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NOAA Technical Memorandum NOS ORCA 92

Environmental Sensitivity Index Guidelines

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noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

National Ocean Service

Office of Ocean Resources Conservation and Assessment
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

The Office of Ocean Resources Conservation and Assessment (ORCA) provides decisionmakers comprehensive, scientific information on characteristics of the oceans, coastal areas, and estuaries of the United States of America. The information ranges from strategic, national assessments of coastal and estuarine environmental quality to real-time information for navigation or hazardous materials spill response. Through its National Status and Trends (NS&T) Program, ORCA uses uniform techniques to monitor toxic chemical contamination of bottom-feeding fish, mussels and oysters, and sediments at about 300 locations throughout the United States. A related NS&T Program of directed research examines the relationships between contaminant exposure and indicators of biological responses in fish and shellfish.

ORCA provides critical scientific support to the U.S. Coast Guard during spills of oil or hazardous materials into marine or estuarine environments. This support includes spill trajectory predictions, chemical hazard analyses, and assessments of the sensitivity of marine and estuarine environments to spills. The program provides similar support to the U.S. Environmental Protection Agency's Superfund Program during emergency responses at, and for the cleanup of, abandoned hazardous waste sites in coastal areas. To fulfill the responsibilities of the Secretary of Commerce as a trustee for living marine resources, ORCA conducts comprehensive assessments of damages to coastal and marine resources from discharges of oil and hazardous materials.

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Contents

Appendices

1 Description of Geographic Themes and Data Tables
2 ESI Atlas Identification Numbers
3 ESI Species ID# Master Species

List of Figures

List of Tables

1 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 I 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 year of publication and number of maps for each atlas completed as of July 1995. 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 available at a different scale or too outdated to be of use. For all of Alaska, 15-minute USGS topographic quadrangles at a scale of 1:63,360 have been used as base maps. In Canada, 1:50,000 scale topographic maps are used (Harper et al. 1986).

Traditional sensitivity maps have been produced as 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 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 provide a ready source for development of automated sensitivity maps for oil spills. With the power of GIS, sensitivity mapping has moved from a static product of limited distribution to a valuable tool for planning and response to oil spills. NOAA first used GIS technology to produce ESI maps in Louisiana, where satellite imagery was used to update areal photograph interpretations to produce the base maps and habitat rankings. Since 1989, ESI atlases have been generated from all-digital databases; those atlases in bold type in Table 1 are available in both hard copy and digital formats.

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 and how this information can be developed using GIS technology. The primary objectives of this report are to: 1) outline the basic elements of a sensitivity mapping system; 2) provide guidance on the collection and synthesis of data for the system; and 3) define the data structure for development of a digital ESI application using GIS technology. There are many aspects of a fully functional application that are still under

Table 1. Listing of all environmental sensitivity index (ESI) atlases published for the U.S. Bold names indicate atlases produced in digital GIS format.

Name	Year Published	No. of Maps
Alabama	1981	20
Alabama	**1995**	**29**
Alaska (6 atlases)	1982-1986	371
Alaska (Southeast)	**1993**	**98**
California (Central)	**1994**	**41**
California (Northern)	**1994**	**39**
California (Southern)	1980	52
California (Southern)	**1995**	**51**
California (San Francisco Bay)	1986	23
Columbia River, Washington/Oregon	**1989**	**26**
Connecticut	1984	17
Delaware/New Jersey/Pennsylvania	1985	59
Delaware/New Jersey/Pennsylvania	**1995**	**64**
Florida (6 atlases)	1981-1984	246
Florida (5 atlases)	**1995**	**265**
Georgia	1985	29
Guam	1993	15
Hawaii	1986	86
Lake Erie System	1985	66
Lake Huron (Michigan)	**1994**	**69**
Lake Michigan (Eastern Shore)	1986	23
Northern Lake Michigan	**1994**	**70**
Southern Lake Michigan	**1994**	**11**
Western Lake Michigan	**1993**	**54**
Lake Ontario (New York)	**1993**	**34**
Lake Superior (3 atlases)	**1993**	**133**
Louisiana	**1989**	**98**
Maine (Downeast)	1985	42
Maine (Mid-Coast)	1985	35
Maine (Southern/New Hampshire)	1983	25
Maryland	1983	119

Table 1. *Continued.*

Name	Year Published	No. of Maps
Massachusetts	1980	51
Mississippi	**1995**	**29**
New York (Harbor/Hudson River)	1985	37
New York (Long Island)	1985	41
North Carolina (2 atlases)	1983	113
Oregon/Washington (Outer Coast)	1986	55
Puerto Rico	1984	35
Rhode Island/Massachusetts	1983	18
St. Lawrence River	1985	17
Saint Mary's River	1986	15
South Carolina	1982	50
South Carolina	**1995**	**63**
Texas (Galveston Bay)	1979	19
Texas (South)	1980	15
Texas (Upper Coast)	**1995**	**51**
U.S. Virgin Islands	1986	8
Virginia (2 atlases)	1983	113
Washington, Puget Sound	1984	36
Washington (Central/ Southern Puget Sound)	1985	44

development, such as pre-set queries and integration with other spill response systems (e.g., trajectories, equipment inventories), or specific to the type of software being used (e.g., the user interface), which are not addressed at this time. However, recommendations are made for standardized output formats and symbology for maps to be shown on the screen or printed out in hard copy. The production of hard copy products is considered to be as important as development of the on-screen user interface. The printed map is a major product for spill response applications over the next few years. The digital databases will have broad application and use for a wide range of coastal resource management applications.

The Need for Standardized Definitions

Because of the spill contingency planning requirements of the Oil Pollution Act of 1990 (OPA 90) and similar legislation passed by many states, there is a new need for better information on the location of sensitive resources and the basis for establishing protection priorities. Digital databases being developed to support oil-spill planning and response functions are a subset of those needed for a wide range of natural resource management applications. Standardization of the basic elements for a spill application would speed the development of systems and facilitate their use by national response teams and organizations, such as the U.S Coast Guard, industry response staff, and spill co-ops. Data sharing and updates would be greatly facilitated with a uniform data structure.

Report Outline

The rest of this report is divided into four chapters, with the following content and intended user:

Chapter 2—The basic components of sensitivity mapping, data layers and how defined, for the resource manager developing sensitivity data.

Chapter 3—Detailed guidelines on how to collect and draw the resource information on hard copy maps for the biologists providing such data.

Chapter 4—Guidelines on how the data are digitized, stored, and delivered as a GIS product, for all users but especially for the GIS manager.

Chapter 5—What the map product is, for all users.

2 THE ENVIRONMENTAL SENSITIVITY INDEX MAPPING SYSTEM

Types of Information

ESI maps are comprised of three general types of information:

1. Shoreline Classification–which are ranked according to a scale relating to sensitivity, natural persistence of oil, and ease of cleanup.

2. Biological Resources–including oil-sensitive animals, and habitats which are utilized by oil-sensitive species or are themselves sensitive to oil spills, such as submerged aquatic vegetation and coral reefs.

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 is discussed in the following sections.

Shoreline Classification

Shoreline Types

Shoreline habitats are at risk during spills because they are very likely to be directly oiled when floating slicks beach. 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 (Michel et al. 1995). Table 2 lists the standardized ESI shoreline

Table 2. Proposed habitat ESI ranking for all habitats in the U.S.

ESI NO.	ESTUARINE	LACUSTRINE	RIVERINE (large rivers)
1A	Exposed rocky cliffs	Exposed rocky cliffs	Exposed rocky banks
1B	Exposed sea walls	Exposed sea walls	Exposed sea walls
2	Exposed wave-cut platforms	Shelving bedrock shores	Rocky shoals; bedrock ledges
3	Fine- to medium-grained sand beaches	Eroding scarps in unconsolidated sediments	Exposed, eroding banks in unconsolidated sediments
4	Coarse-grained sand beaches	Sand beaches	Sandy bars and gently sloping banks
5	Mixed sand and gravel beaches	Mixed sand and gravel beaches	Mixed sand and gravel bars and gently sloping banks
6A	Gravel beaches	Gravel beaches	Gravel bars and gently sloping banks
6B	Riprap	Riprap	Riprap
7	Exposed tidal flats	Exposed flats	Not present
8A	Sheltered rocky shores	Sheltered scarps in bedrock	Vegetated, steeply sloping bluffs
8B	Sheltered seawalls	Sheltered seawalls	Sheltered seawalls
9	Sheltered tidal flats	Sheltered vegetated low banks	Vegetated low banks
10A	Salt marshes		
10B	Freshwater marshes	Freshwater marshes	Freshwater marshes
10C	Freshwater swamp	Freshwater swamp	Freshwater swamp
10D	Mangroves		

rankings currently used for all shoreline habitats, showing the types for estuarine, lacustrine, and riverine habitats. These shoreline types and ranks should be used on all sensitivity mapping projects to facilitate data use and exchange.

The intertidal ranking scheme is based on understanding the physical and biological character of the coastal environment, not just the substrate type and grain size. The sensitivity ranking is controlled by the following factors:

1. Relative exposure to wave and tidal energy
2. Shoreline slope
3. Substrate type (grain size, mobility, penetration, and trafficability)
4. Biological productivity and sensitivity

All of these factors are used to determine the relative ESI ranking for a shoreline segment. Key to the rankings is understanding the relationships among physical processes, substrate type, and associated biota. These relationships produce specific geomorphic/ecological shoreline types and predictable patterns in oil behavior, sediment transport patterns, and biological impact. Each of these factors is discussed in detail below.

Relative Degree of Exposure to Wave and Tidal Energy

It has long been recognized by biologists that the makeup of intertidal biological communities is closely correlated with relative degree of exposure. Rickets et al. (1968) in *Between Pacific Tides* classified the coastal habitats of the central California coast as *exposed* and *sheltered*, differentiating between settings subject to intense pounding by the large waves on that coast and those sheltered by offshore rocks, barrier beaches, and other protective features. Early geomorphology studies at the *Metula*, *Urquiola*, and *Amoco Cadiz* oil spills showed that the level of impacts of oil spills is closely related to the relative degree of exposure of the affected habitat (Hayes and Gundlach 1975; Gundlach and Hayes 1978; Gundlach et al. 1978; Michel et al. 1978).

Two physical factors, wave-energy flux and tidal-energy flux, primarily determine the degree of exposure, also referred to as the hydrodynamic energy level, at the coastline. Wave-energy flux is basically a function of the average wave height, measured over at least one year. Where waves are typically large (e.g., heights >1 meter [m] occur frequently), the impact of oil spills on the exposed habitats is reduced because: 1) offshore-directed currents generated by waves reflecting off hard surfaces push the oil away from the shore; 2) wave-generated currents mix and rework coastal sediments, which are typically coarse-grained in these settings, rapidly freeing them of

oil; and 3) organisms adapted to living in such a setting are accustomed to short-term perturbations in the environment.

Although not as pervasive as wave-energy flux, tidal-energy flux is also an important consideration in determining the potential of oil-spill impacts on coastal habitats. The potential for strong tidal currents to remove stranded oil and to build and move intertidal sand and/or gravel bars that bury oil are the most important considerations. The effect of the currents on biological communities can also be pronounced; for example, highly mobile substrates set in motion by strong tidal currents typically harbor considerably fewer infauna than stable substrates. As a generalization, tidal currents increase with increasing tidal range.

The degree of energy is relative to the overall energy levels within the mapping region. A continuum of energy levels must be divided into broad classes. High-energy shorelines are regularly exposed to large waves or strong tidal currents during all seasons. They most commonly occur along the outer coast or where waves from the dominant winds can impinge on the shoreline by wave refraction or through breaks in the shoreline. Low-energy shorelines are sheltered from wave and tidal energy, except during unusual or infrequent events. In between, medium-energy shorelines often have seasonal patterns in storm frequency and size of waves.

Inherent in these energy classes are inferences about the persistence of stranded oil. "High energy" means rapid natural removal, usually days to weeks. "Low energy" means slow natural removal, usually years. "Medium energy" means that stranded oil will be removed when the next high-energy event occurs, which could be days or months after the spill. It is an event-driven process. Those shorelines that do not have predictable, seasonal patterns in the frequency of storms that generate waves from a particular direction or size are more difficult to characterize. Along these shorelines, high-energy events usually occur more than once each year. These shorelines typically have active storm berms with one to three years of vegetation growth. The macroalgae coverage on the larger boulders in the intertidal zone is higher than on those exposed to annual storms. These kind of features are used to identify those shorelines with the potential for longer-than-usual oil persistence. Efforts should be made to differentiate these shorelines, particularly for gravel beaches.

Shoreline Slope

Shoreline slope is a measure of the steepness of the intertidal zone, between maximum high and low tides. It can be characterized as steep (greater than 30 degrees), moderate (between 30 and 5 degrees), or flat (less than 5 degrees).

The primary importance of shoreline slope in exposed settings is its effect on wave reflection and breaking. Steep intertidal areas are usually subject to abrupt wave run-up and breaking, and even reflection in places, which enhances natural cleanup of the shoreline. Flat intertidal areas, on the other hand, promote dissipation of wave energy further offshore, which allows for longer residence time of oil in the intertidal zone. Also, the broad intertidal areas typically have more extensive areal development of biological communities (e.g., mussel beds, clam beds, and plant communities). In sheltered habitats, slope is a less important distinguishing factor with regard to oil-spill impacts, except that sensitive biological communities have more area to develop where the slopes are flatter.

Substrate Type

Substrate types are classified as:

- *Bedrock*, which can be further divided into impermeable and permeable, depending on the presence of surficial deposits on top of the bedrock.

- *Sediments*, which are divided by grain size as:
  - Mud, consisting of silt and clay, less than 0.06 millimeters (mm)
  - Fine-to-medium-grained sand, ranging from 0.06-1 mm
  - Coarse-grained sand, ranging from 1-2 mm
  - Granule, ranging from 2-4 mm
  - Pebble, ranging from 4-64 mm
  - Cobble, ranging from 64-256 mm
  - Boulder, greater than 256 mm

- *Vegetation*, intertidal or emergent

- *Manmade materials*, such as:
  - Riprap, or broken rock of various sizes, usually cobble or larger, that are permeable to oil penetration
  - Seawalls that are composed of solid material, such as concrete or steel, which are impermeable

Certain characteristics of the substrate type affect the potential for coastal habitats to be impacted by oil spills. The most important distinction is between bedrock and unconsolidated sediments, in that the sediments have the added potential for: 1) penetration and burial of the oil; and 2) residence of important infaunal organisms, which may be susceptible to oil-spill effects. Penetration and burial in sediments increases the persistence of oil, leads to potential long-term biological impacts, and makes cleanup much more difficult and intrusive. Penetration and burial are very different. Penetration is strongly a function of permeability, which, in turn, is controlled by the grain size of the substrate, as well as the sorting (range of grain sizes in the sediments). Deepest penetration is expected for coarse sediments (gravel) that are most uniform in grain size (well sorted). On gravel beaches, oil penetration up to one meter can occur under heavy oil accumulations. If the sediments are poorly sorted, such as on mixed sand and gravel beaches, penetration is usually less than 50 centimeters (cm). Sand beaches are also differentiated into grain-size categories (fine-to-medium grained versus coarse-grained) which differ by permeability and thus potential depths of penetration. Muddy sediments have the lowest permeability and also tend to be water saturated, so oil penetration is very limited, except where infauna burrow into the substrate. (Burrows can provide a mechanism for oil to penetrate an otherwise impermeable substrate.)

Burial occurs when clean sediments are deposited on top of oil layers. The rate of burial can vary widely and can be as short as six hours (one-half of a tidal cycle) after the initial stranding. The most rapid burial usually occurs on coarse-grained sand beaches because they have the highest mobility under normal wave and tidal conditions. During storms, oil in gravel beaches can be buried by the building of gravel berms or bars. Along shorelines with strong seasonal storm patterns, there can be annual erosion/deposition cycles in the beach profile and sediment distribution patterns. These shorelines have the greatest potential for burial, particularly if the oil is stranded at the beginning of the depositional period.

Substrate type also affects the trafficability. Fine-grained sand beaches are typically compacted and hard, and they are the most likely substrate type to be trafficable. Use of equipment on muddy substrates is not possible because of their innate softness.

Definitions of ESI Rankings

ESI = 1: Exposed, Impermeable Vertical Substrates

The essential elements of the ESI = 1 rank are:

- Regular exposure to high wave energy or tidal currents.
- Strong wave-reflection patterns.
- Substrate is impermeable (usually bedrock) with no potential for subsurface penetration.
- Slope of the intertidal zone is 30 degrees or greater, which results in a narrow intertidal zone.
- By the nature of the high-energy setting, attached organisms are hardy and accustomed to high hydraulic impacts and pressures.

Shoreline types that meet these elements include:

- Exposed rocky cliffs
- Exposed, vertical seawalls made of concrete, wood, or metal

Where both shoreline types exist in the same region, usually the natural shoreline is designated as 1A and the manmade equivalent is designated as 1B. These shoreline types are exposed to large waves, 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, within a time frame of a few weeks. 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 generally required or recommended.

ESI = 2: Exposed, Impermeable Substrates, Non-Vertical

The essential elements of the ESI = 2 rank are:

- Regular exposure to high wave energy or tidal currents.
- Strong wave-reflection patterns on a regular basis.
- Slope of the intertidal zone is usually less than 30 degrees, which results in a wider intertidal zone, although it can be less than 5 degrees and the intertidal zone can be up to hundreds of meters wide.
- Substrate is impermeable (usually bedrock) with no potential for subsurface penetration over much of the intertidal zone, although there can be a thin, mobile veneer of sediment in patches on the platform.
- Accumulations of sediments at the base of the cliff are regularly mobilized by storm waves.

- By the nature of the setting, attached organisms are hardy and used to high hydraulic impacts and pressures.

Shoreline types which meet these elements include:

- Exposed, wave-cut platforms in bedrock
- Exposed scarps in unconsolidated sediments with associated wave-cut platforms
- Shelving bedrock shores

Within a region, only one of these shoreline types is typically present along the exposed coast. There has never been a need for subdivision of the ESI = 2 ranking. As with ESI = 1, these shorelines are 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 several weeks or months. When the sediments have been formed into a beach that has multiple, wave-built berms, it is designated as a separate shoreline type on the maps. Along bedrock-dominated shores, it is very common to have wave-cut platforms in combination with mixed sand and gravel or gravel beaches. Biological impacts can be immediate and severe, particularly if fresh oil slicks cover tidal pool communities on the rocky platforms. However, the oil is usually removed quickly from the platform by wave action. Cleanup is not necessary except for removal of oiled debris and oil deposits at the high-tide line in areas of high recreational use or to protect a nearshore resource, such as marine birds.

