8 The Archetypical Environmental Sensitivity Index

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Chapter 8.
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. Figure 8-1 shows the areal coverage of existing ESI atlases and Table 8-1 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, Oman, 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 Geographic Information System (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 for NOAA by RPI into an all-digital ESI product for southeastern Alaska.

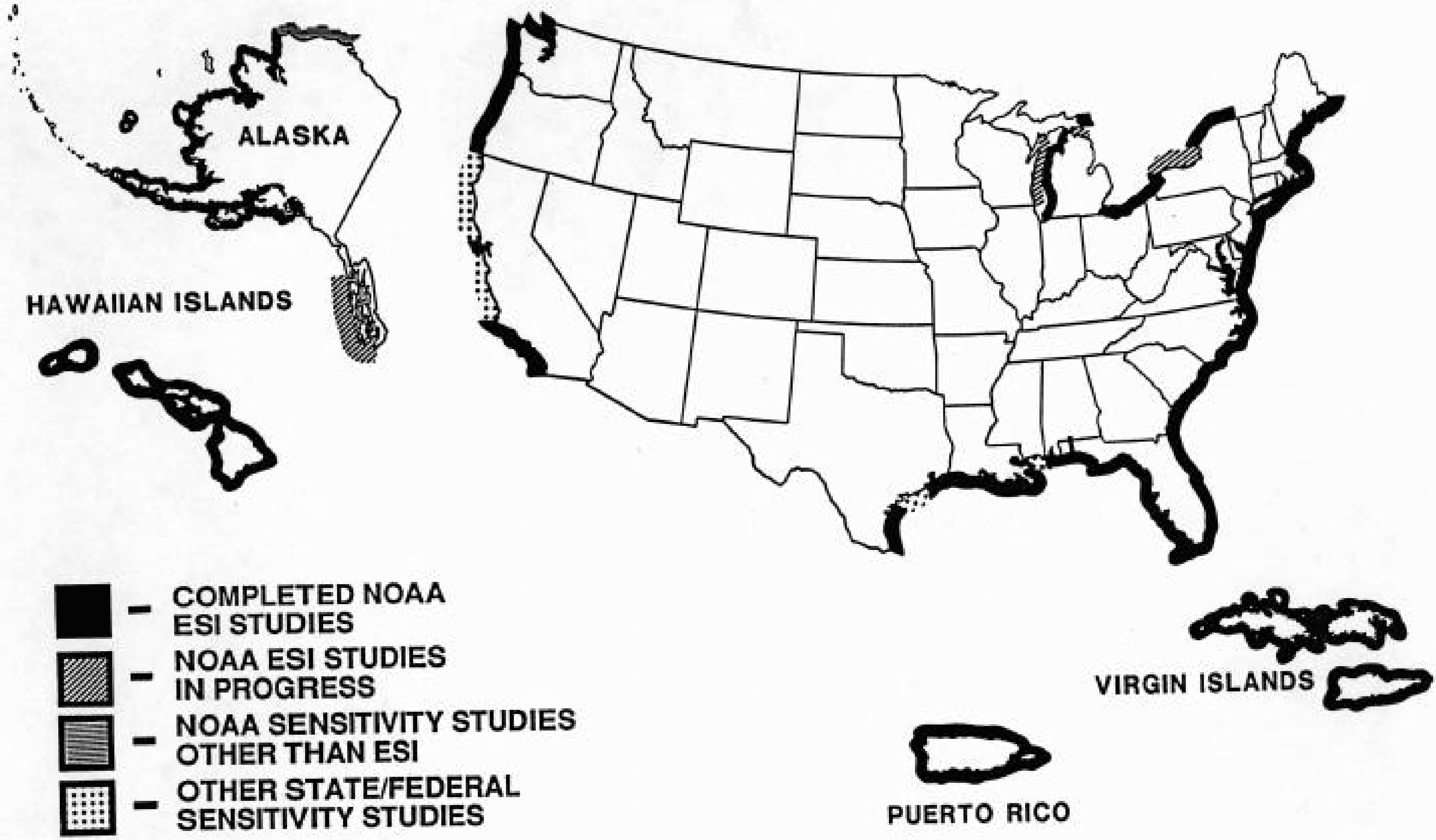


Figure 8-1. Status of Environmental Sensitivity Index mapping.

Table 8-1. Listing of all environmental sensitivity index (ESI) atlases published for the United States.

