

Guidelines for Developing a Spill Preparedness Plan:
Focus on Environmental Information

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The Archetypical Environmental Sensitivity Index

Introduction

Environmental Sensitivity Index (ESI) maps have been an integral component of oil spill contingency planning and response since 1979, when the first ESI maps were prepared days in advance of the arrival of the oil slicks from the IXTOC 1 well blowout in the Gulf of Mexico. Since that time, ESI atlases have been prepared for most of the U.S. shoreline, including Alaska and the Great Lakes. Table 1 lists the publication date, number of maps, and scale for each atlas. With the exception of northern and central California, central Texas, and Mississippi, all of the atlases have been prepared with funding by the National Oceanic and Atmospheric Administration (NOAA). Furthermore, all the ESI atlases, except for those listed above and the Chukchi Sea in Alaska, were prepared using standardized methods and products (Hayes et al., 1980; Getter et al., 1981). Sensitivity mapping projects have also been conducted for coastal areas of France, Germany, Italy, Nigeria, Kuwait, Saudi Arabia, the United Arab Emirates, Malaysia, and New Zealand among others.

Traditional sensitivity maps have been produced in color-coded paper maps, of limited distribution (because of the cost of reproduction), and without a means for ready updating. With the advent of GIS software for microcomputers, automation of ESI information has been a major new focus. Digital, georeferenced databases are being developed for natural resources management at Federal, State, and local levels. These digital databases can provide a ready source for development of automated sensitivity maps for oil spills. With the power of GIS, sensitivity mapping moves from a static product of limited distribution to a valuable tool for planning and response to oil spills. The first use of GIS technology for production of ESI maps was in Louisiana, where satellite imagery was used to update air photograph interpretations to produce the base maps and intertidal habitat rankings. The technique is being further refined into an all-digital ESI product for southeastern Alaska.

As the oil spill response community moves toward development of automated sensitivity maps, it is important to define the archetypical ESI mapping system.

The Archetypical ESI

This guideline can help define the collection of data for the system, allowing for regional differences in resource distribution, data availability and currency, and extent of supporting information. The primary objective here is to outline the basic elements of a sensitivity mapping system. The second objective is to describe how sensitivity maps are used for contingency planning and during spills. These uses will drive the development of automated systems, the user interface, preset queries, standardized output formats, and map symbology.

Elements of an Environmental Sensitivity Mapping System

General Coverage and Types of Information

The areal coverage of existing marine sensitivity maps is along the coastal zone and extending up rivers to the "head of tide," or the furthest inland extent of tidal influence. Along coastal navigable rivers, the ESI maps extend to the boundary of the U.S. Coast Guard response zone, except along the Mississippi River, where the ESI maps extend to Baton Rouge. Existing maps extend to Troy on the Hudson River, to Trenton on the Delaware River, and to the John Day Dam (river mile 215) on the Columbia River. As part of a special Florida project, the Apalachicola River was mapped to the upper reaches of Lake Seminole.

In the Great Lakes, all of Lake Erie, eastern Lake Michigan, St. Mary's River, and both sides of the St. Lawrence River from Lake Ontario to the New York/Canada border have been mapped. Efforts are underway to produce digital ESI atlases for the U.S. shoreline of Lake Ontario and the Wisconsin shoreline of Lake Michigan.

Nearly all of the maps of the lower 48 states were prepared at a scale of 1:24,000, using U.S. Geological Survey (USGS) 7.5 minute quadrangles as the base map. There are a few exceptions where USGS maps were not available or were not at the appropriate scale. For all of Alaska, 15-minute USGS topographic quadrangles at a scale of 1:63,360 were used as base maps. Southeast Alaska-Part I is a totally digital product. Columbia River and Louisiana were produced with the intertidal shoreline types in digital format.

Table 1. All environmental sensitivity index (ESI) atlases published for the U.S.

Name	Year Published	No. of Maps	Map Scale
Alabama	1981	20	1:24,000; 1:62,500
Alaska	1982-1986	371	1:63,360
California	1980-1986	75	1:24,000; 1:40,000
Connecticut	1984	17	1:24,000
Delaware/New Jersey/Pennsylvania	1985	59	1:24,000
Florida	1981-1984	217	1:24,000
Georgia	1985	29	1:24,000
Hawaii	1986	86	1:20,000; 1:24,000; 1:32,500; 1:40,000 1:62,500; 1:80,000 1:100,000
Louisiana	1989	98	1:50,000; 1:95,000 1:100,000; 1:105,000
Maine	1985	77	1:24,000; 1:40,000
Maine/New Hampshire	1983	25	1:24,000; 1:40,000
Maryland	1983	119	1:24,000
Massachusetts	1980	49	1:24,000
Michigan	1985-1986	38	1:24,000; 1:50,000 1:62,500; 1:163,360
New York	1985	77	1:24,000; 1:50,000
North Carolina	1983	113	1:24,000; 1:62,500
Lake Erie	1985	66	1:24,000; 1:62,500
Oregon/Washington	1986-1989	81	1:24,000; 1:62,500
Puerto Rico	1984	35	1:20,000
Rhode Island/Massachusetts	1983	18	1:24,000; 1:25,000
South Carolina	1982	50	1:24,000
Texas	1979-1980	34	1:24,000; 1:40,000
U.S. Virgin Islands	1986	8	1:24,000
Virginia	1983	113	1:24,000
Washington	1984-1985	80	1:24,000; 1:62,500
Total		1,955	

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ESI maps are comprised of three general types of information:

1. Habitats—which are further divided into:
 - A. Intertidal shoreline habitats, which are ranked according to a scale relating to sensitivity, natural persistence of oil, and ease of cleanup.
 - B. Subtidal habitats, which are utilized by oil-sensitive species or are themselves sensitive to oil spills, including eelgrass beds, kelp, and coral reefs.
2. Biological Resources—including oil-sensitive animals and plants.
3. Human-use Resources—specific areas that have added sensitivity and value because of their use by humans, such as high-use amenity beaches, parks and marine sanctuaries, water intakes, and archaeological sites.

Each of these elements are briefly discussed in the following section.

Habitats

Intertidal Shoreline Types.—Intertidal habitats are at risk during spills because of the high likelihood of being directly oiled when floating slicks impact the shoreline. Oil fate and effects vary significantly by shoreline type, and many cleanup methods are shoreline-specific. The concept of mapping coastal environments and ranking them on a scale of relative sensitivity was originally developed in 1976 for lower Cook Inlet (Michel et al., 1978). Since that time, the ranking system has been refined and expanded to cover shoreline types for all of North America, including the Great Lakes and riverine environments. Table 2 lists the various existing ESI classifications for intertidal shoreline types. There are significant regional differences, to account for the different coastal types. For most areas, the 1-10 scale was used, with subdivision of the numerical ranking for different shoreline types with similar relative sensitivity.