ESI = 3: Semi-Permeable Substrate, Low Potential for Oil Penetration and Burial; infauna present but not usually abundant

The essential elements of the ESI = 3 rank are:

- The substrate is semi-permeable (fine- to medium-grained sand), with oil penetration usually less than 10 cm.
- Sediments are well-sorted and compacted (hard).
- The slope is very low, less than 5 degrees.
- The rate of sediment mobility is low, so the potential for rapid burial is low.
- Surface sediments are subject to regular reworking by waves.
- There are relatively low densities of infauna.

Shoreline types that meet these elements include:

- Fine- to medium-grained sand beaches
- Eroding scarps in unconsolidated sediments

Compact, fine-grained sand beaches inhibit oil penetration, and they generally accrete slowly between storms, making the potential for oil burial low. However, burial depths may be large when the oil is stranded at the beginning of a seasonal accretionary period, such as along the California coast. Cleanup is simplified by the hard substrate which can support vehicular and foot traffic. Biological use by infauna is highly variable spatially and temporally.

In the Great Lakes, eroding scarps in unconsolidated sediments are mapped as this shoreline rank, because they have a small accumulation of sediments at the base of the scarp that behaves similar to a sand beach.

ESI = 4: Medium Permeability, Moderate Potential for Oil Penetration and Burial; infauna present but not usually abundant

The essential elements of the ESI = 4 rank are:

- The substrate is permeable (coarse-grained sand), with oil penetration up to 25 cm possible.
- The slope is intermediate, between 5 and 15 degrees.
- Rate of sediment mobility is relatively high, with accumulation of up to 20 cm of sediments within a single tidal cycle possible; there is a potential for rapid burial and erosion of oil.
- Sediments are soft, with low trafficability.
- There are relatively low densities of infauna.

Shoreline types that meet these elements include:

- Coarse-grained sand beaches

Coarse-grained sand beaches are ranked separately and higher than fine- to medium-grained sand beaches because of the potential for higher oil penetration and burial, which can be as great as one meter deep. These beaches can undergo very rapid erosional and depositional cycles, with the potential for rapid burial of oil, even after one tidal cycle. Cleanup is more difficult, as equipment tends to grind oil into the substrate because of the loose packing of the sediment. Also, cleanup techniques have to deal with multiple layers of oiled and clean sediments, increasing the amount of sediments to be handled and disposed of. These more mobile sediments usually have low infaunal populations, which are also highly variable over time and space.

In some areas, there is no clear distinction between beach types because they cannot be differentiated by grain size. Under these conditions, such as along the Great Lakes, all sand beaches are ranked as ESI = 4.

ESI = 5: Medium-to-High Permeability, High Potential for Oil Penetration and Burial; infauna present but not usually abundant

The essential elements of the ESI = 5 rank are:

- Medium-to-high permeability of the substrate (mixed sand and gravel) allows oil penetration up to 50 cm.
- Spatial variations in the distribution of grain sizes are significant, with finer-grained sediments (sand to pebbles) at the high-tide line and coarser sediments (cobbles to boulders) in the storm berm and at the toe of the beach.
- The gravel component should comprise at least 20 percent of the sediments.
- The slope is intermediate, between 8 and 15 degrees.
- Sediment mobility is very high only during storms. Thus, there is a potential for rapid burial and erosion of oil during storms.
- Sediments are soft, with low trafficability.
- Infauna and epifauna populations are very low, except at the lowest intertidal levels.

Shoreline types that meet these elements include:

- Mixed sand and gravel beaches

The gravel-sized component can be composed of bedrock, shell fragments, or coral rubble. 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 may 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 use is low, because of high sediment mobility and rapid drying during low tide.

These types of beaches have a wide range in relative degree of exposure, and sediment mobility can be inferred by the extent of attached fauna and macroalgae. Indicator species or assemblage coverages can be used to reflect the potential rate of sediment reworking. For example, in southeastern Alaska, the presence of greater than 20 percent attached algae, mussels, and barnacles indicates beaches that are relatively sheltered, with the more stable substrate supporting a richer biota. Where there are

significant differences in the degree of exposure of sand and gravel beaches, the more exposed or mobile beaches are designated as 5A and the less exposed or stable beaches are designated as 5B. Pocket beaches, in particular, can have microenvironments that are more protected from wave energy (called wave shadows) where natural removal may be much slower than the adjacent beach.

ESI = 6: High Permeability, High Potential for Oil Penetration and Burial

The essential elements of the ESI = 6 rank are:

- The substrate is highly permeable (gravel-sized sediments), with penetration up to 100 cm likely.
- The slope is intermediate-to-steep, between 10 and 20 degrees.
- Rapid burial and erosion of shallow oil can occur during storms.
- There is high annual variability in degree of exposure, and thus in the frequency of mobilization by waves.
- Penetration can extend to depths below those of annual reworking.
- Sediments have lowest trafficability of all beaches.
- Natural replenishment rate of sediments is the slowest of all beaches.
- Infauna and epifauna populations are very low, except at the lowest intertidal levels.

Shoreline types that meet these elements include:

- Gravel or shell beaches (subdivided by gravel classes as needed)
- Riprap

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 removing oiled sediment highly undesirable, and so cleanup of heavily oiled gravel beaches is 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. Where there is a wide variation in the size of the gravel or the relative rate of sediment mobilization by storm waves, this class can be subdivided when there are distinct grain-size classes, such as A) pebbles to cobbles, and B) cobbles to boulders as follows. Shell fragments can be the equivalent of gravel along Gulf of Mexico beaches.

Fine-grained gravel beaches are composed primarily of pebbles and cobbles (from 4 to 256 cm), with boulders as a minor fraction. No sand is evident on the surface, and there is less than 20-percent sand in the subsurface. There can be zones of pure pebbles or cobbles, with the pebbles forming berms at the high-tide line and the cobbles and boulders dominating the lower beachface. Sediment mobility limits the amount of attached algae, barnacles, and mussels to low levels. The distinction can also be made on the basis of grain size and extent of rounding of the sediments on a shoreline. The gravel is rounded or well-rounded only on those beaches regularly mobilized during storms.

Large-grained gravel beaches have boulders dominating the lower intertidal zone. The amount of attached algae and epifauna is much higher, reflecting the stability of the large sediments. A boulder-and-cobble armoring of the surface of the middle- to lower-intertidal zone is a common phenomenon on these beaches. Armor may have a very important effect on oil persistence in gravel beaches. Oil located beneath an armored surface would tend to remain for a longer period of time than subsurface oil on an unarmored beach with similar grain size and wave conditions because of the higher velocities required to mobilize the armor (Research Planning, Inc. 1991). Sub-rounded to sub-angular gravel is a very good indicator of these less mobile beaches.

Riprap is a manmade equivalent of this ESI rank, with added problems because it is usually placed at the high-tide line where the highest oil concentrations are found and the riprap boulders are sized so that they are not reworked by storm waves. Often, the only way to effectively clean riprap is by removal and replacement. Riprap can be the only shoreline type in a region with an ESI = 6 (such as along the Gulf of Mexico where there are no gravel-sized sediments). Where gravel beaches are also present, riprap is designated as 6B.

ESI = 7: Exposed, Flat, Permeable Substrate; infauna usually abundant

The essential elements of the ESI = 7 rank are:

- They are flat (less than 3 degrees) accumulations of sediment.
- The highly permeable substrate is dominated by sand, although silt and gravel components may be present.
- Sediments are water-saturated so oil penetration is very limited.
- Exposure to wave or tidal-current energy is evidenced by ripples in sand, scour marks around gravel, or presence of sand ridges or bars.

- Width can vary from a few meters to nearly one kilometer.
- Sediments are soft, with low trafficability.
- Infaunal densities are usually very high.

Shoreline types that meet these elements include:
- Exposed tidal flats

Exposed tidal flats commonly occur in association with other shoreline types, usually marsh vegetation, on the landward edge of the flat. 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. Even when large slicks spread over the tidal flat at low tide, the tidal currents pick up the oil and move it along shore. Because of the high biological use, however, impacts to benthic invertebrates by exposure to the water-accommodated fraction or by smothering can be significant. Cleanup is always difficult because of the potential for mixing the oil deeper into the sediment, even with foot traffic.

ESI = 8: Sheltered Impermeable Substrate, Hard; epibiota usually abundant

The essential elements of the ESI = 8 rank are:
- They are sheltered from wave energy or strong tidal currents.
- Substrate is composed of bedrock or rocky rubble.
- The type of bedrock can be highly variable, from smooth vertical bedrock, to rubble slopes, which vary in permeability to oil.
- Slope is generally steep (greater than 15 degrees), resulting in a narrow intertidal zone.
- There is usually a very high coverage of attached algae and organisms.

Shoreline types that meet these elements include:
- Sheltered vertical rocky shores
- Sheltered rubble slopes
- Sheltered scarps in bedrock and unconsolidated sediments (Great Lakes)
- Sheltered solid manmade structures, such as bulkheads

Spilled oil tends to coat rough rock surfaces in sheltered settings, and oil persistence is long-term because of the low-energy setting. 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.

Sheltered, impermeable, rocky shores have the following characteristics:

- Bedrock shore of variable slope (from vertical cliffs to wide, rocky ledges) that is sheltered from exposure to most wave and tidal energy.
- The wider shores may have some surface sediments, but the bedrock is the dominant substrate type; thus it is termed "impermeable."
- This shoreline type is usually classified as 8A.

Sheltered, semi-permeable, rocky shores have the following characteristics:

- Relatively steep and short rocky shore that is covered with a thin-to-thick veneer of angular rubble without any evidence of rounding or sorting by sediment transport.
- The surface rubble is highly variable in packing, but there is always some permeability in the surface material.
- Other shoreline types frequently occur in combination with permeable rocky shores, which are usually classified as 8B.

Cleanup of these shorelines is always labor-intensive and can affect biological communities.

ESI = 9: Sheltered, Flat, Semi-Permeable Substrate, Soft; infauna usually abundant

The essential elements of the ESI = 9 rank are:

- They are sheltered from exposure to wave energy or strong tidal currents.
- The substrate is flat (less than 3 degrees) and dominated by mud.
- The sediments are water-saturated, so permeability is very low, except where burrowed.
- Width can vary from a few meters to nearly one kilometer.
- Sediments are soft, with low trafficability.
- Infaunal densities are usually very high.

Shoreline types that meet these elements include:

- Sheltered tidal flats
- Sheltered sand/mud flats
- Sheltered vegetated low banks

The high biological use, 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. Natural removal rates are very slow. In areas without a significant tidal range, such as the Great Lakes, sheltered flats are created by less-frequent variations in water level. These flats are unique in that low-water conditions can persist for weeks to months, providing a mechanism for contamination of sediments in areas that can be subsequently flooded.

ESI = 10: Vegetated Emergent Wetlands

The essential element of the ESI = 10 rank is:

- Various types of emergent vegetation, including herbaceous grasses and woody vegetation, cover the substrate.

Marshes, mangroves, and other vegetated wetlands are the most sensitive habitats because of their high biological use and value, difficulty of cleanup, and potential for long-term impacts to many organisms. Where there are multiple wetland types present, different subclasses can be assigned based on likelihood of being oiled, relative wave energy, species composition, and geomorphology. Historically, the following subclasses have been delineated:

A. Saltwater marshes
B. Freshwater marshes (herbaceous vegetation)
C. Freshwater swamps (woody vegetation)
D. Mangroves

In previous atlases, efforts have been made to differentiate between sheltered and exposed wetlands, inferred from a rough analysis of the fetch and evidence of tidal current scour. However, there are no systematic field indicators of exposure that can be readily observed. An energy differentiation of vegetated wetland types would best be conducted using automated searches of the digital data, using fetch distances and other parameters, as discussed below.

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, effective fetch, general geomorphology, general biological sensitivity, etc., then use algorithms to calculate exposure to wave and tidal energy for each shoreline

done in a highly supervised classification mode. Although existing intertidal habitat maps are a good source for mapping discrete sediment 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 ESI assignments can be developed from field observations, aerial photography, and videography by experienced coastal geologists. The resolution of shoreline types is ±30 meters for maps made on USGS 7.5-minute quadrangles.

Biological Resources

There are numerous animal species and habitats that are potentially at risk from oil spills. Table 3 lists the major groups (elements) and sub-elements that are included on sensitivity maps. There are seven major biological elements and each element is further divided into groups of species or sub-elements 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 and wildlife is mostly shown by patterns and symbols representing these ecological groupings, with annotations for each species present.

The "Comments" section in Table 3 lists the types of biological resource areas that 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 distribution of fish species, for example, can cover very large areas and thus not help responders in assessing resources at risk and setting 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;

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

Data Element	Sub-Element	Comments
Marine Mammal	Dolphin	Population concentration areas
	Manatee	Population concentration areas
	Polar Bear	
	Sea Lion	Haulouts
	Sea Otter	Population concentration areas
	Seal	Haulouts
	Walrus	Haulouts
	Whale	Seasonal use areas; migration routes
Terrestrial Mammal	Bear	Intertidal feeding species
	Deer	Intertidal feeding species
	Mustelid	Concentration areas
	Rodents	Concentration areas
	Threatened/Endangered Species	Important habitats
Bird	Alcid	Rookeries; wintering concentration areas
	Diving Coastal Bird	Rookeries; forage/wintering areas
	Gull/Tern	Nesting sites
	Petrel/Fulmar	Rookeries
	Raptor	Nest sites; critical forage areas
	Shorebird	Nesting beaches; migration stopover areas
	Wading Bird	Rookeries; critical forage areas
	Waterfowl	Wintering areas; migration stopover areas
Fish	Anadromous Fish	Spawning streams
	Beach Spawner	Spawning beaches
	Kelp Spawner	Spawning in kelp
	Nursery Areas	For estuarine, demersal, pelagic fish
	Special Concentrations	Estuarine and demersal fish
Shellfish	Abalone	Harvest areas; high concentrations
	Clam	Harvest areas; abundant beds
	Conch/Whelk	Harvest areas; high concentrations
	Crab	Nursery areas; high concentrations
	Echinoderm	Harvest areas
	Lobster	Nursery areas; high concentrations
	Mussel	Leased beds; abundant beds
	Oyster	Seed beds; Leased beds; abundant beds
	Scallop	Harvest beds; abundant beds
	Shrimp	Nursery areas; high concentrations

Table 3. *Continued.*

Data Element	Sub-Element	Comments
Shellfish, cont.	Squid/Octopus	Harvest areas; high concentrations
Reptile/ Amphibian	Alligator	Concentration areas
	Sea Turtle	Nesting beaches; concentration areas
	Threatened/Endangered Species	Important habitats
Habitats	Coral Reef	
	Kelp Bed	
	Submerged Aquatic Vegetation	Includes all types of subtidal grass beds
	Worm Bed	
	Plant	Threatened/endangered species
Recreation	Beach	High-use recreational beaches
	Boat Ramp	
	Boating/Fishing	High-use recreational areas
	Diving Area	
	Marina	
	Park	State and regional parks
Management Area	Marine Sanctuary	Areas of special biological concern
	National Park	
	Preserve/Reserve	
	Refuges	
	Wildlife Management Area	
Resource Extraction	Aquaculture Site	Fish/shrimp/bivalves/plants
	Commercial Fishery	
	Log Storage Area	
	Mining	Intertidal/subtidal mining leases
	Subsistence	Designated harvest sites
	Water Intake	Industrial; drinking water; power plants
Cultural	Archaeological Site	Water-associated features
	Historical Site	Water-associated features
	Indian Reservation	

- 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.

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.

Attribute data is included, allowing 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. Chapter 3 provides detailed explanations on how natural resource data are compiled and synthesized.

Table 4 lists the attribute data for biological data as typically shown on the back of each ESI map.

For mammals and birds, life stages include adult, adult breeder, and juvenile, or just present if the life stage is unknown. The months of breeding activity of marine mammals and birds are used to infer the presence of eggs or young. Calving apply only to whales, dolphins, and manatees, whereas pupping applies to sea lions, seals, and sea otters. The number of individuals or breeding pairs is listed under concentration (CONCEN on Table 4) (if known); otherwise descriptive qualifiers of the number or relative size of the population likely to use the area can be indicated. 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 included since these data are seldom known in detail.

Table 4. Example of the data associated with biological data represented on ESI maps, as listed on the back of each map.

No. California ESI Map 1

Biological Resources:

BIRD:

RAR#	Species	S/F	T/E	Concen	J	F	M	A	M	J	J	A	S	O	N	D	Nesting	Laying	Hatching	Fledging
197	American avocet				X	X	X	X				X	X	X	X	X	–	–	–	–
	Canvasback			HIGH	X	X	X					X	X	X			–	–	–	–
	Double-crested cormorant				X	X	X				X	X	X				APR-AUG	MAR-JUN	APR-JUL	MAY-AUG
	Greater scaup			HIGH	X	X	X	X				X	X				–	–	–	–
	Marbled godwit				X	X	X	X			X	X	X	X	X		–	–	–	–
	Osprey			LOW	X	X	X	X	X	X	X	X	X	X	X	X	MAR-APR	APR-JUN	MAY-JUL	JUL-AUG
	Peregrine falcon	F	E	HIGH	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–
	Western grebe				X	X	X	X			X	X	X	X			–	–	–	–
	Willet				X	X	X	X			X	X	X	X	X		–	–	–	–
199	Brown pelican	F	E		X	X	X	X	X	X	X	X	X	X	X	X	FEB-NOV	FEB-JUL	MAR-AUG	JUN-NOV
	Double-crested cormorant				X	X	X				X	X	X				MAR-AUG	MAR-JUN	APR-JUL	MAY-AUG
	Peregrine falcon	F	E	HIGH	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–
	Sooty shearwater								X	X	X	X	X	X	X	X	–	–	–	–

FISH:

RAR#	Species	S/F	T/E	Concen	J	F	M	A	M	J	J	A	S	O	N	D	Spawning	Outmigration
197	Pacific herring			HIGH	X	X	X							H	H	H	OCT-MAR	–
199	Rockfish				X	X	X	X	X	X	X	X	X	X	X	X	–	–
200	Pacific herring			HIGH	X	X	X							H	H	H	OCT-MAR	–
201	Rockfish				X	X	X	X	X	X	X	X	X	X	X	X	–	–
207	Pacific herring			HIGH	X	X	X							H	H	H	OCT-MAR	–
209	Rockfish				X	X	X	X	X	X	X	X	X	X	X	X	–	–
730	Rockfish				X	X	X	X	X	X	X	X	X	X	X	X	–	–

HABITAT:

RAR#	Species	S/F	T/E	Concen	J	F	M	A	M	J	J	A	S	O	N	D
60	Salt marsh bird's-beak	F	E		X	X	X	X	X	X	X	X	X	X	X	X
197	Eelgrass			HIGH	X	X	X	X	X	X	X	X	X	X	X	X
199	Bull kelp				X	X	X	X	X	X	X	X	X	X	X	X
200	Eelgrass			HIGH	X	X	X	X	X	X	X	X	X	X	X	X
201	Bull kelp				X	X	X	X	X	X	X	X	X	X	X	X
202	Beach layia	F	E		X	X	X	X	X	X	X	X	X	X	X	X
	Clover lupine	F	E		X	X	X	X	X	X	X	X	X	X	X	X
207	Eelgrass			HIGH	X	X	X	X	X	X	X	X	X	X	X	X
209	Bull kelp				X	X	X	X	X	X	X	X	X	X		X

M_MAMMAL:

RAR#	Species	S/F	T/E	Concen	J	F	M	A	M	J	J	A	S	O	N	D	Mating	Calving	Pupping
20	Harbor seal			HIGH	X	X	X	X	X	X	X	X	X	X	X	X	–	–	MAR-JUN
198	Dall's porpoise				X	X			X	X	X			X			–	–	–
	Gray whale			HIGH	X	X	X		X	X					X	X	–	–	–
	Harbor porpoise				X	X	X	X	X	X	X	X	X	X	X	X	–	–	–
199	California sea lion			HIGH	X	X	X	X	X	X	X	X	X	X	X	X	–	–	MAY-AUG
	Northern (Stellar) sea lion	F	T	MED						X	X	X	X				–	–	MAY-AUG
	Northern elephant seal			LOW	X	X	X			X	X			X			–	–	DEC-MAR

SHELLFISH:

RAR#	Species	S/F	T/E	Concen	J	F	M	A	M	J	J	A	S	O	N	D	Spawning
197	Common Pacific littleneck clam			HIGH	X	X	X	X	X	X	X	X	X	X	X	X	APR-SEP
	Gaper clam			HIGH	X	X	X	X	X	X	X	X	X	X	X	X	FEB-APR
	Washington butter clam			HIGH	X	X	X	X	X	X	X	X	X	X	X	X	–
198	Dungeness crab			HIGH	X	X	X	X	X	X					X		–
199	Abalone																–
	Red sea urchin				X	X	X	X	X	X	X	X	X	X	X	X	–

Human use Resources:

AQUACULTURE:

RAR #	Name	
H202	Parcel 2	Johnson Oyster Co.
H203	Parcel 1	Johnson Oyster Co.