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		1,954	

As the oil spill response community moves towards development of automated sensitivity maps, it is important to define what comprises the archetypical ESI mapping system. 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 of this analysis 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, pre-set 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 Appalachicola 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. Work is currently underway to produce ESI atlases in digital format 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 have been 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 at the appropriate scale. For all of Alaska, 15-minute USGS topographic quadrangles at a scale of 1:63,360 have been used as base maps. Southeast Alaska-Part I is being done as a totally digital product. Columbia River and Louisiana have been produced with the intertidal shoreline types in digital format.

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 8-2 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 8-2. 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 and coastal structures		
8B				
9	Sheltered tidal flats	Sheltered tidal flats		Sheltered tidal flats
10A	Marshes	Marshes		Salt marshes
10B				
11				

Table 8-2. 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	Swamp	Gravel beaches/ Riprap	Riprap	Riprap
6B				
7A	Mangroves	Exposed tidal flats	Exposed tidal flats	Supratidal marshes
7B				
8A		Sheltered rocky shores/seawalls	Sheltered seawalls	Freshwater marsh/swamps
8B				
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 8-2. Continued.

ESI NO.	DEL/NJ/PA	NORTHEAST (NY to ME)	GREAT LAKES	APALACHICOLA 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 Exposed tidal flats (MA)	Sand and gravel beaches	Mixed sediment beaches
5B				
6A	Gravel beaches	Gravel beaches	Gravel beaches	Gravel beaches, riprap, and cross levees
6B	Riprap	Riprap		
7A	Exposed tidal flats	Exposed tidal flats	Riprap structures	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/hard-wood swamps
10A	Marshes	Marshes	Fringing wetlands	Freshwater marshes
10B			Extensive wetlands	Saltwater marshes
11				

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 the:

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, and
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) <u>Exposed, vertical rocky shores and seawalls.</u>

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) <u>Wave-cut rocky platforms, scarps in clay, and exposed sedimentary bluffs.</u>

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) <u>Fine-grained sand beaches.</u>

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) <u>Coarse-grained sand beaches.</u>

Coarse-grained sand beaches are ranked higher because of the potential for higher 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 loose packing of the sediment.

5) <u>Mixed sand and gravel beaches.</u>

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 1-2 per year. Biological utilization is low, because of the sediment mobility and rapid drying during low tide.

6) <u>Gravel beaches and riprap.</u>

Gravel beaches are ranked the highest of all beaches primarily because of the potential for very deep oil penetration and slow natural removal rates of subsurface oil. The slow replenishment rate of gravel makes removal of oiled sediment highly undesirable, and so cleanup of heavily oiled gravel beaches is particularly difficult. For many gravel beaches, significant wave action (meaning large enough waves 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) <u>Exposed tidal flats.</u>

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 the high biological utilization, however, impacts to benthic invertebrates by exposure to the water-accomodated 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 persistence is 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 8-2).

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, general biological sensitivity, etc., 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 done in a highly supervised classification mode. Although existing intertidal habitat maps are a good source for mapping discrete classes, i.e., 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 8-2). 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 the 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 U.S., 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.

<u>Subtidal Habitats.</u>–In a subtidal setting, oil vulnerability of habitats is much lower because they 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 beds of kelp
- Coral reefs

Other subtidal bottom types have not been included. If there are other subtidal areas that are important to a specific species, those areas 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 8-3 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 waterbodies and feed on fish or seabirds. On the maps, the distribution of oil-sensitive fish and wildlife is mostly shown by patterns and symbols representing these ecological groupings, with annotations for each species present.

Table 8-3. 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
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

Table 8-3. Continued

Data Element	Sub-Element	Comments
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	
	Boating/Fishing	High-use recreational areas
	State Parks	
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.	

Note that under "Comments" on Table 8-3 is listed the types of areas which should be included. 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.
- 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.

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 8-4 lists the associated data for each element which should be included, at the species level. These data allow identification of the most sensitive periods

Table 8-4.

DATA ELEMENTS AND ASSOCIATED DATA FOR RESOURCES AT RISK

=Polygon, L=Line, *=Point)

State/Federal Endangered or Threatened species marked by *.