Table 2. Summary of the various ESI ranking scales used throughout the United States

ESI No.	Alaska	West Coast	Columbia River	Texas
1	Exposed rocky shores	Exposed rocky shores/seawalls	Unvegetated steep banks and cliffs	Exposed scarps
2	Wave-cut platforms	Wave-cut platforms	Sand/gravel beaches	
3	Fine sand beaches	Fine sand beaches	Riprap	Exposed fine-grained sand beaches
4	Coarse sand beaches	Coarse sand beaches	Flats	Sheltered fine-grained sand beaches
5A	Exposed tidal flats (low biomass)	Sand and gravel beaches	Vegetated banks	Exposed tidal flats (low biomass)
5B				
6A	Sand and gravel beaches	Gravel beaches /exposed riprap	Marsh/swamp	Mixed sand and shell beach
6B				
7A	Gravel beaches	Exposed tidal flats		Exposed tidal flats (moderate biomass)
7B	Exposed tidal flats (high biomass)			
8A	Sheltered rocky shores	Sheltered rocky shores/coastal structures		
8B				
9	Sheltered tidal flats	Sheltered tidal flats		Sheltered tidal flats
10A	Marshes	Marshes		Salt marshes
10B				
11				

The Archetypical ESI

Table 2. Continued

ESI No.	Louisiana	Florida/Puerto Rico/USVI	Southeast (AL/GA/SC)	Mid-Atlantic (MD,VA,NC)
1	Developed/ unforested upland	Exposed rocky shores/seawalls	Exposed seawalls	Consolidated shores/seawalls
2	Sand beach/spoil bank	Exposed rocky platforms	Not present	Exposed fine sand beaches
3	Tidal mudflat	Fine sand beaches	Fine sand beaches	Sheltered fine sand beaches
4	Freshwater flat	Coarse sand beaches	Coarse sand beaches	Coarse sand beaches
5A	Salt marsh	Sand/gravel beaches	Sand and shell beaches	Exposed tidal flats
5B	Fresh marsh			
6A 6B	Swamp	Gravel beaches/riprap	Riprap	Riprap
7A 7B	Mangroves	Exposed tidal flats	Exposed tidal flats	Supratidal marshes
8A 8B		Sheltered rocky shores/seawalls	Sheltered seawalls	Freshwater marsh/swamps
9		Sheltered tidal flats	Sheltered tidal flats	Sheltered tidal flats
10A		Exposed marshes/ mangroves	Marshes	Fringing intertidal marshes
10B		Sheltered marshes/ mangroves	Sheltered marshes	
11				Extensive intertidal marshes

Table 2. Continued

ESI No.	DE/NJ/PA	Northeast (NY to ME)	Great Lakes	Appalachicola River
1	Not present	Exposed rocky shores	Exposed bedrock bluffs/seawalls	Vertical rocky shores/seawalls
2	Eroding bluffs	Wave-cut platforms	Exposed unconsolidated sediment bluffs	Exposed bluffs
3	Fine sand beaches	Fine sand beaches	Shelving bedrock shores	Fine sand beaches
4	Coarse sand beaches	Coarse sand beaches	Sand beaches	Coarse sand beaches
5A	Sand and gravel beaches	Sand and gravel beaches	Sand and gravel beaches	Mixed sediment beaches
5B		Exposed tidal flats (MA)		
6A	Gravel beaches	Gravel beaches	Gravel beaches	Gravel beaches, riprap, levees
6B	Riprap	Riprap		
7A	Exposed tidal flats	Exposed tidal flats	Riprap	Exposed tidal flats
7B				Vegetated bluffs
8A	Vegetated riverine banks	Sheltered rocky shores	Sheltered bluffs (bedrock)	Vegetated low banks
8B			Sheltered impermeable structures	
9	Sheltered tidal flats	Sheltered tidal flats	Low banks	Cypress/hardwood swamps
10A	Marshes	Marshes	Fringing wetlands	Freshwater marshes
10B			Extensive wetlands	Saltwater marshes
11				

The Archetypical ESI

The intertidal ranking scheme is based on an understanding of the coastal environment, not just the substrate type and grain size. The sensitivity ranking is an integration of:

1. Shoreline type (substrate, grain size, tidal elevation, origin)
2. Exposure to wave and tidal energy
3. Analysis of the natural persistence of the oil on the shoreline
4. Biological productivity and sensitivity
5. Ease of cleanup without causing more harm

All of these factors are used to determine the relative ESI ranking for a shoreline segment. Key to the rankings is an understanding of the relationships between physical processes and substrate which produce specific geomorphic shoreline types and predictable patterns in oil behavior and sediment transport patterns. Historically, the rankings were defined from field surveys and literature analysis, then mapped directly as the shoreline type during aerial surveys. The most common shoreline rankings used in the U.S., with a short summary of the oil behavior, biological sensitivity, and ease of cleanup, are listed below.

1. *Exposed, vertical rocky shores and seawalls.*

These shoreline types are exposed to high wave energy or tidal currents, which tend to keep oil offshore by reflecting waves. The substrate is impermeable so oil remains on the surface where natural processes will quickly remove any oil that does strand. Also, any stranded oil tends to form a band along the high-tide line or splash zone, above the elevation of the greatest biological value. No cleanup is required or recommended. Along developed shorelines, exposed concrete seawalls and steel bulkhead are man-made equivalents.

2. ***Wave-cut rocky platforms, scarps in clay, and exposed sedimentary bluffs.***

These shorelines are also low in rank because they are exposed to high wave energy. However, they have a flatter intertidal zone, sometimes with small accumulations of sediment at the high-tide line, where oil could persist for up to several weeks to months. Biological impacts can be severe, particularly if there are tidal pool communities on the rocky platforms. Cleanup is not necessary except for removal of oiled debris and tarballs at the high-tide line in areas of high recreational use, or to protect a nearshore resource.

3. ***Fine-grained sand beaches.***

Compact, fine-grained sand beaches inhibit oil penetration, and, as they generally accrete very slowly between storms, the depth of oil burial is minimal. Cleanup is simplified by the hard substrate. Biological utilization is low and populations can recover after a few months.

4. ***Coarse-grained sand beaches.***

Coarse-grained sand beaches are ranked higher because of the higher potential for oil penetration and burial, which can be as great as one meter. Cleanup is more difficult, as equipment tends to grind oil into the beach because of the loosely packed sediment.

5. ***Mixed sand and gravel beaches.***

Because of higher permeabilities, oil tends to penetrate deeply into sand and gravel beaches, making cleanup by removal of contaminated sediment difficult without causing erosion and sediment disposal problems. These beaches undergo seasonal variations in wave energy and sediment reworking, so natural removal of deeply penetrated oil may only occur during storms with a frequency as low as one to two per year. Biological utilization is low because of the sediment mobility and rapid drying during low tide.

6. Gravel beaches and riprap.

Gravel beaches are ranked the highest of all beaches primarily because of the potential for very deep oil penetration and the slow natural removal rates of subsurface oil. The slow replenishment rate of gravel makes removal of oiled sediment highly undesirable and cleanup of heavily oiled gravel beaches particularly difficult. For many gravel beaches, significant wave action (meaning waves large enough to rework the sediments to the depth of oil penetration) occurs only every few years, leading to long-term persistence of subsurface oil. Riprap is a man-made equivalent, with added problems because it is usually placed at the high-tide line where the highest oil concentrations are found and the clasts are not reworked by storm waves. Often, the only way to clean riprap is by removal and replacement.

7. *Exposed tidal flats.*

Oil does not readily adhere to, or penetrate, the compact, water-saturated sediments of exposed sand flats. Instead, the oil is pushed across the surface and accumulates at the high-tide line. Because of high biological utilization, however, impacts to benthic invertebrates by exposure to the water-accommodated fraction or by smothering can be significant. Sometimes, highly mobile sand flats, such as those at the mouths of large inlets, are ranked lower when infaunal densities are low.

8. *Sheltered rocky shores and seawalls.*

Spilled oil tends to coat rough rock surfaces in sheltered settings, and oil persists long-term because of the low wave energy. Mapping should differentiate between solid rock surfaces which are impermeable to oil and rocky rubble slopes which tend to trap oil beneath a veneer of coarse boulders. Both types can have large amounts of attached organisms, supporting a rich and diverse community. Cleanup of these shorelines is always labor-intensive and can affect biological communities.

9. ***Sheltered tidal flats.***

The high biological utilization, soft substrate, and low energy setting makes these habitats highly sensitive to oil spill impacts and almost impossible to clean. Usually, any cleanup efforts result in mixing oil deeper into the sediments and prolonging recovery.

10. ***Vegetated wetlands.***

Marshes, mangroves, and other vegetated wetlands are the most sensitive habitats because of their high biological utilization and value, difficulty of cleanup, and potential for long-term impacts to many organisms. Where there are multiple wetland types present, different rankings can be assigned based on likelihood of being oiled, relative wave energy, species composition, and geomorphology (see Virginia rankings in Table 2).

