monitoring and mitigation projects are categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2) and (7): "Day-to-day resource management and research activities"; "Removal of park resident individuals of non-threatened/endangered species which...threaten park resources...when such removal is included in an approved resource management plan". Some of the recommended activities (i.e., heathland management) may require public meetings to communicate the objectives of the program. Management and protection of many of these listed species are required by the Massachusetts Endangered Species Act.

2. Evaluate Vigor and Effectiveness of Dune Planting Program: Observations indicate dune plantings, specifically beachgrass, effectively arrest dune migration. However, the long term endurance of beachgrass and its corresponding erosion-halting effectiveness is not known. Monitoring and research are necessary to determine if beachgrass plantings survive after nutrient input from imported soil decreases as dunes stabilize. The effectiveness and applicability of planting secondary successional species (e.g. oaks, pines, and shrubs) need to be evaluated. URI researchers will begin testing different species used in dune plantings with mycorrhizal soil inoculates in 1991.

		Budget	FTE
COSTS:	CY:	20.0	
	OY1:	-	
	OY2:	-	
	OY3:	-	

3. Inventory and Monitor Trails and Impacted Visitor Use Areas: Trails created by pedestrian traffic off established walkways and trails have created an indiscriminate and arbitrary network of pathways to and from CACO facilities, roads and beaches. No systematic inventory of these social trails has been made since the late 1970's. An inventory of all trails is necessary to prepare plans for confining pedestrian traffic to established trails and for revegetating impacted sites. Data collected will be entered in the CACO GIS and alternate routes identified. Until the extent of maintained and volunteer trails and their use is evaluated, natural resource damage, including erosion, loss of sand and destroyed vegetation by soil compaction will continue to accrue in high visitor use areas. Aesthetic values to both the natural and cultural landscapes are further diminished by haphazard volunteer trail establishment and use.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	12.0	.5
	OY2:	12.0	.5
	OY3:	12.0	.5

4. Develop an interpretive exhibit for the Province Lands Visitor Center showing dune morphology and migration, revegetation, and healing.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	3.5	.2
	OY2:	-	
	OY3:	-	

CACO-N-025: MONITOR WETLAND PLANT SPECIES

SYSTEMWIDE ISSUE:

N12, Alteration of Natural Flow Regimes

N20, Lack of Basic Data: Insufficient Understanding of Park Ecosystems and Threats to Them

PROBLEM STATEMENT:

Anthropogenic pressures on both freshwater and saltwater wetlands potentially impact wetland plant species occurring in, on or adjacent to wetland shores. Nutrient runoff from household septic systems and the resulting accelerated growth of aquatic plants is a critical concern. Municipal groundwater withdrawal plans, the subsequent lowering of the water table and changes in nutrient availability could alter plant species composition of some CACO wetlands allowing for increased encroachment of upland plants (Cortell, 1983). In addition, recreational use including: foot traffic, flora and fauna collecting, littering and shellfishing impact wetland plant communities. While inventories have been completed that identify wetland plant species within CACO (Cortell, 1983; LeBlond, 1990; Patterson, 1988) little quantitative monitoring has been implemented to document changes in species communities from human impacts. Without field monitoring that documents changes in wetland plant species communities, CACO managers will lack quantitative data to support potential wetland protection measures.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Synthesize Existing Wetland Plant Inventory Data: Existing inventory and monitoring plots will be identified, located and mapped on CACO'S GIS.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	8.0	
	OY2:	5.0	
	OY3:	3.0	

2. Define Monitoring Methodology: Existing wetland inventory and monitoring plots use different classification and sampling systems. A resampling and monitoring scheme will be developed after reviewing initial data and determining applicability to future management needs. Wetland areas without established monitoring plots and in need of quantitative sampling data will be identified in priority order. Standards for classification and sampling wetland plant species and communities will be identified. The time interval between monitoring efforts will be identified.

CACO-N-028: MANAGE KETTLE PONDS

SYSTEMWIDE ISSUE:

N11, Degradation of Park Water Quality Due to External Activities

N16, Visual and Biological Impacts of Urbanization and Other Near-Park Development on Park Resources

PROBLEM STATEMENT:

The 20 kettle ponds within CACO are a unique and sensitive resource with significant ecological, aesthetic and recreational value. They support a myriad and diverse aquatic fauna from leeches to dragonflies, including many State listed rare species. The kettle pond environment is also the preeminent rare plant habitat in CACO. LeBlond (1990) identified 8 state listed plant species at 18 sites within kettle pond habitats. Essentially oligotrophic and naturally acidic (Soukup, 1977), the ponds are extremely clear, biologically unproductive and are very susceptible to changes in water quality due to increased sedimentation and nutrient loading.

After the ocean and bay beaches, the freshwater kettle ponds are probably the most visited natural area within CACO. Fishing, boating, swimming, picnicking and bathing occur at many of the ponds. In addition, there are year-round and seasonal houses on some of the pond shorelines. Land ownership of the ponds and adjacent shoreline varies among the NPS, state, towns and individuals. Given the intensity of recreation, varying ownership patterns, multiple jurisdictions and inherent fragility of the ponds, managing them to protect water quality and the adjacent freshwater habitats has become one of the most complicated and important management programs at CACO.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Monitor Kettle Pond Water Quality: With concerns for apparent eutrophication coincident with anthropogenic nutrient loading, an intensive annual water quality monitoring program has been ongoing at CACO's kettle ponds for the last four years. Weekly measurements of pH, temperature, conductivity, water transparency and dissolved oxygen are now determined during the summer months at 8 of the 20 kettle ponds within CACO. This monitoring program has become institutionalized at CACO and is being conducted by seasonal (CACO funded) resource management biological technicians.

		Budget	FTE
COSTS:	CY:	12.0	.8
	OY1:	292.0	2.5
	OY2:	10.0	.4
	OY3:	10.0	.4

5. Conduct Scientific Review Of Pond Water Quality Monitoring Program: As part of CACO's commitment to long term kettle pond water quality, is the need for a periodic synthesis of the monitoring data. To date, no such analysis and review has been conducted despite the availability of good historical (i.e., Soukup, 1977) and contemporary data sets (four years of continuous seasonal water quality data. In addition, we have not had a detailed and critical evaluation of our current water quality monitoring program. We propose a scientific critique of kettle pond water quality monitoring efforts to 1) provide a more detailed analysis of our data and to interpret the results (with respect to historical data and current management objectives); 2) review our sampling methodology, and; 3) recommend ways to improve the program so that future sampling will incorporate the most appropriate procedures, ensure quality control and be sensitive to important changes in water quality. Without this technical assistance, existing data will not be analyzed and important signs of resource deterioration may go undetected.

