DRAFT COASTAL PARK INVENTORY AND MONITORING PROTOCOLS

Edited by

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VEGETATION INVENTORY AND MONITORING
AT BARRIER ISLAND PARKS

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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.
Ecological-Geographical Units

Nine national seashores (CACO, FIIS, ASIS, CAHA, CALO, CUIS, CANA, GUISO, 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 exist (e.g., GUISO 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 updated. 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 made 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.
Permanent Sampling

Transects and Plots

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.

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.
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 0.25m² (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.
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 permanently 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)
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 constituents
  - pH
  - Conductivity/salinity

For each 0.5 x 0.5 m herb layer plot:
- Photosynthetically active radiation (PAR) measured with light meter at center of each plot (with vegetation sampling)
- Mean elevation, slope, aspect (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.
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 objectively assess relationships between vegetation composition and other variables (Gauch 1982). Gibson et al. (1992) used Canonical Correlation Analysis (CANOCO) to demonstrate 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 trends, 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 abundance 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 density data, can be particularly 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,
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 100m² 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.
a) At one eco-geographic unit for each of the three regions, sample a contiguous
    cross-island swath of 100m² 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 \( t_0 \) and \( t_{0+1} \) using the

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 / ecophysiological
   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
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.
LITERATURE CITED


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Fig. 1. Barrier island units in the National Park Service system.
Fig. 2a. Schematic of cross-island transect. Note the permanent plots are off-set from the elevation profile line.
Permanent Plot Layout

Fig. 2b. Detailed schematic of 100m² permanent plot layout.
INTRODUCTION

The development of responsible, consistent long-range coastal management plans has been hindered historically by the lack of appropriate data sets upon which decisions are based. In part, the problem resides in a technology gap between desired data collection and the physical limitations of working in the high-energy surf zone, especially during critical storm-conditions. In part, the lack of available data reflects historically a reactive rather than proactive stance on the part of coastal managers and funding agencies.

The active conservation, preservation and/or maintenance of a beach resource traditionally uses either soft structure (i.e., beach fill) or hard structure (i.e., breakwaters; groins) methods. Passive conservation relies on adaptive use strategies keyed to natural fluctuations or changes in the system. Both approaches require knowledge of the behavior of the natural beach system. Prior to developing a long-range beach management program, it is necessary to collect data on the physical processes contributing to the condition of the coastal reach in its undeveloped state. These processes include wind, wave, current, and tide conditions. In addition, it is necessary to appreciate the geomorphological response to the process conditions which is reflected in the shoreline position, profile configuration and sedimentology. Because most of the stress on the system occurs during infrequent, high energy events, it is also necessary to understand the coastal response to extreme events, usually defined as extratropical and tropical storms, but also including processes such as tsunamis, El Nino events, flooding and drought. Monitoring a project after emplacement allows one to judge the effectiveness of the management strategies by comparing post-project conditions to the "natural" state. This requires regular measurements of the response characteristics, including nearshore profile configuration and sediment distribution and variability.

This chapter is intended to provide the methodology necessary to implement a nearshore monitoring program to evaluate both natural and post-project physical conditions in seashore parks along the Atlantic and Gulf of Mexico coasts. Processes that are dominant on the Pacific coast, but do not exert a controlling force along the Atlantic and Gulf coasts, are not considered here.
The following elements of the coastal process/response system are considered in subsequent sections:

1. Waves and Currents
2. Sediments
3. Shoreline Position
4. Profile/Beach Volume

WAVES AND CURRENTS

The position of the shoreline and the resilience of the system are dependent on three variables: water level, sediment supply and wave/current energy. In order to anticipate stresses on particular elements of the system, especially in response to extreme events, it is necessary to develop a wave climatology for a nearshore area. A wave climate defines the long-term, averaged wave energy conditions that control the morphological and ecosystem characteristics of the shoreface. By understanding the wave climate, one can design management protocols for the perturbations.

Wave climatologies are developed with either hindcast values or measured data. A wave hindcast is calculated as a function of wind speed, wind duration and fetch (unimpeded open water distance across which the wind blows). A series of nomograms are used to determine the maximum deep water wave height that can be generated with a given set of storm conditions (U.S. Army Corps of Engineers, 1984). Numerical wave refraction/diffraction models are applied to the hindcast wave field to simulate breaking wave conditions. Using 50 years of published storm records, one can simulate the wave climate for any given location along the coast. The advantage to this method is that the published storm records are readily available, as are simple wave refraction models, and the wave climate can be developed for any location. The disadvantages are that the wave hindcasting itself is a time-intensive process; the calculated values provide only significant wave height estimates and not a true spectrum of wave conditions and, more important, that these values are not measures of true wave conditions, but are approximations based on a simple model of air-sea interactions.

Measured wave data provide the most reliable estimates of wave climatology. There are a number of wave measurement devices available, including wave staffs, wave buoys, slope or Sxy arrays, and puv gages. The wave buoy network is established and maintained by the NOAA National Buoy Data Center in Bay St. Louis, Mississippi (Figure 1). The data are transmitted and updated monthly and are available for distribution. These data provide a reliable and cost-effective source of offshore, deep water wave heights for model applications. However, they do not provide directional information, which must be inferred. Similarly, wave staffs are economical to deploy and maintain, but provide only wave height information.

Slope and Sxy arrays consist of groups of bottom mounted pressure sensors located in an array designed to measure a given segment of the wave spectrum. These arrays produce reliable measurements of wave height, and inferences of wave direction can be made.
The most desirable wave measurement device is the PUV gage, which permits the direct calculation of both wave height and direction. The typical configuration includes a bottom mounted tripod equipped with a high-precision quartz pressure transducer (measuring pressure), an internal compass and a 2-axis electromagnetic flow sensor (measuring the horizontal flow components \( u, v \)). For open ocean applications, either a 4-cm or a 10-cm diameter flow sensor sphere may be used, depending on durability and the expected flow components induced by typical sea conditions in the region. Sensors mounted in shallow, protected water characterized by short-period waves may use smaller diameter sensor spheres. The flow sensor should be colocated on the tripod with the pressure sensor at approximately 1.5 m above the sea bed.

Measurements can be recorded and transmitted by several means: hard-wired to the shoreline; in situ data logger; or telemetry.

To best estimate wave climates, the gage should be installed for a continuous period of no less than one year, but preferably five years. In an open ocean environment, the logger should be set to record simultaneous pressure and horizontal velocity measurements for a minimum of 17 minutes, every three hours at a sampling rate of 2 Hz (0.5 sec interval; 2048 measurements). The internal compass readings should be recorded in concert with the PUV measurements, typically at 1/10 the rate. Directional wave spectra can be calculated from the recorded measurements using standard statistical methods; parameters should follow the accepted definitions published by the Permanent International Association of Navigational Congresses (PIANC, 1973) and the IAHR Working Group on Wave Generation and Analysis (IAHR, 1989).

SEDIMENTS

Estimating Sampling Frequency

Temporal Frequency.

The type and texture of sediments on a beach are the result of processes operating in geologic and sub-geologic time scales. They are functions of the available source material, the type of weathering process, the transport distance and the character of the longshore and cross-shore sediment transport mechanisms. Although the sedimentology of a barrier island complex is controlled by geologic processes, short-term variability can be introduced by high energy events, a change in the source area for sediments, a change in the sediment transport characteristics and/or anthropogenic stresses. It is important that the distribution of the type and texture of the shoreface sediments be understood because the sedimentology controls, in large measure, the shoreface slope, profile characteristics, reflectivity of the beachface, and stability of the beach and nearshore.

Because the sediments on a barrier island are created and amassed by processes acting on time scales much longer than a tidal cycle, and because the sediment distribution is in dynamic equilibrium with the annual or semi-annual (in those areas with a distinct winter/summer wave climate) energy budget, the average sedimentological characteristics of a coastal area tend to
persist until they are disturbed by a high energy event or by man's activities. Thus, in a natural environment, a complete baseline survey of longshore and cross-shore sedimentology should be established, but subsequent surveys need to be performed only at one to five year intervals, depending on local changes in sediment sources and variability in the wave climate. Exceptions to this schedule are following high energy events that deposit/remove large volumes of sediment from the shoreface and subsequent to any disturbance in the natural sediment transport cycle (e.g., beach renourishment).

Spatial Frequency.

The spatial distribution of sediment sample locations is largely site-specific; a function of sediment supply and source and incident energy. Linear beaches drawing from a single source are more consistent in both the long- and cross-shore directions than are less regular configurations. Little information is available on how to predetermine the number of sediment samples that should be acquired to characterize a coastal reach at any given confidence level. Anders et al. (1987) reported on an experiment designed to provide estimates of sampling requirements for given confidence levels dependent on the distribution of the grain sizes about the mean.

Figure 2 illustrates the typical distribution of sediment grain sizes across a moderate energy barrier coast. Samsuddin (1986) documented the model distribution with coarse, negatively skewed grain sizes near the beach step (shore break point), fining both landward and seaward. Anders et al., (1987), working at Ocean City, Maryland, and generally applicable to poorly sorted, medium sand beaches subjected to moderate wave energy, used 400 sediment samples collected at ten locations between the dune and -11 m, along 36 transects to test theories of sediment sampling frequency. Figure 3 shows the optimal number of samples required to maintain 0.25 phi accuracy at 95%. In general, variability is less in the longshore direction than in the cross-shore direction. Because of the high variance in cross-shore sediment distributions, the sampling frequency can be unnecessarily high. Reorienting the sampling grid to an along-shore focus will result in fewer samples to achieve the same degree of accuracy. For instance, instead of taking a full suite of samples on all profile transects, one or two samples may adequately characterize the backshore, 50% of the possible transect locations may characterize the upper shoreface, 100% of the transects may be sampled in the foreshore and step region, and 25% of the possible transects may be used to describe the offshore conditions.

Sediment Sampling and Analysis.

Sediment sampling should be coordinated with profile measurements, using the same transect grid. The following subenvironments should be sampled (Figure 4): toe of the dune, backshore, berm crest, mid-foreshore, step or lower foreshore, and offshore at one meter depth intervals. On the sub-aerial beach, the top 2 cm of material should be removed (to remove the effects of aeolian winnowing or beach traffic) and a 500 gram surface sample scraped from the fresh surface. Alternatively, short cores (0.5 - 2.0 m) may be obtained by pushing a short PVC tube (10 cm diameter) into the sediments. Short cores taken in the foreshore have the advantage of showing the short term history of cut-and-fill over a tidal cycle or through a storm.
Sediment samples should be described for mineralogic characteristics and color. Samples may be processed in the laboratory to remove and weigh the silt and clay fraction (<0.063 mm) and calculate the size distribution of the sand fraction (0.063 mm -2.0 mm). The size distribution in the silt and clay fraction may be calculated using either a pipette or a Coulter counter (for large clay percentages). Sand fractions may be processed using either dry sieves or a Rapid Sediment Analyzer (RSA). Sieving has the advantage of inexpensive equipment; however, unless a sonic sifter is used, it is time intensive and may not measure the effects of grain shape. A RSA detects sediment size distributions based on the hydraulic equivalent radius of the particles. The RSA is a computerized settling tube filled with de-ionized water and containing an electrobalance connected to a personal computer. This technique is preferable to mechanical sieving when the transport characteristics of a material are important, because grain shape and density are considered when particles are grouped in a size classification. Standard statistical methods (moments measures) are used to produce estimates of sample size means and distributions, including size sorting. Statistics are graphically represented in series of frequency and probability curves.

SHORELINE POSITION

Variability in the horizontal position of the land/water interface traditionally has been used as a measure of beach response to ambient energy conditions and an analog for assessing the "health" of a barrier island system. Dolan et al. (1991) indicate that the reliability of the estimate is based on (1) the accuracy of the shoreline measurements, (2) the temporal variability of the shoreline, (3) the number of data points, (4) the proximity of each observation to the time of an actual change in the trend of shoreline movement, (5) the period of time between the shoreline measurements, (6) the total time span over which data are collected, and (7) methodology. Three methods of measuring shoreline position are commonly used: field surveys, aerial imagery, and kinematic GPS (satellite positioning) surveys.

Field surveys are conducted in accordance with methodologies established for profile monitoring. The shoreline position is established as the plotted intersection between the surveyed profile and the elevation of mean sea level (MSL). Surveys of this type have the advantage of being accurate and precise; however, they are time-, cost-, and labor-intensive.

Analysis of aerial imagery has become the standard for the estimation of shoreline position and historical rates of shoreline change. The high water mark, or wetted perimeter, is used as the defined shoreline position (El-Ashry, 1962) because is stands out as a distinct tonal change on both black-and-white and color (real and infrared) images. Using aerial imagery has the distinct advantage of providing a "real-time" snapshot of coastal conditions. Regional coverage can be obtained minimizing within-reach variability due to tide and surge conditions. Errors associated with using aerial imagery can be grouped into the following categories (Smith and Zarillo, 1990; Dolan et al., 1991): short-term fluctuations of the water line due to swash processes; residual storm surge lines; fluctuations due to tides; measurement error.
Figure 5 (McBride et al., 1991) is a schematic illustrating a shoreline change mapping strategy that has been implemented by the State of Louisiana. Byrnes and McBride (1992) describe the strategy:

State-of-the-art mapping software, compatible with existing NPS Geographic Information Systems, should be used. Cartographic data sources represent existing map products that often are presented a varying scales and projections with different ellipsoids and datums. Accurate temporal comparison of this information must be done within a set of common parameters. Consequently, cartographic transformation software should be used to bring all existing digital data sets to a common surface. Proposed characteristics are a scale of 1:24,000, Universal Transverse Mercator Projection, the GPS 1980 ellipsoid, and the North American 1983 datum. Maps are stored at a 1:1 scale and actual ground distances and areas can be determined directly. Shoreline position change can be quantified at 50-m longshore intervals for each site. Aerial imagery will be referenced to the most recent map base available. Distortion inherent in all photography should be removed using a series of control points. A portable Global Positioning System (GPS) should be used in the field to accurately locate control points than can be recognized on the photography for image rectification.

The recent availability of GPS instrumentation has provided the means to quickly and accurately record a shoreline position (high water line) in the field. This technique has been employed as part of the King's Bay coastal monitoring program at Cumberland Island (CUIIS), and is recommended for adoption in the coastal parks. Byrnes et al. (1993) describes the methodology established at CUIIS:

During the late 1970's through the 1980's, significant advances in satellite surveying were made with the development of the Navigation Satellite Timing and Ranging (NAVSTAR) Global Positioning System (GPS). This surveying technique can be very accurate under certain conditions; however, signal degradation through selective availability [of satellite channels] causes significant positional errors if only one station is used. Differenting the satellite signals at two stations eliminates most of the error. Differential GPS provides the capability for accurately delineating high-water shoreline position from ground surveys. . . . [At CUIIS] two six-channel Trimble Navigation Pathfinder Professional GPS receivers were deployed. One unit was referenced with a first-order leveled benchmark at the southern end of CUIIS (U.S. Army Corps of Engineer marker PAUL-ST). The other unit was used to collect shoreline position information from a four-wheel ATV and four-wheel drive pickup truck. The base station collected a data point every 10 seconds while the mobile unit collected information at a one-second interval. Base station data were used to differentially correct shoreline position data for signal degradation by selective availability and differences in signal transmission. Numerous secondary benchmarks (third-order leveled) along the length of Cumberland and Amelia Islands were used to gage the accuracy of
shoreline measurements (± 1 to 3 m) relative to the base station. The horizontal position of the high-water shoreline as recognized on the beach was determined visually using a hierarchy of criteria dependent on morphologic features present on the subaerial beach. The primary criterion was a well-marked limit of uprush by waves associated with high tide. This generally was recognized as a dune or beach scarp, marking the upper limit of the foreshore. If a scarp did not exist, a debris line usually could be identified associated with the berm crest. Sometimes a debris line existed landward and at a lower elevation than the berm crest. When this was encountered, the position of the berm crest was tracked as the high-water shoreline because different physical processes affect the location of the debris line relative to those associated with a scarp or upper foreshore demarkation. The criteria adopted are consistent with those used by field topographers and photo interpreters.

An initial base map should be developed in a GIS format for each of the coastal parks. Subsequently, either low-altitude aerial imagery should be flown or a kinematic GPS survey of the shoreline made annually, and the GIS database updated accordingly. Following the recommendations of Morton (1989) these surveys should be made at the time of the year when the beach is at its most stable configuration and least susceptible to short-term fluctuations induced by extreme events (usually early summer). The survey should be made at the same time each year to insure that the measured rates of change represent the long-term trend. In addition, a survey of the shoreline should be completed immediately following each storm that results in measurable change to the coastal configuration, and one-month and six-month intervals following the storm to record recovery rates that represent coastal stability, resilience, and variability.

PROFILE MONITORING

Estimating Sampling Frequency

Temporal Frequency.

Field techniques for the estimation of shoreface profiles are labor and time intensive, but provide the most accurate data to calculate volumetric changes. It is important to measure short-term changes in beach planform, especially following the implementation of an erosion mitigation project, in order to observe and later predict initial readjustment of the beach profile in response to the project. However, water level fluctuations due to tides, storms, global climate changes, and tectonic processes produce morphological variations in the beach that affect the measured position of the shoreline. Consequently, the most reliable estimates of shoreline position and morphology are those averaged over long (decadal) periods of time.

Along the Atlantic coast, seasonal variations in the tracks of low pressure centers result in characteristic seasonal fluctuations in beach morphology. Winters are dominated by northeasterly
winds generated by storms that track either eastward through the Ohio Valley to the Atlantic or northward along the eastern seaboard. These storms produce gale-force winds and seas that are dominated by energy input from the local wind field. The dominant direction of sediment transport is from north to south on the Atlantic shoreline. Summers are characterized by southerly winds and, along the Atlantic shoreline, by organized "swell" waves generated farther offshore by a generally pervasive high pressure system.

The seasonal climatic variability results in seasonal morphological changes in the nearshore and beach regions. The volume of sand stored in the subaerial and surf-zone portions of the shoreface can vary dramatically on a seasonal basis. In regions dominated by seasonal transport directions (the Atlantic coast seashore parks), it is desirable to survey a beach seasonally (4 times/yr). At a minimum, profile surveys in the Atlantic seashore parks should be undertaken following the winter and summer maxima for directional transport (ideally, April and October). In those regions governed by unidirectional transport (the Gulf coast seashore parks), an annual beach profile survey should be performed. The timing of surveys should be coordinated from year to year to assure consistent analyses of seasonal variability. In addition, a beach should be surveyed immediately pre- and immediately post-storm when those events have been predicted early (i.e., before and after a probable hurricane landfall). When storms occur without adequate preparation time, the beach should be surveyed immediately after the storm. Much of the catastrophic and/or quasi-permanent changes to a beach occur as the result of major storm activity.

A special case exists when a beach nourishment project has been implemented. It is critical to know the range of beach configurations prior to the design of the project. This requirement demonstrates the need for survey data even when a project is not imminent. Subsequent to the emplacement of sediment, it is necessary to document the initial redistribution of material and reconfiguration of the nearshore profile. This information can be used to predict short-term behavior of the project for the calculation of renourishment volumes and the design of future projects. Because redistribution and settling of the material begins to occur immediately upon emplacement, monitoring should begin within a week of project completion and continue on a monthly basis for at least one year. At the end of the first year, analysis of the data will determine if redistribution has slowed and the sampling frequency can be reduced to a quarterly effort.

Spatial Frequency.

Accuracy of volumetric estimates will increase as the profile lines become more closely spaced. Ideally, profiles should be surveyed every 50 m to 100 m along the beach. However, parks rarely have the resources to maintain such an intensive field effort. The spatial distribution of profile lines cannot be prescribed; it should be site-specific. In general, long, linear, stable beaches will require sampling at less frequent intervals than will convoluted shorelines. A profile line should be established on each side of a major change in orientation. In areas protected by groins, profiles should be initiated on the immediate updrift and downdrift sides of the groin and in the center of each groin compartment. Behind breakwaters, profile lines should run along the
tombolo crest and across the breakwater, at the center of the curvature of the beach, and across the side of least curvature. Profile lines ideally are oriented perpendicular to the trend of the beach at the point that the profile line crosses the land/water interface. However, this is difficult to achieve along very arcuate shorelines. In these cases, profiles should be spaced at close intervals along the beach to calculate a truer estimate of beach volume.