With GIS capabilities, it may be possible to build the shoreline sensitivity classification from other basic parameters, such as substrate, sediment size or type, elevation, width, slope, general geomorphology, and general biological sensitivity, then use algorithms to calculate exposure to wave and tidal energy for each shoreline segment and assign a sensitivity rank. However, this type of sensitivity ranking must be performed in a highly supervised classification mode. Although existing intertidal habitat maps are a good source for mapping discrete classes, e.g., gravel, sand, or mud, they are not good sources when these classes are mixed (sand and gravel), and they do not contain the information needed to identify coastal geomorphological types. The existing ESI maps are usually the best source of information on intertidal habitats for ranking of shoreline sensitivity. The scale of mapping is usually at ± 100 feet for maps made on U.S. Geological Survey 7.5 minute quadrangles.

Development of a standardized sensitivity mapping protocol brings up some special questions on shoreline mapping issues:

- Should all intertidal habitats be ranked on a scale of 1 to 10?
- If so, should subdivisions into 5A, 5B, etc. be used for different shoreline types of similar sensitivity?
- Should an "ESI number" always refer to a specific shoreline type? That is, should ESI = 9 always be sheltered tidal flats?

From one perspective, the 1 to 10 ranking scheme is not as important as the shoreline classifications. The relative rank can be assigned or calculated based on the various factors listed above and attribute data. However, the ESI rankings have significant precedent and acceptance. If a 1 to 10 ranking was always used, then one would always know that the most sensitive shoreline type was ESI = 10, without having to consider that there might be an ESI = 11 type. Thus, the ESI numbers would not always refer to a specific shoreline type, but the relative sensitivity to the impacts of spilled oil. In fact, seldom has a responder asked about a shoreline type by its ESI number; instead, responders either ask, "Where are the marshes?" or "What is most sensitive?"

Nearly all of the existing ESI maps follow this basic 1 to 10 convention, with little variation in the assignment of ESI number by shoreline type (Table 2). The only exceptions are Virginia, Maryland, and North Carolina, which have marshes ranked ESI = 7, 8, 10, and 11; Louisiana, which has ESI = 1 to 7; and Columbia River, which has ESI = 1 to 6. In an automated system, the ESI rank would be part of the attribute information, along with the specific shoreline geomorphology, so that thematic maps could be made using any combination of data attributes.

Because the sensitivity mapping system will eventually be applied to most of the United States, including coastal, lacustrine, and riverine systems, uniformity in classification, color-coding, and symbology will be of great benefit. Research on optimization of mapping colors and symbology for ESI maps is currently underway, and the results will be published in a separate report.

Subtidal Habitats.—In subtidal habitats, oil vulnerability is much lower because these areas are not likely to be directly contaminated by floating slicks. Exceptions include some sites or tidal stages when these habitats become intertidal. The sensitivity of a subtidal habitat usually derives from the species which use the habitat. Thus, kelp beds, which have not been shown to be directly affected by oil, are nonetheless very sensitive because they provide habitat and shelter for animals which are sensitive, such as sea otters. These habitats represent whole communities which have complex interrelationships and functions. The subtidal habitats have not traditionally been ranked; rather, they have been treated more as living resources which vary in sensitivity with season and location. The approach has been to map only the subtidal habitats that have been determined to be most sensitive. In the past, mapping has covered:

- Eelgrass beds
- Submerged aquatic vegetation
- Worm reefs
- Large kelp beds
- Coral reefs

Other subtidal bottom types have not been included. Other subtidal areas important to a specific species are designated according to the species, life stage present, and season of use, not the habitat.

Biological Resources

There are numerous animal and plant species that are potentially at risk from oil spills. Table 3 lists the major groups (elements) and sub-groups of species which are included on sensitivity maps. There are seven major biological elements and each element is further divided into groups of species with similar ecological behavior relative to oil spills. Each of these sub-element groups is composed of individual species that have similar oil-spill sensitivities. For example, there are eight sub-elements for birds, with raptors including those species of accipiters, falcons, and osprey which nest close to major water bodies and feed on fish or seabirds. On the maps, the distribution of oil-sensitive fish

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and wildlife is mostly shown by patterns and symbols representing these ecological groupings, with annotations for each species present.

Note that under "Comments" on Table 3 the types of areas which should be included are listed. Many marine and coastal species are wide-ranging; they can be present over a very large area at any time. Maps or data indicating the entire area of occurrence of fish species, for example, can cover very large areas and thus not help responders in assessing resources at risk and protection priorities. However, natural resources are most at risk from oil spills when:

- Large numbers of individuals are concentrated in a relatively small area, such as bays where rafts of waterfowl concentrate during migration and overwintering;
- They come ashore for birthing, resting, or molting, such as seal haulouts;
- Early life stages are present in somewhat restricted areas, such as nursery areas for anadromous fish, turtle nesting beaches, and bird rookeries;
- Areas important to specific life stages or migration patterns, such as foraging or overwintering sites, are impacted by oil;
- Specific areas are known to be vital sources for seed or propagation;
- The species are threatened or endangered; or
- A significant percentage of the population is likely to be exposed to oil.

Therefore, sensitivity maps show where these most sensitive species, life stages, and areas are located, not the entire area over which the species are known to occur.

Table 3. Components of biological and human-use resources included on sensitivity maps

Data Element	Sub-Element	Comments
Habitats	Shoreline types	ESI or other geomorphological class
	Eelgrass beds/SAV	Includes all types of subtidal grass beds
	Kelp	
	Coral reefs	
	Worm beds	
Marine Mammals	Whales	Seasonal use areas; Migration routes
	Dolphins	Population concentration areas
	Sea lions	Haulouts
	Seals	Haulouts
	Sea otters	Population concentration areas
	Manatees	Population concentrations areas
	Walruses	Haulouts
	Polar bears	
Terrestrial Mammals	Mustelids	Concentration areas
	Rodents	Concentration areas
	Deer	Intertidal-feeding species
	Bear	Intertidal feeding areas
Birds	Diving coastal birds	Rookeries; Forage/wintering areas
	Waterfowl	Wintering areas; Migration stopover areas
	Alcids	Rookeries; Wintering concentration areas
	Petrels/fulmars	Rookeries
	Shorebirds	Nesting beaches; Migration stopover areas
	Wading birds	Rookeries; Critical forage areas
	Gulls/terns	Nesting sites
	Raptors	Nest sites; Critical forage areas

Table 3. Continued

Data Element	Sub-Element	Comments
Fish	Anadromous fish	Spawning streams
	Beach spawners	Spawning beaches
	Kelp spawners	
	Nursery areas	For estuarine, demersal, pelagic fish
	Reef fish	Includes fish using hardbottom habitats
	Special concentrations	Estuarine and demersal fish
Mollusc	Oysters	Seed beds; Leased beds; Abundant beds
	Mussels	Leased beds; Abundant beds
	Clams	Harvest areas; Abundant beds
	Scallops	Harvest areas; Abundant beds
	Abalone	Harvest areas; High concentrations
	Conch/whelk	Harvest areas; High concentrations
	Squid/octopus	Harvest areas; High concentrations
Crustaceans	Shrimp	Nursery areas
	Crabs	Nursery areas; High concentration sites
	Lobster	Nursery areas; High concentration sites
Reptiles	Sea turtles	Nesting beaches
	Alligators	Concentration areas
Recreation	Beaches	High-use recreational beaches
	Marinas	
	Boat ramps	
	Diving areas	High-use recreational areas
	Boating/fishing	
	State parks	

Table 3. Continued

Data Element	Sub-Element	Comments
Management Areas	Marine sanctuaries/	
	National parks	
	Refuges	
	Preserves/Reserves	Areas of special biological concern/WMA
Resource Extraction	Subsistence	Officially designated harvest sites
	Commercial fisheries	
	Water intakes	Industrial; Drinking water; Power plants
	Mining	Intertidal/subtidal mining leases
	Aquaculture sites	Fish/shrimp/bivalves/plants
	Log storage areas	
Cultural	Archaeological sites	
	Native American Res.	