		Budget	FTE
COSTS:	CY:	10.0	
	OY1:		
	OY2:	-	
	OY3:	-	

6. Study Paleo-Limnology of Kettle Ponds: Contemporary human disturbances in the watershed, including nutrient loading via septic leakage, bank erosion, and increased visitation, have been suggested as sources for potential eutrophication of these ponds. However, the natural evolution of these systems, in relation to the surrounding landscape, may be in part responsible for any observed chemical differences. Sediment analyses and dating will allow comparisons between the timing of both natural and anthropic watershed changes and observed changes in the chemistry of the sediment. This information will also provide a valuable understanding of the historic pond pH and community assemblage, so that future proposals to lime the ponds by the Commonwealth of Massachusetts can be adequately evaluated.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	17.0	
	OY2:	-	
	OY3:	-	

7. Inventory Human Impacts At Kettle Ponds: Given the intense public use of the ponds during summer, some environmental impacts to the adjacent shoreline are inevitable. Unfortunately, relatively little quantitative information exists on the condition of pond trails and beaches. These areas, if severely eroded, could be contributing to a deterioration in pond water quality. Most trails have not been cataloged and erosion associated with trail and shoreline use is not known.

9. Study Public Use Patterns and Attitudes: Given the intensity of recreation and potential impacts of CACO visitors, a vital component of any future pond management program must focus on people. Unfortunately, we have no information available about pond users, including how many people visit the ponds, recreational uses and public attitudes and expectations about pond management issues. Baseline data about recreation use patterns and people's attitudes are critically needed to provide an objective record of current conditions and to help in directing future management actions to protect resources. This information would also enable us to adequately evaluate the success or failure of these actions following their implementation. Specific data needs include: 1) Visitor Use Patterns: estimation of the numbers of visitors at each pond by time of day; relative abundance of visitors engaging in various recreational activities; 2) Public Attitudes: who are pond visitors?; what is their knowledge about the sensitivities of the ponds?; what are their attitudes about various management alternatives?; why do they visit the ponds (what are they expecting from their visit)?; what is the quality of their site visit?; what are their perceptions of crowding?

		Budget	FTE
COSTS:	CY:	-	
	OY1:	18.0	1.2
	OY2:	15.0	1.0
	OY3:	12.0	.8

10. Develop Pond Specific Management Plans: Each of the 20 kettle ponds within CACO has different physical and ecological characteristics, public recreation uses and land ownership patterns. In order to meet the specific needs of these diverse resources, efforts are underway to develop management plans for each of these ponds. These plans will establish the purpose and needs, program direction, responsibilities and scheduled activities to be carried out to accomplish stated recreation and conservation objectives. Management plans for three kettle ponds completely within NPS jurisdiction (Snow, Round West and Spectacle), have been completed. Development of plans for two other ponds with multiple ownership (Duck and Gull) is ongoing, with the assistance of an ad-hoc public advisory group. The order in which other pond plans will be written will be based upon existing and potential impacts, public interest, available baseline information and adequacy of existing management actions. Management plans for Round (West), Snow and Spectacle Ponds are currently in draft; plans for Duck and Gull Ponds are planned to be developed next. Funds will support permanent staff time needed to prepare the plans.

		Budget	FTE
COSTS:	CY:	10.0	.2
	OY1:	10.0	.2
	OY2:	10.0	.2
	OY3:	10.0	.2

CACO-N-030: MONITOR HERRING RIVER DISSOLVED OXYGEN

SYSTEMWIDE ISSUE:

N11, Degradation of Park Water Quality Due to External Activities

N16, Visual and Biological Impacts of Urbanization and Other Near-Park Development on Park Resources

PROBLEM STATEMENT:

The 5-km long Herring River is part of a 405 ha historical salt marsh estuary that has been dramatically disturbed by humans over the last 150 years. Tidal flow in the Herring River was first modified by the construction of the railroad in the 1850's and further reduced by a dike built in 1908. The subsequent large scale construction of drainage ditches and stream channelization in the 1930's for mosquito control, also significantly altered the wetland community. This long-term and system-wide habitat modification has resulted in numerous contemporary water quality problems, including most seriously, summertime anoxia in downstream reaches of the Herring River (Portnoy, et. al., 1987). In 1984 and 1985, these oxygen depletions caused massive kills of alewives and herring, anadromous species that annually spawn in the kettle ponds at the river's headwaters. In order to mitigate further die-offs, a fish gate was constructed in 1986 at the outlet of Herring Pond in Wellfleet. The gate is used in the summer to block downstream passage of juvenile fish until adequate oxygen levels return to the river.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

Dissolved oxygen levels are monitored daily in summer at a permanent sampling station within the Herring River. When anoxic conditions are identified (DO of 3ppm or less), the fish gate is closed. Monitoring continues during this period and once oxygen levels increase above lethal levels, the gate is re-opened. The public is annually informed about this program through media releases and an interpretive sign adjacent to the Herring Pond fish gate. Funds are required to support a seasonal biological technician in the monitoring of the oxygen levels at this location.

		Budget	FTE
COSTS:	CY:	2.0	.1
	OY1:	2.0	.1
	OY2:	2.0	.1
	OY3:	2.0	.1

COMPLIANCE: This ongoing project is categorically excluded under the Department of Interior, 516 Departmental Manual 6, Appendix 7.4.E(2): "Day-to-day resource management and research activities."

CACO-N-032: SALT MARSH RESTORATION AT HATCHES HARBOR

SYSTEMWIDE ISSUE:

N12, Alteration of Natural Flow Regimes

N17, Loss of Biological Diversity

PROBLEM STATEMENT:

Since 1930, at least 100 hectares of the Hatches Harbor (Provincetown) coastal floodplain and salt marsh complex have been isolated from tidal exchange by a dike. Originally constructed to de-water the landward half of the wetland for mosquito control, the structure's sole present purpose is flood protection for a municipal airport. However, NPS research has shown that the complete diking of tidal flow is not necessary to protect the airport from occasional storm tides. Bathymetric surveys, tide height studies and modeling have shown that a substantial area of the original marsh can be restored by reintroducing tidal flow through enlarged culverts through the dike structure, with no impact to the airport.