Establishing the Baseline

The baseline is the surveyed line laid out parallel to the shoreline (or as close to parallel as is practical) from which profile lines are laid out perpendicularly at regular intervals. It should be located inland of the extent of beach erosion anticipated during the period of surveying. The baseline is surveyed from permanent benchmarks established by the U.S. Geological Survey, National Ocean Survey (Coast and Geodetic Survey), and/or U.S. Army Corps of Engineers. Benchmarks are registered in three dimensions, keyed to state plane coordinates and mean sea level (MSL). Permanent markers (i.e., steel pipe) should be used to locate the baseline and the end points of the profile lines.

Profiles are surveyed from the baseline seaward. Ideally, they would reach to the point of profile closure, or the seaward limit of the active beach profile. Practically, this translates to the point where the vertical accumulation of sediment during successive survey periods approaches the limits of accuracy of the surveying technique. Along the mid-Atlantic bight, this is generally recognized as -9.15 m relative to the 1929 National Geodetic Vertical Datum (NGVD), or - m relative to 1983 NGVD. Within the sounds and bays and in the tidal tributaries backing the barrier islands, this depth may not be reached except in the deep navigation channels. Here, it is desirable to survey to minimum depths of -6 m. Rod and transit methodologies limit the seaward extent of a survey by the depth into which the rodman can wade. Every effort should be made to extend the profile line to the maximum seaward limit achievable by the surveying technique.

The spacing of data points along the profile line is variable, depending on the precision required. Several points should always be included (Figure 3): dune crest and dune toe (or top and toe of bulkhead, if present); berm crest; top and bottom of shore step, if present; high and low water lines; bar crests; top and toe of breakwater, if present; and any other significant change in slope.

Surveying and Recording a Profile Line

Surveying instrumentation has become very sophisticated. Laser-based "total stations" record distance and elevation based on light reflections from a prism mounted on a rod or tripod. These instruments have self-contained data collection modules that eliminate the need for position transcriptions from field notes. A typical survey technique is a self-leveling transit or level and a graduated rod, usually marked with feet and tenths of feet.
Data and notes from surveys should be kept for reference. Notes should be detailed enough to allow reconstruction of field conditions by anyone working with the data in the future. In addition, notations of site conditions will be useful to analyze changes in beach profiles through time.

Several software packages are available, either through public domain or at minimal cost, that reduce the raw data from the instrument format, correct to MSL, plot the profiles, calculate changes in beach volume, and plot statistics of beach variability through time. A commonly used package is ISRP developed by the U.S. Army Corps of Engineers.

LITERATURE CITED


## IMPLEMENTATION

### SHORELINE INVENTORY AND MONITORING

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NDBC Moored Buoy Stations
ATLANTIC BASIN

Category
- Permanent — NWS
- LNB/ELB — NWS
- Other Agencies
- Developmental — NDBC
- Directional Waves

Figure 1.
Figure 2. Distribution of sediment sizes across profile line 188 on 17 March 1981 (Howd and Birkemeier, 1987).
Figure 3 Plot of mean grain size versus number of samples required to maintain 0.25 phi accuracy at 95% confidence. The number in parentheses after each sub-environment indicates the number of sample means used to derive the point (Anders et al., 1987).
Sediment and Profile Sampling Points

- TD = Toe of Dune
- BS = Backshore
- B = Berm
- UF = Upper Foreshore
- MF = Mid-Foreshore
- LF = Lower Foreshore
- S = Step
- T = Trough
- BC = Bar Crest
- OB = Offshore edge of Bar

ELEVATION

OFFSHORE

\[ \triangle MSL \]
INTRODUCTION

These draft procedures are a preliminary outline to suggest objectives and a framework for meteorologic and hydrologic inventory and monitoring in barrier island parks and to raise questions for reviewers' comment. More specific details on appropriate methodology will be incorporated into later revisions. Certain meteorologic parameters are necessary components of hydrologic monitoring, but a system for meteorologic data collection and analysis should be designed to consider all the needs for weather and climate data. The objectives of meteorologic and hydrologic inventory and monitoring in a barrier island park are to:

1. Characterize the climate of the park and its island setting and establish a database for monitoring long term climate change.

2. Provide a database for meteorologic and hydrologic modeling.

3. Characterize the elevation and general shape of the water table surface, document seasonal and annual fluctuations, and develop a database for determining long term impacts of climate change and sea level rise.

4. Determine the hydroperiod of important wetlands in the park and the relationships of vegetative communities to water table depth.

5. Determine the impact of groundwater withdrawal on the spatial and temporal variation of water table elevation.

6. Provide the database for analyzing water use and promoting water management where competing uses may have an adverse impact on park water supply and ecosystems.
PLANNING AND INVENTORY

Determine the location of any current or historic weather or hydrologic stations and data sets on the island and obtain copies of available data sets. Review/inventory existing literature on meteorologic/hydrologic monitoring or research that has been done in the past on the island. Conduct a problem analysis of the park and its island setting to determine specific climatic or hydrologic questions that must be addressed and develop a specific set of objectives for the inventory and monitoring system. What is the climatic/hydrologic character of the island? What impact has development had on hydrology, both subsurface and surface? What are current and projected groundwater withdrawals? Will the "standard" meteorologic/hydrologic monitoring system provide the data needed for any currently foreseen questions? Are there specific climatic or hydrologic issues in this park or elsewhere on the island that should be addressed with specific data collection? Are there past or ongoing research projects that may have applicability to issues in this park?

METEOROLOGIC MONITORING

The minimum long-term monitoring should include daily rainfall and daily maximum and minimum temperature. One such standard station on an island is adequate to characterize the climate. An additional station in the park is not necessary where a U. S. Weather Bureau station is located on the island (e.g. Hatteras Island) or another agency is collecting the needed data.

Rainfall - U. S. Weather Bureau type standard manual rain gauge, mounted according to standard specifications. Check daily early in the morning.

Temperature - Max-min thermometer mounted in standard ventilated shelter. Record maximum and minimum temperatures daily early in the morning.

Other data - where estimates of potential evapotranspiration (ET) may be needed for use in hydrologic models, decisions should be made during the problem analysis process on the potential need for data on ET model parameters. Evaporation pan data or radiation data may be needed to supplement the temperature data.

Recording Instruments - where data on diurnal variation or storm event character is needed, recording instruments may be used. A tipping bucket rain gauge and a thermocouple temperature sensor, as well as other meteorologic or hydrologic sensors, may be connected to one multi-channel data logger. Standardization of such equipment for use on all sites throughout the barrier island parks is important.
HYDROLOGIC MONITORING

Water Use

Where significant groundwater withdrawal is occurring, develop an inventory of all withdrawal points within the park and a procedure for recording seasonal and annual withdrawal. For major water users located on the island outside the park, develop a cooperative effort with state and/or local agencies to inventory withdrawal points and collect seasonal and annual water use data. The fate of sewage effluent (on- or off-island disposal) should be determined also.

Surface Water Features

Develop a general, qualitative description of surface water features, whether surface runoff from the island occurs, and whether development has affected the character of the surface hydrology.

Aquifer Surface (Water Table Elevation)

At least one transect of widely spaced water table wells (500-1000 feet apart) should be installed across the island to monitor the general shape and elevation of the aquifer surface and the impact of seasonal, annual, and long term hydrologic, meteorologic, and sea level variability. Measure water depth in the wells biweekly.

Wetland Hydroperiod, Vegetative Community Vs. Water Table Depth

Locate water table wells with representative vegetation monitoring plots or in critical wetland habitats. Location and number of wells should be planned as an integral component of the vegetation monitoring system. Water table depth should be measured manually once each week, or more often in situations where wetland hydroperiod is a critical issue.

Impact of Groundwater Withdrawal

Where large well fields may significantly alter the water table and adversely affect park ecological resources, a transect of water table wells may be installed to document the seasonal, annual, and long term behavior of the water table in the vicinity of the well field. The number and spacing of the wells will depend on the nature of the well field and the characteristics of the aquifer and the local topography and vegetation. Measure the water table depth once each week.

Water Table Wells

Installation and water table data collection, manual or automatic recording procedures (more detail in next draft).
DATA MANAGEMENT

A standard system for computer management of the meteorologic and hydrologic data should be developed that can be implemented at all the barrier island parks with minimal cost for hardware, software, and personnel training. A standard spreadsheet program is adequate for storage and summarization and is compatible with all current data logger data formats.

REVIEW COMMENTS

Park Resource Managers are requested to provide information in their review comments on the following questions:

1. Objectives - are these objectives appropriate; are there other objectives that should be added to the list?

2. Is there a basic set of meteorologic/hydrologic data that you feel should be standard for all barrier island parks?

3. What are the highest priority climatic and hydrologic issues at your park?

4. What opportunities are available at your park for cooperation with other agencies or private organizations in data collection?
COASTAL PARKS AQUATIC CHEMISTRY MONITORING PROTOCOLS

Gary Rosenlieb
National Park Service
Water Resources Division
1201 Oakridge Dr. - Suite 250
Fort Collins, CO 80525
(303) 225-3500

INTRODUCTION

The Coastal Parks Inventorying and Monitoring Workshop was conducted during the week of August 9, 1992 at Charlottesville, Virginia for the general purpose of exchanging information and progress reports among resource managers, scientists, and management on ongoing monitoring programs in coastal parks in four natural resource areas: water resources (quantity and quality), shoreline dynamics, vegetation, and endangered and indicator species. Workshop session leaders agreed to develop monitoring protocols which, when integrated, would form the minimum coastal parks monitoring requirements for the four subject areas addressed at the workshop. The draft protocol objectives are to:

1. Develop monitoring objectives and goals
2. Establish provisions for obtaining estimates of sample precision
3. Identify trigger points for management action, and
4. Identify quality control and data management protocols,
5. Estimate the cost to the parks of implementing the program

SCOPE

This draft aquatic chemistry monitoring protocol seeks to obtain the stated objectives below, while at the same time develop a protocol for the parks that meets two basic criteria common to any successful monitoring program, those being to: (1) be technically, physically and economically sustainable, and (2) provide timely, useful, and relevant information to management. Unfortunately, more broad-based and objective specific water quality monitoring programs must increasingly rely upon obtaining and utilizing expensive analytical laboratories, a necessity that can increase the economic costs and time commitments for park-operated water quality monitoring programs. Such programs cannot be economically sustained by some, if not most, parks.
At this time the administrative and funding mechanisms to initiate this program are as yet undetermined. Likewise, it is a reality that there is a disparity in what economic and personnel resources the parks can commit to or obtain. Therefore, two monitoring program protocols are presented. The first represents the minimum recommended monitoring program for all coastal parks, and consists of the long term monitoring of easy to collect, but nonetheless important, surface water field measurements for dissolved oxygen, temperature, salinity/conductivity, light penetration and pH. This program can be initiated with a relatively small one-time equipment investment and sustained by park personnel that have received very basic training. This protocol is recommended because it can be implemented by most parks with a minimal investment of time and money by eliminating laboratory costs, while at the same time initiating a monitoring program for a set of parameters that are germane in almost all water quality monitoring programs.

The second protocol augments the recommendations of NPS 75 for Level II Geophysical Resources Inventorying and Monitoring. Adoption of this protocol will require a significantly higher commitment of time and fiscal resources that will most likely have to be supported by increases in the parks' base budgets. However, the additional parameters monitored increases by many fold the chances that certain chemical, physical and/or biological changes in the aquatic ecosystem will be detected and recorded.

OBJECTIVES

Even well planned and conducted water quality monitoring programs will not detect every change, or be responsive to every unforeseen emergency that may impact the aquatic ecosystem. However, water quality monitoring can be a means for understanding the condition of the aquatic resources and provide a basis for creating effective policies to improve the condition of the resource. Effective monitoring can answer critical questions about current water-quality conditions, long term trends of improvement or degradation, and determine the success of existing pollution control and resource management programs. Within this context, it is recommended that the following water monitoring objectives be adopted for the coastal parks I and M program:

1. Define the existing water quality status, and identify existing and emerging water quality problems by maintaining a long-term monitoring program.

2. Identify water quality trends by establishing a long-term data record

3. Provide timely information and interpretations to management to support development and implementation of NPS policies and programs

4. Measure the success of park, state, or locally initiated water quality improvement policies, programs, and projects.
MINIMUM RECOMMENDED PROGRAM

This protocol for conducting field measurements of chemical and physical indicators of water quality is recommended as the minimum for all park monitoring programs. It is designed so that it can be conducted long-term solely by trained park personnel without acquiring expensive professional analytical services.

Parameters and Methodologies

The parameters, methodologies, and precision goals that are recommended for all marine, estuarine, riverine, and lacustrine environments in coastal parks are presented in Table 1. References for detailed methodology descriptions are: Methods of Seawater Analyses by Grasshoff, Ehrhardt, and Kremling, Standard Methods for the Examination of Water and Wastewater, by the American Public Health Association, and The National Handbook of Water-Data Acquisition by the Office of Water Data Coordination. NOTE: The above references contain detailed descriptions of methodologies that can be used more extensively in the final protocol.

TABLE 1- PROPOSED MINIMUM MONITORING PARAMETERS AND PRECISION GOALS FOR COASTAL PARKS WATER CHEMISTRY MONITORING

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>METHODS</th>
<th>UNITS</th>
<th>DETECTION LIMITS</th>
<th>PRECISION GOALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Oxygen</td>
<td>Electrometric Oxygen Probe and Electrode</td>
<td>mg/l</td>
<td>&gt; 0.1 mg/l</td>
<td>5%</td>
</tr>
<tr>
<td>Ph</td>
<td>Electrometric: glass electrode and expanded range pH meter</td>
<td>pH units</td>
<td>-</td>
<td>+0.1 pH unit</td>
</tr>
<tr>
<td>Conductance Salinity</td>
<td>Conductivity bridge and meter: Salinity determined by conversion</td>
<td>umhos/cm</td>
<td>-</td>
<td>1%</td>
</tr>
<tr>
<td>Temperature</td>
<td>Mercury Filled Thermometer or Ancillary thermistor on oxygen and conductivity meters</td>
<td>Degrees Celsius</td>
<td>-</td>
<td>0.1 Degree</td>
</tr>
<tr>
<td>Light Penetration (Estuarine and marine)</td>
<td>Spectral Density Recorder/</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Field Procedures

1. Marine and Estuarine Monitoring Site Locations: Monitoring site selection for marine and riverine environments is based on surrounding land uses, known or suspected problems, locations of sensitive aquatic habitats, and availability and access to relatively unimpacted control areas. Ultimately, site selection is, therefore, park specific and should be conducted in consultation with water quality professionals. In general, monitoring sites in marine and estuarine environments should be established near freshwater inputs on either side of the salinity gradient. Where practical and reasonable, at least two longitudinal transects should be established perpendicular from the shoreline to the 10 meter depth contour of the aquatic environment being monitored. Each longitudinal transect should consist of three vertical profile sampling stations that collect surface, midwater, and bottom field measurements at the following water column depths as referenced to bathymetric contours:

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MEASUREMENT DEPTHS FROM SURFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface</td>
</tr>
<tr>
<td>Shoreline</td>
<td>0.5 m</td>
</tr>
<tr>
<td>Five Meter Contour</td>
<td>0.5 m</td>
</tr>
<tr>
<td>Ten Meter Contour</td>
<td>0.5 m</td>
</tr>
</tbody>
</table>

2. Riverine: Where practical, field measurements in rivers and streams should be conducted in mid-stream where there is appreciable water flow, not in stagnant pools or slackwater areas. Measurement points should be 0.5 m below the surface. Also, where practical and reasonable, measurements of stream discharge should be collected.

Monitoring Frequency

Several monitoring frequency scenarios are justifiable depending on the park-specific monitoring objectives. Monthly measurements are sufficient at sites where, based on experience, little variation over time is expected. A diel study (or measurements collected for two-hour intervals over two full tidal cycle) should be conducted once annually at one marine and/or estuarine location. In addition, sample collection times should be standardized to conform to a consistent physical occurrence in the environment; such as one hour before high tide, at high or low tide, or, one hour after low tide. Other time conventions may be suitable depending on the overall monitoring objectives.
Data Management

Data should be entered into the Water Resources Data Management System, a PC based water quality data manager for parks (in development). In addition, the data should be uploaded to EPA's STORET, a national water quality database.

Management Triggers

Management action may be indicated when any of the measurements exceed EPA's published Water Quality Criteria.

Personnel Requirements and Equipment Costs

1. Personnel: The level of effort required to collect the recommended field measurements is park specific, and will depend on travel time to get to the sampling locations, the number of monitoring sites, and time spent per station. Sufficient office time should also be allotted for equipment calibration and repair, and data management. Overall, a park with about 5 to 10 field stations should expect to expend about 3 work days per month, or about 1.5 workmonths per year, to complete the minimal recommended program.

2. Equipment: Assuming that a park needs to purchase new equipment to implement the program, (and the park has access to other essentials such as a personal computer for data management) the total estimated one-time equipment cost per park is:

   Dissolved Oxygen Meter ........................................... $1500
   Salinity, Conductivity and Temperature Meter ..................... $1800
   Expanded Range pH meter ........................................ $ 500
   Spectral Density Recorder ......................................... $3000
   Calibration chemicals ......................................... $ 150
   Van Dorn Bottle ............................................... $ 250

   TOTAL ................................................................. $7200

NOTE: Note for I & M team: Computerized integrated units, such as a Hydrolab Scout that measure and record DO, EC, Salinity, and Temperature to a computer readable ROM pack are worthy of discussion. They would be more expensive, but the overall quantity of equipment would decline. Also, long-term fixed station monitoring with these units is possible. Thus measurements could be collected and recorded at almost any pre-programmed time interval. However, our experience in saline environments at CANA indicates that barnacle fouling of the probes can be a problem.
NPS 75 PROGRAM

This draft protocol presents the methodologies that would be required to implement the recommended NPS 75 aquatic chemistry monitoring program. Adoption of this program would require that the park acquire the services of a competent analytical laboratory, and would increase both the fiscal and personnel resources that a park would have to annually commit to a long-term monitoring program.

Parameters and Methodologies

The parameters of interest include all off the field measurements presented in the minimum recommended program plus the chemical and bacteriological parameters listed in Table 2. This list reflects the recommendations in NPS 75 with appropriate notations for salt and fresh water environments.

Field Procedures

1. Monitoring Sites: See the general guidance given under the minimum recommended program.
2. Water Sample Collection Procedures: Water samples should be collected in low density polyethylene bottles that have been acid-washed and rinsed three times with deionized water. At the sampling site, bottles and caps should be again rinsed three times with stream, ocean, or estuarine water prior to taking the sample. Collect the sample and add any preservatives that are required by the analyses methodology protocol. The samples should then be packed in coolers with a refrigerant that will maintain the samples at 4 degrees C until they are analyzed.
3. Quality Assurance/Quality Control: At least 20% of all sampling and analyses should be conducted in duplicate to provide an indication of the uncertainty associated with the sampling and analyses procedures. Additional quality assurance protocols that should be used are analyses of sampling replicates, blanks, and EPA traceable reference standards.
4. Field Measurements: The field measurements as described in the minimal program should be collected at each water sample monitoring site.

Sampling Frequency

All chemical parameters should be collected and analyzed quarterly. Field measurements should be conducted on a monthly schedule.

Data Management

See recommendations for the minimum recommended program.
Personnel Requirements and Equipment and Laboratory Costs

1. Personnel: The level of effort required to implement this program depends upon the same factors that were presented in the minimal program. Additional time above and beyond that estimated in the minimal program should be allotted for field time and data management. A park that is monitoring 5 - 10 permanent stations should plan on expending 4 work days per month, or about 2.5 workmonths per year to run this program long-term.