(S/E) = Start date/End date

(Ar.) = Arrival date

arine mmals	Lifestage Present (Adult, Adult breeder, Juvenile, Present)													Concentration			Species/	Expert Contact		Breeding	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low	(*Endangered)	(Name, agency, phone)	Mating (S/E)	Calving (S/E)	Pupping (S/E)
P Whales																					
P Dolphins																					
*/P Sea lions																					
*/P Seals																					
P Sea otters																					
P Manatees																					

errestrial Mammals	Lifestage Present (Adult, Adult breeder, Juvenile, Present)													Concentration			Species/	Expert Contact
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low	(*Endangered)	(Name, agency, phone)
P Mustelids																		
P Rodents																		
P Deer																		
P Bear																		

irds	Lifestage Present (Adult, Adult breeder, Juvenile, Present)													Concentration			Species/	Expert Contact		Breeding		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low	(*Endangered)	(Name, agency, phone)	Nesting (Arr.)	Laying (S/E)	Hatching (S/E)	Fledging (S/E)
*/P Diving Coastal birds																						
P Waterfowl																						
*/P Alcids																						
*/P Petrels/fulmars																						
*/P Shorebirds																						
*/P Wading birds																						
*/P Gulls/terns																						
*/P Raptors																						

ish	Lifestage Present (Adult, Juvenile, Larvae, Egg, Present)													Concentration			Species/	Expert Contact		Breeding
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low	(*Endangered)	(Name, agency, phone)	Spawning (S/E)	Outmigration (S/E)
L/P Anadromous																				
L/P Beach spawners																				
P Kelp Spawners																				
P Nursery areas																				
P Reef fish																				
P Special concentrations																				

ollusc	Lifestage Present (Adult, Juvenile, Larvae, Egg, Present)													Concentration			Species/	Expert Contact	Breeding	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low	(*Endangered)	(Name, agency, phone)	Mating (S/E)	Spawning (S/E)
P Oysters																				
P Mussels																				
P Clams																				
P Scallops																				
P Abalone																				
P Conch/whelk																				
P Squid/Octopus																				

rustaceans	Lifestage Present (Adult, Juvenile, Larvae, Egg, Present)													Concentration			Species/	Expert Contact	Breeding	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low	(*Endangered)	(Name, agency, phone)	Mating (S/E)	Spawning (S/E)
P Shrimp																				
P Crab																				
P Lobster																				

eptiles	Lifestage Present (Adult, Juvenile, Egg, Present)													Concentration			Species/	Expert Contact	Breeding	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Count	High	Medium	Low	(*Endangered)	(Name, agency, phone)	Nesting (S/E)	Hatching (S/E)
L/P Sea turtles																				
P Alligators																				

Table 8-4. Continued

DATA ELEMENTS AND ASSOCIATED DATA FOR RESOURCES AT RISK
(P=Polygon,L=Line,*=Point)

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	Phone/Contact							
	L	Beaches										
	*	Marinas				# Slips	Access Capabilities					
	*	Boatramps				Size	Construction					
	P/*	Diving areas										
	P	Parks										
	P/*	Boating/fishing				Boating	Fishing	Type				
Management Areas			Name	Owner	Phone/Contact							
	P	Nat. Park/Mar. Sact.										
	P	Refuges										
	P	Preserves/reserves										
Resources Extraction			Name	Owner	Phone/Contact	Type						
	L/P	Subsistence					Season					
	P	Commercial Fishery					Season					
	*	Aquaculture					Season					
	*	Water Intakes					Depth	Volume				
	*	Mining					Active					
	L/*	Log Storage										
Cultural			Name	Owner	Phone/Contact	Type						
	*	Historical										
	*	Archeological					# Sites					
	P	Native American										

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.

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, whereas 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 usually not 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 the 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 very 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. 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-grouping under birds in Table 8-3. These symbols allow the user to readily 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 on-going research effort to identify symbology and patterns for use in generation of hardcopy maps and screen views from GIS databases.

On the ESI maps, biological resource information is noted by colored circles (Fig. 8-2). The color of the circle identifies the type of organism present: yellow =

marine mammal; green = bird; orange = shellfish; blue = fish; red = reptile. Biological groups are identified by symbols within the circles (Table 8-5). Numbers in the circles refer to species or species groups listed in each atlas. Dots in the circle indicate seasonality. This information allows the prediction of species' presence or absence during a specific time of the year. A red border indicates that the species is rare, threatened, or endangered. The location and range of species are indicated by the bars and arrows that extend from the circle. Special symbols identify the approximate perimeter of kelp beds and the extent of seagrass beds.