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 a stream used for spawning by anadromous fish is shown. Nursery areas are delineated for larval and juvenile fish in estuarine settings, particularly for species of commercial or recreational importance. Reef and shallow hard-bottomed habitats are included as areas of fish concentration at risk from floating slicks. Life-stage information includes larvae and eggs, and breeding activity includes months when spawning and outmigration of fry occur.

Molluscs and crustaceans are always indicated as areas, designated as important seed beds, harvest areas, abundant beds, or otherwise concentration or use areas. Breeding activity start-and-end months include mating and spawning.

On turtle-nesting beaches, the data include the start month and end month for laying of eggs and hatching of the young. Information for alligators is shown as concentration areas, 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, and the data include the status, source, and date of the list.

The element "Habitats" in Table 3 includes important subtidal benthic habitats and wetland and upland plant species of concern. 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 is usually derived from the species that use the habitat. Thus, kelp beds, which have been shown not to be directly affected by floating oil (Antrim et al. 1995), 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 as living resources that vary in sensitivity with season and location. The approach has been to map only the habitats that have been determined to be most sensitive either

directly or because of the species they harbor. In the past, mapping of habitats has covered:

- Submerged aquatic vegetation
- Worm beds
- Large beds of kelp
- Coral reefs
- Threatened and endangered plant habitats

Other subtidal bottom types, such as mud bottoms, 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 itself. Benthic habitats are usually identified and located based upon existing surveys or reports, rather than delineated during sensitivity-mapping surveys.

Even though dispersant use changes the perspective of which resources are at risk during an oil spill, the concern centers mostly on water-column organisms, their sensitive life stages and on the benthic habitats listed above. The normal restrictions on dispersant use (e.g., not in waters less than 10 m deep and not in restricted bays with slow mixing and dilution rates) would minimize the potential for impacts to benthic habitats and their associated biota.

Plant habitats are usually restricted to wetland and upland species that are listed as threatened or endangered. See the discussion on page 27 as to how location-sensitive species are treated.

Human-Use Resources

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

- High-use recreational use and shoreline access areas;
- Officially designated natural resource management area;
- Coastal resource extraction sites; and
- Close-to-shore archaeological, historical, and cultural sites.

Each of these components is discussed below.

Recreational areas shown on sensitivity maps should include high-use recreational beaches and sport-fishing, boating, and diving areas. Boat ramps and marinas are shown, both as recreational sites and access points for response activities.

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 with special resource management status.

Resource extraction elements include aquaculture, commercial and subsistence fisheries, log storage areas, mining lease sites, and water intakes. 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 that 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 oiled sediment can be removed.

High-value commercial fishing areas are also a critical component to ESI mapping, 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. 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.

Cultural resources include archaeological and historical sites, as well as lands managed by Native Americans. The most sensitive types of cultural resources are sites that are actually located in the intertidal zone, such as parts of Alaska where subsidence exposes important archaeological sites to coastal erosion. Also, sites located very close to the shoreline where they may be crossed by response or cleanup crews are included. If there are multiple sites in close proximity, then the general area should be indicated. However, many archaeological, historical, and cultural sites are location-sensitive, so the exact location of the site often cannot be disclosed. In such cases, one of two strategies is used: 1) when the data are transferred by hand onto maps for digitizing, a polygon is drawn to include the site(s) but randomly located so the actual site is not in the center, or 2) when the data are provided in digital format, the actual

location is used to generate a symbol that is then moved to a cartographically pleasing location within one-half mile of the actual site, and the original location is deleted. This approach is used for all location-sensitive data, including threatened and endangered species, where appropriate. It is important to note that users of ESI products must go the original source for location-sensitive data, and there should be no regulatory use of the information provided as part of the ESI data set and maps.

3 COMPILING BIOLOGY AND HUMAN-USE RESOURCE INFORMATION

Introduction

This chapter presents the mapping conventions or rules employed during compilation of biological and human-use (socio-economic) resources onto hard copy maps and tables for data entry. These guidelines are for biologists and other scientists who compile and edit ESI data. The general sequence of data compilation entails making contacts with scientists and resource managers who can provide expert knowledge and suggest relevant source materials; reviewing existing hard copy data sources; meeting with individuals or groups of experts to delineate the locations of resources for which hard copy or digital data are not available; drawing resource distributions onto the compilation maps based on hard copy data and expert opinion; and recording non-spatial or attribute data, and associating it with the resource locations delineated on the maps.

General Guidelines

Gathering Information

Drawing on the Maps

After reviewing available hard copy data sources, and during or after meeting with scientists and resource managers who are providing expert opinion on resource locations, biological and human-use resource distributions are compiled by hand onto USGS topographic maps or NOAA nautical charts for areas without topographical map coverage. Points, lines, and polygons are drawn on the compilation maps to represent the locations of biological and human-use resources. Pencil should be used to draw on the maps, as changes and edits are often necessary. When drawing polygons, lines already present on the topographic maps can be used as part of the polygon. For example, a polygon for a species restricted to the water can include the shoreline as the landward extent of the polygon. Following this convention reduces clutter and

ambiguity, especially along the shoreline. Roads, contour lines, and bathymetry lines can also be used in this manner.

Polygon and Feature Numbering

Biological polygons and human-use features (points, lines, and polygons) are uniquely numbered on the topographic maps and in corresponding data tables to allow easy identification and editing. The numbering system, listed as the Site # in corresponding data tables, includes the topographic map number, a dash, and the feature number. For example, Site # = 001-01 is map number one, polygon number one. Human-use features are preceded by an "H" (e.g., 001-H1). Biology and human-use resources are treated separately. For example, biological polygons might consist of 1 to 25 on map #001 (001-01 to 001-25), while human-use features might consist of H1 to H11 (001-H01 to 001-H11). During the initial compilation and editing, each polygon or feature receives a separate site number. Even if several polygons contain the same group of species, each polygon gets a separate and distinct number. Polygons with the same groups of species are assigned a common identification number during the final map production. During the editing phase of ESI atlas production, the contents of a polygon can change, which results in accessing the specific polygon, not group of polygons.

Edge-Matching Polygons and Lines

When polygons or lines extend to the edge of a map, they must be edge-matched with the corresponding polygons or lines on adjacent maps. The biological or human-use attributes of the polygons or lines must also be edge-matched, so that the resources listed for the polygons correspond (including species, concentrations, seasonality, and life-history information). As an example, if polygon #05 (sawfish and sailfish) extends to the right-hand edge of map #001 but does not end there, and the left-hand edge of map #002 is continuous with the right-hand edge of map #001, there must be a corresponding polygon containing sawfish and sailfish (not sailfish and dogfish) on map #002. During compilation, polygon and line edges do not have to match exactly, but they should be close. Where edge-matching is intended, a note should be written in the map margin indicating which polygon or feature should be edge-matched on adjacent maps. Continuing with the above example, "edge-match 001-05 to 002-01" should be written in the margin of map #001 near the unclosed edges of the polygon #05. On map #002, "edge-match 002-01 to 001-05" should be written in the margin near the unclosed edges of polygon #01. This convention greatly improves data quality

and communication between the data compiler and map digitization technicians. When a polygon extends to the edge of a map, but not beyond, the polygon should be closed to indicate that it does not continue onto the next map.

Biological Resources

Mapping Guidelines

The biological resources to be mapped are arranged hierarchically into elements, sub-elements, and species (see Table 3; Chapter 2). During the biology compilation and editing, separate color codes are used to distinguish among elements:

birds — green
fish — blue
habitats — purple
mammals — yellow
reptiles — red
shellfish — orange

These colors correspond to the final map product and digital data structure. To efficiently digitize the biological data, each Site # is underlined with the appropriate color. This allows the digitizing technician to separate information into the proper element or theme.

Unless otherwise specified by resource specialists or other data sources, generalized rules are followed for each element or sub-element when placing biological information on the maps. The general mapping rules (i.e., distance from shore, type of habitat, etc.) for each biological element and sub-element are described below. For offshore/onshore restrictions, distances can be approximated when hand-drawing polygons. These distances are corrected and made consistent during the data entry and processing stages (e.g., drawing a diving bird polygon from the shoreline to 500 m offshore). Offshore/onshore restrictions incorporate biological generalities, but are also designed to permit ease of display and visibility on the final maps.

Birds

There are eight sub-elements for birds: shorebirds, wading birds, waterfowl, gulls and terns, diving birds, pelagic birds, raptors, and passerine birds. The following guidelines are used to generate polygons for bird concentration areas.

Shorebirds (sandpipers, plovers, etc.) are usually restricted to 75 m on either side (offshore and onshore) of the shoreline along open coasts. Shorebirds may also be further restricted to sand beach, gravel beach, and tidal flat shorelines. In the case of tidal flats, shorebirds could extend across the entire flat, even if it was wider than 75 m.

Wading birds (egrets, herons, ibis, etc.) are usually restricted to wetlands, tidal flats, small tidal creeks, and the margins of sheltered waters (bays, estuaries, lagoons, sloughs). If water depths in sheltered areas are known or indicated to be less than 1 m, wading birds can be shown throughout.

Waterfowl (ducks, geese, coots, etc.) distribution is usually restricted to 500 m offshore and 75 m onshore along open coasts. Waterfowl are also commonly shown extending throughout wetlands, tidal flats, and sheltered waters (bays, estuaries, lagoons, sloughs). Waterfowl can also be shown in isolated fresh- or backwater areas near, but not directly connected to, a major water body. Duck species are often classified into four distinct groups: diving ducks, dabbling ducks, sea ducks, and mergansers. Dabbling ducks generally do not occur offshore. Sea ducks generally do not occur in inland waters or wetlands. In contrast, diving ducks and mergansers can occur across the habitat spectrum considered during ESI mapping.

Gulls and terns are usually restricted to 500 m offshore and 250 m onshore along open coasts. Gulls and terns can occur along any shoreline type. Gulls and terns can also be shown throughout sheltered waters (bays, estuaries, etc.). In addition, gulls and terns can be shown extending entirely across islands.

Diving birds (pelicans, cormorants, loons, etc.) are usually restricted to 500 m offshore and 75 m onshore along open coasts. Diving birds can also extend across small islands and sheltered waters.

Pelagic birds (alcids, fulmars, petrels, etc.) are usually restricted to offshore waters and islands. There is no restriction on their offshore extent.

Raptors (bald eagles, osprey, etc.) are usually restricted to 250 m on either side (offshore and onshore) of the shoreline along open coasts. Raptors can extend across sheltered waters, wetlands, and islands. Nesting sites are shown as individual points or areas with multiple nests. If the exact location is sensitive, it should be displayed as a randomly located polygon containing the point.

Passerine birds (sparrows, gnatcatchers, etc.) are usually not included on ESI maps, as these birds are seldom affected by oil spills. Endangered or threatened passerines who rely on coastal or wetland habitats are included when appropriate.

Fish

Fish are almost always restricted to water. There are generally no restrictions on offshore extent, which is often indicated in terms of bathymetry ("sawfish occur from the shoreline to the 100-m contour"), or distance from shore. Fish can also be shown occurring throughout wetlands, where the location of the land/water interface is often unclear or unknown. During data entry the fish will be restricted to the water bodies. For streams represented as polygons, fish are displayed as polygons. For streams represented as line features, fish are shown as line features.

Shellfish

Shellfish (crustaceans, molluscs, echinoderms, etc.) are usually restricted to water and tidal flats. Shellfish are occasionally shown on both land and water when specifically indicated by a source. In this instance, the onshore extent (e.g., 25 m onshore) should be given by the source. The offshore extent of shellfish is not restricted, and can be indicated in terms of bathymetry or distance from shore.

Marine Mammals

The six most common sub-elements for marine mammals are sea otters, seals, sea lions, whales, dolphins, and manatees. The following guidelines are used to generate polygons for haulouts and concentration areas.

Sea otter concentration areas are restricted to water within the 30-m depth contour.

Seals and sea lions can be displayed on water and land. There are no restrictions on offshore extent. On land, seal and sea lion haulouts can be shown as polygons occurring on beaches and across small islands which do not contain contour lines.

Whales and dolphins are restricted to water. There are no restrictions on offshore extent.

Manatees are restricted to water. Manatees are generally only shown in sheltered or inland waters.

Terrestrial Mammals

Terrestrial mammals can be displayed on land and water. Terrestrial mammals such as river otter, beaver, muskrat, and nutria can be shown throughout wetlands and streams, and are generally shown at the shorelines of sheltered waters such as estuaries and bays. They are generally restricted to 75 m offshore. Bears are shown for the Alaskan region, where they occur in and along streams with salmon runs. Other terrestrial mammals can be displayed on ESI maps when appropriate, such as endangered Key deer in the Florida Keys. Mapping conventions will be assigned to additional species on a case-by-case basis.

Reptiles/Amphibians

There are two major sub-elements for reptiles: sea turtles and crocodilians. In some cases, other threatened or endangered reptiles and amphibians (such as salt marsh snakes) may be included in an ESI atlas.

Sea turtle nesting areas are restricted to 75 m offshore and 75 m onshore, and generally occur only along sand beaches. Other "in water" sea turtle concentration areas, such as critical foraging areas, can be shown where specifically indicated by sources. Under these circumstances, sea turtles are restricted to water.

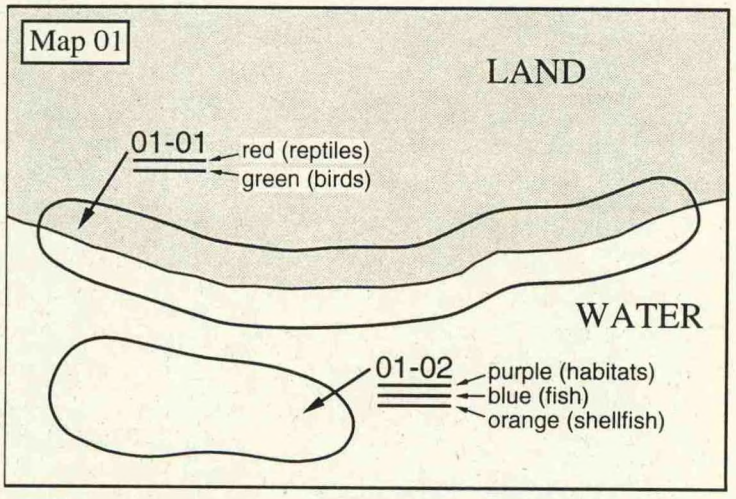
Crocodilians (crocodiles and alligators) are restricted to sheltered waters (estuaries, bays, etc.), streams, and wetlands. They can occur across the entire extent of these habitats. Crocodilians can also be shown up to 75 m onshore.

Habitats

Submerged aquatic vegetation, seagrasses, coral reefs, kelp, and endangered or threatened wetland or coastal upland plants are included in ESI mapping. Submerged aquatic vegetation is restricted to water and tidal flats. All wetland or upland plants are mapped as polygons, even if they are originally provided as point locations (which are used to generate very small polygons).

Overlapping Distributions and Polygons

In most instances, several species will display similar or partially overlapping distributions. If different polygons were displayed for each species, ESI maps would become much too busy, and many features would become wholly or partially obscured. For this reason, individual polygons can contain any number of species, even if they are different sub-elements or elements. Where groups of species have the same or very similar distributions, a single polygon can be used to represent all the species (Figure 1). This polygon would be identified by a single site number on the topographic map and in the data tables. The color code for each element would be indicated with colored pencils near the site number on the topographic map (as described above).

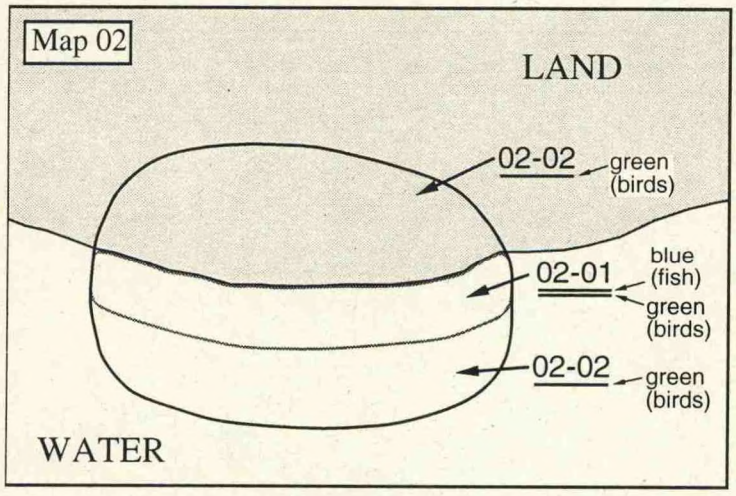


Polygon 01-01 = sea turtles and diving birds
Polygon 01-02 = seagrass, fish, and shellfish

Figure 1. *Biological polygons with multiple elements per polygon.*

In cases where single or multiple species distributions overlap, but are not similar, overlapping portions of the distributions become multi-species polygons (Figure 2). As an example, suppose the distribution of a species of fish extended from the 3-m depth contour to the shoreline. The distribution of a group of diving birds overlaps the fish distribution, extending offshore to the 20-m depth contour and onshore to Beach Road. Both the diving birds and the fish extend along the same length of shoreline. In this case, three polygons would be drawn during the biology data compilation. One polygon would be assigned to the group of diving birds, extending from Beach Road

(onshore) to the shoreline. Another polygon would be assigned to the fish and birds, extending from the shoreline to the 3-m depth contour. The third polygon would be assigned to the birds, from the 3-m depth contour to the 20-m contour. In this case, the polygons containing only the birds would have one number and the polygons containing birds and fish would have another. The species in both sets of polygons would be listed separately in the data tables.