2. Equipment: Assuming that a park needs to purchase new equipment to implement the program, (and the park has access to other essentials such a personal computer for data management) the total estimated one-time equipment cost per park is:

   Dissolved Oxygen Meter ........................................ $1500
   Salinity, Conductivity and Temperature Meter ........ $1800
   Expanded Range pH meter ................................ $ 500
   Spectral Density Recorder ................................... $3000
   Calibration chemicals ........................................... $ 150
   Van Dorn Bottle ................................................... $ 250

   TOTAL ....................................................................... $7200

3. Laboratory Costs: Laboratory costs are highly variable, and will depend again on the number of sites monitored, the final parameters list selected, and the quality of the laboratory that is used. However, for planning purposes, a good estimate to use is $500 per sample. Thus, if a park is monitoring 10 sites quarterly, annual laboratory costs would be $20,000.
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>METHODS</th>
<th>UNITS</th>
<th>DETECTION LIMITS</th>
<th>PRECISION GOALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkalinity*</td>
<td>Gran's</td>
<td>ueq/l</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>Chloride*</td>
<td>Ion Chromatography</td>
<td>mg/l</td>
<td>0.01</td>
<td>5%</td>
</tr>
<tr>
<td>Sulfate*</td>
<td>Ion Chromatography</td>
<td>mg/l</td>
<td>0.05</td>
<td>5%</td>
</tr>
<tr>
<td>Nitrate*#</td>
<td>Ion Chromatography</td>
<td>mg/l</td>
<td>0.005</td>
<td>10%</td>
</tr>
<tr>
<td>Sodium*</td>
<td>Atomic Adsorption Spectrophotometry</td>
<td>mg/l</td>
<td>0.05</td>
<td>5%</td>
</tr>
<tr>
<td>Calcium*</td>
<td>Atomic Adsorption Spectrophotometry</td>
<td>mg/l</td>
<td>0.01</td>
<td>5%</td>
</tr>
<tr>
<td>Potassium*</td>
<td>Atomic Adsorption Spectrophotometry</td>
<td>mg/l</td>
<td>0.01</td>
<td>5%</td>
</tr>
<tr>
<td>Magnesium*</td>
<td>Atomic Adsorption Spectrophotometry</td>
<td>mg/l</td>
<td>0.01</td>
<td>5%</td>
</tr>
<tr>
<td>Total Phosphorous*#</td>
<td>Atomic Adsorption Spectrophotometry</td>
<td>mg/l</td>
<td>0.01</td>
<td>5%</td>
</tr>
<tr>
<td>Total Nitrogen*#</td>
<td>Kjeldahl</td>
<td>mg/l</td>
<td>0.01</td>
<td>5%</td>
</tr>
<tr>
<td>Ammonium*#</td>
<td>Indophenol Blue Technique</td>
<td>mg/l</td>
<td>0.01</td>
<td>5%</td>
</tr>
<tr>
<td>Silica*#</td>
<td>ICP</td>
<td>mg/l</td>
<td>0.05</td>
<td>5%</td>
</tr>
<tr>
<td>Phosphate*#</td>
<td>Molybdenum Blue Technique</td>
<td>mg/l</td>
<td>0.002</td>
<td>20%</td>
</tr>
<tr>
<td>Dissolved Organic Carbon*#</td>
<td>Infrared spectrophotometry</td>
<td>mg/l</td>
<td>0.1</td>
<td>10%</td>
</tr>
<tr>
<td>Enterococcus#</td>
<td>Membrane Filtration</td>
<td>col/100mls</td>
<td>-</td>
<td>10%</td>
</tr>
<tr>
<td>E. coli*</td>
<td>Membrane Filtration</td>
<td>col/100mls</td>
<td>-</td>
<td>10%</td>
</tr>
<tr>
<td>Fecal Coliform*</td>
<td>Membrane Filtration</td>
<td>col/100mls</td>
<td>-</td>
<td>10%</td>
</tr>
<tr>
<td>pH (lab)</td>
<td>Electrometric: Glass Electrode and expanded range pH meter</td>
<td>pH units</td>
<td>-</td>
<td>+0.1 pH unit</td>
</tr>
<tr>
<td>Conductance Salinity (lab)</td>
<td>Wheatstone Bridge</td>
<td>umhos/cm</td>
<td>-</td>
<td>1%</td>
</tr>
</tbody>
</table>

* - Parameter recommended for fresh water systems
# - Parameter recommended for salt water
INTRODUCTION AND OVERVIEW

Biodiversity Studies

In recent years, the emphasis in conservation biology has shifted away from an emphasis on protecting selected endangered or threatened species towards a broader appreciation for the need to preserve functional ecosystems. This approach, known popularly as biodiversity, has attracted considerable attention from both the academic and management communities (Wilson, 1985, 1988). Currently, at least 18 federal laws potentially mandate federal agencies to maintain biological diversity (Breininger et al., 1992; NPS-75, 1992). Such increasing emphasis on biodiversity makes reliable inventory and monitoring programs (hereafter I&M programs) of critical importance to land managers and federal and state resource agencies. Without detailed information on the distribution, habitat requirements, and abundance of native biotas, resource managers may only preserve that portion of the fauna which is highly visible or economically important (Bogan et al., 1988). Clearly, I&M programs are likely to be a high priority for resource managers over the next several years.

Key Issues in Developing Inventory and Monitoring Programs

The NPS has invested considerable time and effort in determining how to design and implement I&M programs (e.g., Anonymous, 1990; Silsbee and Peterson, 1991; NPS-75, 1992) and it is not our intention to repeat information contained in these documents. However, there are a number of critical issues that require specific attention in developing any scientifically valid I&M program, and we discuss some of these issues below.
1. Balancing the relative importance of I&M programs for endangered species versus overall biodiversity:

As noted previously, conservation and resource management plans have emphasized endangered and threatened species, but this emphasis is changing rapidly. Although federal agencies will continue to be mandated under the Endangered Species Act to manage federally-listed species, it is expected that increasing attention will be placed on those species critical to ecosystem function, regardless of their legal status. In addition, because the federal-listing process has traditionally favored birds and mammals, an emphasis on biodiversity may mean a shift towards other taxonomic groups, such as invertebrates, fish, amphibians, and reptiles. These are groups that have received relatively limited ecological study (Gibbons, 1988); even basic inventory lists for some groups may not be available for most parks, and expertise to develop such lists may not be available using NPS personnel. Consequently, developing I&M programs for these groups may require considerable outside expertise (see below).

2. Setting Priorities in Selecting Groups for I&M Programs:

Determining what groups should be selected for I&M programs represents a critical, but difficult, decision (see review by Anonymous, 1990 and Silsbee and Peterson, 1991). Both of these papers ranked rare and endangered species as a first or second priority, and groups important in ecosystem function as a second priority. Although a logical ranking scheme, this presents two problems. First, knowledge of what groups or species are ecologically important or dominant is often lacking, or is based on inadequate data. For example, few resource managers would guess that salamanders are the dominant vertebrate in terrestrial ecosystems, yet this was the case in the classic Hubbard Brook study (Burton and Likens, 1975; see below for more details). Secondly, using ecological importance as a criteria for I&M studies can lead to a "Catch-22 situation"; groups are selected as a priority for I&M programs based on their ecological importance, but their ecological importance cannot be determined until the I&M program is complete. This makes selecting priorities for I&M programs difficult, indeed.

3. Integrating Inventory and Monitoring Programs:

Recent discussions of I&M programs (Anonymous, 1990; Silsbee and Peterson, 1991) have discussed the need for long-term monitoring of resources, and we certainly concur. However, monitoring programs raise another set of issues that require attention and discussion. For example, should inventory and monitoring programs be considered distinct entities,
or should they be integrated? In other words, when setting out to inventory a particular resource, should a monitoring program already be designed, or should the results from the inventory determine whether a monitoring program is warranted? The latter approach would seem to be preferable, as it focuses monitoring efforts on those species or groups suitable for long-term study. However, this would lead to a perhaps significant lag time between the end of the inventory program, and the onset of monitoring.

4. Role of Academic Biologists in I&M Programs:

National Parks are commonly used as sites for ecological research by academic biologists. Frequently, academic biologists have expertise in areas and taxonomic groups that the Park Service needs badly. However, most studies conducted by academic biologists have not been part of a systematic research effort (Anonymous, 1990). Consequently, differences in methodologies, data analysis, and poor database management means that comparisons between studies and parks are difficult (Anonymous, 1990). The value of these studies for I&M programs is thus reduced.

We suggest that academic biologists should be utilized in I&M programs in a more systematic and coordinated manner than has previously been the case, preferably in the planning stages of an I&M program. This would not only add to the expertise necessary for a comprehensive I&M program, but would also aid in assuring compatibility of study design and data.
PROTOCOLS FOR ESTABLISHING I&M PROGRAMS FOR ENDANGERED, THREATENED AND INDICATOR SPECIES

Program Goals

The basic program goals for any I&M program for endangered or indicator species should be as follows:

1. Provide the NPS with a quantified inventory of the group or species selected

2. Provide an evaluation of the field survey techniques to determine their suitability for use by NPS personnel

3. Determine species-specific habitat requirements

4. If appropriate, develop a long-term monitoring program suitable for the Southeastern Coastal Parks.

Overall Program Requirements

We suggest that any I&M program for endangered, threatened, or indicator species should have the following specific program requirements. Programs that fail to meet these requirements should not be implemented, or should be revised prior to initiation.

1. I&M programs must be scientifically valid:

   The sampling protocols and data analyses used for any I&M programs must follow current or standard practices in the appropriate field (i.e., herpetology, mammalogy, ornithology etc). The basic standard should be that the methods and procedures used are repeatable by other researchers. In addition, the methods and data reduction procedures should be subject to anonymous peer review.

2. Data collected during I&M programs must be quantified and contain error estimates:

   Turner (1990) has discussed the need for providing estimates of precision for any valid I&M program, and we concur. Although some aspects of I&M programs are basically qualitative (e.g., simple species lists), most of the data collected should be quantified, and contain estimates of precision. For example, species can be ranked according to their overall relative abundance, and their abundance within habitats can also be estimated. Quantification and error estimates are even more critical when designing and evaluating monitoring programs, which can be used to track long-term changes in abundance and habitat utilization.
3. Data management must be a critical concern:

In order to be useful, I&M programs must incorporate a mechanism for easy information retrieval. Without an appropriate design for data management, retrieval of information collected by I&M programs becomes difficult, if not impossible. Some aspects of data management are obvious, such as mandating use of standard database programs (e.g., DBASE III+), but it is critical that careful thought be given to (a) the frequency with which current data sets are archived, (b) keeping copies of data sheets and field books, and (c) providing the NPS with a detailed data management guide, listing all abbreviations used, the accuracy with which data were recorded, etc. This should be an area of careful review prior to funding.

Minimum Requirements for Inventory Programs

1. Contact with local NPS Personnel:

If inventories are to be conducted by outside academic personnel (as is likely to be the case for many endangered and indicator species), it is critical that inventories be designed with the cooperation and input from local park personnel. The first step in designing a basic inventory should therefore be detailed discussions between NPS personnel and any outside investigators to determine the specific goals of the inventory. The next step is the establishment of clear commitments on the level of support that will be provided by the NPS.

2. Detailed Literature Reviews:

In many coastal parks, considerable baseline data may be available in both published and unpublished reports, master's theses, doctoral dissertations, etc. It is critical that these data be retrieved and reviewed; although it may not be possible to use such information in a quantitative manner, these data may still be highly useful in establishing study areas, determining valid field techniques, and in suggesting long-term trends in population abundance. Literature reviews should be conducted using both on-line systems (e.g., BIOSIS), via contacts with local universities, and by inspection of NPS files.
3. Establishment of study sites and field techniques:

Once the specific goals of the study have been established, the level of participation by the NPS has been determined, and appropriate literature reviews have been conducted, field work can commence. It is critical that both field sites and techniques be chosen carefully. For example, field sites should be established in a coordinated manner with other ongoing I&M programs, especially those concerned with vegetation analyses. Although this may not be possible in all cases, linking study plots allows potentially important correlation's between habitat changes and inventory results.

Selection of field techniques also calls for careful consideration. Although field techniques have become relatively standardized for some taxonomic groups, two restrictions must be recognized. First, the costs of some techniques (in terms of both funds and manpower) may be higher than is feasible. As an example, drift fences are the most effective technique for sampling amphibians and reptiles, but requires a considerable investment in both money and time. Training, to reduce observer variability when inventorying groups such as shorebirds, can be a substantial and continuing cost. In addition, some field techniques may be inappropriate for use on coastal parks, especially in areas which receive considerable public use. Examples include many kinds of live-traps, which cannot be easily disguised. This represents a difficult decision; failure to use specific techniques as a result of public concern may result in incomplete or possible biased results.

Establishing Monitoring Programs

1. Selecting target species:

Once inventory programs have been established, consideration should be given to initiating monitoring programs. As noted previously, deciding what resources should be monitored is a difficult decision. Clearly, monitoring programs cannot be established for all resources, even those which were part of inventory programs (Probst and Crow, 1991; Silsbee and Peterson, 1991) Perhaps the most criteria for selecting species for monitoring is whether the data necessary for making valid statistical comparisons can be collected (Turner, 1990). Without a valid statistical framework, making conclusions from monitoring programs is not scientifically valid. Because endangered or threatened species obviously may exist at relatively low densities, their suitability for monitoring programs may be low. Hence, monitoring programs may need to focus on relatively common species that are more amenable to statistical comparisons.
2. Monitoring endangered and threatened species:

The above discussion does not mean that endangered and threatened species cannot or should not be the target of monitoring programs. In addition to legal requirements, some endangered species may exist in sufficient numbers so that appropriate monitoring programs can be implemented. Examples in the coastal parks include sea turtles and Piping Plovers. In both cases, standard techniques exist for monitoring which allow valid statistical comparisons. Sea turtles can be monitored using nest counts and crawl counts on selected beaches (WATS, 1980). Such programs have been established at many of the coastal parks, so a long-term database is already available.

3. Guidelines and responsibilities:

Guidelines and responsibilities for carrying out a monitoring program must be clearly defined before any program is initiated. Guidelines include: the frequency of monitoring, methods to be used, the duration of the monitoring program, and the criteria to be used to evaluate if the program should be modified, continued or terminated. Responsibilities include: determining who will conduct the monitoring, who will fund the monitoring, who will manage and interpret the data, and who will periodically evaluate the program. These guidelines and responsibilities should be stated explicitly in a monitoring plan and implemented through a combination of contracts, agreements, performance standards and the park's resource management plan.
AN I&M PROGRAM FOR AMPHIBIANS AND REPTILES: A MODEL APPROACH FOR SOUTHEASTERN COASTAL PARKS

Rationale

Reptiles and amphibians are important, yet often ignored, components of terrestrial and aquatic ecosystems (Gibbons, 1988; Vitt et al., 1990). Because of their ectothermic physiology, amphibians and reptiles have extremely low energy requirements, and, consequently, may have a biomass that exceeds that of nearly all other vertebrates in aquatic and terrestrial ecosystems. For example, Burton and Likens (1975) found that salamanders had the highest biomass of any vertebrate group in a forest ecosystem in the northeastern United States. A more graphic example of the potential value of amphibians in terms of energy flow was provided by Gibbons and Semlitsch (1991), who found up to 600,000 frogs of a single species (leopard frogs, *Rana sphenocephalia*) emerging from a 10 ha pond in South Carolina in a one month, including 40,000 individuals in a single day (J. Gibbons, pers. comm). At 25 g per individual, this means that predators in the vicinity of the pond received an energy pulse of at least 15,000 kg in one month. Reptiles also achieve impressive densities, with a maximum biomass of up to 583 kg/ha in herbivorous turtles and 27 kg/ha in lizards (Iverson, 1982). The maximum estimates for turtles exceed those for all other vertebrates except salamanders and some fish (Iverson, 1982). Thus, although their role is rarely appreciated (mainly due to lack of comprehensive studies), reptiles and amphibians may be among the most important components of terrestrial and aquatic ecosystems (Scott and Seigel, 1992).

Amphibians and reptiles also have a surprisingly high economic potential; minimum wholesale values have been estimated at over $35 million per year in Louisiana alone (Louisiana Dept. of Wildlife and Fisheries, 1992), and the value of amphibians and reptiles imported into the U. S. exceeds $400 million annually (Scott and Seigel, 1992). These characteristics have led to increasing recognition of the need for collecting better data on the biodiversity and ecology of amphibians and reptiles, both on the part of the academic community and by natural resource managers (Scott and Seigel, 1992).

Very little is known about the herpetological communities within the boundaries of the Southeastern Coastal Parks, especially at Gulf Islands, Canaveral, Cape Lookout, and Cape Hatteras. For example, at Gulf Islands, current species lists have been compiled from casual observations or field guides; estimates of diversity, abundance, and the status of state and federal endangered or threatened species are almost completely absent. To a large extent, the same situation exists for the other Southeastern Coastal Parks; the mean Biological Inventory Status scores for amphibians (11.2) and reptiles (10.4) are the highest for any of the vertebrate or plant groups in the Southeastern Coastal Parks (unpublished NPS data).
Objectives

Clearly, the absence of a quantified, in-depth study of the herpetofauna of Gulf Islands National Seashore means that any species list would be mainly supposition, and would certainly be inadequate to act as the sound basis for a resource management program. The I&M program outlined here will provide the kind of quantified database necessary for such a management program. The specific goals of our I&M program are as follows:

1. To provide the NPS with a detailed species list of the amphibians and reptiles present in each park
2. Determine the habitat requirements of those species
3. Provide an evaluation of the field techniques needed for a comprehensive I&M program for amphibians and reptiles in the southeastern coastal parks
4. Provide the foundation for a long-term monitoring program that can be operated by NPS personnel.

Approach and Protocol

Our basic approach for designing an I&M program for amphibians and reptiles in the Southeastern Coastal Parks emphasizes a cooperative effort between the NPS and academic personnel. In our view, ongoing, long-term I&M programs cannot be run solely by either group. Academic biologists can provide expertise and guidance for specific taxonomic groups, but probably cannot be involved on a long-term basis (at least not with a full-time commitment). Conversely, NPS personnel can provide an ongoing commitment to the program, but may need support and expertise from outside biologists.

The I&M program for amphibians and reptiles of the National Seashores has the following major goals:

1. Provide the NPS with a quantified inventory of the herpetological communities present on Gulf Islands, with more limited field work at Canaveral
2. Provide an evaluation of the field survey techniques to determine their suitability for use by NPS personnel
3. Determine species-specific habitat requirements
4. Conduct literature surveys for all the units in the Southeastern Coastal Parks
5. Develop a long-term monitoring program suitable for the Southeastern Coastal Parks.
Logically, these goals can be accomplished in two major phases: an inventory phase (subdivided into four tasks) and a monitoring phase, each of which is described below. However, because the program is designed to meet the specific needs of individual units, the methodology outlined below is designed to be as flexible as possible.

Inventory Phase

The inventory phase of the program is designed to meet the first four goals noted above, and is sub-divided into four major tasks. Field work at local sites is the last priority of the inventory phase. This reflects the need to determine the availability of previous data on biodiversity of herpetological communities at these sites, and to get input from local NPS personnel on the individual needs of each site.

1. Contact with local NPS personnel-- As noted above, this program can only succeed with the cooperation and involvement of local NPS personnel. Such contacts would be best made by visits to the individual seashores. Contacts would allow local NPS personnel to provide input into the planning of the field work, allow access to historical records of past surveys (which are often unpublished and available only as letters or unpublished reports), and allow inspection of potential field sites.

2. Literature Reviews-- Although faunal inventories are frequently unpublished, considerable data on herpetological communities may be available. We will initiate a thorough literature review using both BIOSIS and manual searches to determine the availability of inventory data for each site.

3. Contact with State and University Personnel-- In addition to literature searches, we will contact personnel at both state agencies (e.g., Natural Heritage Offices), and nearby university faculty to determine the availability of any existing survey data for each site. From past experience, it is likely that university faculty may have considerable unpublished data available. Natural Heritage Programs frequently have large databases of localities for amphibians and reptiles.

4. Field Work - Once the above tasks have been accomplished, field work can begin. The timing, duration, and methods used for each field inventory will depend on the availability of funding, the availability of previous surveys, input and degree of participation from local NPS personnel, and the size and nature of each Seashore. See the section on Methods for details of the collecting techniques to be used.