A conceptual plan has been accepted by all ten local, state and federal agencies with interests in either airport operations or local land management, including wetland protection. Continual liaison and coordination are required to finalize the operation of enlarged culverts and to secure funding for final plans and dike reconstruction. Completed ecological baseline studies must be followed with monitoring to document changes with restoration management. Strong local support for the project is lacking because of insufficient dissemination of information about the project's objectives and impacts.

DESCRIPTION OF RECOMMENDED PROJECTS:

1. Coordinate planning and construction of enlarged culverts. This aspect of the work is a continuation of the process begun in 1987 to bring together the data and multi-agency interests for a well articulated and generally acceptable plan. The present proposal for a concrete box culvert (2.5 X 20 ft opening), fitted with drop boards to allow total closure, appears to meet the criteria of maximizing marsh restoration and preventing all tidal flooding above the airport's critical elevation of 10 ft above mean low water (MLW). The present conceptual plan must be finalized into construction drawings, a step that will again require considerable interagency coordination and field data collection. Partial funding for construction plans ($10,000) has been obtained from the NPS North Atlantic Region Office (Natural Resource Management Program) for use in FY92.

		Budget	FTE
COSTS:	CY:	10.0	
	OY1:	15.0	
	OY2:	150.0	
	OY3:	35.0	

CACO-N-033: SALT MARSH RESTORATION AT HERRING RIVER

SYSTEMWIDE ISSUE:

N12, Alteration of Natural Flow Regimes

N17, Loss of Biological Diversity

PROBLEM STATEMENT:

The Herring River estuary has been dramatically altered by a dike at Chequesset Neck since 1908. The dike was built to allow mosquito control drainage and to create arable land. However, the mosquito nuisance continued after diking, with abundant breeding by fresh and brackish water species in stagnant water behind the dike. This led to extensive ditch drainage of the freshened marshes starting in 1910, and culminated in the channelization and straightening of the main stream and tributary creeks in the early 1930's. The dike gradually deteriorated in the late 1960's, allowing increased tidal flow and the recolonization by oysters and soft clams in previously freshened portions of the estuary. These events spurred local public support to remove the dike and restore tidal flow to the system. However, despite great opposition, the original dike was rebuilt in 1975 by the state, but with specific conditions imposed by the town conservation commission which required a minimum amount of tidal flow through an adjustable gate in the structure. These water levels were not achieved until CACO staff demonstrated a shortfall in the dike's operation to the state attorney general's office in 1981. However, though present tidal flow approaches those prescribed by the Order of Conditions, serious biogeochemical disturbance remains.

Since 1980, CACO has studied the hydrology, chemistry and biology of this system. This work was initially prompted by a series of massive fish kills. Over the past ten years, CACO has shown that reduced tidal flushing and seawater excursion into the estuary, and increased salt marsh peat oxidation due to drainage, have lead to sulfate oxidation, surface water acidification and seasonal oxygen depletions. Cooperating scientists quantified the loss of estuarine habitat due both to reductions in salinity and flooding frequency and to vegetative shifts from *Spartina* cover to *Phragmites*, fresh water wetland and even upland plant species. Rutger's University researchers modeled the full range of dike opening alternatives and predict major ecological and social benefits for restored tidal flow.

Socio-economic impacts of tidal restoration include increased water levels in a golf course and near two private dwellings within the flood plain. A water balance study for the Mill Creek subbasin, containing the golf course, showed that the area could be protected with a small dike and pumpout facility.

3. Seek funding for acquisition and removal of dwellings. The post-1959 structure (Feil) is subject to acquisition. The second dwelling (Rosenberg) is not subject to acquisition and is dependent on the willingness of the owner to sell to the government. Alternatives to outright sale can be explored, including a land exchange to remove the structure(s) to a more appropriate site. Importantly, the restoration project can probably not go forward without resolution of the disposition of these houses.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	-	
	OY2:	500.0	
	OY3:	-	

4. Monitor ecological changes resulting from restoration. CACO and cooperators have established a detailed description of this estuary's biological, physical and chemical environment over the past ten years of research. Tide heights, water quality, wetland vegetation and aquatic fauna must be regularly monitored as tidal flow is returned, probably, given the adjustability of the dike structure, in small increments. This strategy will also provide the opportunity for an experimental analysis of the hydrological and geochemical effects of sea level rise, projected with global warming.

		Budget	FTE
COSTS:	CY:	15.0	.2
	OY1:	8.0	.2
	OY2:	25.0	.6
	OY3:	25.0	.6

5. Over the eighty-odd years of local controversy about the diking of the Herring River, public interest has always been high. However, since CACO only became involved in the early 1980's, there has been little attempt to exploit this interest in estuarine preservation. CACO interpretation staff could take an active and pivotal role in communicating the objectives and anticipated public benefits to local and visiting populations. From the perspective of cultural resources and specifically the history, and impacts, of human use of native Cape resources, the Herring River example makes an engrossing story.

		Budget	FTE
COSTS:	CY:	-	
	OY1:	8.0	.4
	OY2:	4.0	.2
	OY3:	4.0	.2

CACO-N-036: MONITOR NAUSET MARSH

SYSTEMWIDE ISSUE:

N11, Degradation of Park Water Quality Due to External Activities

N20, Lack of Basic Data: Insufficient Understanding of Park Ecosystems and Threats to Them

PROBLEM STATEMENT:

This estuarine system is unique because of its largely undisturbed natural habitats (little mosquito control ditching). Adjacent residential and commercial developments are threatening the system through groundwater nutrient transport. The marsh provides habitat for many federal and state listed endangered species as well as commercially important species. A monitoring program was initiated in 1990 as recommended in a Rutgers University study. Continued monitoring will be required for a thorough understanding of the threats to the marsh and the potential for mitigation. CACO will also be assisting in the preparation of a joint (two-town) resource management plan for the system.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Continue the intensive monitoring program initiated in 1990 to quantify better the impacts of nitrate/nitrogen inputs feeding into Nauset Marsh. Investigations of the impacts of adjacent land-use on marine habitats will continue for eelgrass, *Cladophora* algae and anoxic deep-water zones. Other macro-algae will be sampled to determine changes in species composition since the original Rutger's University report. Specific parameters to be monitored include: physical parameters (temperature and salinity) at four sites weekly; eelgrass wasting disease indices bi-weekly at two sites in the spring and monthly during the winter (ending in June, 1991); algae biomass on mudflats and species occurrence in tidal channels. Techniques will be adapted from Roman and Able (1989). Field work will be conducted with a seasonal biological technician and volunteers with assistance from CACO resource management and research staff. Groundwater transects for determining nitrate/nitrogen inputs into the marsh were developed in 1990, and will be continued and expanded through a separate project investigating estuarine eutrophication by the staff research biologist (CACO-N-WATR-05). The results of a NPS investigation of estuarine monitoring needs and opportunities for the effective use of a citizens monitoring program will be incorporated into study methods (Burroughs and Lee, in press).