Polygon 02-01 = fish and diving birds
Polygon 02-02 = diving birds

Figure 2. *Overlapping biological polygons containing different elements.*

Element or Sub-Element Assemblages

Use of assemblages is a technique to simplify map compilation when the same group of species occurs in several polygons. For instance, 15 species of waterfowl may be present on all tidal flats and wetlands in a group of maps. All 15 species are listed in the data tables for the first polygon containing the group, and the assemblage is identified as "waterfowl assemblage A." Instead of re-listing the individual species for successive polygons, the assemblage name can be listed in the data tables. When the species in an assemblage are known, it is of utmost importance that they are clearly identified. When listing a group of species as an assemblage, the most precise level of classification should be used. Assemblages can consist of species within the same element (e.g., a fish assemblage), but should consist of species within the same sub-

element when appropriate (e.g., separate shorebird and wading bird assemblages, rather than a bird assemblage). In cases where a large number of species within an element or sub-element is present in a polygon, an assemblage can be indicated to save time. However, the final mapped database will include the species present, not the assemblages.

Common-Throughout Designations

During the biology data compilation, "common throughout" is used when a species or group of species displays 100-percent coverage of a map, an open-water area, a landmass, or a major geographical feature. If a species or group of species does not display 100-percent coverage of an area, polygons must be used. During the GIS phases of ESI production, "common throughout" designations on the compilation maps are converted to polygons that completely fill the areas or habitats specified by the element and sub-element conventions, previously discussed. If a "common throughout" designation is meant to indicate a distribution that differs from specifications given in the element and sub-element conventions, this must clearly be expressed.

To indicate "common throughout," a small box entitled "Common Throughout _____" is drawn on the map within the area or major geographic feature identified, and a site number is assigned to the box as if it were a polygon. As an example, several species of waterfowl, wading birds, fish, and shellfish may occur throughout Fish Bay. A box would be drawn within the bay and "Common Throughout Fish Bay" would be written in the box along with the site number, say "001-34," and the color code for each biological element. Following the element and sub-element conventions during GIS processing, the waterfowl would be displayed across all bay waters to 75 m onshore, the wading birds would be displayed along the shoreline margin of the bay, and the fish and shellfish would be displayed across all bay waters. If it was also intended for the wading birds to be shown throughout all bay waters, this would have to be written within or near the "common throughout" box on the compilation map.

Tabular Data Guidelines for Biological Data

As the biological features (polygons, lines, points) are drawn on the maps, attribute data (species, concentration, seasonality, source information) are recorded in

associated data tables. Attribute data are collected and recorded at the feature level (i.e., for each biological polygon, line, or point). These tables, in combination with the maps, allow for complete and accurate data compilation, entry, and processing.

The Biological Resources Table (Table 5) is used to identify the various species associated with the biology polygons on the ESI maps and their individual concentrations. Numbered code fields for seasonality and source for each species in a polygon link to other tables. Each of the headings in the Biological Resources Table is described below.

1. Site (map#—poly#) identifies each polygon by map number and polygon number. The map number is entered in the bottom-right corner of the map.

2. Species Name refers to the common name of a species found within a polygon. When a polygon contains an assemblage of species, each species associated with the site (map#—poly#) should be listed separately. Species name, in combination with Season ID#, is linked to the Seasonality/ Life history Data Tables. Species name is also linked to the Atlas Species List.

3. Concentration refers to the concentration of a species within a polygon. Concentration can be given as "high," "medium," or "low," or as the number of individuals within the polygon. If relative categories are used, the definition or range of values represented by each category must be entered in the Source Data Dictionary Forms (discussed below).

4. Season ID# refers to a code number (e.g., 1, 2, 3) that represents the seasonal distribution of a species within a polygon or group of polygons. The code number, in combination with species name, is linked to the seasonal information given in the Seasonality/Life history Data Tables. When the same species is present in different seasons, different season ID#s are used. For instance, least terns may be present in several different polygons at two different times of the year. Least terns may be listed for map-01—polygon-05 (and other maps and polygons) as being present in spring only, while least terns listed for map-01—polygon-12 (and other maps and polygons) are present year round. In this case, the first group of listings for least terns would have season ID# given as "1", and the second listing would have Season ID# given as "2". This convention is followed throughout the set of maps and data tables for a given ESI atlas.

5. Geog Source is a number that corresponds to the source of the locational information on a species included in a polygon, line, or point feature.

Table 5. Biological resources table.

Site #[1] (Map#-Poly#)	Species Name[2]	Concentration[3] (High, Medium, Low, #)	Season ID#[4]	Geog Source[5]	Seasonality[6] Source
001-01	Brown pelican	High	1	1	3
001-02	Brown pelican	High	2	1	3
001-02	Loggerhead turtle	Med	1	2	2

October 1995

1 = unique id indicating the location of the biological resource
2 = species common name
3 = descriptive concentration or # individuals per polygon
4 = number code to differentiate polygons in which the same species has different seasonal distributions
5 = unique id identifying the source that provided locational information
6 = unique id identifying the source that provided seasonality information

6. Seasonality Source is a number that corresponds to the source of the seasonality information on a species included in a polygon, line, or point feature.

The Seasonality/Life history Tables (Table 6) are used to list seasonal presence information and sensitive life history stage and reproductive periods for each species. Separate tables are completed for each biological element included in the ESI coverages. Each of the headings in the Seasonality/Life history Tables is described below.

1. Season ID# and;

2. Species Name link the seasonality tables with the Biological Resources Table (Table 5), described above.

3. Seasonal Presence is indicated by checking-off the months (JAN, FEB, MAR, etc.) when a species or species-seasonal ID# combination is present. Months where a species is known not to be present are indicated by a dash (-). If the seasonal preference is unknown, it is left blank. If relative concentrations are known for the monthly presence, the following letters may be used:

   R = Rare

   U = Uncommon

   C = Common

   A = Abundant

   H = Highly Abundant

   This ranking conforms with data sets such as NOAA's Estuarine Living Marine Resources Program.

4-7. Life history Stage and Reproductive Time spans refer to special time periods when certain species might be particularly sensitive to injury or impact due to oil or other hazardous material spills. Sensitive life history stages and reproductive time periods differ by element. Life history or reproductive time periods are listed as a range in months (e.g., APR-JUL). Four fields are available for listing sensitive time periods. Where sensitive stages or time periods are not indicated on the table template, the user can make informed suggestions. For instance, it is possible that certain species may have specific sensitive stages not common to all species in the particular data element. When the information is not available, the table is left blank, and when the stage does not occur, a dash (-) is entered.

Table 6. Seasonality/life history data table.

element = BIRD

		Seasonal Presence[3]												Lifehistory Stage and Reproductive Timespans			
SEASON[1] ID#	SPECIES NAME[2]	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NESTING[4]	LAYING[5]	HATCHING[6]	FLEDGING[7]
1	Brown pelican	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–
2	Brown pelican	–	–	–	–	–	X	X	X	X	–	–	–	JUN-SEP	JUN-JUL	JUL-AUG	AUG-SEP

October 1995

1 = number code which differentiates polygons in which the same species has different seasonal distributions (see Table 1)
2 = species common name
3 = check the months in which the species/season ID# combination is present
4 = the entire timespan in which eggs/young are present (includes laying, hatching, and fledging)
5 = time period when eggs are being laid and incubated
6 = time period when young are hatching
7 = time period when young are being reared (until they leave the nest)

For birds, the special reproductive time periods are nesting, laying, hatching, and fledging. Nesting refers to the entire period when birds are laying eggs, hatching eggs, and fledging young. Laying, hatching, and fledging are subsets of nesting.

For fish, the special life history and reproductive time periods are spawning, juvenile, and outmigration. Spawning includes the actual spawning act and any spawning-related migration or concentration periods, especially those associated with anadromous or estuarine fishes. Juvenile refers to the time period when larval and juvenile life history stages are present. Outmigration refers to the time period when late juveniles or young adults (young of the year) are leaving spawning streams (anadromous fishes) or estuarine areas (estuarine-dependent fishes).

For shellfish, the special life history and reproductive time periods are mating, spawning, and juvenile. Mating refers to spawning-related migration or concentration periods, especially those associated with commercial shrimp, crab, and lobster. Spawning is the actual spawning act. Juvenile refers to the time period when larval and juvenile life history stages are present.

For reptiles, the special reproductive and life history time periods are nesting and hatching. Nesting refers to the deposition of eggs by sea turtles and the time period when turtle eggs are present. Nesting also refers to the laying and tending of eggs and nests by crocodilians. Hatching refers to the time period when young are hatching and emerging from the nests.

For marine mammals, the special life history and reproductive time periods are calving, pupping, and molting. Calving (whales) and pupping (seals, sea lions, sea otters, manatees) refer to time periods when females are giving birth to young. Molting refers to the time when seals and sea lions haul out to shed fur and skin.

Special life-history or reproductive categories are not listed for terrestrial mammals. For habitats such as corals, spawning and juvenile life history stages can be used. For plants, special reproductive categories are not usually listed. However, flowering, fruiting, or other relevant time-periods could be listed when appropriate.

Human-Use Resources

Mapping Guidelines

Each human-use resource is assigned to a feature type, and the features and codes used are shown in Table 7. Color codes are not used. A leader line is attached to the point so that the map and feature number can be clearly indicated (except for location-sensitive resources). Pipelines, state borders, and international borders are represented as line features. Reserves, preserves, refuges, state and Federal parks, marine sanctuaries, and Indian reservations are represented as polygons, similar to the biological resources. The polygon borders follow the boundaries of the management area concerned. Where a resource, such as an archaeological site or fishing area, is large enough to require several point symbols to delineate the extent of the resource, the same site number can be given to each point symbol, unless the resource extends across multiple topographic maps.

Table 7. Human-use feature types and codes used during map compilation.

Feature Type	Code	Feature Type	Code
Access	A2	International Border	IB
Airport	A	Lock and Dam	LD
Aquaculture	AQ	Log Storage	LS
Archaeological Site	AS	Marina	M
Beach (City or County Beach)	B	Marine Sanctuary	MS
		Mining	MZ
Boat Ramp	BR	National Park	NP
Bridge	R	Oil Facilities	OF
Campground	CP	Pipeline	PL
Coast Guard	CG	Platforms	PF
Commercial Fishing	CF	Recreational Fishing	RF
Diving	DV	Regional or State Park	P
Factory	F2	State Border	SB
Ferry	F	Subsistence	S
Historical Site	HS	Water Intake	WI
Hoist	H	Wildlife Refuge	WR
Indian Reservation	IR		

The Human-Use Resources Table (Table 8) is used to identify various human-use resources with point, line, and polygon features on the ESI maps. The various point symbols are generally used to represent the locations of human-use resources such as aquaculture sites, archaeological sites, boat ramps, fisheries locations, water intakes, etc. Human-use line and polygon features include recreational beaches, state parks, and wildlife refuges. Each of the headings in Table 8 is described below.

1. Site (map#—feat.#) refers to the location of each human-use resource by map number and feature number. The feature # is always preceded by the letter "H" to denote human-use resources.

2. Resource Type refers to the type of human-use resource (e.g., wildlife refuge). Resource type should correspond to resources listed in the SocEcon Data Definitions (Table 7).

3. Resource Name refers to the name of the resource (e.g., Sabine Pass National Wildlife Refuge). Some resource types may not have names.

4. Geog Source is a number that corresponds to the source of locational (geographic) information on a resource depicted on the maps. Codes are sequentially numbered and refer to the sources listed in the Source Master List.

5. Attribute Source is a number that corresponds to the source of attribute information such as feature names. This number references the sources in the Source Master List.

Source (Metadata) Documentation

Two tables document source information. The Source Master List (Table 9) provides detailed information on the sources used to compile biological and human-use data. For the biological data, sources for spatial, concentration, seasonality, and life history information need to be documented. The source information is needed for metadata documentation of the ESI atlas. Each of the headings in the Source Master List is described below.

Table 8. Human-use resources table.

Site[1] (Map#-Feat.#)	Resource Type[2]	Resource Name[3]	Geog[4] Source	Attribute[5] Source
001-H01	WR	Wild Goose Chase National Wildlife Refuge	4	4

October 1995

1 = location of the socio-economic resource
2 = type of human-use resource (access, recreational beach, water intake, etc.)
3 = name of the facility
4 = unique id identifying the source that provided locational information
5 = unique id identifying the source that provided attribute information

Table 9. Source Master List.

SOURCE_ID[1]	ORIGINATOR[2]	DATE[3]	TITLE[4]	RESOURCE[5] ELEMENTS	DATA[6] FORMAT	PUBLICATION[7] INFORMATION	SCALE[8]	TIME[9] PERIOD
1	Chuck E. Audubon The Byrd Society Wingtown, ST	None	None	Birds (Brown pelicans)	Personal knowledge	None	N/A	1995
2	State Natural Resources Agency	1994	Turtle Nesting Locations	Turtles	X,Y Coordinates	None	Unknown	1965-1993
3	John Murre and David Thorough	1993	ACME Atlas of Breeding Birds	Birds	text and data tables	ACME University Press, Campus City, ST, 1002 pp.	65,000	1990-1992
4	Jessica Geographer USFWS GIS Director	None	NWR Boundaries	Wildlife refuges	Digital maps (ARC/ INFO)	Unpublished GIS coverages, USFWS, Office of Map Resources, Washington, D.C.	24,000	1994
5	State Office of Control State Capital	1993	Infrastructure and Protected Areas	Human-use	Digital	None	24,000	1990-1992

October 1995

1 = unique id for each source in the database
2 = the author, editor, database manager, expert, etc. who produced the original information
3 = date of publication
4 = title of the source document, map, or database
5 = the biological or human-use elements the source provided information for
6 = format type (allowable descriptions are: digital maps, digital tables, hardcopy maps, hardcopy tables, text descriptions, personal communication, or personal knowledge)
7 = information which would be needed for a reference citation
8 = original scale at which data were mapped
9 = dates over which the original data were collected, or date to which the information is current

1. The unique id for each source in the database, which is assigned sequentially and is references by Geog Source, Attribute Source, and Seasonality Source.

2. Originator refers to the author, editor, database manager, or expert who produced the original information used to compile information for the ESI maps. Originator does not necessarily refer to the person who provided a document or information, an agency or group that published or funded a study or document, or a person who interpreted an original source during the ESI production. For instance, if John Smith of State DNR used the "Atlas of Colonial Breeding Water Buffalo" sent to him by Jane Doe of the USFWS (the project officer for the study), to indicate water buffalo nesting colonies on the ESI maps, the originator would be none of the above. The originator would be the persons who conducted the study, produced the maps, and wrote the report. For persons providing expert knowledge, the agency or affiliation of the originator should be included.

3. Date refers to the date of publication. If the source is unpublished, "none" is placed in this field.

4. Title refers to the title of the source document, map, or database. If the source does not have a title (e.g., personal communications), "none" is listed under this field.

5. Resource elements refer to the specific biological elements (e.g., mammals, reptiles, habitats) or human-use elements for which the source provided locational and other information. Many sources cover a variety of resources. However, only those resources for which information was gathered from the source should be listed. For instance, the title of a source book could be "ACME Coastal Resource Guide." This publication might cover birds, fish, shellfish, marine mammals, commercial fisheries, recreation areas, and archaeological resources. If only fish and shellfish distributions were gathered using this source, "fish and shellfish" should be the only resource element listed.

6. Data Format refers to the type of source used. Digital maps, digital tables, hard copy maps, text, hard copy tables, personal communications, and personal knowledge are the data formats.

7. Publication information includes all information that would be needed for a reference or bibliographic citation, except for the author, date, and title (which are listed under other fields). Information for this field usually includes the publisher or agency name, city, and state; the journal name, volume, and pages; the report or map number; and the total number of pages. If the source is

unpublished, enough information should be provided so that readers would be able to locate the document or database. Agency affiliations listed for persons contributing expert knowledge (listed under originator) should provide information needed by persons interested in contacting expert sources.

8. Scale applies to digital maps, hard copy maps, and some digital databases. For instance, one common map scale is "1:24,000." If scale does not apply, "N/A" is placed in this field.

9. Time period refers to the dates over which data were collected by a source. This will usually be a year or range of years (e.g., "1979-1982"), that precedes the publication date. This information may be contained in the "introduction" or "methods" section of a book or paper. For extensive data compilations or literature reviews, time period can sometimes be estimated by examining the references or literature-cited sections of the source. For personal communications or personal knowledge, the year the source was contacted is usually given as the source time period, indicating the date to which the information was current.

The Source Data Dictionary Form (Table 10) is used to document the study methods used by a particular source (sampling method, spatial referencing and accuracy, study area boundaries, and sampling dates and frequency). This information is necessary so that geographic completeness and temporal consistency can be monitored while merging different data sets from many different sources. A separate form should be completed for each source. Each of the headings in the Source Data Dictionary Form is described in detail on the form, found below. For some data sources, such as expert knowledge, entries for the different headings will need to be estimated. To maintain data quality, it is important to fill in this form as completely and accurately as possible.

Species List

The atlas species list (Table 11) is linked to Species Name in the Biological Resources Table. The atlas species list provides information used to track species identifications within an ESI atlas.

Table 10. Example of a source data dictionary form.