Monitoring Phase

The final overall goal of this program is to establish a quantified monitoring program for amphibians and reptiles at each site. Such a program will allow determination of temporal variation and changes in population sizes and habitat utilization of selected
species of amphibians and reptiles. This will facilitate determination of impacts of NPS operations on selected species, and will be critical in determining what management steps need to be implemented for rare or endangered species.

The species or communities selected for the monitoring programs will vary widely among sites. Obvious candidates for monitoring include Federally-listed species, critical or keystone species (as determined by the inventory phase), or species selected because of abundance and ease of sampling. The decision as to which species or communities should be monitored will be made jointly by local NPS personnel, the NPS regional office, and Southeastern personnel. The techniques used for monitoring will be selected from the same basic set used for the inventory phase (see Table 2 and section on Methods).

Timing and Duration of Studies

Predicating the exact amount of time for each phase of the study is difficult. The timing of the first four tasks of the inventory phase will depend on the access to unpublished information, input from local NPS personnel, and cooperation from state and university personnel. Timing and duration of the field phase is also unpredictable, depending on the size and complexity of the site, the degree of participation of local NPS personnel, and weather conditions. The minimum duration of the field inventories would be a complete field season (approximately January-July and November-December). Data from a second season would reduce the probability that uncommon or rare species were missed.

The monitoring phase would be expected to begin after either the first or second complete field season. Our basic concept is that the monitoring program would be initially set up and run by personnel from Southeastern, with input and cooperation from NPS personnel. After a full season of monitoring, NPS personnel would be expected to run the program, with support and input from Southeastern.

Park Participation

Participation from the NPS will be an essential component of this study, especially considering the eventual goal of establishing a long-term monitoring program of the reptiles and amphibians of the Southeastern Coastal Parks. To this end, we envision a cooperative research program, where faculty and students from Southeastern will help NPS personnel learn how to capture, identify, and work with reptiles and amphibians in exchange for assistance in operating the inventory.
LITERATURE CITED


Systematic protocols for assessing the diversity and abundance of coastal waterbird populations in National Seashores are lacking. These birds are often the most common vertebrate species in these parks and their populations are thought to serve as indicators of benthic and nearshore productivity. Several species including Snowy (Charadrius alexandrinus) and Piping Plovers (Charadrius melodus) and Gull-billed Terns (Gelochelidon nilotica) are currently listed as threatened, endangered, or species of special concern due to declining populations. For these reasons, the need for monitoring coastal waterbirds has been identified in the resource management plans of most coastal parks.

This discussion will present examples from a monitoring program developed at Gulf Islands National Seashore in 1990 and 1991. The program developed a monitoring handbook and tested protocols at several locations in the Seashore. We have selected examples from the monitoring handbook and an annual summary report to provide examples of how a monitoring program for coastal waterbirds could be structured, the types of data that can be obtained, and how they can be analyzed.

Sections from the monitoring handbook are presented first (pages 17-33). The handbook was based on the format used at Channel Islands and provides an example of a "cookbook" approach to a monitoring protocol. The handbook describes the program's objectives and methods, provides reference materials for training observers, and suggests formats for data management and analysis. A document of this sort could be expected to evolve with use and be tailored to the resources and management objectives of individual parks. For example, we no longer use the database referred to in the handbook having found graphical spreadsheet programs like Microsoft Excel to be much simpler and more versatile for storing, analyzing, reporting, and sharing these types of data with other database or statistical software. To reduce the amount of material presented, sample reference materials have only been provided for two species, the Willet and the Laughing Gull.

Following the handbook is a sample summary report produced at Gulf Islands (pages 34-60). The report illustrates the types of analyses that are possible using the protocol and how they can be interpreted. A data archiving scheme is provided as are sample results for the Willet and Laughing Gull.

Finally, census data are used to analyze sampling precision for Willets and Laughing Gulls (pages 61-71). The results illustrate how the variability of populations in time and space will constrain the interpretations that can be made of census data and factors to consider when selecting species for monitoring.
Coastal Waterbird
Monitoring Handbook
Gulf Islands National Seashore

TED SIMONS
MARK WOODREY

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OCEAN SPRINGS, MS 39565
INTRODUCTION

This monitoring handbook has been compiled to assist the park staff of Gulf Islands National Seashore in assessing changes in population levels of waterbirds. The objectives of this monitoring program are four-fold:

1. To provide a species inventory of coastal waterbirds of Gulf Islands National Seashore.

2. To provide quantitative counts of individuals appropriate for the long term monitoring of population levels.

3. To provide data on the distribution of habitats important to coastal waterbirds.

4. To provide data concerning the status, abundance and distribution of two species of threatened shorebirds, the Snowy Plover (Charadrius alexandrinus) and the Piping Plover (Charadrius melodus).

We hope that this handbook will assist park staff in meeting these objectives and provide park managers with the information needed to make decisions about this important park resource.

MONITORING DESIGN CONSIDERATIONS

The degree of resolution and the effort required to detect changes in waterbird populations was a major consideration in the design of this monitoring program. The technique employed in this program allows the determination of absolute densities with minimum effort. The use of absolute densities over relative density estimates when monitoring populations is preferable. Although actual numbers of birds are counted in either situation, local population distributions and movements may require interpreting census data as relative rather than absolute. The interpretation of census data attempts to account for the variability due to local population distributions and movements, thus reducing the "error" in the population estimate. The variability in the estimate could potentially bias the estimate, rendering the data suspect for monitoring waterbirds at the population level.

The most appropriate method for sampling waterbirds along a coastline is to utilize a linear density transect scheme. Conditions for the census are set prior to conducting the census which allows for the calculation of absolute linear densities along shorelines. In coastal areas, the most important decisions concern the tidal conditions. Setting these conditions is central to intertidal waterbird census-taking because shorebirds move between habitat areas on a tidal schedule, and the area of available habitat changes on a tidal schedule. For foraging birds on mudflats or sandflats, a falling tide is best because the birds have been denied access to feeding areas during the previous high tide. However, if very low tides expose extensive feeding areas, birds may forage too far from observation points along shorelines. In this case, a mid-tide level may be more practical. For censusing birds on a beach or roosting sites, a very high tide may be best, because this forces birds out of foraging areas and concentrates them in restricted areas. Also, at Gulf Islands National Seashore, beach erosion and dune vegetation destruction are major resource concerns. Because tidal extremes are minimal at Gulf Islands and upland roost sites are rare, the optimal time for censusing waterbirds is several hours before low tide.

The frequency and duration of censusing should be established prior to conducting censuses. During the summer and winter when waterbird populations show minimal fluctuations, less frequent censusing is required. During periods of major migrations (spring and fall), censuses should be conducted more frequently to determine peak movements. The duration of the census should be kept as short as possible to minimize variability due to local movements and the possibility of double counting.

There are at least 56 species of waterbirds found in Gulf Islands National Seashore (Appendix A). These include loons, pelicans, herons, waterfowl, shorebirds, gulls and terns. Of these, only 14 species breed in the park (Appendix A).
several species (Table 1) to be used as indicator species. We based our selection of indicator species on four criteria: (1) abundance of species, (2) representation of different foraging guilds, (3) status, with respect to regional distribution, in the southeast region (4) status, with respect to breeding activity, along the Gulf coast. Data from these indicator species can be analyzed for location-specific differences in distribution and abundance, as well as changes in population levels.

Reproductive data for each of the indicator species should provide relative information on reproductive phenology and operative environmental constraints on all waterbirds in that guild. The species chosen to represent each guild were the most obvious and most easily observed, and should act as indicators for changes in major park resources which might affect all members of that guild. Population parameters to be monitored and methods for sampling of indicator species will be developed and added to future revisions of this handbook.

MONITORING PROTOCOL

SAMPLING METHODS

The objective of the censusing program is to monitor the diversity and abundance of waterbirds in order to detect population changes.

Bi-monthly Census

Materials

* 4-wheel ATV with odometer
* Census data sheet (See Appendix B)
* Pencils
* Binoculars and/or spotting scope
* Bird Field Guide

Personnel

A single observer who is capable of identifying waterbirds by sight (in both breeding and nonbreeding plumages) should be used. To assist the observer, a slide file and field identification notes have been included with this handbook. An observer unfamiliar with any of the birds should carefully review the slides and field notes, and conduct practice sessions (i.e. walk along the beach and practice identifying birds encountered) before attempting an actual census.

Methods

Censuses are conducted at four locations within Gulf Islands National Seashore: (1) West Ship Island, (2) the Perdido Key Unit, (3) the Fort Pickens Unit, and (4) the Santa Rosa Unit (Fig. 1). Specific areas of shoreline to be censused are the entire shoreline of West Ship Island (7 mi, 11.2 km), the south shores of the Perdido Key Unit (6.5 mi, 10.4 km; from the west entrance to the east tip), the Fort Pickens Unit (8 mi, 12.8 km; from the eastern boundary to the west tip), and the Santa Rosa Unit (7.5 mi, 12 km; from the eastern to the western boundary).

Linear Density Transects

The most appropriate method for sampling waterbirds along a coastline is a linear density transect scheme. This sampling method allows for the calculation of absolute linear densities along shorelines.

Birds are identified and counted continually from an ATV while moving parallel to the shoreline. Birds are recorded on prepared data sheets (Appendix B). Only birds from the water line to the primary dunes and out to 200 meters offshore should be counted and recorded. All birds should be tallied for every 0.5 mi (0.8 km) section of beach. At each 0.5 mi (0.8 km) point, the observer should scan the water surface counting and tallying species and number of individuals for a distance of 200 meters offshore.

General Rules for Conducting Census

* Drive the beach at a moderately slow, steady pace. Consecutive counts of the same area should take about the same amount of time.
Pause only to confirm an identification or record birds on the data sheet.

- Record all sightings of waterbirds seen while conducting census (including birds flying over). Count only those birds detected in the area directly to the sides or in front of the observer. Do not count birds detected behind the observer.

- Avoid counting the same bird twice. Keep track of birds as they flush ahead of you. Note where they land or watch them until they fly out of the census area to avoid double counting.

- Birds may be counted if they are on the ground, in vegetation, or in flight. Flying birds may be counted at any height, as long as they are within 200 m of the shoreline.

- Remember: The goal is not the largest count possible but the most accurate count possible. Stick to the methodology outlined above. Do not bend the rules. Do not list a bird unless you are positive of its identification. The accuracy and integrity of the count can only be maintained by minimizing variations in methodology. This is accomplished by rigorously following the established census procedures.

Census Conditions

Censuses should only be conducted if conditions meet the following criteria:

- Visibility greater than 200 m
- Wind is 30 knots or less
- Only one observer conducts each census (no additional persons may accompany the observer)
- The waterbird census must be the first priority of the count. If anything else is done in addition, (e.g. beach patrol), it must not in any way detract from the time and attention you are giving the census, nor should it affect the pace at which you cover the census route.

Schedule for Census

During spring (early April to early June) and fall (late July to late September) migration, counts should be conducted weekly. During the rest of the year, counts should be conducted bi-monthly.

DATA MANAGEMENT

Data Input

The waterbird census data sheet was designed to allow rapid, accurate entry of the data into a database program. Each observer should photocopy the completed data sheet, keeping the copy
for their files, and place the original form in the waterbird data sheet folder for input into the waterbird database. Sample instructions are given for the R:BASE database program.

Data Analysis

After data entry, the data are summarized using tables and graphs for the annual summary report.

Tables

The first table in the annual report is a species inventory list. This table includes the common name for each species, the scientific name and the total number of individuals sighted for the year. The R:BASE command for generating the inventory list is:

```
select species sum numindiv from census
  group by species
```

The second table gives the abundance and occurrence of waterbird species in the Seashore. It includes the species seen (by common name) and the mean number of individuals per survey by location. The R:BASE command to generate these data for West Ship Island is:

```
select section sum numindiv from census
  group by section where location eq wsi
```

The output data are then divided by the number of surveys contributing to the data set to give mean number of individuals per survey.

The next figure is a comparison of the mean number of individuals per section for each species by location. Data for each location and species are generated by substituting the location codes and species codes after "eq" in the command. The R:BASE command to generate these data for Laughing Gulls on West Ship Island is:

```
select section sum numindiv from census
  group by section where location eq wsi and
  species eq lagu
```

The output data are then divided by the number of sections for each location multiplied by the number of surveys to give the mean number of individuals per section.

Figures are also produced for each of the indicator species. One shows the mean number of individuals per section for each location. Data for each species is generated by substituting the location codes (e.g. WSI, PK, FP and SR) after "eq" in the command. The R:BASE command to generate these data for Sanderlings is:

```
select location sum numindiv from census
  group by location species where species eq sand
```

The output data are then divided by the number of sections for each location multiplied by the number of surveys to give the mean number of individuals per section.

The second figure for indicator species shows the distribution of individuals by section for each location. Data for each species and location are generated by substituting the species codes and location codes after the appropriate "eq" in the command. The R:BASE command to generate these data for Laughing Gulls on West Ship Island is:

```
select section sum numindiv from census
  group by section where location eq wsi and
  species eq lagu
```
The output data are then divided by the number of sections for each location multiplied by the number of surveys to give the mean number of individuals per section.

At the end of each 5-year period, a trend analysis should be conducted for each indicator species to determine any changes in the population levels.

**Reporting**

Survey results should be summarized in an annual report. A sample report, summarizing the 1990 surveys is included in this handbook. Briefly, the report consists of written sections including an introduction, methods, results and discussion. Also included are tables showing the survey schedule, a species inventory, and summaries of the abundance and occurrence of waterbirds at Gulf Islands National Seashore. Figures are included which show the distribution of individuals by location, and compare the number of individuals by species and location.

At the end of each 10-year period, data should be summarized and submitted to a peer reviewed publication. Appropriate outlets for these papers include the Wilson Bulletin, the Journal of Field Ornithology, or the NPS Technical Report Series.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>RESIDENCY STATUS</th>
<th>BREEDING STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laughing Gull</td>
<td>year-round</td>
<td>yes</td>
</tr>
<tr>
<td>Royal Tern</td>
<td>year-round</td>
<td>yes</td>
</tr>
<tr>
<td>Willet</td>
<td>year-round</td>
<td>yes</td>
</tr>
<tr>
<td>Snowy Plover</td>
<td>year-round</td>
<td>yes</td>
</tr>
<tr>
<td>Herring Gull</td>
<td>year-round</td>
<td>no</td>
</tr>
<tr>
<td>Black-bellied Plover</td>
<td>year-round</td>
<td>no</td>
</tr>
<tr>
<td>Sanderling</td>
<td>year-round</td>
<td>no</td>
</tr>
<tr>
<td>Human</td>
<td>year-round</td>
<td>?</td>
</tr>
</tbody>
</table>

Table 1. Indicator species and their status.

<table>
<thead>
<tr>
<th>KEY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abundance Codes</strong></td>
</tr>
<tr>
<td>abundant - several individuals per day and/or very conspicuous.</td>
</tr>
<tr>
<td>common - few individuals per day and/or conspicuous.</td>
</tr>
<tr>
<td>uncommon - several individuals per season and/or inconspicuous.</td>
</tr>
<tr>
<td>occasional - few individuals per season and/or very inconspicuous.</td>
</tr>
<tr>
<td>rare - few individuals per year, small localized distribution.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Season of Occurrence</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring: March - May</td>
</tr>
<tr>
<td>Summer: June - August</td>
</tr>
<tr>
<td>Fall: September - November</td>
</tr>
<tr>
<td>Winter: December - February</td>
</tr>
</tbody>
</table>

Table 2. Waterbird abundance codes and seasonal occurrence.
HOW TO IDENTIFY WADERS

There are two basic points which all birdwatchers should bear in mind when identifying waders. Firstly, there is no substitute for getting to know thoroughly the common species. Usually there are only a dozen or so species in this category in any one locality and, once their behaviour, habits, calls and variations of plumage have been learnt, then it becomes much easier to locate and identify the scarce waders. Secondly, by definition, rare waders are very few in number! The great majority seen will be of the commoner species, so when identifying an odd-looking wader it is prudent to consider seriously an unusual individual of a common species before the possibility of a rare one.

Careful unbiased observation is the key to successful identification.

Shorebird topography
Throughout this handbook we use various technical terms referring to the topography of the bird. In order to identify some waders — and especially to determine the age, sex or race — it is important that particular feather tracts or parts of the bird are accurately located and carefully observed. We have followed the standard names now recommended by the authoritative British Birds magazine. The drawings overleaf show these on a typical wader.

Types of patterns found on feathers

Submarginal marks

Notched

Spotted

Dark central wedge

Shaft-streak

Subterminal band

Tipped

Edged

Fringed

Paler towards edge

Frequent reference is given in the species texts to patterns of markings on feathers. Terms such as 'fringed', 'edged' or 'tipped' are not used as alternative descriptions, but have separate meanings. Some typical patterns are illustrated below.

Plumage sequence
Wader identification can be much easier if the observer is aware of the age of the individual. Thus, if a bird of unknown species can be aged as a juvenile, then all adult plumages can be disregarded and only juveniles considered in further attempts to identify the species. Many misidentifications happen needlessly because of the failure to appreciate the age of the bird.

Migratory northern species are normally well synchronised in their breeding seasons, plumages and moults, so that for example it is possible to find a calidrid in full juvenile plumage only during July to November, no matter where in the world you happen to be.

The typical plumage sequence for such a bird is described below. Several systems are in use for naming plumages; we have chosen one which can cope with a worldwide approach. Our 'breeding' and 'non-breeding' correspond respectively to the widely-used American terms 'alternate' and 'basic'. Terms such as 'summer plumage' and 'winter plumage' may obviously lead to confusion when describing species which cross the equator. Where
Once these disappear, the full juvenile plumage is especially on the nape and rear flanks and loosely-structured downy feathers may remain, the breeding area. We are however referring to the season prevailing in we write of 'winter quarters' or 'spring migration', grown almost together, and tend to show a fairly strikingly-patterned feathers. These feathers were characterised by rather small, neat and usually not so strongly structured. In most, if not all, species, juvenile primaries are shorter and narrower than those of the adult and wear more rapidly to a uniform degree of wear and fading (although those most exposed to abrasion and sunlight wear faster). Probably as a result of the physiological strain of growing so many feathers at once, these juvenile feathers all tend to be smaller than those of the adult and not so strongly structured. In most, if not all, species, juvenile primaries are shorter and narrower than those of the adult and wear more rapidly to a pointed shape. In many species, rows of juvenile covers are exposed below relatively small and neat scapulars; this is in contrast to adults, where the large, rather loose scapulars droop over most lesser, median and greater coverts.

**Adult and juvenile. length of scapulars**

Typically, the wing-coverts and back feathers in juvenile *Calidris* species are fringed with whitish-buff or chestnut; in *Tringa* species they are spotted buff or whitish; while in *Charadrius* species they are finely fringed pale buff with a fine subterminal band of darker colour. The plates show these and other patterns. During the period when juveniles are fresh, the adults are at the end of the breeding season and in worn plumage, and so there is great contrast between the ages.

The juvenile plumage is retained for a few weeks, exceptionally up to three months. It is then usually partially replaced by a first non-breeding plumage which at least superficially resembles that of the adult; in the hand it can be seen that most individuals usually retain a number of the characteristic juvenile inner wing-coverts. The juvenile flight feathers are also normally retained and are paler brown, more pointed and more worn than those of adults, owing to a faster rate of abrasion. This age can be distinguished with certainty by field observation only in a few species, although in the hand it is relatively easy. Juveniles of some small and highly migratory species may moult some or all of the primaries as part of the post-juvenile moult, and thus become very difficult or impossible to separate from adults after only about six months.

As the breeding season approaches, birds hatched ten months previously may attain a full breeding plumage indistinguishable from that of the adult. Most larger waders, however, do not breed in their first year, and either retain very worn first non-breeding feathers or moult partially into a very poor version of the breeding plumage. During the latter part of the breeding season, first-year birds undergo a complete moult and enter adult non-breeding plumage. Any retained feathers from the juvenile plumage, including the primaries, are replaced during this moult, having lasted for up to 12 months.