CACO-N-039: INVENTORY SUBMERGED NATURAL RESOURCES

SYSTEMWIDE ISSUE:

N20, Lack of Basic Data: Insufficient Understanding of Park Ecosystems and Threats to Them.

PROBLEM STATEMENT:

CACO's boundary extends 1/4 mile into nearshore coastal waters, yet the submerged natural resources have never been comprehensively inventoried. The need for a basic inventory was identified in CACO's 1990 Operations Evaluation: "Conduct a systematic survey of present conditions of the resources and identify the potential for threats and changes in management policy". It is proposed herein to develop a natural resource inventory program that will describe submerged habitats with respect to physical structure, species composition, density (for select biotic groups), ecological quality and function. Threats to sensitive habitats and species will also be described.

The task of performing a complete inventory of submerged resources at CACO will be a continuing and long-term effort. The overall objective of this proposed project is to design a submerged resources inventory program for CACO. The program will identify the resources to be inventoried, recommend appropriate resolution of inventory data (e.g. aerial survey vs. quantitative field studies), establish a preliminary schedule and budget, and most importantly, identify appropriate data collection techniques.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Convene a workshop to address the present state of knowledge. The participants will include representatives of the responsible management agencies, scientists, and commercial and public users. This forum will focus on reviewing available information sources and on identifying the presence of important biotic species and habitats by ecologic, regulatory and economic criteria. Preliminary evaluations of their location, controlling processes, seasonality, and threats (both human and natural) will be made. Specific attention will also be given to methodologies whereby any data, existing or to be gathered, can be incorporated into CACO's geographic information system. Data collection methods will be addressed, including field and remotely sensed data, along with discussion of indicator species, habitats and processes.

		Budget	FTE
COSTS:	CY:	7.0	
	OY1:	-	
	OY2:	-	
	OY3:	-	

CACO-N-041: MONITOR SHORELINE RETREAT AND ACCRETION

SYSTEMWIDE ISSUE:

N09, Disruption of Natural Coastal Dynamics

N20, Lack of Basic Data: Insufficient Understanding of Park Ecosystems and Threats to Them

PROBLEM STATEMENT:

Currently CACO does not have any plan for the quantitative monitoring of shoreline geomorphology, although a number of important issues exist. CACO has replanted eroding beach areas and performed salvage excavation of eroding archaeological sites. Erosion of the town-owned beach within the CACO boundary in Chatham is responsible for several million dollars worth of damage to private homes on the adjacent shore, and decisions on the management of that beach will affect CACO resources. A local historical society is pursuing fund-raising activities for the relocation of the Highland Lighthouse away from the eroding bluff where it now sits. Shoreline configuration determines the access routes and available corridor for off-road vehicles in the eight mile public-use area from Race Point to High Head, and in the past has been responsible for re-routing ORV traffic closer to nests of the federally listed piping plover.

There has been no long-term monitoring of shoreline retreat anywhere along the coast of CACO, although intensive studies have been undertaken in the past. Some points from the 1800's that were re-surveyed in the 1970's are in existence within CACO, although the location and condition of these points are uncertain at this time. Effective monitoring of shoreline retreat requires surveying on the ground rather than extrapolation from aerial photography. The Province Lands dunes are recognized as migrating systems although the role of humans in this process is not well understood. Sediment budgets for the dunes have not been determined.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Develop a geomorphology monitoring plan based on a clear set of management questions or hypothesis. The plan would take into consideration the efforts made to understand coastal geomorphology in the 1970's for the off-road vehicle management plans, including the re-survey of ORV plots established at that time. Efforts are underway by the NPS to examine dune revegetation in the Province Lands and the role of sea-level rise on the coastal barrier beaches enclosing Nauset Marsh. A geographic information system (GIS) is available at CACO to be used in evaluating historical and current shoreline movement.

CACO-N-045: MONITOR MARINE DEBRIS

SYSTEMWIDE ISSUE:

N02, Impacts on Threatened, Endangered and Other Sensitive Species

N16, Visual and Biological Impacts of Urbanization and Other Near-Park Development on Park Resources

PROBLEM STATEMENT:

The amount of debris found on beaches and at sea over the last few years has become a national concern. Debris washed ashore diminishes the scenic value of beaches, and while adrift at sea can be lethal to marine wildlife. Of particular concern is plastic debris, which may entangle and kill marine mammals, birds fish and sea turtles. The ingestion of plastics is also a significant threat to marine animals.

Some of the human-generated debris washing ashore on CACO beaches present hazards to visitors, employees and marine wildlife. Bottles, nails in boards, light bulbs and other sharp objects, hazardous materials and derelict or discarded fishing nets and traps are among the many items routinely recovered from beaches.

Prior to 1988, data on the types and distribution of debris washing up on CACO and other coastal areas were generated primarily from voluntary beach clean-ups. While these data are useful for public education and media purposes, they are inadequate for quantitative assessment of the problem, developing solution strategies and evaluating the effectiveness of recent legislation that prohibits ocean dumping of plastics (Marpol V Annex).

In an effort to establish a national database on the marine debris problem, the National Marine Fisheries Service (NMFS) entered into a five-year cooperative research program with the NPS. This venture establishes systematic surveys in each region of the coastal United States to assess the types, quantities and sources of human-generated debris washing ashore. CACO is one of eight NPS units participating in this national monitoring program.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

Since 1988, marine debris found along five 1-km sections of accessible shoreline (two bay and three ocean beaches) has been quarterly monitored (Manski 1990, 1991). All human-generated debris observed along these permanent survey transects are recorded and either removed or marked.

CACO-N-047: ACQUIRE LONG-TERM WEATHER DATABASE

SYSTEMWIDE ISSUE:

N20, Lack of Basic Data: Insufficient Understanding of Park Ecosystems and Threats to Them

N24, Other Issues

PROBLEM STATEMENT:

Weather affects most resource issues at one time or another. Unexpected occurrences, past and present, including oil spills, wildland fire, and insect dispersion can be investigated thoroughly with accurate local weather records. The success of most hydrological and ecological field research and monitoring is dependent on continuous and reliable meteorological information. A long-term weather database would enhance current research and management by giving CACO managers easily retrievable weather information. Weather observations in CACO are collected once daily during fire season (fire weather 1300 hrs observations). Precipitation data are recorded continuously at the Truro NADP site and Race Point Ranger Station. NOAA weather observations are collected at Provincetown and Chatham weather stations. Current weather observations are not easily retrievable for CACO managers.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:

1. Continue Daily Fire Weather Observations: Fire Weather Observations will be taken at 1300 hrs EST between April through November. Observations will be entered into AFFIRMS (1991) and WIMS (1992 on).