Several types of distributions are shown. Point locations (in the form of latitude and longitude) are used for sites of very small areal extent, such as bird rookeries and mammal haulouts. Range bars or lines are used to show sites along a shoreline which is used for a specific activity, such as the length of a stream used for spawning by anadromous fish or the extent of a beach where turtles nest. Biological distributions which are spread over an area are shown by polygons with patterns, such as oyster seed beds, important nursery areas for estuarine fish, or high-concentration waterfowl overwintering areas.

Table 4 lists the associated data for each element which should be included at the species level. These data allow identification of the most sensitive periods for each species and determination of protection priorities on a seasonal basis. For each species or species group, detailed information is provided on the life stage present by month of year.

Table 4. Data elements and associated fields for resources at risk

Element	Sub Element	Data Fields																						
Marine Mammals		Lifestage Present (Adult, Adult breeder, Juvenile, Present)												Concentration			Species*	Expert (Name, agency, phone)		Breeding				
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low			Mating (S/E)	Calving (S/E)	Pupping (S/E)		
	P	Whales																						
	P	Dolphins																						
	PVP	Sea lions																						
	PVP	Seals																						
Terrestrial Mammals	P	Sea otters																						
	P	Manatees																						
			Lifestage Present (Adult, Adult breeder, Juvenile, Present)												Concentration			Species*	Expert (Name, agency, phone)					
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low							
	P	Mustelids																						
	P	Rodents																						
Birds	P	Deer																						
	P	Bear																						
			Lifestage Present (Adult, Adult breeder, Juvenile, Present)												Concentration			Species*	Expert (Name, agency, phone)		Breeding			
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low			Nesting (Arr.)	Laying (S/E)	Hatching (S/E)	Fledging (S/E)	
	PVP	Diving coastal birds																						
	P	Waterfowl																						
Fish	PVP	Alcids																						
	PVP	Petrels/fulmars																						
	PVP	Shorebirds																						
	PVP	Wading birds																						
	PVP	Gulls/terns																						
	PVP	Raptors																						
Molluscs			Lifestage Present (Adult, Juvenile, Larvae, Egg, Present)												Concentration			Species*	Expert (Name, agency, phone)		Breeding			
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low			Spawning (S/E)	Outmigration (S/E)			
	L/P	Anadromous																						
	L/P	Beach spawners																						
	P	Kelp Spawners																						
	P	Nursery areas																						
Crustaceans	P	Reef fish																						
	P	Special concentrations																						
			Lifestage Present (Adult, Juvenile, Larvae, Egg, Present)												Concentration			Species*	Expert (Name, agency, phone)		Breeding			
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low			Mating (S/E)	Spawning (S/E)			
	P	Oysters																						
	P	Mussels																						
Reptiles	P	Clams																						
	P	Scallops																						
	P	Abalone																						
	P	Conch/whelk																						
	P	Squid/octopus																						
			Lifestage Present (Adult, Juvenile, Larvae, Egg, Present)												Concentration			Species*	Expert (Name, agency, phone)		Breeding			
Amphibians		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low			Mating (S/E)	Spawning (S/E)			
	P	Shrimp																						
	P	Crab																						
	P	Lobster																						
			Lifestage Present (Adult, Juvenile, Egg, Present)												Concentration			Species*	Expert (Name, agency, phone)		Breeding			
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low			Nesting (S/E)	Hatching (S/E)			
Amphibians	L/P	Sea turtles																						
	P	Alligators																						

Abbreviations: Arr-Arrival Date, L-Line, P Polygon, Pt Point, S/E-Start Date/End Date

* Endangered species identified with an asterisk

Table 4. Continued

Element	Sub-Element	Data Fields									
Habitat	L/P Shoreline type	ESI-1	ESI-2	ESI-3	ESI-4	ESI-5	ESI-6	ESI-7	ESI-8	ESI-9	ESI-10
	P Eelgrass/SAV										
	P Kelp										
	P Coral reef										
	P Worm beds										
Recreation		Name Owner/no/Contact									
	L Beaches										
	Pt Marinas									# Slips	Access Capabilities
	Pt Boat ramps									Size	Construction
	Pt/P Diving areas										
	P Parks										
P/P	Boating/fishing									Type	Season
Management Areas		Name Owner/no/Contact									
	P Nat. Park/Mar. Sanct.										
	P Refuges										
	P Preserves/reserves										
Resource Extraction		Name Owner/no/Con/Type									
	L/P Subsistence									Season	
	P Commercial fishery									Season	
	Pt Aquaculture									Season	
	Pt Water intakes									Depth	Volume
	Pt Mining									Active	
	L/Pt Log storage										
Cultural		Name Owner/no/Contact									
	Pt Historical									Type	
	Pt Archeological									# Sites	
	P Native American										

Abbreviations: Arr-Arrival Date, L-Line, P-Polygon, Pt-Point, S/E-Start Date/End Date

* Endangered species identified with an asterisk

For mammals and birds, life stages include *adult*, *adult breeder*, and *juvenile*, or just *present* if the life stage is unknown. *Not present* is indicated to differentiate from no data available. The earliest start and latest end dates for breeding activity of marine mammals and birds are used to determine the presence of eggs or young. Calving dates apply only to whales, dolphins, and manatees, whereas pupping dates apply to sea lions, seals, and sea otters. The number of individuals or breeding pairs is listed (if known); otherwise, descriptive qualifiers of the number or relative size of the population likely to use the area are indicated. For example, heavily used seal haulouts can be ranked as high, while sites which are infrequently used can be ranked as low. Previously, information on sensitivity maps showed only presence of these animals by season; the user had to obtain numbers of animals present and life stage and breeding status from other sources or general life history profiles. The availability of life-stage and concentration information helps planners and responders make better decisions on protection and cleanup priorities.

For terrestrial mammals, breeding information is not usually included since these data are seldom known. Rather, the life-stage presence by month is used to indicate when young are likely to be present.

For fish, emphasis is placed on important spawning and rearing areas in shallow-water environments, where sensitive life stages are concentrated and at risk of exposure to high levels of oil in the water column. Therefore, shallow water and intertidal spawning areas are shown for anadromous fish, beach spawners such as grunion, and kelp spawners such as herring. The entire length of stream used for spawning by anadromous fish is shown. Nursery areas for larval and juvenile fish in estuarine settings, particularly for species of commercial or recreational importance, are highlighted. Reef and shallow hardbottom habitats are included as areas of fish concentration at risk from floating slicks. Life-stage information includes larvae and eggs, and breeding activity includes start and end dates for spawning and outmigration of fry.

Molluscs and crustaceans are always indicated as areas, designated as important seed beds, harvest areas, abundant beds, or otherwise high concentration areas. Life stages present for each month include adults, juveniles, larvae, and eggs, and breeding activity start and end dates include mating and spawning.

The concentration descriptors can be used to designate relative importance of the site or area. For example, seed oyster beds would be designated as high, whereas viable but closed oyster beds would be designated as low. The objective is to provide responders with the information needed to determine protection priorities.

The only information usually shown for turtle nesting beaches is the start and end date for laying of eggs and hatching of young. For all other life stages, turtles range widely and have no habitat preferences which increase their likelihood of encountering oil. Information for alligators is shown as areas of occurrence, with designation of life stages present, if known.

Threatened and endangered species are shown with a special flag to indicate their management status. Species on both State and Federal lists are shown. It may be important to include the expert contact for a specific resource, someone who could be contacted to provide current species status or special protection requirements. General resource-wide contacts, such as the State Historic Preservation Office for archaeological sites, should be listed elsewhere. However, this section of the database lists the key person or agency knowledgeable about a specific resource, if there is one.

In the past, standardized symbols for each of these resources have been used, with general color patterns for major ecological groups (blue for fish, green for birds, orange for shellfish, yellow for mammals, red for reptiles). Symbols are used to represent important species groupings within a major group. For example, a different symbol is used for each of the eight sub-groupings under birds in Table 4. These symbols allow the user to identify the general group of organism and its general risk without having to know the specific species composition. As mentioned above for habitats, there is an ongoing research effort to identify symbology and patterns for use in generation of hard-copy maps and screen views from GIS databases.