Eventually the adult breeding plumage is attained. In many species (calidrids, godwits and golden plovers, for example), the breeding plumage is dramatically different from the non-breeding plumage: pale underparts may become red, black or strongly barred. Few non-migratory species exhibit great changes in pattern between breeding and non-breeding plumages.

After the breeding season the plumage of adults becomes very worn and is replaced in a complete moult (of both body and flight feathers), which usually takes place later than that of first-year birds.

In some species the two groups of feathers are moulted simultaneously, in others body moult precedes wing moult, while yet others show the opposite pattern. The bird thus returns to its adult non-breeding plumage; this is retained throughout the non-breeding season, which may be as long as nine months. The strong, dark, fresh-looking primary feathers prove to be a good indicator of adults when birds are examined in the hand.

**Other factors affecting colours and patterns**

The changes in appearance of shorebirds are due primarily to the moult sequence as described above, but there are a number of other variables which may cause the birds to look different.

Strong sun, particularly in tropical areas, results in the bleaching of colours, so that buff goes rapidly to whitish and brown becomes pale brown. At its most extreme, one-year-old birds which have not replaced all body feathers can become very pale and 'washed-out'. In addition, bright sun may make a bird appear pale: for example, Western Sandpipers in South America or Little Stints in Africa may look as pale as Sanderlings. As the feathers fade, they become weaker and abrade faster. This contributes to changes in the overall neatness as
well as in the colour of the individual. Abrasion is ultimately the reason why feathers are replaced by moult: they steadily lose their functions of flight, insulation and display. Tertials and scapulars overlap and protect most of the feathers of the wing; being much more exposed to light, they abrade faster than other feather tracts. On all feathers the pale areas (usually fringes or tips) are lost first, and it is only later that the dark central areas start to break down.

Particularly on the upperparts, wear is very important in determining the appearance of birds in breeding plumage. Often, the fresh feathers are tipped grey, and have bright edges and a dark centre; thus the upperparts first appear greyish, then brightly patterned, then blackish towards the end of the season.

Some typical patterns of feather-wear are illustrated:

Moult does not occur randomly, but in a well-defined sequence within each feather tract. Typically, moult starts with the innermost (first) primary and progresses outwards. When primary moult is about half completed, the outermost (first) secondary is dropped and secondary moult progresses towards the body. At this stage, waders in flight show a large gap half-way along the trailing edge of each wing. The loss of flight feathers impairs flying ability, so birds may flap faster in order to keep up speed; this can alter the characteristic 'jizz' of the species. The tertials are replaced soon after secondary moult starts; in most waders, the innermost secondary is then lost and secondary moult proceeds in two directions towards the inner central secondaries. Tail feathers are replaced during the period of secondary moult, mostly from the middle (first) feathers outwards towards the edge of the tail. Typically, primary moult spans the entire period of wing and tail moult. The tertials are frequently replaced again during the partial body moult into breeding plumage.

There are many slight variations in the replacement patterns of flight feathers, but these are detectable only on birds in the hand. The timing of moult depends on many complicated and interrelated factors, such as the age of the individual bird, latitude of its breeding grounds, wintering grounds, timing of breeding season, length of migration, feeding conditions in different parts of its range, etc. Comments made here are, of necessity, generalised summaries and exceptions do occur. Albinism, leucism and melanism all occur in shorebirds. There are many degrees of albinism, with examples ranging from the very rare pure albino (white with pinkish bare parts) to the much more frequent partially albinistic (showing abnormal white patches). Leucistic (colours paler, tending towards dull yellowish-white) and melanistic (colour tending towards black) individuals are generally less frequent than partial albinos, although they occur more commonly among some species (for example, Common Snipe and Eurasian Woodcock) than among others.

During detailed ringing (banding) studies on shorebirds in many countries throughout the world, a number of species are being colour-dyed. This technique enables the birds to be followed without having to be recaptured. Picric acid (orange-yellow) is the commonest dye, but other colours such as pink, blue, violet and green may be used. It should always be obvious when a bird has been dyed, but there is a potential hazard to identification which should be recognised. Colour-marked birds should always be reported (see page 31). In some areas natural staining may occur. Dirty legs, caused by dirt such as soft black mud or orange dirt from sand- or gravel-workings, may obscure the true colour of the legs and toes, and this possibility should be borne in mind. Leg colour is in general a very useful identification feature, but has a slight inherent variability; apparent leg colour can also depend on an extent to the quality of the light.

Size and shape
When attempting to identify a wader, it is important to gain an impression of its size and shape, but it must be realised that neither is absolute, even for a single individual bird.

Size may not always be easy to judge, particularly if there are no other birds for comparison (see Grant 1980). Grant (1983b) has drawn attention to the fact that, when using powerful optical aids such as a telescope or a telephoto lens, optical illusion ('size-illusion') can play tricks on the unwary: birds behind the plane of focus tend to appear larger, and those in front smaller, than they really are. Thus a Dunlin photographed against a background of Little Stints or Least Sandpipers may turn out looking the same size, although it is actually a larger bird!

Waders wintering in the tropics tend to weigh less than those in colder zones and may actually appear smaller. This impression is heightened by the feathers being flattened against the body, rather than fluffed up to retain heat.
Most waders have a characteristic shape, but many factors can influence this in the field. The stance may vary depending on whether the bird is alert or relaxed, feeding or resting, or in a strong or light wind. A bird feeding in a hunched attitude in the chill of the early morning may appear erect and slim when disturbed by a raptor in the afternoon. The diagram below illustrates the variety of attitudes and poses which may be adopted by a single individual bird.

Range of postures possible for a single individual bird

The relative length of the folded wing against the tail is an important identification pointer in several species. The exact distance from wing-tip to tail-tip in an individual bird, however, varies to some extent depending on how neatly it has folded its wings. Where possible, this feature should be observed over a long time-period, so that the typical value can be assessed.

Similarly, on a flying wader, the projection of legs or toes beyond the tip of the tail should be looked for. A number of long-legged waders, however, particularly in cold weather, may fly with the legs tucked into the body feathering rather than trailing behind. Grant (1983a) has drawn attention to the potential this habit gives for misidentification, for example between a Spotted Redshank flying with legs retracted and a dowitcher.

Behaviour

The way a bird is behaving is often a vital clue to its identity. Important elements of the behaviour of individual species are mentioned in the ‘Habits’ section of the text.

It should, however, be recognised that the value of behaviour in identification is limited. Most species have a repertoire of feeding methods, and the mode of feeding at any one time may depend on many factors, including the food items being taken, their spacing and density, the presence or absence of other feeding birds, and so on.

Where vagrants are concerned, habitat choice and feeding habits are often not representative of the behaviour of the species within its normal range.
Wader topography II:

- mantle
- forehead
- lore
- scapulars
- marginal coverts
- lesser coverts
- carpal joint
- lesser primary coverts
- alula
- median primary coverts
- greater primary coverts
- tiny outermost primary
- shaft
- axillaries
- back
- rump
- uppertail-coverts
- tail
- tertials
- secondaries
- median coverts
greater coverts
secondaries
primaries

- arm
- marginal underwing-coverts
- lesser underwing-coverts
- median underwing-coverts
lesser under primary coverts
median under primary coverts
greater under primary coverts
primaries
secondaries
greater underwing-coverts
undertail-coverts

breast
belly
flank
vent
Fig. 11. Gull topography

1 Scapulars
2 Back
3 Uppertail-coverts
4 Rump
5 Median coverts
6 Greater coverts
7 Secondaries
8 1st-10th primaries (functional)
9 Greater primary-coverts
10 Alula
11 Median primary-coverts
12 Marginal coverts
13 Lesser coverts
14 Mantle

1 Mantle
2 Scapulars
3 Greater coverts
4 Tertials
5 Primaries
6 Secondaries
7 Median coverts
8 Lesser coverts

1 Culmen
2 Loa
3 Forehead
4 Iris
5 Orbital ring
6 Crown
7 Ear-coverts
8 Nape

1 Eye crescent
2 Cap
3 Ear spot
4 Crescents above and below eye (eye-ring if joined)

1 Hindneck
2 Side of neck
3 Forehead
4 Throat
5 Orbital ring
6 Chin
7 Gape
8 Nape
Willet (Catoptrophorus semipalmatus) *

Status: Common throughout the year.

Habitat: Swash zone to the primary dunes. Fairly evenly distributed throughout the barrier islands of GUIS.

BREEDING: Marshy lake margins and adjacent uplands (w); salt marshes, intertidal zone (e). 1 brood. DISPLAYS: Nest relief ceremony incl male bow. Prominent white-wing flash in courtship. See: Shorebird Communication, p. 139. NEST: Conspicuous, elaborate, or concealed by short, thick veg (esp where wet) on open beach or flat. Grasses bent to form hollow, lined with few dead rushes, dry grass/sedge, etc. Completed during laying. Female chooses site. EGGS: Olive, marked with olive-brown. 2.1" (53 mm). DIET: Aquatic insects, worms, crustaceans, mollusks, fish. CONSERVATION: Winters s along coast to n Chile (w) and throughout West Indies to n Brazil (e). Moderately abundant, partly from tolerance of mowing and burning. Market hunters depleted population n of VA; now recovering and range expanding in e. NOTES: Semicolonic, oft nesting synchronously. Maintain separate feeding and nesting territories. Strong fidelity to mate and to feeding territory between years. Male incubates at night, occ during midday. Female abandons mate and brood 2–3 weeks posthatch; male attends brood for 2 more weeks. Oft wade to belly and swim. Adults leave breeding grounds before young fledge. Oft defend winter territories along sandy beaches. ESSAYS: Transporting Young, p. 103; Determining Diets, p. 535; Color of Birds, p. 111; Site Tenacity, p. 189; Spacing of Wintering Shorebirds, p. 147; Parental Care, p. 555. REFS: Howe, 1982; Ryan and Renken, 1987; Sordahl, 1979; Wilcox, 1980.
This rather odd American wader has a genus to itself, but seems to be closely related to the 'shanks' of genus *Tringa* (136-142) despite its unusual wing pattern.

**IDENTIFICATION** A rather heavy and inelegant wader on the ground, shank-like in proportions, per­
genus

Despite its unusual wing pattern. The underwing-coverts are largely black, recalling the longer-billed Hudsonian Godwit (124), but the strongly-contrasted translucent white band across the bases of the primaries, the pale secondaries and leading lesser underwing-coverts, and the grey-tipped tail are distinctive. On the ground, the strong blue-grey legs and
tinctive. On the ground, the strong blue-grey legs and
white but tips black. Outer secondaries with little
blackish-grey on tips, but essentially white. Greater,
median and lesser coverts are mostly grey. Underwing white, except for greyish lesser coverts, and
black median and greater coverts, primary coverts,
primary tips and axillaries. Underparts whitish, vari­
ably spotted on breast or irregul arly barred on
flanks. Rear belly whitish. Non-breeding: As
breeding, but all upperparts almost plain pale grey,
with mantle, coverts and scapulars narrowly fringed
dark grey or white. Central tail feathers uniform light grey.

Underparts white, washed grey on throat, breast and
flanks. Juvenile: As non-breeding, but feathers of
mantle, coverts, scapulars and tertials all grey-brown
with dark subterminal bar and quite broad buff
fringes; larger feathers are also notched with buff. The
inner 6 primaries are tipped white. Breast slightly
brownier than on adult.

**AGE/SEX** Most juvenile feathers are replaced by mid­
winter, but the primaries are retained throughout the
first year and become very worn. Females are larger
on average, but otherwise the sexes are similar.

**RACES** Two: nominate *semipalmatus* ('Eastern Willet'); coastal E North America south to N Mexico, also
Bahamas, Greater Antilles and Los Roques Is. of SW Canada and NW USA). Plumages distinct only
inornatus.

**DESCRIPTION** Breeding: Head pale grey, streaked
brown; whitish area above lores together with nar­
row whitish eye-ring gives a spectacled appearance. Dark brownish line across the lores, but eye-stripe
is indistinct behind eye. Chin is white. Neck, mant­
le, scapulars and tertials are grey-brown, barred
whitish-buff and dark brown to a variable extent.

**IDENTIFICATION** And inelegant wader on the ground, shank-like in proportions, per­
genus

**MOVEMENTS** Northern breeders are strongly migratory, but those breeding around the Gulf of Mexico
and the Caribbean are probably fairly sedentary. The
most northerly breeding areas are occupied by late
Apr, but many adults depart again in June-July before
the young have fledged. Eastern birds typically shift
southwards along the Atlantic seaboard and into
the Caribbean, some reaching N Brazil. Western birds
migrate mostly to the Pacific coast from Oregon to
N Peru, including Galapagos. Some enter the Carib­
bean and have reached Surinam. Vagrant to S
British Columbia, Hudson Bay, Bermuda, once to
Alaska (two, Aug 1961), and recently to the Azores
(long dead, Mar 1979) and Finland (Sept 1983). There
is also an old undated specimen from France, and
other unconfirmed European records.

**DESCRIPTION** Breeding: Head pale grey, streaked
brown; whitish area above lores together with nar­
row whitish eye-ring gives a spectacled appearance. Dark brownish line across the lores, but eye-stripe is
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**EXPERENCES** Stenzel et al. (1976), Burger and Shis­

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Laughing Gull (*Larus atricilla*)

**Status:** Common throughout the year.

**Habitat:** Coastal sand beaches. Laughing Gulls are usually found in large concentrations near the tips of the barrier islands.

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**Laughing Gull**

Larus atricilla Linnaeus

NG–144; G–148; PE–88; PW–pl 33; AE–pl 43; AM(II)–42

**Breeding:** Marshes, scattered patches of long grass in sand. 1 brood. **Displays:** Long calls, head tosses, and crooning directed at potential mate by courting male. **Nest:** Esp in tall grass, also in grass under bushes, between dunes, oft concealed in surrounding veg. Scrape minimally lined; saucer elaborately interwoven of coarse grass lined with fine grass, sticks, debris. Building continues throughout reproductive cycle in areas subject to flooding. **Eggs:** Olive-buff/olive-brown, marked with brown, wreathed. 2.1" (54 mm). **Diet:** Also fish, rarely seabird eggs and chicks. Young initially fed half-digested regurgitant. **Conservation:** Winters on coast to n Peru (w) and to Colombia e to Amazon delta (e). **Notes:** Nests in colonies, occ with 1000s of nests; occ assoc with terns, Black Skimmers. Herring Gulls oft prey on eggs and young, compete for nest sites within established Laughing Gull colonies. Nest in center of colony more successful, eggs larger, hatch earlier, females older, than nests on perimeter. Adults forage more successfully than young birds. Adult plumage attained in third year. **Essays:** Parent-Chick Recognition, p. 193; Vocal Functions, p. 471; Gull Development, p. 171; Coloniality, p. 173; Geometry of the Selfish Colony, p. 19; Gulls and Predators, p. 169. **Refs:** Burger, 1976; Burger and Gochfeld, 1985; Montevecchi, 1978; Schreiber and Schreiber, 1980.
Laughing Gull (Larus atricilla) **

Length 38–43cm (15–17in.), Wingspan 90–107cm (35–42in.). Iris black, orbital ring dull red. Bill, legs/feet dull red.

**FIRST-SUMMER:** Little change from first-winter, usually with less grey on head, nape and breast; wings and tail further faded.

**SECOND-WINTER:** Head Dull white with partial grey hood extending from ear-coverts to nape and hindneck (varies individually). Body Upperparts: saddle uniform dark grey, rump white. Underparts white except breast and flanks pale grey, Wing Upperwing: outer primaries and their coverts blackish, remainder mostly dark grey; secondaries and inner 5–6 primaries tipped white forming trailing edge. Tail White; partial broken band.

**SECOND-SUMMER:** Bill/legs dusky-red. As second-winter except: Head Partial blackish hood; white crescents. Body Underparts: breast and flanks whiter.

**THIRD-WINTER / ADULT NON-BREEDING:** Bill blackish-brown, tip often red; legs blackish-grey. Plumage as second-winter except: Body Upperparts: grey confined to sides of breast. Wings Upperwing mostly dark grey; outer primaries black decreasing in extent inwards to small subterminal bar on 5th and 6th, all except outer 2 primaries with small white apical spots increasing in size inwards and uniting with white tips of secondaries to form trailing edge. Underwing mostly grey, tip smudgy-black; white trailing edge along secondaries and inner primaries. Tail White.

**ADULT BREEDING:** As non-breeding adult except: Head Smooth-black hood extending to hindneck and throat; thin white crescents above and below eye.

FHJ: Compared with smaller Franklin’s Gull (p. 352) has distinctly flatter, longer crown and heavy (particularly at tip) drooping bill. In flight appears much larger due to longer, narrower wings, which taper to thin points. When perched wings project well beyond tail, accentuating attenuated jizz; thin legs longer than in Franklin’s Gull, and in flight reach almost to tip of tail. Capable scavenge along tidelines and harbours, often competing with larger gulls. Call ‘ha-ha-ha-ha’.

DM: L. atricilla breeds West Indies, Venezuela, French Guiana; L. megalopterus N America.

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DM: L. atricilla breeds West Indies, Venezuela, French Guiana; L. megalopterus N America.
INVENTORY AND MONITORING OF WINTERING COASTAL WATERBIRDS

SUMMARY REPORT TO THE SUPERINTENDENT
GULF ISLANDS NATIONAL SEASHORE

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INTRODUCTION

Systematic protocols for assessing the diversity and abundance of marine and shorebird populations in National Seashores are lacking. These populations form a significant component of the wildlife resources in many coastal parks in the Southeast Region, including Gulf Islands, and the need for monitoring has been identified in the resource management plans of most coastal parks. Several species, including Snowy (Charadrius alexandrinus) and Piping Plovers (Charadrius melodus) and Gull-billed Terns (Gelochelidon nilotica) are currently listed as threatened, endangered, or species of special concern due to declining populations. There is a pressing need to develop and test approaches to monitoring marine and shorebird populations in coastal parks and devise long-term strategies for population management.

OBJECTIVES

The objectives of this study were:

1. To evaluate current methodologies for monitoring wintering and breeding coastal waterbird populations in the context of the needs and resources of coastal parks in the Southeast Region

2. To generate a baseline inventory of coastal waterbird populations and quantitative population estimates appropriate for the long term monitoring of population levels at Gulf Islands

3. To provide data on the distribution of habitats important to coastal waterbirds at Gulf Islands

4. To provide data on the status, abundance and distribution of two species of threatened waterbirds

5. To develop a shorebird population monitoring handbook which will serve as a protocol in the park’s long term inventory and monitoring program.

BACKGROUND

The development of conservation strategies for marine and shorebird populations is complicated by fact that most species migrate over vast distances during their annual cycles (Myers et al. 1987). In addition, the habitats on which they depend are often prime locations for recreational and commercial development (Senner and Howe 1984).

Although they form a significant component of the fauna of most Seashore Parks in the Southeast Region of the National Park Service information on coastal waterbird abundance, distribution, habitat preferences and long-term population trends in these areas is almost totally lacking.

These birds are well suited to serve as bioindicators in a coastal park’s long term resource monitoring program. They are sensitive to human disturbance associated with recreational use (Burger 1981) as well the effects of environmental contaminants (White et al. 1983, Evans and Moon 1981) and channel dredging (Smith and Mudd 1976)

A shorebird population monitoring program was implemented by the Manomet Bird Observatory in 1974 (Morrison and Harrington 1979). This survey has established
protocols for monitoring shorebird populations during migration but lacks long term data on wintering and breeding populations (Howe et al. 1989). This report summarizes an approach to monitoring wintering and breeding marine and shorebird populations at Gulf Islands National Seashore that was begun in 1990. It is hope that this project can serve as a prototype for other barrier island parks in the Southeast Region.

The abundance and distribution of waterbirds wintering on the barrier islands of Gulf Islands National Seashore are poorly known. Amateur bird watchers along the northern coast of the Gulf of Mexico have developed seasonal relative abundance and distribution schedules for mainland shorelines (Toups and Jackson 1987). However, these schedules are inappropriate for the inventory and monitoring of coastal waterbirds for two reasons. First, these data were not systematically collected. Thus, only relative abundances can be obtained which are inadequate for monitoring population levels. Second, these data do not cover species wintering on the off-shore barrier islands.