		Budget	FTE
COSTS:	CY:	.5	.1
	OY1:	.5	.1
	OY2:	.5	.1
	OY3:	.5	.1

2. Repair RAWS Unit: The Remote Access Weather Station which records temperature, relative humidity, wind speed and direction, and precipitation duration and amount every hour is currently not operational. When operational, observations are satellite-relayed to an archive center in Colorado. Repair and maintenance of this station will offer CACO managers current and historic hourly weather observations.

		Budget	FTE
COSTS:	CY:	8.0	
	OY1:	1.5	.1
	OY2:	1.5	.1
	OY3:	1.5	.1

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Vegetation Inventory and Monitoring at Barrier Island Parks

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December 1992

In, *Draft Coastal Park Inventory and Monitoring Protocols*, edited by Ted Simons (NPS Cooperative Park Studies Unit, Univ. of Virginia). No date.

Ecological-Geographical Units

Nine national seashores (CACO, FIIS, ASIS, CAHA, CALO, CUIS, CANA, GUIS, PAIS) and Gateway NRA (GATE) encompass over 800 km of linear shoreline. Based on physiographic considerations, such as shoreline orientation and inlet configuration, the NPS barrier islands were divided into seventeen (17) ecological-geographical units (Table 1). Flora inventories, vegetation mapping and permanent vegetation transects should be established at each ecological-geographical unit according to the guidelines and criteria identified below.

Inventory and Mapping

The inventory needs for each ecological-geographical unit can be accomplished in two ways.

Vascular Plant Flora

An up-to-date vascular plant flora should be assembled for each ecological-geographical unit. Information from existing flora (i.e., species lists), available literature, and herbaria should be compiled. In some cases extensive floral lists already exists (e.g., GUIS Perdido Key, Looney et al. 1993; ASIS, Higgins et al. 1971; CAHA, Burk 1962; GATE, Venezia and Cook 1991; among others). In conjunction with vegetation map field checks and permanent plot sampling (see below), the flora lists will be continually up-dated. It is strongly recommended that each park maintain a herbarium with voucher numbers entered according to the NPS Automated National Catalog System. Given the effort necessary to establish and maintain a complete herbarium, some park units may find it appropriate to enter into a cooperative relationship with a local university or natural history museum.

Vegetation Map

A vegetation map for each ecological-geographical unit should be produced every three (3) years, and following major disturbance events. High resolution, color, vertical aerial photographs, at a scale of 1:9000 or larger, are suggested for production of the map. To coincide with the permanent vegetation plot sampling (see later section), the aerials should be flown between June 15 and September 15, and following major events. Efforts must be make to maintain consistency in cover-types to be mapped along the latitudinal gradient. Obviously the dominant plant species will vary, yet the general range of community structure will be consistent (e.g., herbaceous dune community, shrub community, maritime forest, salt marsh, etc.). A mapping working group should develop a universal list for mapping purposes. Further, the working group must define criteria for aerials in more detail, define minimum mapping units, identify GIS requirements, and address other issues related specifically to mapping.

The vegetation sampling plots will be offset 3-5 meters from an elevation profile to be established by the geomorphological team, thereby avoiding disruption of the permanent sampling site during the surveying phase of the project. One or more concrete monuments will be installed on each transect to aid in re-location and periodic elevation profiling.

Since the width of various barrier island sites ranges over an order of magnitude, from a minimum critical width of about 100 m (defined as 122 m for ASIS by Leatherman 1979) to a maximum of over 1000 meters, there will be a minimum of 10 plots or 10% coverage (which ever is greater) in each transect. For example, for transects that are ≤ 1000 m, 10 plots will be located at equidistant intervals beginning at the ocean side MHW line. For transects > 1000 m, at least 10% of the transect length will be sampled (e.g., 1400 m transect -- 14 plots). It is guessed that the average island width is 250-400 meters, meaning that 10 plots would represent 25-40% coverage of the cross-island swath.

Strata definitions. The ***herb layer*** includes all non-woody species as well as woody species individuals that are ≤ 1.0 meters in height. The ***shrub layer*** includes all woody individuals >1.0 meters in height with a diameter at breast height (dbh at 1.5 meters above ground level) of < 3.0 cm. The ***tree layer*** includes all woody individuals with a dbh of ≥3.0 cm. ***Vines*** include single stems that are ≥1 meter of various species such as *Rhus radicans* (poison ivy), *Smilax* spp. (briers), *Celastrus* spp. (bittersweet), *Lonicera* spp. (honeysuckles), *Parthenocissus virginiana* (Virginia creeper), *Vitis* spp. (grapes), etc.

Vegetation data collection

It is noted that the abovementioned definitions of vegetation strata, plot size and data collection techniques to be presented below represent a synthesis of methods successfully employed on barrier island ecosystems along the Atlantic and Gulf coasts (e.g., FIIS - Art 1976; CAHA - Bourdeau and Oosting 1959; GUIS - Cousens 1988). Several other studies can be cited.

The herb layer will be sampled in the 9 plots arranged as shown in Figure 2b. Each plot will be 0.25m^2 (0.5 x 0.5 meters) and will be marked appropriately in diagonal corners so that a sampling frame can be positioned exactly during future monitoring. For the purposes of counting densities, the individual must be rooted within the plot. For the purpose of estimating cover, a leaf surface must be overhanging the plot, but the plant does not necessarily have to be rooted in the plot. The following data will be collected in each herb layer plot:

1. Cover of each species present using a modified Daubenmire (1959) scale(0-4%, 5-25%, 26-50%, 51-75%, 76-95%, 96-100+%)
2. Density by species of all woody individuals ≤1.0 meters in height.
3. Density of vines.
4. Density of *Ammophila* and/or *Uniola* flowering stems.
5. Maximum height of the dominant herbaceous species vegetative organs.
6. Cover of bare sand.
7. Cover of leaf litter.
8. Cover of lichens.
9. Cover of moss.
10. Cover of wrack debris.
11. Cover of fallen longs and branches.