Human-Use Areas

Previously designated as socioeconomic resources on ESI maps, human-use areas can be divided into four major components (Table 3):

- High-use recreational use and shoreline access areas
- Officially designated natural resource management areas
- Marine and coastal resource extraction sites
- Close-to-shore archaeological and cultural sites

For biological resources, recreational areas shown on sensitivity maps should include high-use recreational beaches and sport fishing, boating, and diving areas. Shoreline parks indicate high amenity value. Boat ramps and marinas are shown, both as recreational sites and for shoreline access. Marina size (number of slips) can help set protection priorities. Name/phone contacts for marinas and parks can facilitate notification and collection of information on site suitability for shoreline access and construction details needed for operations support.

Officially designated natural resource management areas include national parks and marine sanctuaries, national wildlife refuges, wildlife management areas, preserves and reserves set aside by various agencies and organizations, and other ecological sites that have special resource-management plans or status. In the event of a spill, the contact and phone number for the management area are needed for notification and inquiry as to current conditions (e.g., number/species of waterfowl actually present or expected in the near future). Likewise, contact information for water intakes and aquaculture sites (including exact location, depth of intake, use, volume, and presence of alternative sources) is critical.

Where appropriate, log storage sites and intertidal/subtidal mining leases are included so appropriate protection and cleanup strategies can be developed. Each has a unique problem or issue which can significantly complicate oil removal strategies. Log storage sites can contain large numbers of valuable wood products, which, when oiled, must be cleaned at great expense prior to sale. Owners of intertidal mining leases must be contacted before removal of oiled

sediment can begin. For each site, the boundary, owner/user contact, and type of activity should be provided.

High-value commercial fishing areas are a critical component, particularly leased shellfish beds and nearshore, shallow-water fisheries such as crabbing, shrimp harvest, lobster harvest, and estuarine fisheries. Many times the concern is to minimize impacts to the catch and fishing equipment as gear is pulled from the water through surface slicks. For each area, the boundary, species being utilized, time of use, and data on catch for that area should be provided. Non-commercial seafood harvest areas, including subsistence use areas, identify sites where monitoring of seafood quality may be needed to protect local populations in the event of a spill.

The most sensitive type of archaeological sites are those located in the intertidal zone, such as parts of Alaska where subsidence exposes important sites to coastal erosion. Also, sites located very close to the shoreline where they may be crossed by response or cleanup crews should be shown. The type and status (e.g., on National Register) of each site should be included. If there are multiple sites in a general area, then the area and number of sites should be indicated. Site-specific information for some highly sensitive or important archaeological resources may need to be restricted in distribution to prevent unnecessary site visits by the curious, as well as destruction by vandals. In such a case, the general area of the sites should be designated and a contact for access to specific location information and methods of protection provided.

How Sensitivity Maps are Used

Contingency Planning

Integral to the pre-spill planning process is the designation of protection priorities for selected spill scenarios so that site-specific protection equipment requirements can be identified. These priorities, as determined by local, area, and/or regional planning committees, are derived from analysis of the resources at risk. Pre-planning also includes development of shoreline cleanup strategies based on the shoreline type and use.

Sensitivity maps play an extremely important role in training and the development of credible spill scenarios. In particular, seasonal differences in resource presence and sensitivity can be significant, altering the resources at risk, protection priorities, and appropriate response and cleanup activities. For example, the presence of early life stages of commercially important fish and shellfish species in the water column usually precludes the use of dispersants in the vicinity. However, in the winter, when large numbers of waterfowl are concentrated in nearshore waters, dispersant use might be a viable means to reduce bird impacts. Cleanup priorities are often driven by the seasonal arrival of a species or sensitive life stage, such as concentrating efforts to remove oil from turtle nesting beaches prior to the arrival of nesting turtles. The physical disturbances of cleanup activities alone have been shown to disrupt nesting success of birds, so setting exclusion dates for cleanup activities by species can significantly affect cleanup planning and scheduling.

Pre-planning is made more powerful with access to an automated system; being able to generate maps at various scales increases the power of planning. Very detailed maps are needed for site-specific protection strategies and equipment pre-staging. In contrast, maps of sensitive resources are often better presented in overview for analysis of risks and priorities. For example, the need, type, and location of bird rescue operations in Puget Sound is best determined by analysis using maps of nesting colonies and waterfowl concentration areas for the entire Sound, with symbols and patterns representing relative size and species sensitivity. *Ad hoc* querying by the user for any combination of resource information is needed for automated systems. Thus, unique, non-interfering symbology is critical, and this is very difficult to achieve for all ranges of possible combinations.

Spill Response

When the initial notification of an actual or potential spill is received, ESI maps are used to determine the resources likely to be present and their relative risks to impacts from exposure to oil. Having all the resource information on one set of maps greatly facilitates this resources-at-risk assessment. The maps are multi-disciplinary, allowing quick evaluation of the potential magnitude of the spill's

impact, based on initial information and the general trajectory of the slick. Only if such data have been compiled onto one set of maps can they be quickly used to support time-critical decisions, such as the use of chemical agents to disperse the slick or identification of the most important sites for exclusion booming.

Once the area of impact is more defined, the resource information is used to create spill-specific sensitivity maps (based on impact area and season). These spill-specific maps are distributed to response personnel in the field and command posts for incorporation into response strategies and determination of protection priorities. These maps are used to identify potential bird and mammal impacts so appropriate rescue and cleanup actions can be planned. Resource managers for the impacted areas are contacted to verify the species and number of animals actually present, and to determine specific response strategies.

As the response moves from establishing priorities to developing cleanup criteria, sensitivity maps are used to determine the need and limitations of shoreline cleanup techniques. Used in conjunction with degree-of-oiling maps, summary maps and statistics can be generated to show the areas proposed for various treatment methods, or the percent of a shoreline type proposed for treatment. Exclusion zones can be plotted for certain types of cleanup activities; for example, exclusion zones for aircraft above bird rookeries and marine mammal haulouts during nesting and pupping season can be plotted on maps for distribution to pilots. The location of exclusion booms can be indicated on maps for distribution to boaters, to show areas which they should avoid.

In the future, determination of resources at risk and protection strategies during oil spills will be assisted by the development of GIS applications with automated mapping functions. State and Federal agencies are using GIS technology for management of natural resource information, and applications for oil spill planning and response are planned in many states. Automation brings many powerful tools to the spill-response community and managers of natural resources. However, the role and benefit of automated sensitivity mapping in spill response may be overvalued—too much may be expected too soon, and there are many complex issues that need to be resolved. Furthermore, it will take years to digitize the data. However, GIS technology will facilitate the

The Archetypical ESI

generation of thematic maps for specialized planning requirements and preparation of maps at various scales. The primary analytical products of an oil spill GIS are still maps, which are distributed to many types of users. GIS technology provides the ability to analyze complex spatial data trends and display the results in a powerful format. However, the tough decisions still must be made in an environment where conditions rapidly change and systems may not be able to keep up with the pace.

Resources at Risk Data Acquisition

Introduction

State and Federal agencies were polled as to the types of data available for use in sensitivity mapping efforts during August and September 1991. Of particular interest was a determination of the status of each agency's GIS technology, as well as the currency of analog and digital data and/or extent of updates to established databases. For this project, agencies from all 22 coastal states and two U.S. Territories, more than ten Federal agencies and their branch offices, as well as public and private institutions nationwide were contacted. The overall objective was to develop a database of information sources addressing natural resources for coastal states, excluding Alaska and the Great Lakes. The database is the primary product; this report is a brief summary of the methods used for data collection and status of coverage by state.