Source ID#: 3

Originator: *John Murre and David Thorough*

Title: *ACME Atlas of Breeding Birds*

I. **Source Sampling Method.** Describe how the data were collected, e.g., aerial overflights, visual surveys, photography, physical collection methods (nets, traps, etc.), radio-tracking. Also describe the sampling method (point, quadrat, transect, etc.) and any statistical design (random, stratified, etc.):

survey of coastal bird rookeries by aerial overflights along multiple overlapping transects oriented parallel to the shoreline

II. **Spatial Referencing Method.** Describe how sampling sites or areas were defined and how geographic locations were determined (e.g., landmarks, compass triangulation, aerial photography, traditional surveying and mapping, township-range-section, LORAN C, GPS):

flight path and the location of bird rookeries were recorded using a GPS, with 15-meter accuracy

III. **Study Area.** Define the boundaries of the study; these should also be indicated on the quad maps (boundaries for land and water areas should be included as appropriate):

entire state coastline was surveyed except for the Big Bend Region from Crystal River north to Horseshoe Beach; surveys were conducted from the shoreline to roughly 35 km inland along mainland coastlines. All the barrier islands were completely surveyed

IV. **Sampling Period and Interval.** Give the starting and ending date of the study. Also check the sampling frequency. Include at least the months when data were collected. If yearly or quarterly sampling was conducted, but at different months in different years, list the month(s) when sampling occurred for each year under "Other":

Start-End Dates (month/year): *3/90-11/92*

❑ Yearly/Annually, month(s) when sampling occurred _____

❑ Quarterly/Seasonally, months when sampling occurred _____

✔ Monthly ❑ Weekly

❑ Other (describe in detail): _____

Table 11. Atlas species list.

SPECIES[1] ID#	SPECIES[2] NAME	SCIENTIFIC[3] NAME	STATE[4]	F/S[5]	T/E[6]	DATE[7]	ELEMENT[8]	SUBELEMENT[9]
118	Brown pelican	*Pelecanus occidentalis*	DE	S	E	1994	BIRD	DIVING
118	Brown pelican	*Pelecanus occidentalis*	NJ	—	—	1994	BIRD	DIVING
1	Common loon	*Gavia immer*	DE	—	—	1994	BIRD	DIVING

1= species identification code from the ESI Species ID# Master List

2= common name

3= scientific genus and species (Latin name)

4= if the atlas covers more than one state, use the two-letter abbreviation code to indicate state

5= protection status for Federal and/or state

6= threatened and/or endangered status

7= date of list used to determine status

8= biological element

9= biological subelement

This list is particularly useful where there are several common names used for the same species. This list is also useful when a species is used in the ESI process for the first time.

1. Species ID# is a number code used to identify and track species during GIS data processing. An ESI Species ID# Master List contains number codes for all species that have been included in previous ESI atlases. If the person compiling biological data for an ESI map has the most recent copy of the ESI Species ID# Master List (Appendix 3), species code can be entered. New species can be added to the ESI Species ID# Master List upon request to NOAA.

2. Species Name is the common name of the species listed in the biology tables.

3. Scientific name is the Latin genus and species name of the species. This field is extremely important when there are several common names used for the same species.

4. Refers to the two-letter state abbreviation code. For a single-state atlas, this code needs to be entered only once for all species. If an atlas spans more than one state, each state in which the species is mapped must be listed on a separate line. "State" is entered regardless of protection status, so that the species included in the atlas by state can be determined.

5. Federal and/or State protection status. Indicate both using F_S or just one using either "F" or "S."

6. Threatened/endangered status. Indicate both using T_E in the same order as the jurisdictional designation.

7. Date of list used to determine status.

8. Biological element.

9. Biological subelement.

4 ESI DATABASE ORGANIZATION

Environmental Sensitivity Index (ESI) geographic information system (GIS) data contain base map, human-use, and biological information. The base map data are hydrology, shorelines (including classification ranking), and annotation. The shoreline classification contains the arcs delineating the water/land interface and environmental sensitivity ranking codes. The human-use data are features such as water intakes, marinas, political boundaries, and managed lands such as wildlife refuges or national parks. The biological data contain concentration areas for animals and sensitive habitats. A complete description of the contents of ESI atlases is given in Chapter 1.

The following sections detail the data structure, data contents, and rules for coding each of the data sets. The ESI Metadata Report details particular characteristics specific to each atlas.

The ESI-GIS data are produced in two different structures. First, to digitize and store the data, an intricate data structure is used that implements a one-to-many data structure with complex polygons. Second, the digital database product has all data converted to a one-to-one data structure using lookup tables. The database product is helpful for those users who need to convert the tabular databases to other formats. Figure 3 diagrams the one-to-many data structure and Figure 4 diagrams the one-to-one data structure.

Appendix I contains a descriptive list of geographic themes, data tables, and lookup tables. Figures 3 and 4 and Appendix I are comparable and may be used together to visualize the ESI-GIS.

Basemap Data

Three coverages establish basemap, or baseline, information in the ESI-GIS: ESI; HYDRO; and INDEX. ESI and HYDRO contain polygonal water and land features as well as linear features for rivers and streams. In both coverages, all polygons are designated as either water or land. The WATER_CODE item stores this information as "L" for land and "W" for water. The arc attribute item LINE contains a code that corresponds to the type of geographic feature (Figure 5). The following rules apply:

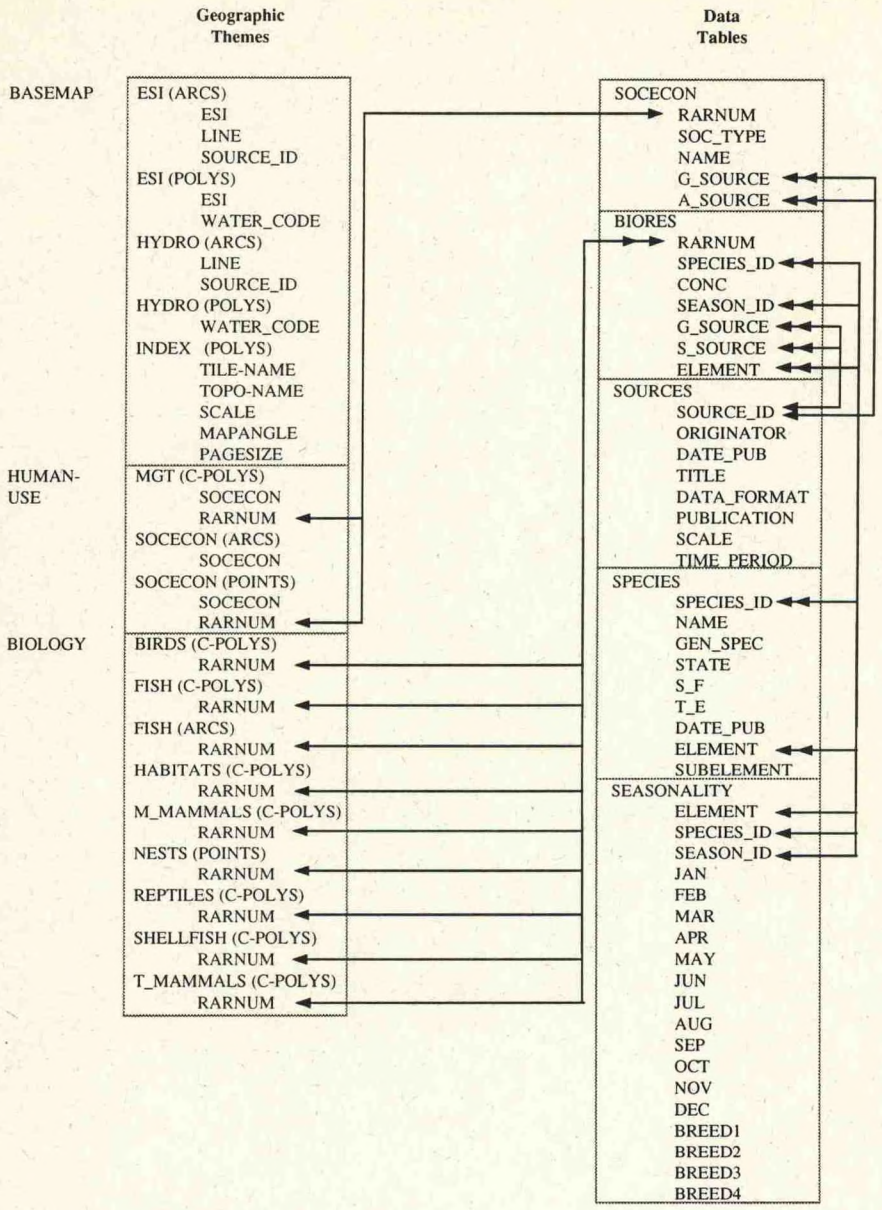


Figure 3. The one-to-many data structure. A single-headed arrow indicates one record and a double-headed arrow indicates many records. C-POLYS refers to complex polygons such as disaggregated or overlapping polygons.

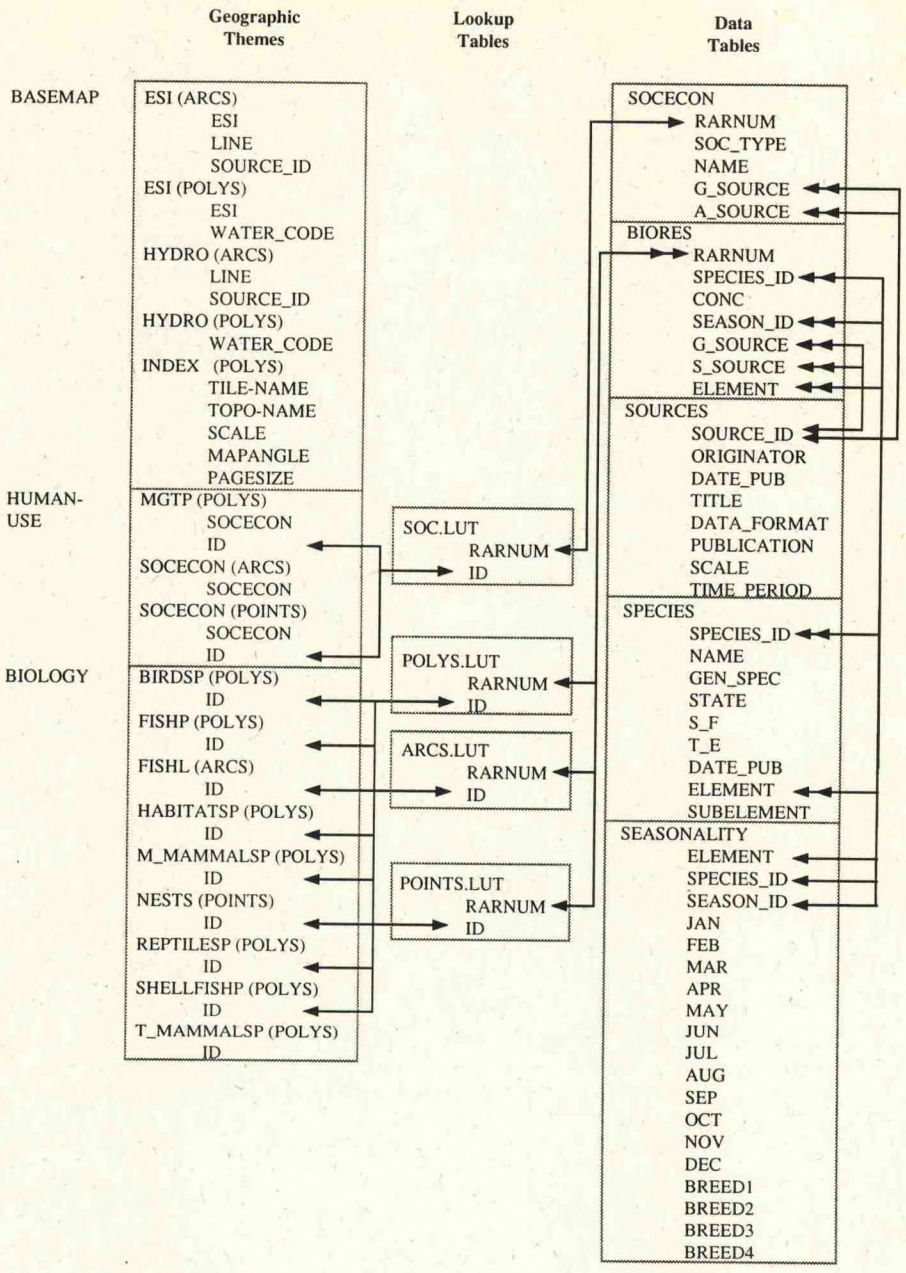


Figure 4. *The one-to-one data structure.*

- Arcs that form the boundary between open water and land are shoreline ("S").
- Arcs where land is on both the right and left must be hydrography ("H").
- Arcs that form an inland water polygon are classified as hydrography ("H").
- Quad/map boundaries are classified as Index ("I").

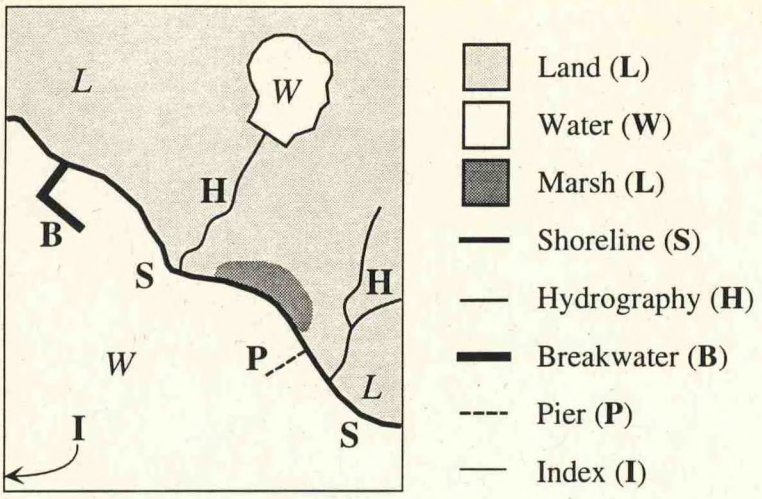


Figure 5. *Polygon WATER_CODE and Arc LINE coding rules.*

- Polygons or arcs that are on the water side of the shoreline are breakwaters ("B") or piers ("P").

The SOURCE_ID arc attribute item contains the source code for the shoreline arcs. The values of SOURCE_ID are commonly: 0 (digital, with sources listed in the meta data report); 1 (low-altitude overflight); 2 (aerial photograph); 3 (digitized off paper quad); 4 (digitized off scanned quad); and 5 (National Wetlands Inventory digital data).

To ensure that the shoreline is consistent between layers, the ESI coverage is copied to the HYDRO coverage. The HYDRO coverage contains all linear features (streams, creeks, etc.) and polygonal features (oceans, lakes, etc.). The ESI coverage is then edited leaving only the arcs and polygons required for the user to examine the sensitivity of the shoreline. The LINE, SOURCE_ID, and WATER_CODE attributes are the same in both the ESI and HYDRO coverages.

The HYDRO coverage also contains all annotation used in producing the atlas. The annotation is usually digitized from the USGS quadrangles and consists of text that is located in the water and is cartographically important for producing the map product. The annotation features are categorized into three subclasses, hydrography (water body names), geography/all land features, and socioeconomic (parks, city and town names, etc.), in order to standardize annotation across atlases. The annotation is created by using fonts and sizes that mimic those used on the USGS quadrangles.

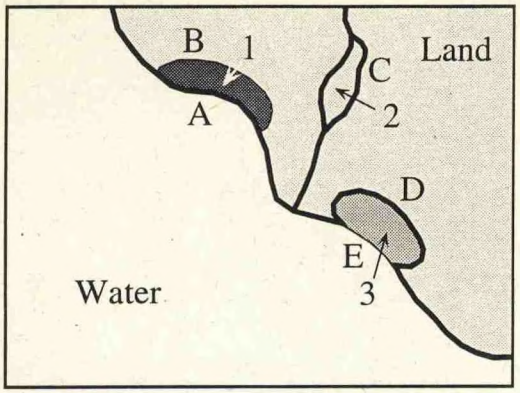
The ESI shoreline classification is topologically stored as arcs (shorelines) and polygons (platforms, marshes, and flats). The item ESI contains values according to the ESI classification of the shorelines and polygons. A detailed description of the shoreline classification scheme is given in Chapter 1. The ESI item may have multiple codes such as 10/2. The first number is the most landward shoreline type, and the second number is the shoreline type closest to the water. The Metadata Report for each atlas lists the specific ESI rankings used in the atlas.

The following rules are enforced when classifying the arcs and polygons in the ESI coverage (Figure 6):

- When ESI classified arcs form polygons and are unranked (e.g., land) the ESI code for the polygon is "U" for unranked.
- Arcs whose left or right polygon is a flat or marsh is designated as "F" or "M," respectively.
- Polygons classified as flats (ESI = 7 or 9) are water (WATER_CODE = W) and have ESI arc attributes on the inland side of the polygons.
- Polygons classified as marshes (ESI = 10) are land (WATER_CODE = L) and have ESI arc attributes on the water side of the polygons.

The coverage INDEX contains the map boundary polygons for each map (usually USGS 1:24,000 quadrangles) in the atlas. The attributes assigned to each polygon are TILE-NAME (map number according to the layout of the atlas); TOPO-NAME (the USGS map name and latest published date); SCALE (value of the denominator of the scale); MAPANGLE (value to rotate the final map product so that it is situated straight up and down); and PAGESIZE (value of the width and height of the map in the final map product).

The next two sections describe the human-use and biology data using the two data structure formats. Refer to Figure 3 for the one-to-many data structure and Figure 4 for the one-to-one data structure. The major difference between the two data structures is the use of lookup tables to access the tabular data and the addition of unique identification codes for each feature in the one-to-one structure. The unique identification codes help those users who need one feature per database record and facilitates merging data sets from different ESI atlases.



Polygons:

Number	ESI	Water Code
1	10	L
2	U	L
3	7	W

Arcs:

Letter	ESI	Line
A	10/3	S
B	U	M
C	8	H
D	3/7	S
E	U	F

Figure 6. ESI shoreline with marsh and flat polygons.

Human-Use Data

The One-to-Many Data Structure

Several human-use features are included in ESI atlases. Points and arcs are digitized into the SOCECON theme and managed land polygonal data are stored as complex polygons in the MGT theme. The complex polygon data structure is used to store the managed land polygons because overlapping polygons are grouped with one attribute entity. The complex polygon data structure (e.g., the REGIONS topology of ARC/INFO®) is efficient and appropriate for data that are overlapping and therefore appropriate for this data set. When the boundaries for a managed land polygon are outside the study area, the data are stored as arcs in the SOCECON theme. Both the SOCECON and MGT themes have the item RARNUM (resource at risk number). This item contains an identification number that links to the database SOCECON. The SOCECON data table contains SOC_TYPE (feature type); NAME (facility name); G_SOURCE (source for the geographic information), and A_SOURCE (source for the attribute information). The source codes are unique and are linked to the SOURCES data table.

The SOURCES table is used to identify the source(s) of the data. The items and contents of the SOURCES data table meet the requirements of the U.S. Federal

Geographic Data Committee's Content Standards for Digital Geospatial Metadata (June 8, 1994). All data, both human-use and biology, reference the SOURCES table. The following items are in the SOURCES table: SOURCE_ID (a unique identifier for each source that provided information); ORIGINATOR (person or organization who provided the data); DATE (production or publication date); TITLE (name of the original data set or body of work); DATA_FORMAT (media); PUBLICATION (citation); SCALE (denominator); and TIME_PERIOD (range of time when data were collected). The information in this table is downloaded and published in the Metadata Report for the atlas.