For each 10 x 10 m plot

- Water table level (seasonal, 4 time per year)
- Groundwater salinity/conductivity (seasonal, 4 time per year)
- Soil (with vegetation sampling):
  - Classification
  - Organic matter content
  - Inorganic nutrient constitutents
  - pH
  - conductivity/salinity

For each 0.5 x 0.5 m herb layer plot:

- Photosynthetically active radiation (PAR) measured w ith light meter at center of each plot (with vegetation sampling)
- mean elevation, slope, apect (with vegetation sampling)

Data Analysis

Data analysis will seek to address the objectives of the inventory and monitoring program at a variety of spatial, temporal and hierarchical scales. Specifically, analyses will address the following questions and objectives:

What patterns of species diversity and community composition are exhibited within and between the 10 coastal national park and 17 ecological-geographical units?

Data investigation techniques will identify patterns at local (within an ecological-geographical unit), regional (one or several park units), and latitudinal (comparing all or a subset of ecological-geographical units) levels. Appropriate analyses will range from compilation of simple species presence and absence lists for specified communities (e.g., maritime forest) within each unit to the comparison of summary indices and the application of multivariate methods.

Species diversity will be quantified at several levels, ranging from species richness counts (number of species) to diversity and evenness indices (i.e., exponent of Shannon's H', Alatalos' modified Hill's ratio -- see Ludwig and Reynolds 1988).

Multivariate methods include the use of clustering algorithms to objectively identify and characterize plant communities. For example, Gibson and Looney (1992) recently used Two Way Indicator Species Analysis (TWINSPAN) to characterize plant communities on Perdido Key (GUIS). This procedure will be used to identify plant communities within an ecological-geographical unit. A larger analysis would identify similarities between plant communities across all units. The resulting classifications that these objective analyses provide would allow quantification of the relationships between the plant communities or cover types used in the baseline vegetation mapping.

As part of investigating the spatial extent of vegetation types within ecological-geographical units, the initial vegetation maps and the updated maps will be entered into a GIS to allow investigation of spatial and temporal relationships.

Markov matrix models (Facelli and Pickett 1990) in which the probability of shifts of permanent plots from one state (plant community in this case) to another will allow predictions of the longevity and dynamics of the plant communities to be predicted at the local, regional and latitudinal levels. The more complex computer models, such as the CENTURY grassland model (Parton et al. 1987), will be developed to allow predictions of the response of barrier island communities to various scenarios (e.g., rising sea level, increased or decreased grazing, altered water table level) to be made. Specific to barrier island ecosystems, a stochastic/deterministic model (ISLAND) is being developed and applied at the Virginia Coast Reserve LTER site to predict barrier responses to altered geomorphological and hydrological parameters (Hayden et al. 1991).

Are there immediate applications at the park level?

At all stages of analysis the results and their interpretations will be of immediate use to resource managers. Simplified conceptual "box and arrow" diagrams (Au 1974, Art 1976, Ehrenfeld 1990) illustrating the relationships between community types will be constructed and included in annual reports. As the project develops these will become more sophisticated and incorporate predictive levels of confidence for projected changes and scenarios. A not unrealistic expectation would be that resource managers could have an on-site interactive program in which various questions could be posed (e.g., what will happen to the composition and extent of maritime forest on Cumberland Island if annual growing season temperature rises by 2 degrees C) and answered with a given degree of confidence.

Preliminary Study

Several questions related to the proposed sampling regime must be addressed.

1. What is the minimum number or appropriate spacing of cross-island transects needed for each eco-geographic unit?

2. What is the optimum number of 100m^2 plots required along the transects?

3. What is an appropriate sample frequency?

The draft sample design provides guidance on these three questions based primarily on experience from the literature and cost-benefit considerations. To address the first question (transect density), criteria have been identified in the draft protocol clearly requiring that all major vegetation cover types be sampled in each eco-geographic region. Obviously, more transects would be better, but time and cost become limiting factors.

The second question is actually the most critical and asks how many times per eco-geographic unit should any one vegetation cover-type be sampled. Preliminary sampling will allow a determination of the variance associated with many of the variables that are being measured (e.g., cover, stem density, tree diameter, etc). According to the procedures outlined by Ekblad (1991), the optimum number of sample plots per vegetation cover-type can be determined. The following preliminary study is proposed.

Each team will have a team leader or team co-leaders being responsible for 1) consistent data collection and data management, 2) coordination with other vegetation teams and other discipline teams (e.g., geomorphological, indicator species, etc.), 3) training of team members, and 4) preparation of annual technical reports and professional publications. It is intended that team members will be park resource management specialists, park seasonal staffs, park volunteers, and graduate students. It is strongly recommended that each team leader have extensive experience in barrier island vegetation research and a demonstrated commitment to long term NPS involvement (i.e., NPS scientist, NPS schedule A appointment, university faculty at a CPSU). Each team leader should have direct access to a full-time technician dedicated to this effort, or at least 2 graduate students.

INITIAL SCHEDULE

Year One and Two

- Establish 3 teams
- Visit parks to establish approximate location of transects
- Conduct preliminary study in each of the three regions
- Teams meet to evaluate protocol and make appropriate refinements
- Develop draft monitoring manual

Year Three

- Select one park from each region and conduct complete field an mapping survey
- Revise protocol as necessary and finalize monitoring manual

Year Four

- Begin first full sampling program according to schedule that will include sampling of all ecological-geographical units at 3 years intervals.

Leatherman, S.P. 1979. Migration of Assateague Island, Maryland, by inlet and overwash processes. *Geology* 7: 104-107.

Looney, P.B., D.J. Gibson, A. Blyth, and M.J. Cousens. 1993. Flora of the Gulf Islands National Seashore, Perdido Key, Florida. *Bull. Torrey Bot. Club*, in press.

Ludwig, J.A. and J.F. Reynolds. 1988. *Statistical ecology*. Interscience, NY.

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Parton, W.J., D.S. Schimel, C.V. Cole, and D.S. Ojina. 1987. Analysis of factors controlling soil organic matter levels in Great Plains grassland. *Soil Sci. Soc. Am. J.* 51:1173-1179.

Roman, C.T. and K.F. Nordstrom. 1988. The effect of erosion rate on vegetation patterns of an east coast barrier island. *Estuarine, Coastal and Shelf Science* 26: 233-242.

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Venezia, K. and R.P. Cook. 1991. Flora of Gateway National Recreation Area. National Park Service, Gateway National Recreation Area, NY. 40p.