All information in the database was obtained through phone interviews. State and Federal contacts were thoroughly questioned regarding the detail and extent of coverage of each data source available within their agency. A separate questionnaire was filled out for each resource available from each contact (see Figure 1). Table 4 lists the components of biological and human-use resources of interest needed to accurately conduct sensitivity mapping for each state. Many of the state contacts requested the chance to fill out the questionnaires themselves in order to assure the completeness and accuracy of the data collected. In these instances, we faxed the individual copies of the questionnaire and data needs after going over in detail the project requirements.

An effort was made to contact all potential sources. However, it should be noted that our survey efforts are incomplete and in many instances, key sources might not have been identified or might not have responded to requests for information. Additionally, the information gained from our survey efforts was not evaluated as to the extent and complexity of the data sources. The emphasis of the survey was to locate and describe the data, not to analyze each source in detail. Universities were not considered primary contacts as their data are most often too site-specific.

Natural Resources Data Sources

However, when referenced by other state and Federal agencies as having pertinent information, every effort was made to contact these sources.

The following is a brief synopsis of the data available from the sources contacted on a state-by-state basis. More detailed information regarding these resources should be obtained from the *Natural Resource Inventory* database on the enclosed diskette. Within the state summaries, several terms are repeatedly used regarding the data formats. These terms are defined below.

1. Digital map - Any spatial data that have been entered into a computer system whether it is in raster or vector format. Also included are point data that are georeferenced and associated with a map that has been digitized into a computer system.
2. Digital tabular - Any data that are currently entered into a computer system, regardless of the format of the data. These data usually have some location reference information, so they can be easily transferred into a digital map.
3. Analog map - Data that have been compiled onto paper maps. These maps can be published atlases, figures in reports, or rough work products.
4. Analog tabular - Lists of data that are present in reports or in files. These data are usually used and available for point data, such as bird nesting, water intakes, boat ramps, etc. Location reference information in this format may be vague (e.g., referenced by a name of a place), making it difficult to transfer the data into a digital map product.
5. Analog text - Typically this term refers to technical reports. Normally this is the most difficult medium from which to extract the necessary information for resource mapping. It requires reading the report and interpreting the information to be able to geographically locate and quantify the data.
6. GIS - Geographical Information System is a combination of digital maps and digital tabular data, that allows a user to identify items by geographic location, and allows geographical as well as tabular relationships to be built between different elements.

TELEPHONE LOG	
TELEPHONE #: _____	AFFILIATION: _____
PERSON(S) SPOKEN WITH: _____	
Name (title of reference)	
Author (author/publisher of the reference)	
Address (author/publisher's address)	
Contact (author/publisher contact)	
Format (digital map, digital tabular, analog map, analog tabular)	
Telephone (contact's telephone number)	
Source (compiled/original)	
Status (completed/not completed)	
Start-End Date	
Coordinate Units-How is it Georeferenced (latitude/longitude, state, other)	
Scale (set scale)	
Geography Covered (national, state, port, river, etc.)	

Figure 1. Data sheet used for each of the references collected

Natural Resources Data Sources

State Summaries

State of Alabama

The State of Alabama has no protocol regarding a statewide GIS. The majority of the State agencies do not have the funding or the need to establish a GIS.

Presently, only one agency has a GIS, the Alabama Department of Economic and Community Affairs, which used ERDAS to develop habitat maps from 1956, 1979, and 1989 aerial photographs to determine coastal change. Future plans include the conversion of this database to ARC/INFO. Digital habitat maps of the Alabama coastline are also available from Federal sources.

The Alabama Department of Conservation and Natural Resources and the Alabama Geological Survey have ongoing studies for a majority of the coastal resources at risk. These data collections are in digital tabular or analog map formats. The Alabama Coastal Characterization study and the Tuscaloosa Trend study provide detailed digital tabular and analog map information on all elements from data gathered in the mid- to late-1980s.

State of California

Several agencies in California are developing natural resource GISs using ARC/INFO. The State is trying to coordinate the effort among the different State and Federal agencies that may have digital data or mapping projects in the State. The primary State agencies are State Lands Commission, California Department of Fish and Game (CDF&G), Teale Data Center, and California Coastal Commission. The Coastal Commission development is mostly driven by needs for particular types of data to plan coastal projects or support legislative efforts. Therefore, the coverage by this group is limited to project areas. The other three agencies are building statewide or regional databases. The coverage from these agencies can be fairly complete for the data that they have available. The data are being extracted from local, State, and Federal sources. CDF&G's Office of Oil Spill Prevention and Response is in the initial planning phases of producing an oil spill GIS. They are currently identifying the information that is available, both within CDF&G and from other local, State, and Federal agencies.

Digital data are available to a limited extent for habitat information, resource extraction, and cultural sites. Complete current data are available in digital format for marine mammals and birds. Base map and other land features are also fairly complete, including bathymetry data for Southern California. Much of the digital data that exist were digitized from pre-existing paper maps or data.

State of Connecticut

Connecticut's Department of Environmental Protection, Natural Resource Center is implementing a statewide GIS. The structure for collecting and initially entering the data is in place and much of the data have been collected by regional offices or specialty branch offices, but it has yet to be entered into the central database. The statewide system is not ready to receive the information so data collection is being conducted at the branch offices level, and many of these offices have set up systems to meet their specific needs. Some offices separately maintain data in a digital tabular format.

The fish and shellfish information is current to 1991, with additional surveys still being conducted. The fisheries information is constantly being updated, and is in digital database. Much of the non-biological information is in analog format.

State of Delaware

The Delaware Department of Natural Resources and Environmental Conservation plans to implement a statewide GIS running on an ARC/INFO system. The GIS department has digital data on some of the inland waters but no work has been done in the coastal zone. No local efforts are underway to implement a GIS system.

Biological resource information is available in analog map form for most of the coastal area, and was updated in 1987. These data are to be updated again in the near future, in preparation for installation of a computer-based system. The non-biological data, cultural sites, recreational information, and resource extraction are almost all available in digital format as database files. Historical sites are on analog maps. Most of these data are constantly being updated as new information is added.

Natural Resources Data Sources

State of Florida

The Florida Department of Natural Resources (FL DNR) is using ARC/INFO and Florida Game and Fresh Water Fisheries Commission (FL G&FWFC) is converting its digital tabular data into GIS.

The FL DNR has "cleaned up" the National Oceanic and Atmospheric Administration (NOAA) digital shoreline data for coastal Florida as the base map for its coastal Florida system. They have been recently funded to generate updated sensitivity maps for oil spill applications in a GIS, with the project to begin in late 1991. A detailed mapping effort (using GIS) of the John Pennekamp State Park in the Florida Keys is presently underway. An additional digital mapping source is the National Park Service (NPS) barrier islands study, which has highly detailed habitat, biological, and non-biological data for Canaveral, Biscayne, and Gulf islands in Florida. These data were developed from high-resolution aerial photographs with a one-meter resolution.

Data collections by various State agencies are ongoing for most of the data elements. The FL G&FWFC have 1991 digital map data for birds, marine mammals, reptiles, and terrestrial mammals. State and Federal sources have digitally mapped management and recreation areas, and current digital tabular data are available for fish, molluscs, cultural sites, and areas of resource extraction.

State of Georgia

Georgia is beginning to implement a statewide GIS using ARC/INFO systems. Two State agencies have a functioning GIS using ARC/INFO: the Georgia Geological Survey and the University of Georgia's Marine Institute and Geology Department.

Digital map data are available for local bathymetry, coastal geology, and land cover for portions of coastal Georgia, including Sapelo Island. An additional digital mapping source is the NPS barrier islands study, which has highly detailed habitat, biological, and non-biological data for Cumberland Island. These data were developed from high-resolution aerial photographs with a one-meter resolution.

In addition to habitats, the Georgia Geological Survey has digitally mapped the shellfish beds within State waters. Current digital tabular data are available for both biological and non-biological elements. Data for terrestrial mammals are only available in analog formats.