An example of the MGT and SOCECON themes is given in Figure 7. The relationships between the SOCECON and MGT themes and the tables SOCECON and SOURCES are illustrated in Figure 8.

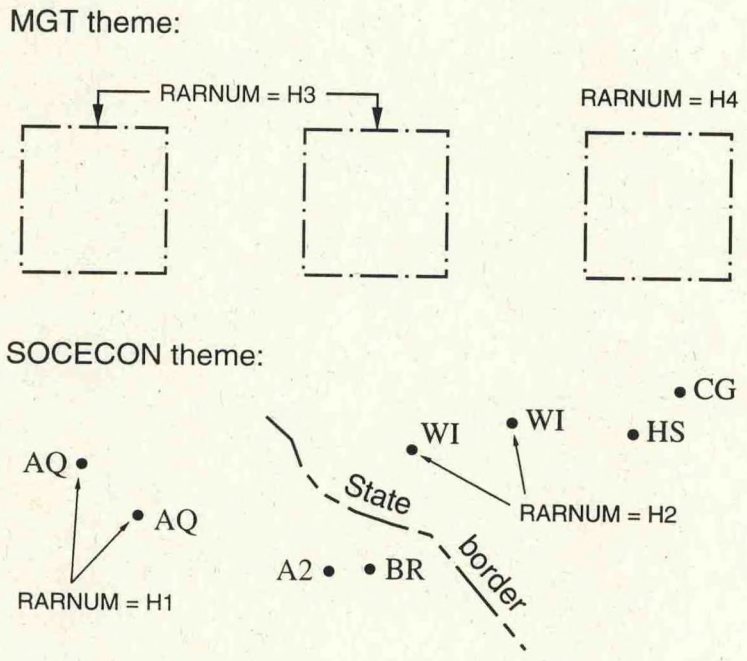


Figure 7. *Example MGT (complex polygons) and SOCECON (points and arcs) themes.*

Examining Figures 7 and 8, there is a many-to-one relationship between SOCECON points (SOCECON.PAT) and records in the SOCECON table. This means that there are two aquaculture sites (H1) and one record in the database (Joe's Shrimp Farm). Alternatively, there is a one-to-one relationship between the managed land complex

SOCECON.PAT:

SOCECON	RARNUM
AQ	H1
AQ	H1
WI	H2
WI	H2
A2	
BR	
H5	
CG	

MGT.PATMGT:

SOCECON	RARNUM
IR	H3
WR	H4

SOCECON:

RARNUM	SOC_TYPE	NAME	G_SOURCE	A_SOURCE
H1	AQUACULTURE	Joe's Shrimp Farm	5	5
H2	WATER INTAKE	City Power Plant	5	5
H3	INDIAN RESERVATION		5	5
H4	WILDLIFE REFUGE	Olympic Coast	4	5

SOURCES:

SOURCE_ ID	ORIGINATOR	DATE	TITLE	DATA_ FORMAT	PUBLICATION	SCALE	TIME_ PERIOD
1	Chuck E. Audubon The Byrd Society Wingtown, ST	None	None	Personal knowledge	None	N/A	1995
2	State Natural Resources Agency	1994	Turtle Nesting Locations	X,Y Coordinates	None	Unknown	1965-1993
3	John Murre and David Thorough	1993	ACME Atlas of Breeding Birds	Text and Data Tables	ACME University Press, Campus City, ST, 1002 pp.	65000	1990-1992
4	Jessica Geographer USFWS GIS Director	None	NWR Boundaries	Digital maps (ARC/INFO)	Unpublished GIS coverages, USFWS, Office of Map Resources, Washington, D.C.	24000	1994
5	State Office of Control, State Capital	1993	Infrastructure and Protected Areas	Digital	None	24000	1990-1992

Figure 8. Example illustrating the relationships between the SOCECON and MGT themes and the data tables SOCECON and SOURCES.

polygons (MGT.PATMGT) and the SOCECON table because even when many polygons make up a feature (such as a national wildlife refuge) they are grouped to form one complex polygon. Also, there is a one-to-one relationship between the SOCECON data table and the SOURCES data table where one feature (aquaculture site) may have one geographic source of information (The Planning Dept.), and one attribute source of information (the State Authority). Also, there is a many-to-one relationship where many features may have the same source information and therefore the same SOURCE_ID in the geog or attribute source fields.

The One-to-One Data Structure

The human-use features in the one-to-one data structure are also stored as points and arcs in the SOCECON theme. Managed land data are converted from complex polygons to polygons and stored in the MGTP theme. In this data structure, a new item, ID, is used to uniquely identify all features. The ID contains a unique value by concatenating the atlas number, the element number, and the feature number. By including the atlas number, the data and associated lookup tables may be merged from multiple atlases, which allows for the creation of new study-area boundaries. The ID item has the syntax:

OOO	*OO*	*OOOOO*
atlas	*element*	*Poly ID*

where the atlas numbers range from 1 to 66 and are listed in Appendix 2. The elements are numbered:

1 BIRD	7 SHELLFISH
2 FISH	8 SPECIAL
3 HABITAT	9 T_MAMMAL
4 M_MAMMAL	10 SOCECON
5 NEST	11 MGT
6 REPTILE	

Expanding on the previous example, the managed land complex polygons are converted to polygons with unique identification codes (Figure 9A). When complex polygons overlap, the overlapped polygon references more than one RARNUM (Figure 9B).

The human-use polygons (MGTP) and points (SOCECON) contain the ID item which is the link to the lookup table SOC.LUT. The relationships between the coverages, lookup tables and data tables are illustrated in Figure 10.

Each managed-land polygon and aquaculture and water intake point has a unique ID. However, multiple IDs may reference the same RARNUM. In the corresponding lookup table (SOC.LUT), notice that the same RARNUM (H3) is referenced by multiple polygons (0011000001 and 0011000002).

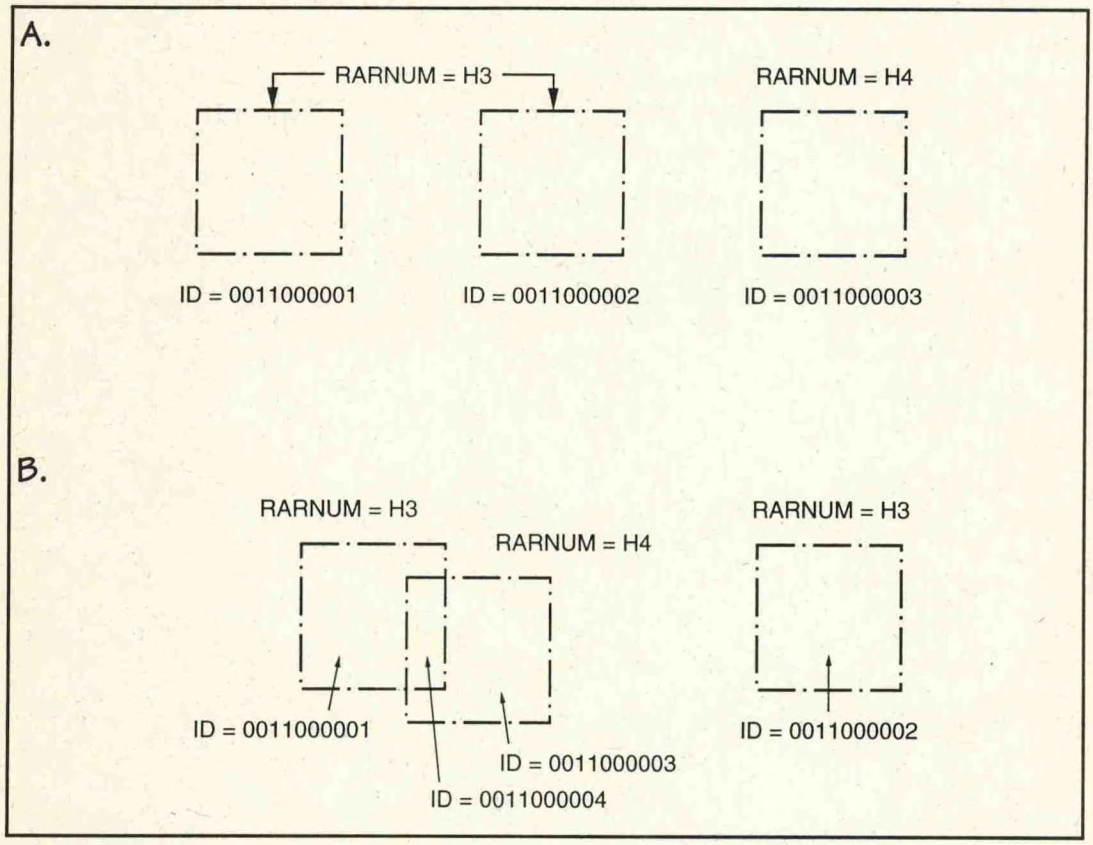


Figure 9. *Sample diagram of managed lands complex polygons and polygon IDs. Multiple polygons may have one RARNUM complex polygon (A) and RARNUM complex polygons may have overlapping polygons (B).*

SOCECON.PAT:

SOCECON	ID
AQ	0010900001
AQ	0010900002
WI	0010900003
WI	0010900004
A2	
BR	
H5	
CG	

MGTP.PAT:

SOCECON	ID
IR	0011000001
IR	0011000002
WR	0011000003

SOC.LUT:

ID	RARNUM
0010900001	H1
0010900002	H1
0010900003	H2
0010900004	H2
0011000001	H3
0011000002	H3
0011000003	H4
0011000004	H5

SOCECON.DAT:

RARNUM	SOC_TYPE	NAME	G_SOURCE	A_SOURCE
H1	AQUACULTURE	Joe's Shrimp Farm	5	5
H2	WATER INTAKE	City Power Plant	5	5
H3	INDIAN RESERVATION		5	5
H4	WILDLIFE REFUGE	Olympic Coast	4	4
H5	INDIAN RESERVATION		5	5
H5	WILDLIFE REFUGE	Olympic Coast	4	4

SOURCES.DAT:

SOURCE_ID	ORIGINATOR	DATE	TITLE	DATA_FORMAT	PUBLICATION	SCALE	TIME_PERIOD
1	Chuck E. Audubon The Byrd Society Wingtown, ST	None	None	Personal knowledge	None	N/A	1995
2	State Natural Resources Agency	1994	Turtle Nesting Locations	X,Y Coordinates	None	Unknown	1965-1993
3	John Murre and David Thorough	1993	ACME Atlas of Breeding Birds	Text and Data Tables	ACME University Press, Campus City, ST, 1002 pp.	65000	1990-1992
4	Jessica Geographer USFWS GIS Director	None	NWR Boundaries	Digital maps (ARC/INFO)	Unpublished GIS coverages, USFWS, Office of Map Resources, Washington, D.C.	24000	1994
5	State Office of Control, State Capital	1993	Infrastructure and Protected Areas	Digital	None	24000	1990-1992

Figure 10. Example of the relationships among the SOCECON and MGTP themes, the lookup table SOC.LUT, and the data tables SOCECON.DAT and SOURCES.DAT.

Biological Data

The One-to-Many Data Structure

The biological data contain the most complex information in the ESI atlas. The data are grouped into coverages based on element or biological category. An atlas usually has BIRD, FISH, HABITAT, M_MAMMAL, NEST, REPTILE, SHELLFISH, and T_MAMMAL coverages. Occasionally, there are special coverages that are documented in the atlas Metadata Report.

The biological data contain numerous overlapping polygons. To efficiently store this information, the complex polygon topology is used where multiple polygons are given a single resource at risk number or RARNUM (Figure 11). The RARNUM value is determined as the unique combination of species, concentration, and seasonality. Unlike the human-use data, the biology RARNUM values do not have a letter prefixing the number. The RARNUM may contain multiple species across elements. From the GIS perspective, this means that polygons are shared between themes. Methodologically, all shared polygons are copied from one theme to another, never digitized more than once.

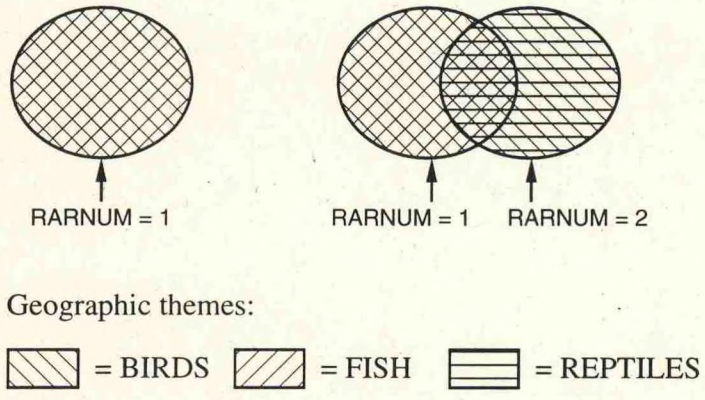


Figure 11. *Sample diagram of biology complex polygons in the one-to-many data structure.*

Each biological coverage is linked to the Biological Resources data table (BIORES) using the item RARNUM. The other items in BIORES are: SPECIES_ID (nationwide species identification code linked to the SPECIES table); CONC (concentration); SEASON_ID

(seasonality code linked to the SEASONALITY table); SOURCE_CODE (a unique identifier to the lookup table SOURCE.LUT which is then linked to the SOURCES table); and ELEMENT (biology group). The seasonality is discussed in detail in Chapter 3. The values for ELEMENT are:

BIRD	REPTILE
FISH	SHELLFISH
HABITAT	T_MAMMAL
M_MAMMAL	

The SEASONALITY data table stores the monthly presence of each species and the characteristics of the presence (life history information). The BIORES data table is linked to the SEASONALITY data table using the SPECIES_ID, ELEMENT, and SEASON_ID variables. The variables BREED1, BREED2, BREED3, and BREED4 contain monthly time spans for reproductive activities. When the BREED variables are blank, the data were not available. When the BREED variables contain a dash (-), the activity does not occur. See Chapter 3 and pages 4-5 in Appendix 1 for a complete description of the breeding variables.

The SPECIES data table contains the species number (SPECIES_ID), common name (NAME), the scientific name (GEN_SPEC), the two-character state abbreviation (STATE), the state and/or Federal status (S_F), the threatened and/or endangered status (T_E), date at which the status is current (DATE_PUB), the biological element (ELEMENT), and the group within the element (SUBELEMENT). The species number is unique within each element. The species list by element and subelement is given in Appendix 3.

If the species is both state- and federally listed, the S_F item will contain "S_F" and the T_E item will contain either "T_E," "E_T," "E_E," or "T_T." The DATE_PUB item contains a two-digit month and four-digit year for all species that are either on a state or Federal list (e.g., 091995). The state abbreviation code is given for all species in the SPECIES table. If the atlas covers more than one state, then all species will be listed in the table for each state in which they are mapped. Therefore, an atlas that covers three states may have all species listed three times. The STATE variable may be used for merging tables from various atlases and determining the presence of species at the state-level without the need of a GIS.

The SOURCES data table contains a list of sources who contributed to the creation of the atlas. BIORES and SOCECON are linked to the SOURCES table using the G_SOURCE, S_SOURCE, and A_SOURCE items. This structure allows for sources to be documented once in the SOURCE table, even if used for multiple polygons or attributes.

The relationships between the themes, lookup tables, and data tables are illustrated in Figure 12.

The following relationships summarize the characteristics of the biology complex polygons and data tables:

- There is a many-to-one relationship between polygons to RARNUM.
- There is a one-to-many relationship between RARNUM (complex polygons) and records in BIORES.
- For each unique occurrence of ELEMENT, SPECIES_ID, CONC, and SEASON_ID, there is a record in BIORES.
- The SPECIES table is linked to BIORES using ELEMENT and SPECIES_ID.
- The SEASONALITY table is linked to BIORES using ELEMENT, SPECIES_ID, and SEASON_ID.

The One-to-One Data Structure

To link the biology themes (BIRDSP, FISHL, FISHP, HABITATSP, M_MAMMALSP, NESTS, REPTILESP, SHELLFISHP, and T_MAMMALSP) to the BIORES.DAT attribute table, a unique identification code (ID) is attached to each feature, which is referenced in the lookup tables POLYS.LUT, POINTS.LUT, and ARCS.LUT. These lookup tables are then linked to BIORES.DAT using the item RARNUM. The ID item is in the same format as the human-use data in the SOCECON and MGTP themes. However, because polygons can be duplicated between themes, the ID values and BIORES are somewhat more complicated (Figure 13). The relationships among the themes, lookup tables, and data tables are illustrated in Figure 14.

BIRDS.PATBIO:

RARNUM
1
2

FISH.PATBIO:

RARNUM
1

REPTILES.PATBIO:

RARNUM
2

BIORES:

RARNUM	SPECIES_ID	CONC	SEASON_ID	G_SOURCE	S_SOURCE	ELEMENT
1	118	HIGH	1	1	3	BIRD
1	118	HIGH	2	5	5	FISH
2	10	MED	1	5	6	FISH
2	12	100	1	7	6	REPTILE

SOURCES:

SOURCE_ ID	ORIGINATOR	DATE	TITLE	DATA_ FORMAT	PUBLICATION	SCALE	TIME_PERIOD
5	Department of Fish and Game	1995	Distri-bution of wildlife	Hard-copy Map	None	24000	Unknown
6	University of South Carolina	1995	Breeding Character-istics of S.C. Wildlife	Book	USC Press	None	1995
7	National Biological Survey	1994	Field Survey of Endan-gered Species	ASCII coordi-nates	Unknown	100000	Sept 1992 - Sept 1993
8	State Wildlife Dept.	1991	Distri-bution of Sea Turtles	dBase file	None	Unknown	1975-1985

SPECIES:

SPECIES_ID	NAME	GEN_SPEC	STATE	S_F	T_E	DATE	ELEMENT	SUB-ELEMENT
118	Brown pelican	*Pelecanus occidentalis*	SC				BIRD	DIVING
118	Yellowfin mojarra	*Gerres cinereus*	SC				FISH	SPECIAL
143	Tarpon	*Megatops atlanticus*	SC				FISH	SPECIAL
6	Atlantic logger-head sea turtle	*Caretta caretta*	SC	S_F	T_T	1995	REPTILE	TURTLE

SEASONALITY:

ELEMENT	SPECIES_ID	SEASON_ ID	JAN	FEB	BREED1	BREED2	BREED3	BREED4
BIRD	10	1	X		JAN-APR	JUN-AUG	AUG-SEP	
FISH	11	1	X	X				
FISH	10	2		X				
REPTILE	12	1	X		MAR-AUG	MAY-OCT		

Figure 12. Example of the relationships among the BIRDS, FISH, and REPTILES themes and the data tables BIORES, SPECIES, SEASONALITY, and SOURCES. The SEASONALITY table contains variables for each month. (Only two months are illustrated for clarity.)