In this project, we systematically censused and inventoried wintering coastal waterbirds at four locations in Gulf Islands National Seashore. Data from this project, collected over the long-term, can be used to monitor changes in the Seashore’s coastal waterbird populations.

METHODS

We conducted eight censuses from mid-January to late March, 1990 (Table 1), at four locations within Gulf Islands National Seashore: (1) West Ship Island (WSI), (2) Perdido Key (PK), (3) Fort Pickens (FP), and (4) Santa Rosa (SR) (Fig. 1).

Specific areas of shoreline censused were the entire shoreline of West Ship Island (7 mi, 11.2 km), the south shores of the Perdido Key Unit (6.5 mi, 10.4 km; from the western boundary to the eastern tip), the Fort Pickens Unit (8 mi, 12.8 km; from the eastern boundary to the western tip), and the Santa Rosa Unit (7.5 mi, 12 km; from the eastern to the western boundary).

Linear Density Transects

The most appropriate method for sampling waterbirds along a coastline is to utilize a linear density transect scheme (Connors 1986). This sampling method allows for the calculation of linear density estimates along shorelines.

We counted and recorded birds on prepared data sheets (Appendix A). We counted birds continually from an ATV while moving parallel to the shoreline. The ATV was only driven below the high tide line to minimize the impact on the beach. Only birds from the water line to the primary dunes were counted and recorded. All birds were tallied for every 0.5 mi (0.8 km) section of beach. At each 0.5 mi (0.8 km) point, we scanned the water surface counting and tallying species and number of individuals for a distance of 200 meters offshore.

RESULTS

A species inventory from this study is summarized in Table 2. Table 3 summarizes the mean number of individuals per survey and total number of individuals by location for each species observed.

The waterbirds surveyed in this study were not randomly distributed. Birds tended to be concentrated in specific areas. On West Ship Island and the Fort Pickens Unit, birds congregated at the tips of the islands (Fig. 2, Fig. 3). Birds at the Perdido Key Unit were
more abundant near newly pumped dredge spoils (Fig. 4). Birds on the Santa Rosa Unit were fairly evenly distributed along the south shore (Fig. 5). Most species roosted just below the primary dunes at high tide. At low tide gulls and terns were generally concentrated just above the intertidal zone while the shore birds concentrated in intertidal feeding areas and the swash zone.

We selected seven coastal waterbirds (Table 4) to be used as indicator species. We based our selection on four criteria: (1) abundance, (2) representation of different foraging guilds, (3) status, with respect to regional distribution, in the Southeast Region (4) status, with respect to breeding activity, along the Gulf coast. Data from these indicator species will be analyzed for location-specific differences in distribution and abundance as well as changes in population levels. For each indicator species, we have included a figure showing the distribution and abundance by location for each species (Appendix B). Overall, shorebirds tended to be more evenly distributed while gulls and terns tended to congregate on the tips of the islands or in the vicinity of the dredging operation.

Laughing Gulls were common on West Ship Island and Perdido Key (Fig. B-1) often congregating on the western tip of West Ship and in the vicinity of the dredging operation on Perdido Key (Fig. B-2). The Laughing Gull is a common opportunistic species along the Gulf Coast. Primarily a fish eater they will also scavenge from fishing boats and on dredge spoil sites.

Royal Terns were most common in the middle of the Fort Pickens Unit but were also found near the dredging operation on Perdido Key and on the tips of West Ship Island (Figs. B-3 and B-4). These birds breed on predator-free sandy beaches along the Northern Gulf and feed primarily on aquatic invertebrates (crab, squid and shrimp). Human disturbance at the nesting colonies and predators (including gulls) are primarily for limiting population levels.

Willets are common on the Fort Pickens Unit and Perdido Key and are fairly evenly distributed throughout the sandy beach areas of the Seashore (Fig. B-5 and B-6). Willets feed in the intertidal zone on benthic invertebrates including aquatic insects, worms, crustaceans and mollusks. They strong fidelity to nesting locations, mates, and feeding territories. Thus, changes in Willet numbers may indicated increasing levels of disturbance, predation, or a deterioration of food resources.

The Snowy Plover is now considered an endangered species in Alabama (Imhof 1986) a threatened species in Florida (Wood 1989) and a species of special concern in Mississippi. Recent population declines in the Southeast have been attributed to a loss of nesting habitat and to human disturbance of nesting birds (Imhof 1976, Woolfenden 1978). These birds are regular winter residents and summer breeders throughout the Seashore (Figs. B-7 and B-8). They feed in the upper intertidal zone on insects, worms, crustaceans, and mollusks and nest in the primary dune habitat. Changes in Snowy Plover numbers will often indicate changing levels of human disturbance.

Herring Gulls are opportunistic and very tolerant of human activity. These birds often scavenge on garbage and fishery by-catch and can be serious predators on other species of seabirds. Populations along the Northern Gulf are increasing and nesting populations my become established in the near future. They were found primarily on the tips of West Ship Island and adjacent to the dredging project on Perdido Key (Figs. B-9 and B-10).

Black-bellied Plover is widely distributed winter resident in the Seashore (Figs. B-11 and B-12). Although birds can be found throughout the year, most depart in March and April for breeding grounds on the Arctic tundra. Wintering birds feed primarily on intertidal
invertebrates, especially polychaete worms. They are fairly tolerant of disturbance on their wintering grounds. Thus changes in numbers within the Seashore would probably reflect changes in food abundance.

Sanderlings are by far the most common wintering shorebird in the park and some individuals can be seen year-round (Figs. B-13 and B-14). Birds can be found on open sandy beaches (generally higher on the beach than other shorebirds) throughout the Park, and are fairly tolerant of disturbance. Their diet is composed primarily of polychaetes and small mollusks making them susceptible to the effects of beach renourishment activities. Global populations are thought to be declining perhaps due to human disturbance of migratory stopover and wintering habitat.

People were most abundant on the Santa Rosa Unit of the Seashore followed by Fort Pickens, Perdido Key and West Ship Island (Fig. B-15). Individuals were fairly evenly distributed with the exception of West Ship Island where they tended to congregate near the developed areas (Fig. B-16). Additional analysis may reveal associations between the distribution of waterbirds and people.

Figure 6 shows comparisons of the distribution and abundance for the 13 most common species and people by location. Sanderlings (Calidris alba), Laughing Gulls (Larus atricilla), Ring-billed Gulls (Larus delawarensis) and Herring Gulls (Larus argentatus) were the four most common species across all locations. Perdido Key and Fort Pickens had the highest average number of species per survey, followed by West Ship Island and the Santa Rosa Unit (Fig. 7).

With the exception of West Ship Island all surveys were conducted on the exposed Gulf side beaches of the islands. Surprisingly, a comparison of the diversity and abundance of birds on the north versus south beach of West Ship Island revealed few differences (Fig. 8). Patterns on the other Seashore islands remain to be evaluated.

DISCUSSION AND RECOMMENDATIONS

The waterbird avifauna of Gulf Islands National Seashore consists primarily of shorebirds (14 species), gulls (4 species) and terns (6 species). These overwintering birds tend to congregate in areas of high food abundance such as tips of islands or at dredge spoils. Data from these censuses can provide a valuable contribution to the Park's resource inventory and monitoring program if they are collected in a systematic fashion over many years.

Censuses should be conducted as close to low tide for two reasons. First, this is the time when most of the birds are foraging and active, thus making them more visible for counting. Second, by driving the ATV below the high tide line, the environmental impact is minimized. If possible, censuses should be conducted no less than twice per month. Waterbird populations tend to be stable during the breeding and nonbreeding seasons, thus not requiring weekly surveys. However, during the migration season (spring and autumn) the composition, distribution and abundance of the waterbird community can change rather quickly. Thus, during this time weekly surveys would yield more information concerning changes in waterbird populations at Gulf Islands National Seashore. Surveys should also be conducted in a manner which maximizes the available sunlight for viewing. Censuses should be run from east to west in the morning and west to east in the afternoon.
LITERATURE CITED


Table 1. Dates and locations of waterbird surveys conducted at Gulf Islands National Seashore Jan. - Mar., 1990.

<table>
<thead>
<tr>
<th>Census #</th>
<th>FP</th>
<th>PK</th>
<th>SR</th>
<th>WSI</th>
</tr>
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<td>17 Jan</td>
<td>10 Jan</td>
</tr>
<tr>
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</tr>
<tr>
<td>8</td>
<td>28 Mar</td>
<td>25 Mar</td>
<td>28 Mar</td>
<td>21 Mar</td>
</tr>
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Table 2. Species inventory of wintering waterbirds at Gulf Islands National Seashore, Jan. - Mar., 1990.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Code</th>
<th>Scientific Name</th>
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<td>Gavia immer</td>
</tr>
<tr>
<td>Horned Grebe</td>
<td>HOGR</td>
<td>Podiceps auritus</td>
</tr>
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<td>BRPE</td>
<td>Pelecanus occidentalis</td>
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<tr>
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<td>Phalacrocorax auritus</td>
</tr>
<tr>
<td>Great Blue Heron</td>
<td>GTBH</td>
<td>Ardea herodias</td>
</tr>
<tr>
<td>Snow Goose</td>
<td>SNGO</td>
<td>Chen caerulescens</td>
</tr>
<tr>
<td>Redhead</td>
<td>REDH</td>
<td>Aythya americana</td>
</tr>
<tr>
<td>Lesser Scaup</td>
<td>LESC</td>
<td>A. affinis</td>
</tr>
<tr>
<td>Scaup sp.</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>COME</td>
<td>Mergus merganser</td>
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<tr>
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<td>RBME</td>
<td>M. serrator</td>
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<tr>
<td>Hooded Merganser</td>
<td>HOME</td>
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<tr>
<td>Black-necked Stilt</td>
<td>BNST</td>
<td>Himantopus mexicanus</td>
</tr>
<tr>
<td>Snowy Plover</td>
<td>SNPL</td>
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<td>WILL</td>
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<td>REKN</td>
<td>Calidris canutus</td>
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<td>DUNL</td>
<td>C. alpina</td>
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<td>SAND</td>
<td>C. alba</td>
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<td>RBGU</td>
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<td>HEGU</td>
<td>L. argentatus</td>
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<td>COTE</td>
<td>Sterna hirundo</td>
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<td>S. caspia</td>
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<td>BLSK</td>
<td>Rynchos niger</td>
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<td>OSPR</td>
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<td>AMKE</td>
<td>Falco sparverius</td>
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<td>Fish Crow</td>
<td>FICR</td>
<td>Corvus ossifragus</td>
</tr>
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<td>LOSH</td>
<td>Lanius ludovicianus</td>
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<td>Humans</td>
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39
Table 3. Abundance and distribution of wintering waterbirds at Gulf Islands National Seashore.

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<tr>
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<td>0.9</td>
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<td>0.1</td>
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<td>Ruddy Turnstone</td>
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</tr>
<tr>
<td>Fish Crow</td>
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<td>0.5</td>
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<tr>
<td>Loggerhead Shrike</td>
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<tr>
<td>Humans</td>
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Table 4. Indicator species and their status in Gulf Islands National Seashore.

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<th>Breeding Status</th>
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<td>Laughing Gull</td>
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<td>yes</td>
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<td>yes</td>
</tr>
<tr>
<td>Willets</td>
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<td>yes</td>
</tr>
<tr>
<td>Snowy Plovers</td>
<td>year-round</td>
<td>yes</td>
</tr>
<tr>
<td>Herring Gulls</td>
<td>year-round</td>
<td>no</td>
</tr>
<tr>
<td>Black-bellied Plovers</td>
<td>year-round</td>
<td>no</td>
</tr>
<tr>
<td>Sanderlings</td>
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<td>no</td>
</tr>
<tr>
<td>Humans</td>
<td>year-round</td>
<td>--</td>
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</tbody>
</table>
West Ship Island

Mean # Indiv's per Survey (All Species)

Section #
Fort Pickens

Mean # Indiv's per Survey (All Species)

Section #
Figure 4

Perdido Key

Mean # Indiv's per Survey (All Species)

Section #
Santa Rosa

Mean # Indiv's per Survey (All Species)

Section #
Waterbird Surveys - GUIS

Mean # Individuals per Section

Fort Pickens  Santa Rosa  West Ship Island  Perdido Key

Figure 6
Species

Mean # Species per Survey

- WSI
- PK
- FP
- SR

Figure 7
Appendix A. Sample data sheet.
### Waterbird Census Data Sheet

<table>
<thead>
<tr>
<th>Species</th>
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</thead>
<tbody>
<tr>
<td>COLD</td>
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</tr>
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<td>BRPE</td>
<td></td>
</tr>
<tr>
<td>DOCO</td>
<td></td>
</tr>
<tr>
<td>GIMB</td>
<td></td>
</tr>
<tr>
<td>BBPL</td>
<td></td>
</tr>
<tr>
<td>SNPL</td>
<td></td>
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<td>WIPL</td>
<td></td>
</tr>
<tr>
<td>SEPL</td>
<td></td>
</tr>
<tr>
<td>PIPL</td>
<td></td>
</tr>
<tr>
<td>WLL</td>
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<tr>
<td>RUTU</td>
<td></td>
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<td>SAND</td>
<td></td>
</tr>
<tr>
<td>DUNL</td>
<td></td>
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<td>IAGU</td>
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</tr>
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<td>RBOGU</td>
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</tr>
<tr>
<td>BITE</td>
<td></td>
</tr>
<tr>
<td>BLSK</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B. Distribution and abundance by location for selected indicator species.
Willets

Figure B5

Mean # Indiv's per Section

Location

WSI  PK  FP  SR
Willet

Mean # Individuals per Section

Figure B6
Laughing Gulls

Mean # Indiv's per Section

Location

WSI
PK
FP
SR

Figure B1
Laughing Gull

Mean # Individuals per Section

Santa Rosa
West Ship Island
Fort Pickens
Perdido Key

Figure B2
Appendix C. Raw data from 1990 waterbird surveys.
Analysis of Sampling Precision:

We can use the data from the Gulf Islands censuses to look at how estimates of sampling precision can help us set monitoring priorities. The formula used to determine the sample size for a prescribed level of confidence is:

\[ n = \frac{\sigma^2 (Z_{1-\alpha/2} + Z_{1-\beta})^2}{(\mu_0 - \mu_1)^2} \]

where \( \sigma^2 \) is the sample variance; \( \mu \) is the sample mean, with \( \mu_0 = 0 \) and \( \mu_1 = \) the difference in population size you are trying to detect such that \( \mu_1 = \mu \) (degree of change), e.g. \( \mu_1 = \mu(.2) \) for a change of 20%; \( \alpha = \) the probability of a Type I error; \( \beta = \) the probability of a Type II error; and \( Z \) is the associated Z-score determined from a t-distribution table.

Possible Monitoring Error Types:

<table>
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<tr>
<th>Monitoring system</th>
<th>No change has taken place</th>
<th>There has been a real change</th>
</tr>
</thead>
<tbody>
<tr>
<td>detects change</td>
<td>False Change Error (Type I)</td>
<td>No Error</td>
</tr>
<tr>
<td>detects no change</td>
<td>No Error</td>
<td>Missed Change Error (Type II)</td>
</tr>
</tbody>
</table>

For example, if the probability of a Type I or False Change Error (concluding that a change has taken place when in fact there is no change) was set to 0.05 and the probability of a Type II or Missed Change Error (concluding that no change has taken place when in fact there has been a change) to 0.2, and the sample size for our test surveys was 8, then

\[ Z_{1-\alpha/2} = Z_{1-.05/2} = \text{the Z-score for } t_{.925} \text{ with } \infty \text{ degrees of freedom (for entire population)} = 1.960. \]

\[ Z_{1-\beta} = Z_{1-.2} = \text{the Z-score for } t_{.80} \text{ with } 7 \text{ degrees of freedom (sample size - 1)} = 0.896. \]
The example from the following table (pg.61) for Willets at Fort Pickens, FL shows mean numbers of birds for eight survey dates. From these values we get a mean of 2.297 and a variance of 0.234. Selecting a $\alpha$ of 0.05 and a $\beta$ of 0.2, to determine a 35% change in the population we get the following values:

$\mu = 2.297$

$\sigma^2 = 0.234$

$\mu_0 = 0$

$\mu_1 = 2.296(0.35) = 0.804$

$\alpha = 0.05$

$Z_{1-\alpha/2} = Z_{0.975} \approx 1.96$

$\beta = 0.2$

$Z_{1-\beta} = Z_{0.80} \approx 0.896$

then

$$n = \frac{0.234(1.96 + 0.896)^2}{(0 - 0.804)^2} = 2.955$$

So an $n$ of $\approx 3$ would, in this example, indicates that at least 3 surveys, taken throughout the winter months, would be necessary to if we wanted to have an 80% chance of detecting a change in Willet populations of at least 35%. The following table gives various combinations for $\beta$ and % change as well as the resulting $n$ value. The results point out some interesting characteristics of these types of data. For example, from the Fort Pickens Willet data we can see that we would need to increase the number of surveys from 3 to 9 if we wanted to be able to detect population changes a small as 20%. We can also see that the sample size requirements increase when we use the Perdido Key data set due to the greater variability of the census data (sample variance = 0.234 at Fort Pickens versus 0.363 on Perdido Key).

Selecting Species for Monitoring:

The variability of the census data will to a large extent determine which species are suitable for monitoring. This is something that can only be determined from a preliminary field study. From the Gulf Islands data we can see that the Willet may be a good candidate for monitoring. They are widely distributed, and their populations are fairly stable over the course of the year because they maintain winter territories.

In contrast, many other coastal waterbird populations tend to be more patchy in time in space. This can make it difficult to detect population changes with any level of statistical confidence.
### WILLET
#### Fort Pickens

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### Example from text...

$\beta = \begin{bmatrix} 0.2 & 0.896 & 0.549 & 0.263 \end{bmatrix}$

$\sigma^2 = 0.363$

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$\mu = 2.240$

$\sigma^2 = 0.363$
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### Z-Score Change

- **Fort Pickens Section**
  - \( \beta = 0.2 \): Z-Score 0.896, Change 20%, \( n = 6 \)
  - \( \beta = 0.3 \): Z-Score 0.549, Change 20%, \( n = 5 \)
  - \( \beta = 0.4 \): Z-Score 0.263, Change 20%, \( n = 5 \)
  - \( \beta = 0.2 \): Z-Score 0.896, Change 35%, \( n = 13 \)
  - \( \beta = 0.3 \): Z-Score 0.549, Change 35%, \( n = 11 \)
  - \( \beta = 0.4 \): Z-Score 0.263, Change 35%, \( n = 7 \)
  - \( \beta = 0.2 \): Z-Score 0.896, Change 50%, \( n = 19 \)
  - \( \beta = 0.3 \): Z-Score 0.549, Change 50%, \( n = 13 \)
  - \( \beta = 0.4 \): Z-Score 0.263, Change 50%, \( n = 9 \)

- **Perdido Key Section**
  - \( \beta = 0.2 \): Z-Score 0.896, Change 20%, \( n = 6 \)
  - \( \beta = 0.3 \): Z-Score 0.549, Change 20%, \( n = 6 \)
  - \( \beta = 0.4 \): Z-Score 0.263, Change 20%, \( n = 6 \)
  - \( \beta = 0.2 \): Z-Score 0.896, Change 35%, \( n = 13 \)
  - \( \beta = 0.3 \): Z-Score 0.549, Change 35%, \( n = 11 \)
  - \( \beta = 0.4 \): Z-Score 0.263, Change 35%, \( n = 7 \)
  - \( \beta = 0.2 \): Z-Score 0.896, Change 50%, \( n = 19 \)
  - \( \beta = 0.3 \): Z-Score 0.549, Change 50%, \( n = 13 \)
  - \( \beta = 0.4 \): Z-Score 0.263, Change 50%, \( n = 9 \)

### Mean

- **Fort Pickens Section**: \( \mu = 0.63 \)
- **Perdido Key Section**: \( \mu = 1.269 \)
The Laughing Gull data (pg. 62) from Fort Pickens and Perdido Key are a good example. Like many other wintering or migrating coastal waterbirds Laughing Gulls tend to congregate where food is available. This is often controlled by winds, tides or other highly variable factors which results in highly variable census data.