State of Hawaii

The Main Hawaiian Island Marine Resources Investigation has established a GIS database using ARC/INFO to evaluate the status of nearshore and inshore living marine resources in Hawaii and to acquire the information necessary to manage these resources rationally. This statewide GIS data collection includes the following participants: Hawaii's Sea Grant College Program, the Hawaiian Institute of Marine Biology (HIMB), USFWS, the Oceanic Institute, NMFS Southwest Fisheries Center, and the Western Pacific Regional Fisheries Management Council.

As this project is newly initiated, the information is current. Digital maps are available for the shoreline habitats, shellfish and fish, reptiles, cultural sites, and management and recreational areas. Because this project focuses on nearshore and inshore living marine resources, information on birds is not yet available in digital map format. HIMB is collecting local data for most of the elements, including birds and areas of resource extraction, but maintains the information in an analog format. Eventually the HIMB data will be incorporated into the State's GIS.

State of Louisiana

Louisiana has established a standardized statewide GIS using Intergraph. The Louisiana Geological Survey (LA GS) is the central repository for the system. Regional offices or specialty branch offices, such as the Louisiana Department of Wildlife and Fisheries (LA DW&F), Louisiana State University, and the Louisiana Natural Heritage Program, refine their data layers which are networked with the State GIS.

Base maps were produced from U.S. Geological Survey (USGS) maps and are subsequently updated annually using aerial photography (video). These base maps are then used by other State agencies when developing data layers for additional

Natural Resources Data Sources

elements. Habitat information has been compiled by LA GS, LA DW&F, and the Louisiana Department of Natural Resources without any ranking assignments.

All State data are current to 1991. Data collections by State agencies are ongoing for all elements using digital mapping format, excluding cultural sites and areas of resource extraction. For these two elements, Federal sources supply the most current data in digital tabular format.

State of Maine

The State has a statewide GIS system (using ARC/INFO) being developed and implemented for spill response mapping and coastal planning. The Maine Department of Environmental Protection is the lead agency in this effort and is currently managing the system. The project was started in 1991 and will include most of the features that are part of the ESI maps. The data are to be obtained from existing data sources with very little new survey work being conducted. The agency is still deciding on the type of data, and may use the ESI maps for input of intertidal habitat information. The system is not yet operational.

Most of the more recent resource information has been gathered by two synthesis programs. The Gulf of Maine program is a joint U.S.-Canada effort to build a spill response database for the entire Gulf of Maine. The program began gathering marine mammals and fishery resources information in 1991. The Ecological Characterization of Coastal Maine report is a multi-volume set, published in 1984, that includes detailed reports and maps for the coast of Maine. The coast is divided into six regions and each has detailed coverage based on 1:24,000 scale base maps of shoreline types, biological resources, and socioeconomic resources. The Manomet Bird Observatory has a current database on the birds of the area.

State of Maryland

The State of Maryland is converting its information and databases to a GIS format. A wide range of software (both GIS and non-GIS) is being used by State agencies, including ARC/INFO, Mapping Image Processing System (MIPS), SAS, and Advance Revelations. The Virginia Institute of Marine Science is an additional source for detailed information on Chesapeake Bay.

New (1991) habitat information (based on wetlands and vegetative cover mapping) has been generated in digital format (ARC/INFO), and interpreted from high-altitude aerial photographs by both the Maryland Office of Planning and the Virginia Institute of Marine Science. New information (1990-1991) is also available from various sources and in various formats for bird and fish concentrations as well as identifying areas of resource extraction and cultural, recreational, and management areas. These data are primarily in digital tabular and/or analog map formats.

State of Massachusetts

The Massachusetts Coastal Zone Management office is building a GIS using ARC/INFO and USGS 1:24,000 scale quadrangles as base maps. Currently, they have only the physical features (roads, topology, boundaries, hydrology, etc.) that relate to land-use planning; they have entered very little biological resource information. They are continually adding new data layers to the system. In addition, the State is initiating some new surveys of biological resources.

Biological resources currently being updated include oyster and clam beds, anadromous fish streams, and wetland areas. They also have entered the endangered species data from the State's Heritage Program and the fisheries and marine mammals data from NOAA/National Marine Fisheries Service (NMFS) databases in their system. They have entered data from the Gulf of Maine project, which involves all the states along the Gulf of Maine.

State of Mississippi

Collection of data from key sources in Mississippi is not complete. The 1984 coastal sensitivity atlas by the Mississippi Department of Wildlife Conservation, and cooperative studies with local states (e.g., the Tuscaloosa Trend study), appear to be the most recent State-generated data sources for coastal resources. The 1984 atlas identifies shoreline types and their protection priorities. Additionally, efforts to evaluate and/or assess the coastal wetlands in Jackson County were developed to establish a ranking system for these resources in terms of their vulnerability to oil spills.

Natural Resources Data Sources

A primary source of current data (both biological and non-biological) are from Federal agencies. Federal habitat data are available in digital map formats. For other elements, the majority of the information is in digital tabular format.

State of New Hampshire

The New Hampshire Departments of Environmental Services and Fish and Game will soon meet to identify the data available and determine requirements of a GIS for environmental resource data management.

Biological resource and habitat information is limited mostly to data collected in the early 1980s. Biological information is available mostly as analog maps. Bird data from Federal agencies and Manomet Bird Observatory are current to 1991.

State of New Jersey

The New Jersey Department of Environmental Protection, has implemented a statewide GIS system (using ARC/INFO) which contains data at state and county levels. Components of the system appropriate for spill response include base maps, and threatened and endangered species. New Jersey is cooperating with New York and EPA in developing a spill response GIS for a section of the New York/New Jersey port area.

Recreational, resource extraction, cultural sites, and management areas are all available through the State's GIS and are relatively current. The biological resources are not as current, with the exception of some Federal bird data which are as recent as 1991. There are plans to update some of the State biological resource information before entering it into the GIS.

State of New York

New York is working to implement a statewide GIS that will be administered by the New York Department of Environmental Control. The State will work with New Jersey and EPA on a spill response and planning GIS for a section of the New York/New Jersey port area. At present no other agencies within the State are implementing a GIS mapping system for natural resources. The infrastructure is in place to start the mapping, but there is currently insufficient funding for the effort.

Some of the most recent biological information for birds is available through Federal groups or the Manomet Bird Observatory. The Long Island Sound Commission has current digital tabular data on fisheries efforts in Long Island Sound. The New York Department of Environmental Control maintains data on shellfish beds in New York waters and the status of whether they are opened or closed.

State of North Carolina

North Carolina has established a standardized statewide GIS using ARC/INFO. The Center for Geographic Information and Analysis is the office in charge of the system. Regional offices or specialty branch offices, such as the North Carolina Department of Natural Resources, refine their data layers which are networked with the State GIS system.

At present, North Carolina is using a standardized base map which is primarily composed of USGS topographic maps. The shoreline types from the North Carolina ESI atlases, as well as the NWI maps and local bathymetry, have been digitized into the system. Four or five wetlands classification categories have been established within this system. An additional digital mapping source is the NPS barrier islands study. This resource has highly detailed habitat, biological, and non-biological data for NPS barrier islands (Cape Hatteras and Cape Lookout) within North Carolina and was developed from high-resolution aerial photographs with a one-meter resolution.

Fish and shellfish data are available in digital map format and are current to 1991 with additional surveys ongoing. Digital mapping efforts for cultural sites and recreational areas are also current. Much of the biological information is in digital format (map or tabular) and includes recent survey data.

State of Oregon

Oregon has developed a GIS for oil spill applications. The State currently has a full ARC/INFO system implemented by the State Service Center for GIS. The data are fairly complete and current. They are continually adding new information and updating existing information.

Natural Resources Data Sources

The shoreline habitat information is based on the ESI maps, but they combined the original 10 ESI categories into five. Cultural sites and recreational features are based on current surveys. Much of the biological resource information is also based on surveys conducted by the State agencies that are interested in the resources. Much of this information is as recent as 1991.

Puerto Rico

Territorial agencies are conducting ongoing studies for the majority of the elements identified as coastal resources. These data are primarily stored in analog map, table, or text formats. Presently, many of the territorial agencies are attempting to upgrade their data systems into digital tabular format.