DRAFT

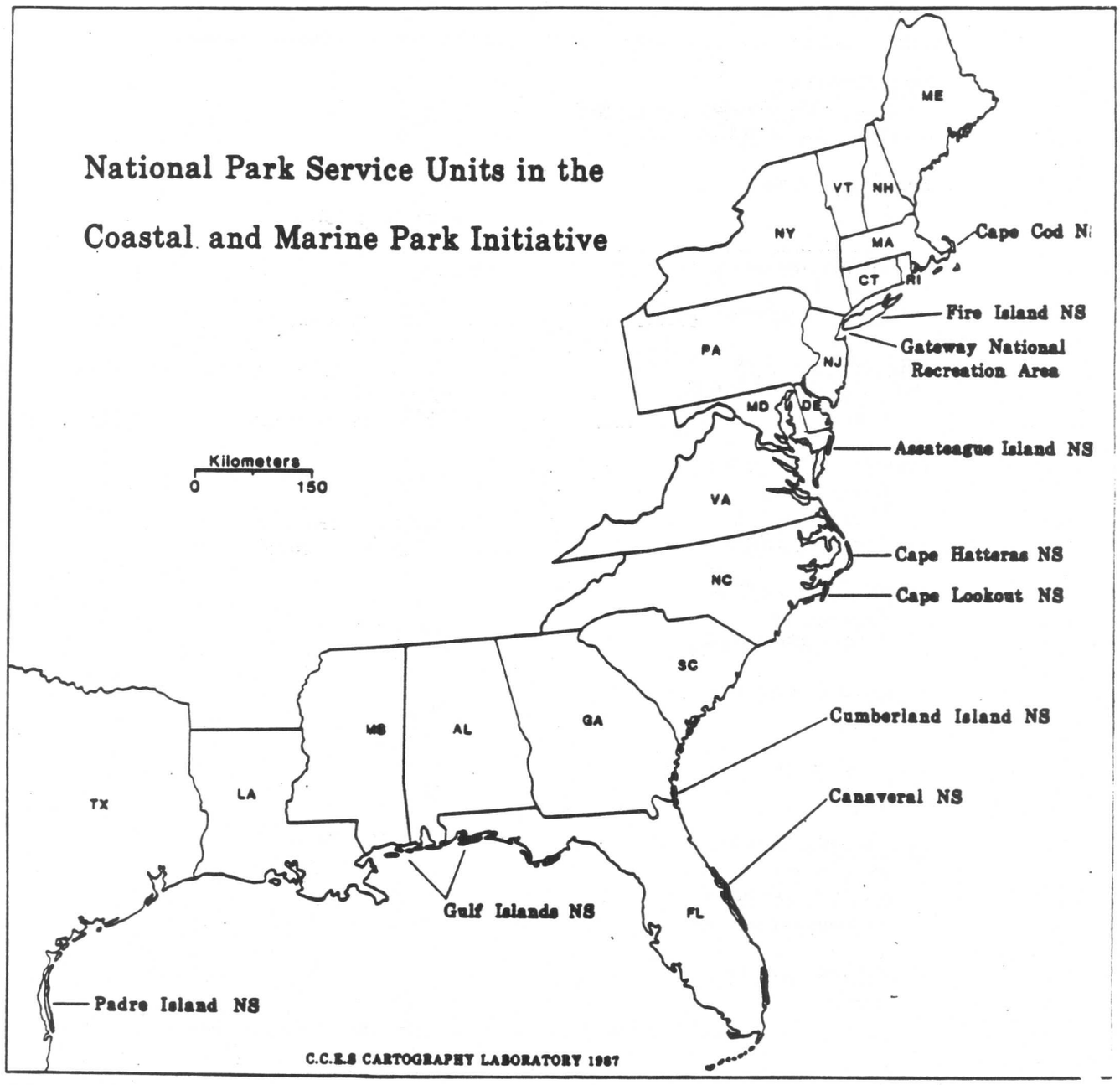


Fig.1. Barrier island units in the National Park Service system.