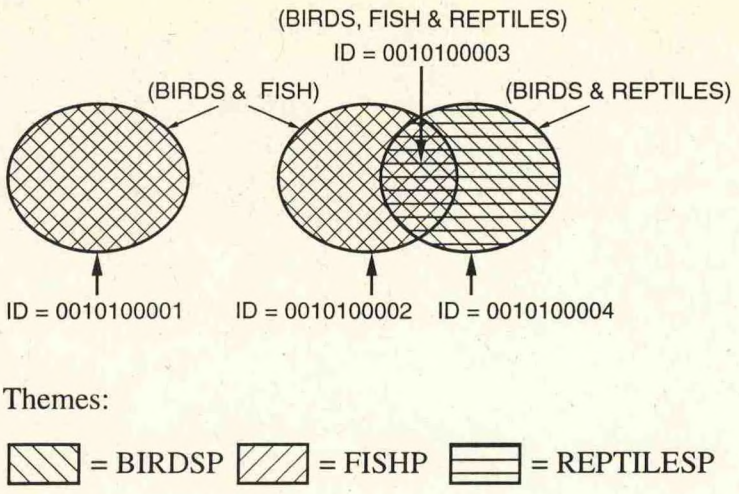


Figure 13. *Polygons for multiple themes and polygon identification codes for the bird theme in the one-to-one data structure.*

The value of ID in the BIRDSP coverage is not the same as the volume in the FISHP coverage. Besides the differences in the element number (01 and 02), the polygon number is determined internally based on the sequence in which the polygons are created. Therefore, even when polygons are copied from one theme to another and share the same RARNUM, they will probably not have the same polygon ID.

In summary, the two data structures (one-to-many and one-to-one) have the same information, but it is presented differently to accommodate various software configurations.

BIRDSP.PAT:

ID
0010100001
0010100002
0010100003
0010100004

FISHP.PAT

ID
0010200009
0010200010
0010200011

POLYS.LUT:

ID	RARNUM
0010100001	1
0010100002	1
0010100003	2
0010100004	1
0010100009	1
0010100010	1

BIORES.DAT:

RARNUM	SPECIES_ID	CONC	SEASON_ID	G_SOURCE	S_SOURCE	ELEMENT
1	118	HIGH	1	1	3	BIRD
1	118	HIGH	2	5	5	FISH
2	10	MED	1	5	6	FISH
2	12	100	1	7	6	REPTILE

SPECIES.DAT:

SPECIES_ID	NAME	GEN_SPEC	STATE	S_F	T_E	DATE	ELEMENT	SUB-ELEMENT
118	Brown pelican	*Pelecanus occidentalis*	SC				BIRD	DIVING
118	Yellowfin mojarra	*Gerres cinereus*	SC				FISH	SPECIAL
143	Tarpon	*Megatops atlanticus*	SC				FISH	SPECIAL
6	Atlantic logger-head sea turtle	*Caretta caretta*	SC	S_F	T_T	1995	REPTILE	TURTLE

SEASONALITY.DAT:

ELEMENT	SPECIES_ID	SEASON_ID	JAN	FEB	BREED1	BREED2	BREED3	BREED4
BIRD	10	1	X		JAN-APR	JUN-AUG	AUG-SEP	
FISH	11	1	X	X				
FISH	10	2		X				
REPTILE	12	1	X		MAR-AUG	MAY-OCT		

SOURCES:

SOURCE_ID	ORIGINATOR	DATE	TITLE	DATA_FORMAT	PUBLICATION	SCALE	TIME_PERIOD
5	Department of Fish and Game	1995	Distribution of wildlife	Hardcopy Map	None	24000	Unknown
6	University of South Carolina	1995	Breeding Characteristics of S.C. Wildlife	Book	USC Press	None	1995
7	National Biological Survey	1994	Field Survey of Endangered Species	ASCII coordinates	Unknown	100000	Sept 1992-Sept 1993
8	State Wildlife Dept.	1991	Distribution of Sea Turtles	dBase file	None	Unknown	1975-1985

Figure 14. Example illustrating the relationships between the BIRDSP and FISHP themes, the lookup table POLYS.LUT, and the data tables BIORES.DAT, SPECIES.DAT, SEASONALITY.DAT, and SOURCES.DAT (see addition to Figure 12).

Quality-Control Standards

To maintain a quality-controlled GIS database, all geographic data must have attributes. No features are uncoded (blank) and strict rules are enforced during the coding process. The digitization of base map data, human-use resources, and biological resources is a complex and highly quality-controlled process. To facilitate digitizing, the entire study area is split into individual quadrangles using the INDEX coverage. The first layer of information digitized is the ESI shoreline. Upon completion of digitization the data are checked for completeness and topological and logical consistency and then plotted and checked by the mapping geologists. Any errors in the shoreline classification are updated prior to digitizing the biological and human-use layers. All layers use the shoreline as the geographic reference so that there are no slivers in the geographic coordinates. The hard copy biological information is compiled onto 1:24,000 USGS topographic quadrangles by a biological expert using data from regional specialists in the form of maps, tables, charts, and written descriptions of resource distributions. The data are digitized, checked using both digital and on-screen procedures, plotted, and sent out for review by the regional specialists. The edited maps are updated, checked once again, and the final product plotted (at approximately 1:50,000 scale). A team of specialists reviews the entire series of maps, checks all data, and makes final edits. The data are then merged to form the study-wide layers. The data-merging includes a final quality-control check where labels, chains, and polygons are checked for attribute accuracy.

To finalize the data-checking process, each coverage is checked for topological consistencies using a standardized form by two GIS personnel (a technician and the GIS manager; Figure 15). Each attribute database is checked using several programs to test the files for missing or duplicate data, rules for proper coding, and geographic-to-tabular consistencies. A final review is made by the GIS manager and programs are run to generate the unique IDs and associated lookup tables (Figure 16).

THEME NAME: _____ DATE: _____

FEATURE CLASS	SUBCLASS	NO. OF FEATURES
ARCS		
POLYGONS		
NODES		
C-POLYS		
POINTS		
ANNOTATION		
SECONDARY FEATURES		
TICS		
ARC SEGMENTS		
POLYGON LABELS		
TOLERANCES		
FUZZY = _____	DANGLE = _____	
COVERAGE BOUNDARY		
XMIN = _____	XMAX = _____	
YMIN = _____	YMAX = _____	

BIOLOGY

Check holes: _____

C-Poly errors: _____

Polys not in regions: _____

Topology: polys: _____

c-polys: _____

GENERAL

Edgematched: _____

Label errors: _____

Slivers: _____

Dangles: _____

Projection defined: _____

Unnecessary nodes: _____

ESI

LINE values: _____

SOURCE_ID values: _____

ESI values: _____

WATER_CODE values: _____

Topology: arcs: _____

polygons: _____

Gaps in ESI: _____

2, 7 + 9 = 'W': _____

10 = 'L': _____

SOCECON

SOCECON values: _____

RARNUM values: _____

C-POLY_MGT values: _____

Topology: arcs: _____

points: _____

polys: _____

c-polys: _____

c-polys errors: _____

Polys not in c-polys: _____

QA/QC by: _____

GIS Manager: _____

Figure 15. GIS technician's QA/QC form.

COVERAGE NAME: _____ DATE: _____

BIRDS	ERASIH	FISH	HYDRO	INDEX	MAMMALS	NETSS	PLANTS	REPTILES	SOCECON	MISC	
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Topology
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Missing or Duplicate Labels
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Tolerance
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Projection Defined
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Create Unique IDs and Lookup Tables
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Order and Syntax of Items
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Check Lookup Labels
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Drop RARNUM from Coverages
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Erase Unnecessary Files from Project Director
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Merge Lookup Tables
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Convert Databases
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Check databases of variable names and order
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Check SOURCES for Extras and Duplicates
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Check SOCECON for Extras and Duplicates
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Make README File
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Export All Data
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Make Tar Tape (low density)

Figure 16. GIS Manager's final QA/QC form.

5 STANDARDS FOR ESI MAP SYMBOLIZATION

Shoreline Sensitivity Ranking Index

On existing ESI atlases, the color schemes for representing the shoreline habitats have varied somewhat, but followed a general trend with "least sensitive" always black and "most sensitive" always red. To standardize the maps, the color scheme has been modified to range in a gradient from cool to hot colors. The numeric ESI values and ESI types associated with each color have varied from atlas to atlas in the past, depending upon the number of subclasses used. The new standardized color scheme from least sensitive to most sensitive is:

ESI Rank	Color	CMYK Percentages
1	Dark Purple	56/94/0/13
2	Light Purple	38/44/0/0
3	Blue	88/19/0/0
4	Light Blue	25/0/0/0
5	Light Blue-Green	50/0/25/0
6A	Light Yellow-Green	100/0/100/0
6B	Green	22/0/100/0
7	Olive	0/0/100/25
8A	Yellow	0/0/100/0
8B	Peach	0/34/28/0
9	Orange	0/40/88/0
10A	Red	0/100/56/0
10B	Light Magenta	0/50/0/0
10C	Dark Red	0/81/56/13
10D	Brown	0/56/69/25

Although many more colors are possible, these colors have been tested and optimized to provide the best contrast and color reproduction using color photocopiers when

used as a narrow band of color along the shoreline. These colors are used on all current NOAA sensitivity maps as a standard. If there are more than 15 shoreline types mapped, it may be necessary to use the same color for subclasses on the maps.

In some areas, the shoreline segment will be composed of two or three different ESI types (riprap behind a sand beach). In this situation, the shoreline color needs to reflect both of these features. Each shoreline combination has a unique line pattern that includes the appropriate colors. That is, when the shoreline is coded as a 6/3, for riprap behind a sand beach, the line pattern is defined as green on the landward half and blue on the seaward half of the shoreline. Some of the ESI features, such as marshes and tidal flats, are polygons. These polygons are drawn and have a solid fill pattern of the appropriate color. Only the shoreline bounding edge of the polygon has the ESI line type or color of that particular ESI.

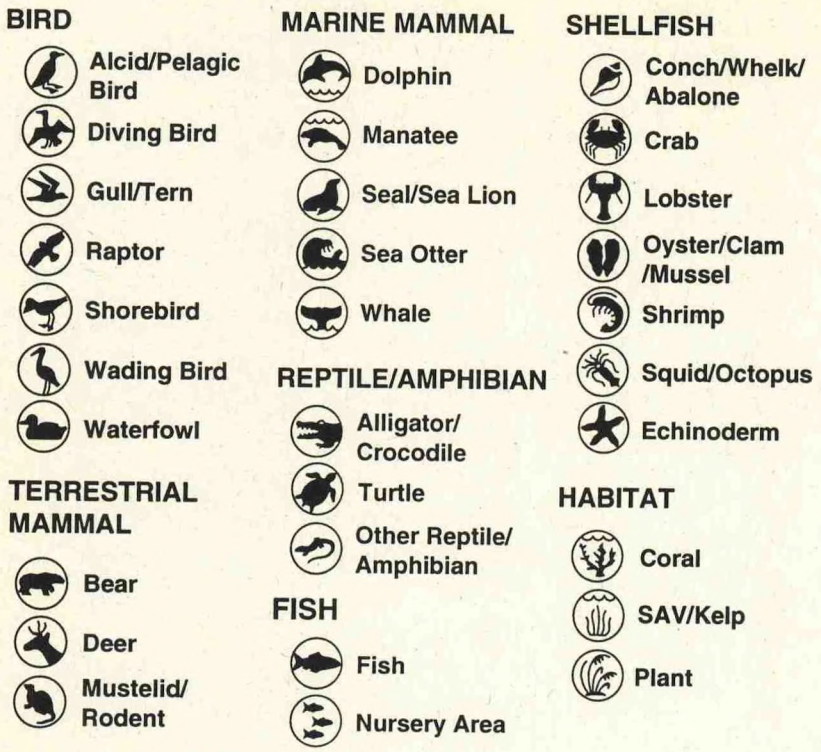
Biological Features Symbolization

The points and polygons representing the different animal groups are color-coded in the same manner as they were colored on traditional ESI maps, with the exception of mammals (which was changed from yellow to brown to be more visible in color copies). The polygons drawn to represent each of the animal groups are colored according to the following scheme:

Fish — Blue	Reptiles — Red
Birds — Green	Shellfish — Orange
Habitats — Purple	Mammals — Brown

Polygons representing the distribution of biological resources are filled with a hatched pattern using the appropriate color, and icons are placed in or connected to the boundary of the polygon. When more than one biological element (e.g., fish and birds) is included in the same polygon, a black-hatched polygon is used. Figure 17 illustrates the symbol set for ESI mapping applications.

SENSITIVE BIOLOGICAL RESOURCES



HUMAN-USE FEATURES

Figure 17. ESI symbols for representation of the biological and human-use resources.

Resources that have widespread distribution are listed in a box labeled ɔcommon throughout. Otherwise, the maps will be too cluttered. This same convention was used extensively on the traditional maps, with good success.

Human-Use Features

Nearly all human-use features are represented as points on the map. The only exceptions are parks, preserves, reserves, and refuges, which are shown as polygons. The symbol for the human-use feature (Figure 17) is placed offset from the feature with a leader line drawn from the symbol to the feature. For the polygon and line features, the boundary of the feature is drawn using a dashed line, and the symbol for the feature is placed somewhere inside the boundary.

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Appendix 1

Description of Geographic Themes and Data Tables

BASEMAP

GEOGRAPHIC THEMES	VARIABLE NAMES	DESCRIPTION	ATTRIBUTE VALUES
ESI (ARCS)	ESI	Shoreline classification	Ranges from 1 through 10 (see Chapter 1 for definitions)
	LINE	Geographic feature	S = Shoreline I = Index for map/quad boundary H = Hydrography P = Pier B = Breakwater F or M = Non-shoreline arcs that form the boundary for a flat or marsh polygon
	SOURCE_ID	Source code for shoreline arcs	0 = Digital 1 = Low-altitude overflight 2 = Aerial photograph 3 = Digitized off paper topo 4 = Digitized off scanned topo 5 = National Wetlands Inventory digital data
ESI (POLYS)	ESI	Shoreline classification	7 and 9 = Flats 10 = Marshes (see Chapter 1 for definitions) U = Unclassified holes
	WATER_CODE	Land and water designations	L = Land W = Water
HYDRO (ARCS)	LINE	Geographic feature	Same as above
	SOURCE_ID	Source code for shoreline arcs	Same as above
HYDRO (POLYS)	WATER_CODE	Land and water designations	Same as above
HYDRO (ANNO)	GEOG	Geography annotations	Islands Points
	HYDRO	Hydrology annotations	Inlets Rivers Ponds Lakes Bays Oceans Coves
	SOC	Human-use annotations	Beaches Wildlife Reserves & Preserves State and Country Names Marine Sanctuaries Cities Parks
INDEX (POLYS)	TILE-NAME	Map number	1 through number of maps in atlas
	TOPO-NAME	USGS 1:24,000 Quadrangle name with latest data	See the meta data report for a complete list of quad names and dates

BASEMAP, continued

GEOGRAPHIC THEMES	VARIABLE NAMES	DESCRIPTION	ATTRIBUTE VALUES
	SCALE	Map production scale	For 11 by 17 inch paper, the scale ranges from 1:45,000 to 1:55,000
	MAPANGLE	Angle to rotate data to plot vertically	Ranges from 0 to 2 degrees
	PAGESIZE	Hardcopy map size	Usually 11 by 17 for full size and inset maps vary. See the meta data report for a complete list of pagesizes

BIOLOGY

GEOGRAPHIC THEMES	VARIABLE NAMES	DESCRIPTION	ATTRIBUTE VALUES
BIRDS (C-POLYS)	RARNUM	Resource at risk number which is linked to RARNUM in the BIORES and BIORES.DAT tables	Integer ranging from 1 through the number of unique combinations of species, their seasonalities and their concentrations
BIRDSP (POLYS)	ID	Unique identifier which is also located in POLYS.LUT table	Integer containing the atlas number, the element number, and the polygon number
FISH (C-POLYS)	RARNUM	Same as BIRDS	Same as BIRDS
FISH (ARCS)	RARNUM	Same as BIRDS	Same as BIRDS
FISHP (POLYS)	ID	Same as BIRDSP	Same as BIRDSP
FISHL (ARCS)	ID	Unique identifier which is also located in ARCS.LUT table	Same as BIRDSP
HABITATS (C-POLYS)	RARNUM	Same as BIRDS	Same as BIRDS
HABITATSP (POLYS)	ID	Same as BIRDSP	Same as BIRDSP
M_MAMMALS (C-POLYS)	RARNUM	Same as BIRDS	Same as BIRDS
M_MAMMALSP (POLYS)	ID	Same as BIRDSP	Same as BIRDSP
NESTS (POINTS)	RARNUM	Same as BIRDS	Same as BIRDS
	ID	Unique identifier which is also located in POINTS.LUT table	Same as BIRDSP
REPTILES (C-POLYS)	RARNUM	Same as BIRDS	Same as BIRDS
REPTILESP (POLYS)	ID	Same as BIRDSP	Same as BIRDSP
SHELLFISH (C-POLYS)	RARNUM	Same as BIRDS	Same as BIRDS

BIOLOGY (continued)

DATA TABLES	VARIABLE NAMES	DESCRIPTION	ATTRIBUTE VALUES
SHELLFISHP (POLYS)	ID	Same as BIRDSP	Same as BIRDSP
BIORES	RARNUM	Resource at risk number which is linked to RARNUM in the biology complex polygon themes	Number ranging from 1 through the number of unique combinations of species, their seasonalities, and their concentrations
	SPECIES_ID	Number identifying a species	Unique number within each element. These species numbers do not change between ESI atlases; they are used across the United States
	CONC	Concentration of the species within the polygon, complex polygon, or point	May be descriptive or a number of individuals
	SEASON_ID	A number code used to differentiate polygons or points which have the same species, but different seasonal distributions	Values range from 1 to usually less than 5
	SOURCE_ID	Unique identifier for each source used in developing the biology database	Character value ranging from B1 through the total number of sources. This is a link to SOURCE.LUT. A lookup table is necessary when there are more than one source per feature
	ELEMENT	Category of species	BIRD FISH HABITAT M_MAMMAL REPTILE SHELLFISH T_MAMMAL
BIORES.DAT		Same as BIORES table	
SOURCES	SOURCE_CODE	Unique identifier for each source used in developing the database	Sequential number from 1 to the number of sources for human-use and biological data. The numbers are atlas specific
	ORIGINATOR	Person or organization who provided the data	Text
	DATE_PUB	Publication date	Formatted as month-year
	TITLE	Name of the original data set	Text
	DATA_FORMAT	Media	Hardcopy map, text, or table; personal knowledge; or digital data
	PUBLICATION	Citation	Text
	SCALE	Denominator	24000 = 1:24,000