As you can see from this analysis, the sample size requirements for comparable levels of sampling precision for Laughing Gulls are substantially higher than they are for Willets. For example, a level of sampling precision for Laughing Gulls on Fort Pickens equivalent to that illustrated in the example for Willets would require about 56 censuses for Laughing Gulls versus 3 for Willets.

When we begin to examine data from multiple years (Table 4 and pages 64-69) we encounter additional sources of variability that must be incorporated into our interpretations of census data. For example, migratory species such as Horned Grebes or Gannets appear in some years but not in others. Even common species such as Willets and Laughing Gulls show considerable year to year variability in distribution and abundance. Multi-year data sets will be required before statistically significant population trends can be distinguished from natural annual variation in population levels.

In summary, the suitability of coastal waterbirds as indicator species in coastal parks will be determined to a large extent by our ability to put estimates of sampling precision on census data. This ability will be a function of the following factors:

1. The spatial and temporal variability of populations which will be determined by extrinsic factors such as weather and migratory patterns and intrinsic factors such as a species behavior, ecology, and life history characteristics.

2. The spatial resolution and sampling precision chosen for monitoring.

3. The amount of time and money devoted to monitoring.

4. The skill level of the observers collecting census data.
Table 4. Abundance and distribution of wintering waterbirds at Gulf Islands National Seashore.

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Table 4. Continued.

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<td>512</td>
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Laughing Gull

Mean # Individuals per Section (1990)

Mean # Individuals per Section (1991)

- Santa Rosa
- Fort Pickens
- Perdido Key
ABSTRACT

A vegetation map for the Cape Hatteras National Seashore was developed and tested from an air photo database. This map was then placed into a computerized geographic information system for subsequent use in natural resource planning. In addition, roads, streams, and ownership boundaries were added to the computer system. The paper focuses on the vegetative data collection technique, its validation, and the use of the geographic information system in Eastern Barrier Island Management.

INTRODUCTION

In 1984 a conference sponsored by the National Park Service was called to define strategies for developing wildfire management plans for the barrier island parks in the eastern United States (Foley and Bratton 1984).

The major concern of the conference was to facilitate the initiation of research focused on problems in the development of these plans. One of the research issues, expressed by six of the eight parks represented at the meeting, was the lack of vegetation maps. Vegetation classification maps have been repeatedly demonstrated to be a key information need for the development of fire management plans (Deeming and Brown 1975, Getter 1976, Trabaud 1977). Cape Hatteras National Seashore (CHNS), a barrier island park off the coast of North Carolina, was one of the parks without a vegetation map.

The College of Forest Resources at North Carolina State University has been involved with vegetation management and computerized mapping systems applied to forest management for a number of years. As a part of that program, a research project was initiated through the Cooperative Park Studies Unit at the university to develop a vegetation map for Cape Hatteras and to place this map along with several other map themes (e.g. ownership) into a GIS. The research focused on constructing a classification
procedure for vegetation that could be used for natural resource planning. In addition, several new sub-processes for capturing, storage, and retrieval of the necessary map data were developed. A statistical verification technique for the vegetation maps was also constructed and implemented. This paper presents the results of the research effort by first defining the specific map and information products produced, then discussing the approaches employed to generate the products, and finally describing the GIS potential for barrier island resource management.

OBJECTIVES

The project had three major objectives. These were:

1. Construct a vegetation map for the CHNS.
2. Develop and implement a verification procedure for exploring the accuracy of the vegetation map.
3. Develop a computerized GIS, including vegetation, infrastructure, and selected natural features, to assist in resource management on Cape Hatteras.

APPROACH AND RESULTS

Each of the objectives required a unique set of procedures for implementation. Therefore, a separate methodological explanation is presented for the vegetation mapping, the accuracy tests, and the GIS construction. The project was centered on the vegetation maps. Coverage included the entire Seashore, with the exception of the Buxton Woods, Bodie Island, Fort Raleigh, and Wright Brothers Memorial developed areas. In addition, some areas outside the National Park Service boundary were mapped where it was appropriate for resource management.

Map Construction

The primary step in the mapping effort was the organization of appropriate base map and air-photo information into a common format. Base maps were developed on the United States Geological Survey (USGS) 7.5 minute topographic series. A complete set of USGS maps was available for Cape Hatteras, and all other data were referenced to this source. The actual vegetation information was developed from a set of 1:24,000 color infra-red aerial photographs taken in 1982 by the North Carolina Department of Transportation. The air photo data were transferred to the USGS base maps via a zoom transfer scope. The vegetation classes used in the project were defined by Mr. Kent Turner, the Natural Resource Specialist on CHNS, in consultation with Mr. John Sheperd, Fire Management specialist with the North Carolina Division of Forest Resources. Mr
Sheperd's assistance was employed because an initial application of the vegetation map was the development of a wildfire management plan for the seashore.

Fifteen vegetation classifications were used. They are described as follows:

1. **Bare Sand.** Generally devoid of vegetation (0 - 15 percent over), pioneer species include *Cakile edentula* (sea rocket), *Euphorbia polygonifolia* (dune spurge) and *Uniola paniculata* (sea oats). The few plants that are able to colonize the berm are often grouped around piles of debris and are usually temporary depending on the frequency of storms.

2. **Dune Grassland.** Forming almost a continuous band along the margin of the inner berm, grasses usually dominate this community affording as much as 90 percent cover. Sea oats and *Spartina patens* (saltmeadow hay) dominate dune grassland though sea rocket and *Iva imbricata* (seashore elder) are found on the more exposed dunes. In the protected areas, *Solidago sempvirens* (seaside goldenrod) is common.

3. **Shrub Savanna <1/3.** The map shows two categories of shrub savanna which will be distinguished on the basis of percent cover. Shrub Savanna <1/3 is a combination of closed grassland and a shrub savanna with less than 1/3 of the cover in shrub savanna. Infrequently flooded closed grasslands (a common occurrence on CHNS due to the artificial dunes blocking overwash) initially invaded by *Baccharis halimifolia* (silverling), *Myrica cerifera* (wax myrtle) and scrub *Juniperus virginiana* (eastern red cedar) develop into shrub savannas. However, high salt marsh areas will also support this classification.

4. **Shrub Thicket.** Shrub thickets are commonly found on protected flats and stabilized dunes. Dominated by wax myrtle and silverling in the wetter areas, dryer areas are characterized by *Ilex vomitoria* (yaupon), *Quercus virginiana* (live oak), eastern red cedar and a tangle of vines such as *Smilax spp.* Shrub thickets form when shrubs coalesce and shade out grasses and forbs.

5. **Reeds.** On CHNS these communities of *Phragmites* are often found in thin bands, intervening between the soundside edge of maritime forest or shrub thicket communities and the high marshes. *Fimbristylis spadicea* (fimbrystylis), *Spartina cynosuroides* (giant cord grass) and *Typha spp.* (cat-tail) are common in these areas.
6. Juncus High Marsh. This community is almost pure *Juncus roemerianus* (black needle rush). A very few scattered shrubs such as silverling and wax myrtle may also be present.

7. Patens High Marsh. *Spartina patens* (saltmeadow hay) dominates this high marsh. As with the Juncus High Marsh, a few shrubs might be present as well including *Distichlis spicata* (salt grass) and *Borrichia frutescens* (sea ox-eye).

8. Shrub Savanna >1/3. This shrub savanna community features shrub cover on one-third to two-thirds of the area. The same species found in Shrub Savanna <1/3 are also found here. However, less grasses and forbs are present.

9. Pinus Maritime Forest. This type is dominated by *Pinus taeda* (loblolly pine), with some hardwoods such as *Quercus laurifolia* (laurel oak). Larger wax myrtle shrub-trees make up the understory.

10. Broadleaf Evergreen Maritime Forest. *Quercus Virginiona* (live oak) and *Persea borbonia* (red bay) make up the majority of the canopy of these small forests.

11. Low Marsh. These areas are almost exclusively dominated by *Spartina alterniflora* (salt marsh cordgrass) and *Salicornia spp* (glasswort).

12. Developed Land. Where the density of homes is too great to show them individually, an area is defined as developed land. Piers, trailer parks, private campgrounds, complexes of motel/hotels are labeled as this type.

13. Water. Ponds and relatively unvegetated fresh marsh areas, as well as significant pools in dune slacks, are designated as water.

14. Freshwater Marsh. These areas are dune slack marshes which are dominated by grasses, rushes and sedges. Salt meadow hay, *Pannicum spp.*, and *Hydrocotyle* (water pennywort) are the major plants. Species diversity in these areas is a function of water table fluctuation and exposure to salt spray. Old interdune swales surrounded by shrub thicket or maritime forest are a common location for freshwater marshes. The marshes are dominated by *Juncus spp.*, *Typha spp.* and *Cladium jamicense* (sawgrass marsh) with the dune slack species present as well. *Sagittaria latifolia* (arrowhead), *Ipomea sagittata* (morning glory) and *Kosteletzkya virginica* (marsh mallow) are common in these zones.

15. Salt Panne. Essentially devoid of vegetation, the communities contain *Salicornia spp.*, but it only covers about 10 percent of the area. It is not unusual for low soundside Salt Panne areas to become an arm of the sound during periods of high water. Only Ocracoke supports this community on CHNS.
Seashore infrastructure (drainage ditches, roads, piers, historical structures, developed areas, etc.) and CHNS boundaries were also added to the vegetation map from the air photos and National Park Service cadastral survey maps.

VERIFICATION PROCEDURE

The large number of cover types to be mapped from the photos made it necessary to derive a measure of how accurately the photos were interpreted. Although field trips were frequently made to correlate interpreted classes with ground truth, a statistical evaluation of the final cover type identification was developed to provide an indication of map accuracy as well as to improve subsequent photo interpretation.

A stratified sampling design that had been initially tested on an earlier mapping project of Ocracoke Island (McCaffray 1983) was modified and repeated for this project. Two strata, boundary and interior, were created under the hypothesis that interior sample points could be identified with greater accuracy as to vegetation cover type than could boundary points. Boundary points were defined as points falling within 75 feet of a vegetation cover type boundary line on the photo. All other points were interior. Sample size was calculated based on maximizing statistical accuracy (as measured by standard error) subject to cost/time constraints. For this project, a sample size of 80 points, yielding an estimated standard error of 4 percent, was the maximum number of samples that could be budgeted. When compared with the acreage totals of the map, reports from the GIS distribution of the 80 sample points provides a reasonable representation of the common cover types found on CHNS (Table 1). The 80 points were allocated to the 2 strata based on the proportion of the total CHNS area in each stratum and its standard deviation. The statistical procedure for both the sample size calculation and the sample point to strata allocation are described in Cochran (1977).
Table 1: Comparison of Sample Point Distribution and GIS Mapped Acreage

<table>
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<tr>
<th>Cover Type</th>
<th>Points</th>
<th>Acreage</th>
</tr>
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<tbody>
<tr>
<td>Shrub Savanna &lt;1/3</td>
<td>21 (26%)</td>
<td>2590 (17%)</td>
</tr>
<tr>
<td>Dune Grassland</td>
<td>15 (19%)</td>
<td>3096 (20%)</td>
</tr>
<tr>
<td>Shrub Thicket</td>
<td>9 (11%)</td>
<td>1048 (7%)</td>
</tr>
<tr>
<td>Bare Sand</td>
<td>8 (10%)</td>
<td>2589 (17%)</td>
</tr>
<tr>
<td>Juncus romerianus</td>
<td>8 (10%)</td>
<td>1209 (8%)</td>
</tr>
<tr>
<td>Other cover types</td>
<td>19 (24%)</td>
<td>4743 (31%)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>80 (100%)</td>
<td>15277 (100%)</td>
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</table>

Forty-three interior and 37 boundary points were selected for sampling. The location of these points was determined by randomly selecting cell intersections from a grid overlay of the seashore. The intersections were then transferred to the photo base and the vegetation map. National Park Service personnel next located and visited each of the sample points noting the vegetation class at the point. These field point classifications were then compared with the photo interpreted classes.

Upon completion of the field checks, comparisons were made between the photo interpreted and field observed classifications. Overall, the photo interpretation accuracy was 70 percent, with 56 of the 80 points correctly identified. Interior points were correctly identified 74 percent of the time, while 65 percent of the boundary points were accurately predicted.

Over three-quarters (61) of all sample points fell into 5 of the 15 cover types. This is consistent with the acreage estimates from the GIS and implies the dominance of the Bare Sand, Dune Grassland, Shrub Savanna <1/3 cover, Shrub Thicket and Juncus Romerianus High Marsh cover types on CHNS. Difficulties with classification occurred primarily in 2 classes. First, there were 7 points (5 interior and 2 boundary) interpreted as Shrub Savanna <1/3 that were Dune Grassland upon field inspection. This indicates that there can be some problem in distinguishing between these classes with the infra-red photography. Three potential explanations are postulated for these errors. First, the small young pioneer shrubs may have only recently invaded a grassland community and much of
the grassland still remains. Second, some dune slack areas, in which surface water resides
throughout most of the winter, may be misinterpreted for the darker shrub patterns.
Finally, during the winter it is common for *Juncus Romerianus* to be blown or washed
over into matts that take on different visual properties from the standing needle rush.

The second major class of error was the 3 boundary points misclassified as Shrub
Savanna <1/3 when, in fact, they were Bare Sand. These errors are of no particular
concern as the dynamic nature of barrier island vegetation accounts for a movement of
sand boundaries over the 2 year period between the photos and the field work. A
complete description of the sampling procedure and results is given elsewhere (Devine and
McCaffray 1985).

Given these results, photo interpretation of cover types appears to be a reasonably
accurate method of mapping barrier island vegetation. Multi-seasonal and different types
of photos (black and white or color) would increase accuracy. When the problems in
interpreting Shrub Savanna are resolved, accuracy rates should improve. The true test of
the accuracy of these maps will come in their sustained management use.

GIS PROCEDURE

The use of a Geographic Information System to store the vegetation map was not
originally a major concern of the project. However, as the mapping developed, the GIS
became the central activity of the effort. It was determined early on in the project that the
impact of the vegetation map on actual seashore resource management would be greatly
compromised if no mechanism for on-going updates of the map were developed. Further,
the establishment of an updateable vegetation map would provide the base upon which all
other resource map layers could be drafted and new projects evaluated (e.g. wildlife
planning, exotic plant species control, beach erosion studies etc.). Therefore, the
establishment of the vegetation based GIS become a coequal objective of the project and
an integral part of the vegetation effort.

The description of the GIS activity here is limited to the details of the actual
activity on the CHNS vegetation project. No general description of GIS technology is
presented. As noted above, the mapping procedure began with the photo interpretation of
vegetation classes. The interpreted vegetation class boundaries were hand copied onto the
paper topographic maps via a zoom transfer scope. The interpretation procedure,
including 2 field trips to the CHNS and the transfer work, was completed without major
difficulty in about 6 man weeks. The CHNS boundaries were then transcribed onto the
topographic source via the same zoom technology in about 2 man days. At this point, the
maps (11 topographic sheets) were ready for entry into the GIS.
The "STRINGS" package (version 2.1) produced by GeoBased Systems Incorporated was selected as the GIS into which the maps would be entered. This system was chosen because it was available at the University and it was the system in use by the state of North Carolina in its own GIS program. Use of the same package allows the easy transfer of map data between the North Carolina statewide program and the CHNS. The digitizing of the vegetation and ownership boundaries was a very time consuming task taking over 4 man months to complete. At project end, it was calculated that it required 5 minutes per polygon to digitize these 2 layers. That is, 5 minutes was required to initially trace each closed area (e.g. shrub thicket path) into the system and correct any tracing errors. Difficulties arose in the digitizing process with editing the very small polygons which characterized the transition zones between vegetation classes and with the large number of polygons contained on each sheet (over 500 on some maps).

Once the map was digitized and edited, 2 other production GIS problems arose. First, the GIS files were constructed by topographic map sheet which, as noted above, could contain a large number of small polygons. This meant that any GIS function performed on these files took a long time to complete. This became very inconvenient, as even activities as simple as producing a color shaded plot of the map could take as long as 2 hours. The problem was alleviated with the construction of a series of arbitrary map sub-sheets. Each sub-sheet covered about 1/4 of the topographic sheet and generated approximately a 5-fold reduction in GIS processing time.

The second major problem with the GIS was the difficulty encountered in the routine handling of point symbol data. The problem, which is likely a function of the "STRINGS" package, centered on the inability of the software to plot symbols to scale when the entire map scale was changed. This resulted in very large plots of symbols (e.g. mileposts) on relatively small maps. No truly effective remedy was found to correct this annoyance.

The benefits of going to the GIS were significant and somewhat unexpected. First, the use of a GIS to store the data made corrections to the map relatively inexpensive and quick. Boundary changes were implemented and new plots generated in less than 1 hour. Second, the production of the GIS boundary layer complete with the seashore infrastructure provided an easily accessed map source for storage of other resource management information such as sea turtle nests, dune movements, and beach access points. A third benefit of the GIS effort is its use in the sampling accuracy for the vegetation map itself. The GIS provided the estimates of vegetation coverage that were used in the sample size calculation and provided a permanent record of sample point locations. The fourth benefit resulted from the use of the GIS to develop acreage estimates of vegetation by survey plot for an ecological analysis that was not a part of the original project. There were ten of these approximately 20 acre plots and the GIS provided the vegetation estimates in less than 1 man day. It was estimated that it would have taken at least a week to develop these estimates by conventional methods. A final benefit has been the use of the GIS to develop a preliminary wildfire fuel map for use in
The vegetation classes were simply recoded into fuel categories and the resultant map then edited to form the base for the wildfire management analysis. This procedure is described in detail in the project report (Devine and McCaffray, 1985).

The major challenge in constructing the GIS vegetation product was to develop a transfer technique for use of the map and the GIS in "on the ground" management. It was determined early in the project that it was unlikely that the human and monetary resources necessary to operate a GIS on the CHNS were going to be available in the near future. Therefore a mechanism that would allow the use of updated, inexpensively produced paper maps for seashore personnel was needed. The first attempt at such a product was the construction of a series of "windowed" maps based on the sub-topographic sheets identified earlier. These maps were produced at the common 1:24,000 scale of the original topographic maps and were plotted on notebook size sheets that were subsequently assembled into book form for field use. This effort proved quite successful as park resource records began to be maintained in these notebooks. An example sheet is presented in Figure 1. However, the continuing support for updating and adding to the original effort was not forthcoming, so a second procedure is now under development. The original GIS files have been moved to a less expensive (i.e. approximately $1,000), easier to use (i.e. requiring no significant training of personnel), map display system in anticipation of installing such a system at CHNS itself. The results of that effort are yet to be determined.

CONCLUSIONS

Each of the three study objectives was realized throughout the course of the project. The vegetative maps were effectively produced from the field work and the Department of Transportation photos. These maps have been successfully applied to subsequent management and research activities on the seashore. A GIS database was developed and stored at the University and has been employed to produce the field handbook for resource management. In addition, implementation procedures for an operating GIS are underway.
FURTHER STUDY

Several steps remain to attain the full promise of this project. First, different photographic techniques should be investigated to see if the classification problems with this effort can be resolved. Second, the development of a relatively simple micro-computer based map display system would greatly improve the usefulness of the GIS product. Preliminary investigations into the transfer of the CHNS database to such a system have shown encouraging results and an extension of this effort would allow the seashore managers to produce map materials and perform map based analyses in their own offices without significant training. However, substantive research in the file management and analyses features of the software needs to be performed for this type of benefit to be realized.

LITERATURE CITED


INTRODUCTION

Barrier islands constitute an interface between aquatic and terrestrial ecosystems and, as such, they tend to be dynamic in terms of vegetation composition and geomorphological change. Changes in barrier island landforms range from the impacts of storms and tidal action, to human-induced changes brought on by dredging and other coastal engineering projects and future impacts should the predictions of global climate change come about. Accurate, high resolution identification and delineation of vegetation communities, particularly over regional landscapes, remains one of the most critical problems in monitoring and detecting change from chronic and acute disturbances.