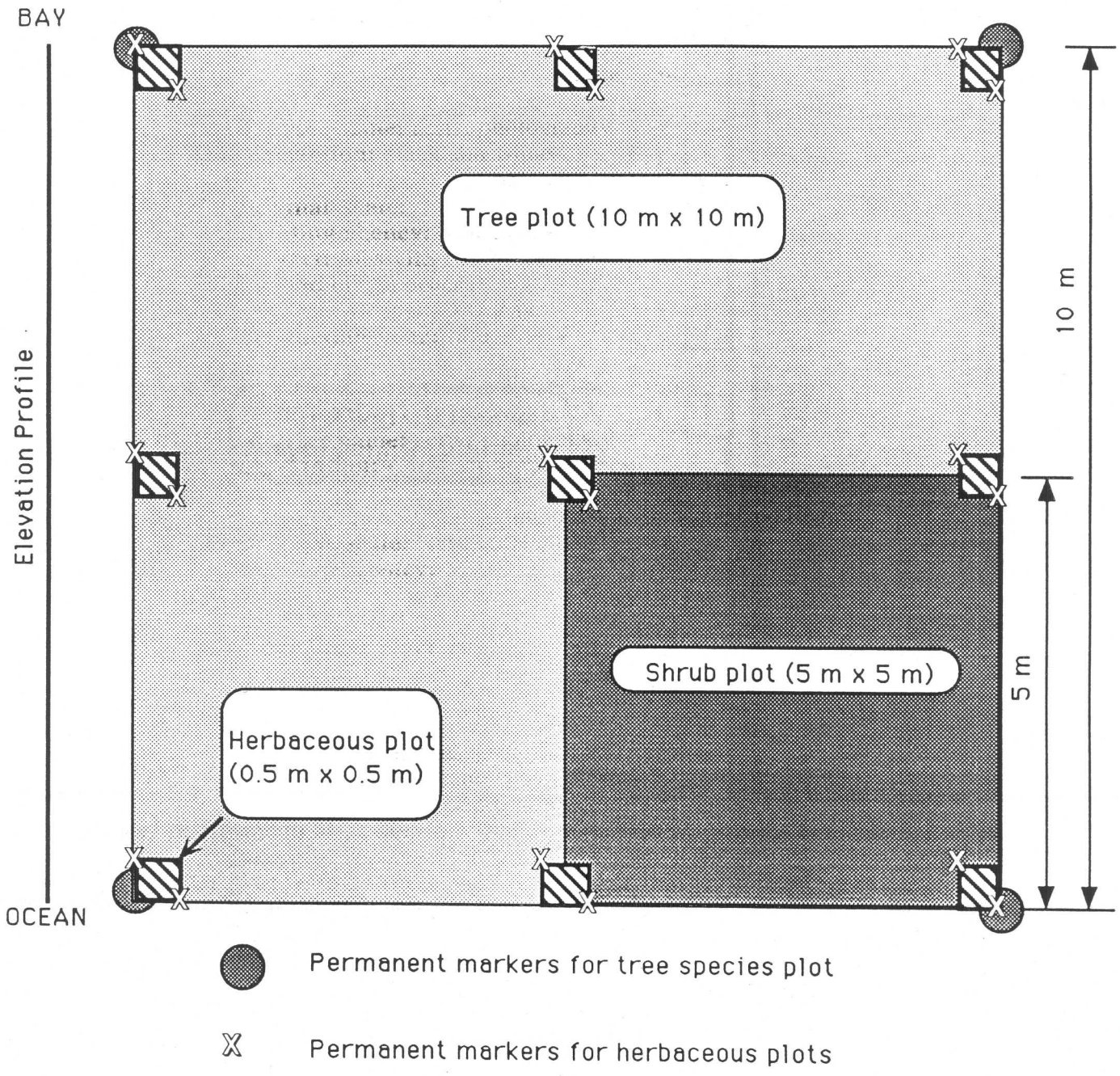


Fig. 2b. Detailed schematic of 100m^2 permanent plot layout.

Reference #1

data set name: luse90
description: 1990 land use and land cover for Cape Cod
26 classes - 0.5-3 acre minimum mapping unit
original scale: 1:25,000
curating agency: MassGIS, Cape Cod Commission GIS
contact: MassGIS (617) 727-3888
Cape Cod Commission (508) 362-3828
format: digital
ARC/INFO vector
production year: 1990

Reference #2

data set name: luse85
description: 1985 land use and land cover for Cape Cod
26 classes - 0.5-3 acre minimum mapping unit
original scale: 1:25,000
curating agency: MassGIS
contact: MassGIS (617) 727-3888
format: digital
ARC/INFO vector
production year: 1990

Reference #3

data set name: veg58
description: 1958 vegetation cover for CACO
25 classes
original scale: 1 acre minimum mapping unit
curating agency: CACO GIS
contact: Marconi Station Headquarters (508) 349-3785
format: digital
GRASS raster
production year: 1958

Reference #4

data set name: veg77
description: 1977 vegetation cover for CACO
25 classes
original scale: 1 acre minimum mapping unit
curating agency: CACO GIS
contact: Marconi Station Headquarters (508) 349-3785
format: digital
GRASS raster
production year: 1977

Reference #9

data set name: roads
description: roads for Cape Cod
from USGS Digital Line Graphs (DLG)
original scale: 1:100,000
curating agency: MassGIS
contact: MassGIS (617) 727-3888
format: digital
ARC/INFO vector
production year:

Reference #10

data set name: DEM
description: USGS 7.5 minute Digital Elevation Models (DEM)
elevations recorded on a 30 meter spacing profile
for select quads on Cape Cod
original scale: 1:25,000
curating agency: USGS
contact: CACO GIS at Marconi Station Headquarters (508) 349-3785
format: digital
GRASS raster
production year: 1990

Reference #11

data set name: hitide.lines
description: coastline for CACO
digitized from 1972 USGS 7.5 minute topographic maps
original scale: 1:25,000
curating agency: CACO GIS
contact: Marconi Station Headquarters (508) 349-3785
format: digital
GRASS vector
production year: 1990

Reference #12

data set name: coastline
description: coastline for Cape Cod
from USGS Digital Line Graphs (DLG)
original scale: 1:24,000
curating agency: MassGIS
contact: MassGIS (617) 727-3888
format: digital
ARC/INFO vector
production year:

Reference #17

data set name: apccwet
description: fresh and saltwater wetlands for Cape Cod
from Association for Preservation of Cape Cod Atlas
digitized from 1972 USGS 7.5 minute topographic maps
original scale: 1:25,000
curating agency: Cape Cod Commission GIS
contact: Cape Cod Commission (508) 362-3828
format: digital
ARC/INFO vector
production year: 1990

Reference #18

data set name: geologic sediment and texture
description: geologic sediment and texture data for Massachusetts Bay
interpreted from side-scan sonar
original scale:
curating agency: USGS
contact: USGS (508) 548-8700
format: digital
production year:

Reference #19

data set name: nauset habitat
description: 1990 Nauset Marsh habitat map
tidal wetlands and submerged ecological features - 10 classes
original scale: 1:6,000
curating agency: CACO GIS
contact: Marconi Station Headquarters (508) 349-3785
format: digital
GRASS raster
production year: 1993 (in production)

Reference #20

data set name: sav
description: submerged aquatic vegetation
pilot mapping for Boston Harbor, Buzzards Bay
plans to extend statewide
original scale: 1:20,000
curating agency: MassGIS
contact: MA DEP Wetland Conservancy Program (617) 292-5907
format: digital
ARC/INFO vector
production year: 1995

Reference #25

data set name: shorebird roosting and foraging habitats
description: delineation of shorebird roosting and foraging areas on Cape Cod
produced under USFWS Gulf of Maine Coastal Estuary Project
original scale:
curating agency: U.S. Fish and Wildlife Service
contact: USFWS Portland, ME (207) 828-1080
format: digital
ARC/INFO vector
production year: 1990's (planning stages)

Reference #26

data set name: anadromous fish runs
description: existing and potential anadromous fish runs and passageways
produced under USFWS Gulf of Maine Coastal Estuary Project
original scale:
curating agency: U.S. Fish and Wildlife Service
contact: USFWS Portland, ME (207) 828-1080
format: digital
ARC/INFO vector
production year: 1990's (planning stages)

Reference #27

data set name: water quality and circulation - Wellfleet Harbor
description: water quality indicators and circulation patterns
Wellfleet Harbor Project
original scale:
curating agency: Barnstable County Health and Environment Department
contact: Cape Cod Commission (508) 362-3828
format: digital
ARC/INFO point
production year: 1990's (automation pending)

Reference #28

data set name: aerial photography
description: true color
shoreline coverage from Monomoy to Race Point
for Dec. 92 storm damage assessment
original scale: 1:4,800
curating agency: CACO
contact: Marconi Station Headquarters (508) 349-3785
format: transparencies
production year: December 1992