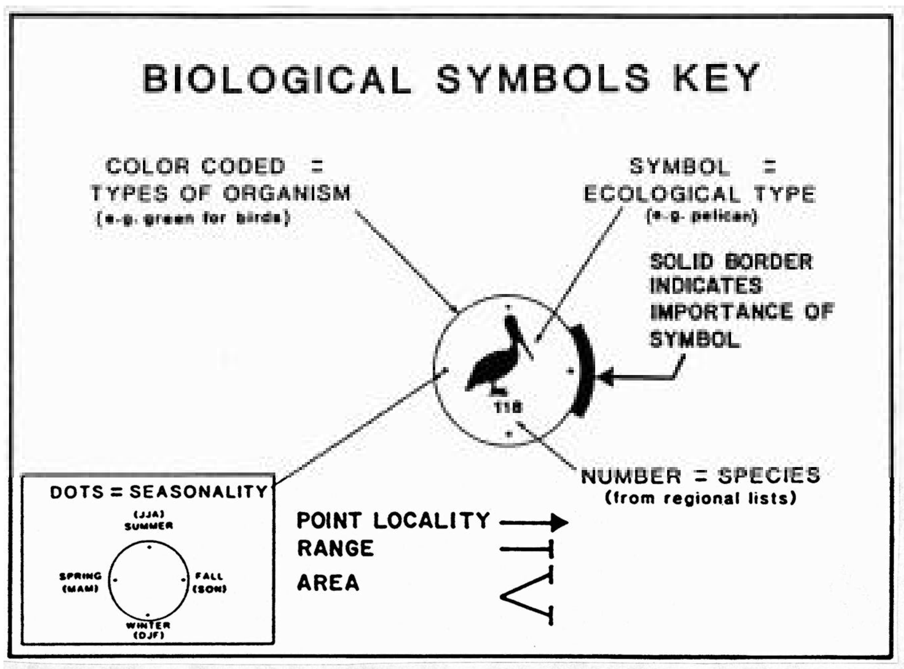
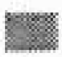


Figure 8-2. Key to information provided on colored biological markers on the ESI maps.

Areas of socioeconomic importance (major state and local parks and marinas) may support high-intensity recreational use, knowledge of which would be important to the on-scene coordinator. These areas are marked by a black decal on a white background. In addition to parks and beaches, other shoreline areas have been specially designated for scenic, wildlife, or other values. These areas include reserves, preserves, refuges, and ecological areas. They are marked by a brown circle and a star with a number keyed to the area's name and the agency with controlling authority. For the California ESI maps, approximate boundaries are given for Areas of Special Biological Significance as designated by the State Water Resources Control Board.

Table 8-5. Symbols used on the Environmental Sensitivity Index maps to indicate dominant groups in southern California.

	Symbol	Occurrence
Resident Marine Mammals		
	Seals or Sea Lions	Haulout grounds or pupping areas
Marine Birds		
	Diving birds	Pelican or Cormorant feeding and roosting areas
	Alcid or Petrels	Auklet, Guillemot, Murrelet, or Petrel rookeries
	Waterfowl	Duck, Goose, or Brant forage areas
	Shorebirds	Oystercatcher, Plover, Avocet, Sparrow, Rail, Stilt or Killdeer forage areas or rookeries
	Gulls or Terns	Rookeries or forage areas
Fish		
	Grunion or Herring	Spawning areas
	Steelhead Trout	Spawning or nursery areas
Shellfish		
	Clams	Clam, Scallop, or Mussel areas
	Abalone	Abalone areas
Reptiles		
	Turtle	Green Sea Turtle areas
Plants		
	Kelp	Abundant brown algae beds
	Seagrass	Subtidal eel grass beds
Socioeconomic Features		
	Parks and beaches	Location
	Marinas	Location
	Areas of special biological significance	Boundaries
Protective Strategy Features		
	Recommended boom	Location
	Skimmers	Deployment
	Closures	Location
	Shoreline washover potential	Location

Human-Use Areas

Previously designated as socio-economic resources on ESI maps, human use areas can be divided into four major components (Table 8-3):

- 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

Each of these components are discussed below.

As 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, presence of alternative sources) is critical.

Where appropriate, log storage sites and intertidal/subtidal mining leases are included so that 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 very critical component, particularly leased shellfish beds and near-shore, 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 that are actually 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, then 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 prespill 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. Preplanning 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 stages, such as concentrating efforts to remove oil from turtle nesting beaches prior to the arrival of nesting turtles. Just the physical disturbances of cleanup activities 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.

Preplanning is made more powerful with access to an automated system; just 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 oftentimes 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 the ranges of possible combinations.

Spill Response

When the initial notification of an actual or potential spill is received, ESI maps are consulted to determine what resources are likely to be present and their relative risks to impacts from exposure to oil. Having all the resource information on one set of maps, addressing oil spills, 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 the initial information on the spill 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 where are 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 be used to identify potential bird and mammal impacts so that appropriate rescue and cleanup actions can be planned. Resource managers for the impacted areas are contacted to verify the species and numbers 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 shown 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, a word of caution. 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 generation of thematic maps for specialized planning requirements and preparation of maps at various scales. It should be noted that 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 geographical 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.