The National Park Service's Southeast Regional Office (SERO) has recognized the need for a comprehensive system that can incorporate both regional and park monitoring data, scientific research, hard copy maps, digital information, aerial photography, digital imagery, databases, predictive models and decision tree responses under an integrated GIS approach. The SERO and the University of Virginia, Department of Environmental Sciences, are developing a coastal barrier island remote sensing and GIS database to function in concert with existing scientific research and resource management databases.

Additionally, the proximity of National Park Service barrier islands to regions of disturbance and differential sediment transport has necessitated the involvement of the National Park Service's Southeast Regional Office (SERO) in long-term inventory, monitoring, prediction and evaluation of impacts regarding human-engineering projects. Examples of national parks being impacted by such project are: Georgia's Cumberland Island (St. Marys inlet/Kings Bay Naval Trident Submarine Base); North Carolina's Cape Hatteras (Oregon Inlet); and Florida's Gulf Islands National Seashore (Perdido). Quantification of, and response to, the short and long-term impacts is critical for the viability of coastal and barrier island national parks.

The National Park Service's (NPS) southeastern barrier island parks contain a suite of relatively undisturbed island landscapes, ranging from narrow outer banks to wide sea islands, that are ideal indicators for monitoring change over a range of potential impacts. Alterations in disturbance regimes, global climate or sea level change could potentially
alter barrier island habitats that the National Park Service is charged to manage. Effective management of these islands' ecosystems depends on the development of a high resolution map perspective of the types, structure, location and areal extent of the plant communities as well as the geomorphology of these landscapes. Equally important for GIS modelling, is the development of a spatial and temporal perspective of the barrier island vegetation/geomorphology upon which to base future impact predictions.

On a regional scale, southeastern and mid Atlantic barrier island national parks have been managed with a patchwork of knowledge regarding the vegetation composition of these parks. The lack of a very high resolution map perspective (5 meters or greater) of the type, composition and areal extent of vegetation communities places resource management specialists at a significant disadvantage. Forecasting future impacts to these ecosystems without benefit of such vegetation maps will be difficult.

The NPS manages 13 barrier islands, six of these are found in the NPS Southeast Region (Cape Hatteras, Cape Lookout, Cumberland Island, Cape Canaveral, and Gulf Islands National Seashores and Biscayne National Park). The initial project design was: (1) to document shoreline position; (2) to document inlet condition and site engineering history; that is, stabilized, maintained by dredging, or natural (= not engineered); and, (3) to establish a baseline of resource condition and shoreline position to assess the impacts of future inlet or shore stabilization project proposals (Patterson and Dawson, 1991). An overview of the project is dealt with in detail in Patterson and Dawson (1991). Coverage full scope of this project is dealt with in detail in the final report (Patterson et al. 1992) and the Users Guide (Patterson et al. 1992b). The project's goal was not simply to document shoreline position and inlet history, but to develop a high resolution vegetation perspective of barrier islands. Barrier islands are landscapes of rapid change. As such, they are ideal for the study of landscape dynamics, ecosystem processes (Hayden et al., 1991), and responses to proposed inlet and shoreline altering projects. However, coastal impact assessment requires a link between the temporal and spatial scales in the ecosystem, and the dynamics of landscape change due to disturbances precipitated by inlet and shoreline engineering projects.

The link between these two concepts can be provided by GIS and remote sensing provided it is of sufficiently high resolution to capture the subtle differences in scale related phenomena. Because barrier island vegetation communities tend to lie in narrow, linear bands that can be as discrete as 3-5 meters wide (Patterson and Dawson, 1991), satellite imagery is unsatisfactory for resolving these subtle yet critical differences in plant community structure. Further confusing any vegetation classification is the tendency of different communities to become intermixed in aggregated, yet distinct, clumps due to impacts from storms and overwash.
PRODUCTS REQUIRED

Remote Sensing:

High resolution aerial photography was regrettably the only method for accurately delineating these barrier island communities versus the use of Landsat Satellite Thematic Mapper data. A major disadvantage in using aerial photography is that the coverage of each frame is vastly reduced (15 x 15 km) when compared to the area encompassed by a satellite image (185 x 185 km). Another disadvantage when using aerial photography is the need to convert the photograph to a digital format of sufficient resolution (dots per inch) so that the vegetation can be accurately classified using computer-based image processing software. Another disadvantage is that the light on each photographic image can be different which can cause extreme problems when doing training sample collection and image classification.

A GIS-based analytical model of the southeastern barrier islands of the United States, was generated from high resolution, digitally scanned (2000 dots/inch) aerial photography (Patterson and Dawson, 1991). Remote sensing of the southeast barrier islands was contracted and flown by NASA's High Altitude Mission Branch using the ER-2 aircraft loaded with three high resolution cameras (3 m to .5 m resolution) and the Daedalus Thematic Mapper Scanner.

Global Positioning Systems:

Following image classification, each digital image must be georectified to an earth-based coordinate system and then edgematched together. This section of the project is as complicated as any operation in the field of remote sensing and image classification. Accurate georectification of the images is based on a physiographic region of the country that is largely devoid of "hard" physical structures or roads upon which to base georectification points. This required the installation of ground control targets and the use of a Global Positioning System (GPS) to georectify the scanned digital images (Patterson and Dawson 1991). The complexity of georectification on CAHA and CALO was further complicated when a storm either covered or blew away the ground control targets one week prior to the NASA flight. At CANA targets were not installed, and at BISC it was very difficult to see the targets against white calcareous backgrounds. Thus in most cases we were forced to find "soft" targets of vegetation, and "hard" targets of roads (if available), buildings, docks, etc. This complicated GPS and georectification matters enormously.

Further complications arose with the GPS system itself. The Global Positioning Satellite (GPS) system offers a method of determining map coordinates in the field with exacting precision of 1 meter or greater. (Stuthelt 1990). The GPS has an accuracy (2 cm
x, y and 3 cm z elevation) far superior to that of the USGS 1:24,000 (40 feet accuracy), NOS, or Corps of Engineers quad maps (Hum 1989). Optimally, the GPS permits the rapid installation and simultaneous registration of a new network of benchmark monuments, as well as reregistration of old benchmarks. But, the GPS system is entirely dependent on the Department of Defense's Global Positioning satellites and some of our most sensitive work was conducted during the Desert Storm War. At times we had significantly scrambled and degraded satellite signals with which to accurately "lock" in our GPS network. This required post processing of the signals with an updated "accurate" location of the true satellite's positioning.

One park, Cape Hatteras, has no image classified imagery. This was due to inadequate GPS coverage of that park by the NPS. Because too few points were taken for the 23 images comprising CAHA, any attempts at image analysis and georectification was stopped pending availability of a greater number of and, more accurate GPS points. This was regrettable but was beyond UVA's control. The provision of other GPS points for the remaining barrier island parks was not of the number and accuracy that was needed for low error georectification of the images at the 2 meter image resolution. Representation of an entire park composite made up of the individual images was deemed critical for the overlay of other GIS themes. Due to the enormous hard disk file size of each image the park composites were reduced in scale (20 meters: CAHA, CALO, and GUIS; 10 meters: GUIS, CANA and BISC) to accommodate these constraints. The edgematching at 20 meter resolution is more forgiving but still not without significant difficulties.

We spent significant amounts of time running different statistical models to develop methods of edgematching the images together, even though on some images we only had the minimum number of points required to even attempt edgematching. Because of these reasons it was extremely difficult to implement the GPS network protocol used successfully in other parts of the country. Finally, to our knowledge, never before has such a high resolution digital image classification of barrier islands been attempted over a regional landscape of this size. Without a classified vegetation base that possesses the high resolution and accuracy of this project, forecasts of change in vegetation composition and areal extent due to coastal engineering projects, storms, global climate change and sea level change would most likely contain significant error.

The global positioning system (GPS) is without question the Achilles heel in any remote sensing image classification project that is conducted in remote areas. It requires expert installation of ground control targets, expert use of the GPS unit itself, an unerring quest for precision in point location both in the field and on the image itself, expert orienteering in remote locations, and expert development of error analysis in the image georectification routine. The two most important points in GPS is the high number of ground control points (10 - 15 points per 9x9" image) for each image (installed as a nonlinear network) and excellent locational accuracy of the points (both in the field and on the digital image itself). Finally, the entire process hinges on the complete seamless cooperation between the field persons installing the targets and performing the GPS work,
and those persons doing the entering of GPS points on the digital images, image analysis and georectification. Should any of these areas not be completely addressed and executed, any future remote sensing and GIS work will not meet project objectives.

Image Classification:

The spectral vegetation classification of the 2 meter resolution imagery was performed using a supervised classification technique. A maximum likelihood image processing algorithm was used on the digital imagery to effectively and accurately delineate the narrow bands and clumps of barrier island vegetation communities (Patterson and Dawson, 1991). This proved to be a most difficult process due to inconsistent light reflection off of the water which caused serious differences in light illumination on the islands. Computer image classification software is very unforgiving to this sort of inconsistent lighting on photos in developing training samples of each class and the subsequent image classification. Enormous amounts of human input and correction were required to solve these spectral inconsistencies. Little of this would have been necessary had a multi-band satellite sensor been of sufficient resolution to accomplish the task.

The final GIS vegetation data layer of the barrier islands has a resolution of 2 meters. The very large size of each image (110 - 350 megabytes) necessitated the aggregation of the imagery to a more coarse scale when the images were edgematched together. Given a typical 1 Gigabyte hard disk, if we had not resampled the aggregated imagery to a more coarse scale, the combined park perspective would not have fit on the hard disk. The parks that are resampled at 20 meter resolution are: CALO and GUIS; while the parks resampled at 10 meters due to a smaller number of frames are: CUIS, CANA, and BISC. However, the 2 meter resolution classified single images are still intact and are able to be worked on but they cannot all be edgematched together due to file sizes. The one park that had all other digital GIS themes processed, but no final image analysis or georectification performed, was CAHA.

The classification methodology employed resulted in 25 classes being delineated (Table 1). The vegetation classification resulted in 6 beach communities being identified, 8 upland/freshwater marsh communities, 5 salt marsh communities and 6 human dominated classes. There is some class overlap between beach and upland communities. Due to the low-lying nature of barrier island landscapes the transitional zone between these two areas becomes very heterogeneous.

Other GIS Themes:

The power of the vegetation classification GIS was augmented by the addition of other GIS themes to each of the parks for use in resource management and particularly for use in forecast modelling. The additional major themes of the GIS are: National Wetlands Inventory Maps and NOAA seagrass maps; geomorphology (from current photographs, shoreline erosion, digitized and digital line graphs); fauna (from U.S. Fish and Wildlife
ecological inventory maps); adjacent land use (from Minerals Management Service ecological characterization studies and Soil Conservation Service maps); cultural resources (from NPS cultural sites inventories); and park infrastructure (buildings and interpretative waysides). Availability of multiple scale data (regional to site specific) allows manipulation and display of GIS information to detect landscape change and habitat distribution (Olson, 1986).

Model and Program Development:

Integration of the vegetation classification GIS of the barrier islands with the U.S. Fish and Wildlife ecological inventory maps (fish/avian/terrestrial animal habitats) led to the development of a program model called FWSDM. The FWSDM program is able to query and show location and occurrence of any species listed in the U.S. Fish and Wildlife Service's Ecological Inventory species maps. This program has the capability of developing a detailed profile of a particular species in any of the NPS Southeast Region's barrier island parks and display where that species occurs in that particular park and with any number of other chosen species location and occurrence. This is one of the most powerful interactive capabilities developed for the project. Another program developed was the USECSI program that utilizes the NPS's Cultural Sites Inventory data and plots this data out on any of the GIS thematic data layers.

Species that occur in a park and the digitized polygon files that depict species location. The FWSDM program and the data derived from it are based on the U.S. Fish and Wildlife Service's Ecological Inventory species maps which consist of polygons showing areas of occurrence of all species with regard to location, state and federally protected status and twelve habitat modifiers. Each of the species location/occurrence polygons on the FWS maps contained the possible occurrence of multiple types of species in each polygon. All polygons were recorded into a database, digitized and linked to the textual database of the master Fish and Wildlife Ecological Inventory species list. The FWSDM program is designed to access the polygon and textual data to produce a GIS file that visually depicts the location of the species (one or more species) queried. We developed a model that integrates our test park (CUIS) shoreline effects model, the vegetation classification and the FWSDM program to produce forecast models of geomorphological change and the resulting change in vegetation areal extent and the loss or gain of specific Fish and Wildlife Ecological Inventory species occurrence habitats. The GIS model's change detection analysis queries the statistical results of the vegetation classification (Table 1, page 11) and gives a prediction of the change in composition, acres, and percent land area of that park's vegetation. A GIS model overlay of these changes in vegetation will be merged with the results of a Fish and Wildlife Ecological Inventory species habitat model query to determine if critical habitat has been lost or gained.
Software and Hardware Requirements:

The minimum standard hardware installation of any image processing and GIS system for this type of work is as follows: Sun workstation (32 mb Random access memory; 24 bit Raster Ops color card); 1 Gigabyte hard disk and 8 mm Exabyte tape archival and backup unit. A DOS 486 Unix machine could be used in lieu of a Sun workstation with the understanding that everything would be much slower. The GIS software used in this project is ERDAS (Earth Data Analysis Systems), a private vendor of image processing and GIS software. The NPS, it appears, has decided to exclusively use GRASS GIS software, a publicly available GIS software. After extensive discussions with the software authors of GRASS (Mark Shapiro and Jim Westervelt) and personal review of GRASS we determined that it was incapable of performing high order image classifications necessary for this project. GRASS is now developing some supervised image classifiers, however we are unsure if they are high order classification algorithms.

As mentioned earlier, development of extensive programs and models was required to use the CSI and Fish and Wildlife Service data and is designed to function in ERDAS. We have written a conversion driver from ERDAS to GRASS that will covert the GIS files from one format to the other. However, this conversion driver WILL NOT be able to access the USECSI and FWSDM programs that we have developed for the Cultural Sites Inventory and the Fish and Wildlife’s Ecological Inventory Maps that depict the occurrence, location and habitat modifiers of all the species noted on the FWS maps.

CONCLUSION

The National Park Service’s southeastern and mid Atlantic barrier islands are morphologically dynamic areas of high public value from both a preservation and recreation standpoint. Different strategies for the effective management of coastal barrier island resources have been advanced. Some researchers stress a management strategy based on accepting the natural episodic and progressive forces which change coastal landscapes (Dolan and Hayden, 1974 and Dolan et al., 1978). Others suggest allowing natural processes to occur in conjunction with dismantling artificially stabilized portions of these islands thereby restoring natural equilibrium (Godfrey and Godfrey, 1976). However, up to this point, the inability of park resource management specialists to accurately and quantitatively predict the impacts of coastal engineering projects and human activities to NPS barrier islands, has significantly compromised decisions that are both appropriate, defensible and in the long-term best interest of the islands.

We feel that the barrier islands remote sensing and GIS project represents one of the most difficult, comprehensive and high resolution regional scale projects done to date. We have solved problems with manipulating and processing massive image databases, developed innovative programs and models to be used with impact forecasting, and
provided a temporal profile of barrier island vegetation and geomorphology from which both hindcast and forecast predictions can be based upon.

Based on the result of this project, high resolution aerial photographic remote sensing and GIS data bases of barrier islands could prove very effective for early forecasting of change in wetlands, dune and upland ecosystems in terms of: species type, abundance, areal extent and composition over regional scale landscapes. Merging the shoreline effects model, the FWSDM species occurrence/location model with the digital photographic vegetation classification of the southeastern and mid Atlantic barrier islands provides a powerful set of tools to effectively respond to current resource management problems and decisions but, more importantly, to predict the impacts to barrier islands should changes in the earth's global climate and sea level change occur in the near future.

REFERENCES CITED


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INFORMATION AND DATA MANAGEMENT REQUIREMENTS

Jeff Marion
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Cooperative Park Studies Unit
Virginia Tech/Dept. of Forestry
Blacksburg, VA 24061-0324
(703) 231-6603

Investigators are required to provide copies and documentation of all pertinent data sets and products collected or generated as part of National Park Service supported research. This information is requested to ensure that valuable computer and hand-recorded data sets and other research products and collections are permanently available for reference and comparison with future research and monitoring efforts.

Contractors and cooperating researchers should be aware that any information collected, compiled, written, or otherwise produced under a government contract is considered government property. Regardless of authorship, contract products are not copyrighted (government works are not subject to copyright protection). Publication rights for particular products or sets of data can be assigned to the contractor, or others, as part of the contractual understanding, but in general the National Park Service is free to reproduce, distribute, publish, translate, or modify its contract products and to authorize others to do so.

Questions regarding the application of these procedures should be directed to the NPS contracting Key Official. The information requested below should be submitted to the Key Official on the due date specified for the draft research report.

INFORMATION REQUESTED

1. A title page listing the research project title; all NPS park units involved in the study; contracting institution; the principal investigator's name and title; contracting agreement number; and project start and completion dates.

2. The most detailed description available of the research design, methods, quality assurance procedures, and materials describing where, when, and how the measurements or observations were taken. This should include a detailed description of any sampling locations and times, field plot locations, field and lab procedures, and type and accuracy of equipment used. If a field manual is

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referenced for this purpose, be sure that it is revised to reflect all the
information requested as well as any changes made during the field season.

3. A bibliographic listing of all research proposals, progress reports, final reports,
and published papers associated with the research study. Each listing should
include the authors, year, title, and source in standard bibliographic format.
Include additional references to sets of maps, photographs, data sets or other
products not included in final reports. As you may publish study results in the
future, we request that you forward copies of each publication based on this
research project to the park(s) and contracting Key Official.

4. The names, addresses, phone numbers and description of research project
functions and holdings of:

A. All investigators involved during the course of the study, including a
listing of data sets or other research products in their possession,

B. Subcontractor(s) used in the study, including commercial labs used for
analysis of any collected materials,

C. Libraries or other archival facilities where documents such as reports,
theses, maps, or photographs have been permanently stored,

D. Regional or national databases in which data or other products from the
study are permanently stored,

E. Museums or herbariums where animal, mineral, and plant specimens
collected during the study are permanently stored, including a listing of
the catalog and accession numbers of all materials.

5. Computer-recorded data: Forward a copy of the data file(s) and supporting
documentation on 3 1/2 or 5 1/4 inch diskettes readable by IBM compatible
computers. Data should be undelimited and in ASCII or Standard Data
Format (SDF), except for files in dBASE and Word Perfect (list version in
data.doc file described below). In an ASCII file named "read.me", copied to
each diskette, include the principal investigator's name, study title, and NPS
agreement number.

Documentation needs vary with type of data. Your objective is to thoroughly
describe the content and structure (or format) of all files so that they might be
accessed and used in the future. In an ASCII file named "data.doc" include
the following information for each data file you submit:
A. A written description of the data file contents, using sufficient detail to
describe the contents of each file

B. The number of records per file

C. The number of rows of data per record

D. A listing of the data variables or fields in the data set including:
   1) variable number - if applicable
   2) variable name or label
   3) variable type - numeric, character (includes alphanumeric), date,
      logical, other
   4) variable width and decimal - total number of spaces or columns
      occupied by the variable in the file and number of decimal places
      or columns
   5) variable category labels or measurement unit - for all categorical
      variables list each category code followed by a category label; for
      all continuous metric variables list their respective measurement
      units
   6) missing data codes - if applicable, code(s) used to denote missing
      data
   7) any other information you feel is necessary to describe your data
      for future access and use

Note: Many software packages have commands which will print much of this
information automatically (e.g. "list structure" in dBASE, "display all" in
SPSS).

Also include supporting non-data files which are vital to the use of your data
files. Examples include statistical package data description files (including
compute and data transformation statements), index files, and programming
files. Include a listing of these files, their content, and use in the "data.doc"
file.

6. Hand-recorded data: Again, documentation needs vary with type of data.
Provide representative copies of all standardized forms, or if forms were not
used, provide a description of the information that was collected. Consult
with the service contracting Key Official regarding further documentation or
the necessity of providing copies of hand-recorded information.