Digital mapping of Puerto Rico has been conducted by Federal agencies. Both habitat and cultural areas are identified on Federal GIS databases. Territorial agencies have produced analog maps of coastal habitats.

Ongoing studies continue to collect data on the coastal resources. Current 1991 data are available for all elements in analog map and tabular format. Many of these studies are also being converted to digital tabular format.

State of Rhode Island

Rhode Island has a central repository, Rhode Island GIS (RIGIS), for all the digital data for the State. All State-funded GIS projects send the final GIS data to RIGIS, which is developing a statewide standard for the data format. Currently, they are using an ARC/INFO system. Most of the data for this system are assimilated by other groups (both State and Federal) and are then transferred in final form to RIGIS. Several of the major contributors to RIGIS are the University of Rhode Island and the Narragansett Bay Project. The Narragansett Bay Project was specifically funded to create an oil spill GIS for Narragansett Bay, which was completed in a draft form in the summer of 1991. Digital data are based on habitat maps interpreted from recent aerial photography. Biological resource data layers include shellfish beds and special concentration areas for fish and lobster.

Habitat, recreation, resource extraction, and cultural information are based on data as recent as 1991. Much of this information is in digital form either as maps or databases. The habitat information is mostly wetland classifications, and identification of worm beds, eelgrass, and kelp. Remaining biological resource data are still in analog format.

State of South Carolina

Digital mapping efforts are available for coastal South Carolina through the University of South Carolina and South Carolina Land Resources Commission. The base maps were compiled from satellite photography (SPOT) and the South Carolina Wildlife and Marine Resources Department intertidal survey maps. A special GIS project for the Ashepoo-Combahee-Edisto (ACE) Basin began in 1991, with plans for collection and automation of natural resource data to support designation of the area as a national wildlife refuge. Although eight land cover classification categories have been established for the State, the majority of these focus on upland areas.

Current digital maps are available for molluscs, recreational areas, and areas of resource extraction. Current State and Federal data are available in digital tabular formats for most elements.

State of Texas

Collection of data from key sources in Texas is not complete. The Texas Water Commission (TWC) has developed an agency-wide GIS framework which is in the early implementation phase. The majority of the State's data are in digital tabular format and are current.

Habitat information is not available in digital map format from any of the State agencies contacted during this survey effort. Federal sources and the Louisiana Department of Natural Resource's EOSAT project have succeeded in digitally mapping portions of the coastal habitats for the State. Additionally, Federal sources have also digitally mapped many of the other elements.

The Texas Spill Response Map Series—Coastal Region, in analog map format, was developed by TWC in 1984 for birds, crustaceans, fish, molluscs, reptiles, cultural

Natural Resources Data Sources

sites, and areas of resource extraction. Only Federal sources are available for management areas, marine mammals, recreational areas, and terrestrial mammals. As with the TWC data, these resources were often created in the 1980s.

U.S. Virgin Islands

In general, data available for the territory are stored in analog format. Some of the elements have been or are in the process of being updated and transposed to digital tabular format.

To date, the USVI habitat data are primarily in digital tabular format. No digital mapping efforts of this area have been undertaken by territorial or Federal agencies. Currently, data from ongoing studies for the following elements are available from USVI agencies: birds, crustaceans, fish, marine mammals, molluscs, recreational areas, reptiles, and terrestrial mammals. The majority of the available data are in descriptive text files or reports. Additionally, post-hurricane *Hugo* studies were established for 35 specific areas to monitor vegetative recovery. These data are ongoing and are maintained in descriptive field observations with some digital tabular records.

State of Virginia

Virginia has a standardized system for State resources employing GIS technology on an ARC/INFO system with MIPS as an alternative resource. Not all State agencies use this GIS. New (1991) habitat information digitized for Virginia were developed from USGS topographic maps and aerial photographs by both the Virginia Council on the Environment and the Virginia Institute of Marine Science. The wetland types and shoreline structures are available from the State's tidal marsh inventories. The standardized base maps, or ECOMAPS, are used by all State agencies when creating data mapping systems or information.

An additional digital mapping source is the NPS barrier islands study. This resource has highly detailed habitat, biological, and non-biological data for the Southeastern NPS barrier islands as well as Assateague and other barrier islands within Virginia, developed from high-resolution aerial photographs with a one-meter resolution.

Virginia state resource agencies update their databases annually. Current (1990-1991) data are available in many formats for all elements collected by State agencies: digital map for bird, fish, and reptile concentration areas, as well as areas of resource extraction have been collected by the Virginia Department of Game and Inland Fish; analog maps are available for mollusc concentration areas as well as cultural, recreational and management areas; and digital tabular data are available for all elements.

State of Washington

The State is initiating a GIS system (using ARC/INFO), which currently contains base map-type features and endangered species data. The system is administered by the Washington Department of Natural Resources. They plan to add much of the new data currently being collected to the system. The U.S. Forest Service has a significant amount of land use and biological data for the national forests. However, these forests cover very little of the shoreline.

The coastal birds data have just recently been resurveyed and there is currently a very accurate accounting of both migratory and nesting birds along the coast of Washington. This information is in digital tabular format, with some in digital maps. The endangered and threatened species are also continually being updated and the data are all in digital map form.

A National Perspective

Almost 750 cards have been created to describe the characteristics of the databases and other sources that exist throughout the coastal portions of the U.S. Table 5 shows the number of cards that apply to each state for each of the 12 elements in the *Natural Resource Inventory*. It is important to note that the amount of resource information represented by a card varies significantly. Simply because a state has more cards for a given element does not mean that the state has more resource information available. One or two excellent sources in one state may be far more useful than a dozen in another.

Table 5. Number of cards in the Natural Resource Inventory by state and element

Element	State																											
	ME	NH	MA	RI	CT	NY	NJ	PA	DE	MD	DC	VA	NC	SC	GA	FL	PR	VI	AL	MS	LA	TX	CA	OR	WA	HI	Total*	
Habitats	23	18	24	22	17	25	28	11	20	27	8	25	30	28	28	49	16	17	30	33	36	31	38	25	28	19	206	
Marine Mammals	18	14	17	16	15	16	16	3	12	14	3	15	16	12	15	21	6	3	14	14	14	12	28	14	19	6	71	
Terrestrial Mammals	4	3	4	4	4	4	4	2	3	3	2	4	4	3	3	7	3	4	6	6	6	5	3	5	7	1	24	
Birds	23	18	21	19	20	24	24	12	20	21	9	23	19	19	20	28	8	15	21	20	24	21	28	21	25	8	107	
Fish	22	16	23	20	18	25	27	4	20	25	3	23	29	25	25	33	9	9	23	22	25	22	26	21	23	7	135	
Mollusc	20	16	22	20	18	22	24	3	17	21	2	23	26	23	20	29	8	6	20	19	21	20	24	15	16	10	115	
Crustaceans	18	15	19	18	16	21	23	3	15	19	2	18	24	19	19	27	7	6	19	18	20	20	21	14	16	6	103	
Reptiles	8	8	9	9	8	9	9	2	9	9	2	14	12	11	15	24	6	9	11	12	13	12	8	6	6	4	65	
Recreation	12	7	11	7	8	11	10	5	9	11	4	9	11	12	8	20	3	4	12	10	12	12	14	12	14	8	98	
Management Areas	11	9	11	8	9	10	8	7	8	11	6	10	13	13	13	14	5	4	16	13	16	13	13	12	12	7	50	
Resource Extraction	10	9	10	9	11	10	11	5	10	10	5	13	11	12	11	13	5	9	12	14	14	14	13	15	13	12	59	
Cultural	9	8	9	9	9	8	8	6	9	8	6	11	11	12	12	12	4	5	13	12	10	10	9	9	8	6	30	
Total*	105	73	98	82	84	92	94	48	84	97	41	111	103	117	100	136	53	73	105	94	108	87	119	93	102	66	741	

* Totals do not agree with column or row summations because duplicate cards are counted only once.