BIOLOGY (continued)

DATA TABLES	VARIABLE NAMES	DESCRIPTION	ATTRIBUTE VALUES
	TIME_PERIOD	Range of time when data was collected	Text
SOURCES.DAT		Same as SOURCES table	
SPECIES	SPECIES_ID	Number identifying a species	Same as BIORES
	NAME	Species common name	Appendix 2
	GEN_SPEC	Scientific name	Appendix 2
	STATE		
	S_F	State and/or Federal status	S = State F = Federal S_F = State and Federal
	T_E	Threatened and/or endangered	T = Threatened E = Endangered T_E = Threatened and endangered
	DATE_PUB	Publication date	Formatted as month-year (i.e., 091995)
	ELEMENT	Category of species	Same as BIORES
	SUBELEMENT	Natural group of species within an element	Appendix 2
SPECIES.DAT		Same as SPECIES table	
SEASONALITY	ELEMENT	Category of species	Same as BIORES
	SPECIES_ID	Number identifying a species	Same as BIORES
	SEASON_ID	A number code used to differentiate polygons or points which have the same species, but different seasonal distributions	Same as BIORES
	JAN	Present in January	X = present; blank = not present
	FEB	Present in February	Same as above
	MAR	Present in March	Same as above
	APR	Present in April	Same as above
	MAY	Present in May	Same as above
	JUN	Present in June	Same as above
	JUL	Present in July	Same as above
	AUG	Present in August	Same as above
	SEP	Present in September	Same as above
	OCT	Present in October	Same as above
	NOV	Present in November	Same as above
	DEC	Present in December	Same as above

BIOLOGY (continued)

DATA TABLES	VARIABLE NAMES	DESCRIPTION	ATTRIBUTE VALUES
	BREED1	The breed1 through breed4 variables store the monthly time spans for reproductive activities. Each element has a different meaning. Time spans are represented as a monthly range, i.e., APR_JUL	BIRD = Nesting HABITAT = Spawning FISH = Spawning M_MAMMAL = Calving REPTILES = Nesting SHELLFISH = Spawning
	BREED2	Same as above	BIRD = Laying FISH = Outmigration HABITAT = Juvenile M_MAMMAL = Pupping REPTILES = Hatching SHELLFISH = Larval/Juvenile
	BREED3	Same as above	BIRD = Hatching FISH = Juvenile HABITAT = Flowering M_MAMMAL = Molting SHELLFISH = Mating
	BREED4	Same as above	BIRD = Fledging
SEASONALITY.DAT		Same as SEASONALITY table	

HUMAN-USE

GEOGRAPHIC THEMES	VARIABLE NAME	DESCRIPTION	ATTRIBUTE VALUES
MGT (C-POLYS)	SOCECON	Code identifying a human-use feature	B = Beach R = Bridge IR = Indian Reservation MS = Marine Sanctuary NP = National Park P = Regional or State Park WR = Wildlife Refuge
	RARNUM	Resource at risk number which is linked to RARNUM in the SOCECON and SOCECON.DAT tables	Integer ranging from 1 through the number of unique human-use features
MGTP (POLYS)	SOCECON	Code identifying a human-use feature	B = Beach IR = Indian Reservation MS = Marine Sanctuary NP = National Park P = Regional or State Park WR = Wildlife Refuge

HUMAN-USE, *continued*

GEOGRAPHIC THEMES	VARIABLE NAME	DESCRIPTION	ATTRIBUTE VALUES
	ID	Unique identifier which is also located in SOC.LUT table	Integer containing the atlas number, the element number, and the polygon number
SOCECON (ARCS)	SOCECON	Code identifying a human-use feature	B = Beach IB = International Border IR = Indian Reservation MS = Marine Sanctuary NP = National Park PL = Pipeline P = Regional or State Park SB = State Border WR = Wildlife Refuge
SOCECON (POINTS)	SOCECON	Code identifying a human-use feature	A2 = Access A = Airport AQ = Aquaculture AS = Archaeological Site B = Beach BR = Boat Ramp CP = Campground CG = Coast Guard CF = Commercial Fishing DV = Diving F = Ferry F2 = Factory H = Hoist HS = Historical Site LD = Lock and Dam LS = Log Storage M = Marina MZ = Mining OF = Oil Facilities PF = Platform RF = Recreational Fishing S = Subsistence WI = Water Intake
	RARNUM	Resource at risk number which is linked to RARNUM in the SOCECON and SOCECON.DAT tables	Integer ranging from 1 through the number of unique human-use features

HUMAN-USE, *continued*

DATA TABLE	VARIABLE NAME	DESCRIPTION	ATTRIBUTE VALUES
SOCECON	RARNUM	Resource at risk number which is the link to MGT and SOCECON coverages	Integer ranging from 1 through the number of unique human-use features
	SOC_TYPE	Type of human-use feature	ACCESS AIRPORT AQUACULTURE ARCHAEOLOGICAL SITE BEACH BOAT RAMP CAMPGROUND COAST GUARD COMMERCIAL FISHING DIVING FACTORY FERRY HISTORICAL SITE HOIST INDIAN RESERVATION LOCK AND DAM LOG STORAGE MARINA MARINE SANCTUARY MINING NATIONAL PARK OIL FACILITIES PARK PIPELINE PLATFORM RECREATIONAL FISHING STATE BORDER SUBSISTENCE WATER INTAKE WILDLIFE REFUGE
	NAME	The name of the facility	Only used for water intakes and aquaculture sites
	SOURCE_CODE	Unique identifier for each source used in developing the human-use database	Character value ranging from H1 through the total number of sources. This is a link to SOURCE.LUT. A lookup table is necessary when there are more than one source per feature

LOOKUP TABLES	VARIABLE NAME	DESCRIPTION	ATTRIBUTE VALUES
SOURCE.LUT	SOURCE_CODE	Unique identifier for each source used in developing the biology and human-se databases	Character value ranging from B1 (biology) or H1 (human-use) through the total number of sources. This is the link to SOCECON and BIORES tables
	SOURCE_ID	Unique identifier for each source used in developing the biology database	Sequential number from 1 to the number of sources for human-use and biological data. The numbers are atlas specific
POLYS.LUT	RARNUM	Resource at risk number which is linked to RARNUM in the biology region coverages	Number ranging from 1 through several hundred depending on the number of unique combinations of species, their seasonalities, and their concentrations
	ID	Unique identifier which is also located in the biology polygon coverages	Integer containing the atlas number, the element number, and the polygon number
POINTS.LUT	RARNUM	Same as above	Same as above
	ID	Unique identifier which is also located in the biology point coverages (NESTS)	Integer containing the atlas number, the element number, and the polygon number
ARCS.LUT	RARNUM	Same as above	Same as above
	ID	Unique identifier which is also located in the biology arc coverages (FISH)	Integer containing the atlas number, the element number, and the polygon number
SOC.LUT	RARNUM	Same as above	Same as above
	ID	Unique identifier which is also located in SOCECON coverage	Integer containing the atlas number, the element number, and the polygon number

Appendix 2

ESI Atlas Identification Numbers

ATLAS NUMBER	ATLAS NAME	ATLAS NUMBER	ATLAS NAME
1	Lake Ontario	35	North Carolina
2	Western Lake Michigan	36	Georgia
3	Lake Huron	37	St. John's River, Florida
4	Northern Lake Michigan	38	Oregon–Columbia River
5	Southern Lake Michigan	39	Washington–Strait of Juan de Fuca and Northern Puget Sound
6	Lake Superior	40	Washington–Central and Southern Puget Sound
7	Northern California	41	Columbia River
8	Central California	42	Eastern Lake Michigan
9	Southern California	43	St. Lawrence River
10	Southeast Alaska	44	St. Mary's River
11	Cook Inlet	45	Massachusetts
12	Delaware Bay	46	Connecticut
13	Upper Coast Texas	47	Maryland
14	Texas–Galveston Bay	48	Midcoast Maine
15	Mid Coast Texas	49	Downeast Maine
16	South Coast Texas	50	Southern Maine and New Hampshire
17	Lake Erie	51	New York Harbor
18	West Florida	52	Hudson River
19	West Peninsula Florida, Vol. 1	53	New York–Long Island
20	West Peninsula Florida, Vol. 2	54	Rhode Island
21	South Florida	55	Virginia
22	East Florida	56	Alaska: Bristol Bay Region
23	West Florida Region 2	57	Alaska: Shelikof Strait Region
24	West Florida Region 3	58	Alaska: Norton Sound and Pribilof Islands
25	Apalachicola River, Florida	59	Alaska: Prince William Sound
26	West Peninsula	60	Alaska: Cook Inlet/Kenai Peninsula (1985)
27	South Florida, Vol. 1	61	Alaska: Southern Peninsula
28	South Florida, Vol. 2	62	American Samoa
29	Northeast Florida	63	Mariana Islands, Vol. 1

ATLAS NUMBER	ATLAS NAME	ATLAS NUMBER	ATLAS NAME
30	San Francisco, California	64	Mariana Islands, Vol. 2
31	Alabama	65	Hawaii
32	Mississippi	66	Puerto Rico
33	Louisiana	67	U.S. Virgin Islands
34	South Carolina	101	Gulf of Aqaba

Appendix 3

ESI Species ID# Master List

(sorted by element and subelement)

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
BIRD	alcid	46	Common murre	*Uria aalge*
		47	Pigeon guillemot	*Cepphus columba*
		48	Marbled murrelet	*Brachyramphus marmoratus*
		49	Cassins auklet	*Ptychoramphus aleuticus*
		50	Rhinoceros auklet	*Cerorhinca monocerata*
		51	Tufted puffin	*Lunda cirrhata*
		81	Horned puffin	*Fratercula corniculata*
		84	Parakeet auklet	*Cyclorrhynchus psittacula*
		104	Murre	*Uria sp.*
		105	Thick-billed murre	*Uria lomvia*
		106	Ancient murrelet	*Synthliboramphus antiquus*
		108	Kittlitzs murrelet	*Brachyramphus brevirostris*
		109	Crested auklet	*Aethia cristatella*
		110	Dovekie	*Alle alle*
		111	Least auklet	*Aethia pusilla*
		112	Black guillemot	*Cepphus grylle*
		143	Xantus murrelet	*Endomychura hypoleuca*
		187.	Razorbill	*Alca torda*
		188.1	Common puffin	*Fratercula arctica*
	diving	1	Common loon	*Gavia immer*
		2	Arctic loon	*Gavia arctica*
		2.1	Pacific loon	*Gavia pacifica*
		3	Red-throated loon	*Gavia stellata*
		4	Red-necked grebe	*Podiceps grisegena*
		5	Horned grebe	*Podiceps auritus*
		6	Eared grebe	*Podiceps nigricollis*
		7	Western grebe	*Aechmophorus occidentalis*
		8	Double-crested cormorant	*Phalacrocorax auritus*
		9	Brandts cormorant	*Phalacrocorax penicillatus*
		10	Pelagic cormorant	*Phalacrocorax pelagicus*
		79	Cormorant	*Phalacrocorax sp.*
		99	Red-faced cormorant	*Phalacrocorax urile*
		118	Brown pelican	*Pelecanus occidentalis*
		121	Anhinga	*Anhinga anhinga*
		168	Olivaceous cormorant	*Phalacrocorax olivaceus*
		173	White pelican	*Pelecanus erythrorhynchos*
		179	Pied-billed grebe	*Podilymbus podiceps*
		216	Belted kingfisher	*Megaceryle alcyon*
		269	Least grebe	*Podiceps dominicus*
		275	Great cormorant	*Phalacrocorax carbo*
		1006	Diving birds	
	gull_tern	36	Glaucous-winged gull	*Larus glaucescens*
		37	Western gull	*Larus occidentalis*
		38	Herring gull	*Larus argentatus*
		39	California gull	*Larus californicus*
		40	Ring-billed gull	*Larus delawarensis*
		41	Mew gull	*Larus canus*

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	gull_tern	42	Bonapartes gull	Larus philadelphia
		43	Heermanns gull	Larus heermanni
		44	Thayers (herring) gull	Larus argentatus thayeri
		45	Common tern	Sterna hirundo
		80	Arctic tern	Sterna paradisaea
		82	Glaucous gull	Larus hyperboreus
		85	California least tern	Sterna antillarum browni
		86	Least tern	Sterna albifrons
		92	Great black-backed gull	Larus marinus
		95	Roseate tern	Sterna dougallii
		98	Laughing gull	Larus atricilla
		101	Aleutian tern	Sterna aleutica
		114	Sabines gull	Xema sabini
		127	Sooty tern	Sterna fuscata
		133	Black skimmer	Rynchops niger
		134	Gull-billed tern	Gelochilidon nilotica
		135	Sandwich tern	Sterna sandvicensis
		136	Caspian tern	Sterna caspia
		137	Royal tern	Sterna maxima
		138	Forsters tern	Sterna fosteri
		145	Elegant tern	Sterna elegans
		193	Black tern	Chilidonias niger
		241	Franklins gull	Larus pipixcan
		264	White tern	Gygis alba
		1001	Gulls	
		1008	Terns	
	passerine	224	Sedge wren	
		225	Marsh wren	Cistothorus sp.
		226	Red-winged blackbird	Agelaius phoeniceus
		228	Brewers blackbird	Euphagus cyanocephalus
		229	Swamp sparrow	Melospiza georgiana
		235	Long-billed marsh wren	Cistothurous palustris
		236	Short-billed marsh wren	Cistothurous platensis
		274	Yellow-headed blackbird	Xanthocephalus xanthocephalus
		276	Attwaters prairie chicken	Tympanuchus cupido attwateri
		277	Seaside sparrow	Ammospiza maritima
		278	Sharp-tailed sparrow	Ammospiza caudacuta
		279	Swainsons warbler	Limnothlypis swainsonii
		281	Yellow-bellied sapsucker	Sphyrapicus varius
		282	Yellow-headed blackbird	Xanthocephalus xanthocephalus
		1011	Migratory songbirds	
		1012	Neotropical migrants	

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	pelagic	35	Parasitic jaeger	Stercorarius parasiticus
		83	Kittiwake	Rissa sp.
		96	Leachs storm-petrel	Oceanodroma leucorhoa
		100	Black-legged kittiwake	Rissa tridactyla
		102	Fork-tailed storm-petrel	Oceanodroma furcata
		119	Magnificent frigatebird	Fregata magnificens
		126	Brown noddy	Anous stolidus
		128	Blue-faced booby (masked)	Sula dactylatra
		129	Northern fulmar	Fulmarus glacialis
		130	Red-legged kittiwake	Rissa brevirostris
		144	Ashy storm-petrel	Oceanodroma homochroa
		146	Black storm-petrel	Oceanodroma melania
		167	Gannet	Morus bassanus
		199	Pomarine jaegar	Stercorarius pomarinus
		200	Sooty shearwater	Puffinus griseus
		201	Short-tailed shearwater	Puffinus tenuirostris
		202	Pink-footed shearwater	Puffinus creatopus
		203	Flesh-footed shearwater	Puffinus carneipes
		247	Wedge-tailed shearwater	Puffinus pacificus
		248	Bulwers petrel	Bulweria bulwerii
		249	Black noddy	Anous minuta
		250	Red-tailed tropicbird	Phaethon rubridauda
		251	Great frigatebird	Fregata minor
		252	White-tailed tropicbird	Pheathon lepturus
		253	Newells shearwater	Puffinus puffinus
		254	Laysan albatross	Diomedia immutabilis
		255	Black-footed albatross	Diomedia nigriped
		256	Bonin petrel	Pterodroma hypoleuca
		257	Sooty storm petrel	Oceanodroma tristrami
		258	Christmas shearwater	Puffinus nativitatis
		260	Red-footed booby	Sula sula
		261	Brown booby	Sula leucogaster
		262	Gray-backed tern	Sterna lunata
		263	Blue-gray noddy	Procelsterna serulea
		1009	Shearwaters	
		1010	Pelagic birds	
	raptor	76	Bald eagle	Haliaeetus leucocephalus
		77	Osprey	Pandion haliaetus
		107	Peregrine falcon	Falco peregrinus
		113	Gyrfalcon	Falco rusticolus

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	raptor	181	Northern harrier	Circus cyaneus
		182	American kestrel	Falco sparverius
		183	Snowy owl	Nyctea scandiaca
		212.1	White-tailed kite	Elanus leucuras
		218	Red-shouldered hawk	Buteo lineatus
		219	Sharp-shinned hawk	Accipiter striatus
		220	Merlin	Falco columbarius
		221	Coopers hawk	Accipiter cooperii
		222	Barred owl	Strix varia
		230	Red-tailed hawk	Buteo jamaicensis
		231	Broad-winged hawk	Buteo platypterus
		232	Rough-legged hawk	Buteo lagopus
		233	Northern goshawk	Accipiter gentilis
		240	Goshawk	
		280	Swallow-tailed kite	Elanoides forficatus
		1005	Raptors	
	shorebird	52	Wilsons phalarope	Steganopus tricolor
		53	Northern phalarope	Phalaropus lobatus
		55	Whimbrel	Numenius phaeopus
		56	Spotted sandpiper	Actitis macularia
		57	Wandering tattler	Heteroscelus incanus
		58	Greater yellowlegs	Tringa melanaleuca
		59	Lesser yellowlegs	Tringa flavipes
		60	Red knot	Calidris canutus
		61	Pectoral sandpiper	Calidris melanotos
		62	Least sandpiper	Calidris minutilla
		63	Dunlin	Calidris alpina
		64	Short-billed dowitcher	Limnodromus griseus
		65	Long-billed dowitcher	Limnodromus scolopaceus
		66	Western sandpiper	Calidris mauri
		67	Sanderling	Calidris alba
		68	Black oystercatcher	Haematopus bachmani
		69	Semipalmated plover	Charadrius semipalmatus
		70	Killdeer	Charadrius vociferus
		71	Black-bellied plover	Pluvialis squatarola
		72	Surfbird	Aphriza virgata
		73	Ruddy turnstone	Arenaria interpres
		74	Black turnstone	Arenaria melancephala
		139	Snowy plover	Charadrius alexandrinus
		152	American oystercatcher	Haematopus palliatus
		153	Piping plover	Charadrius melodus
		154	Wilsons plover	Charadrius wilsonia
		155	Willet	Catoptrophorus semipalmatus
		156	Semipalmated sandpiper	Calidris pusilla
		160	Red phalarope	Phalaropus fulicarius

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	shorebird	161	Rock sandpiper	Calidris ptilocnemis
		164	American golden plover	Pluvialis dominica
		165	Bar-tailed godwit	Limosa lapponica
		196	Common snipe	Capella gallinago
		209	Long-billed curlew	Numenius americanus
		210	Marbled godwit	Limosa fedoa
		213	Stilt sandpiper	Calidris himantopus
		214	Solitary sandpiper	Tringa solitaria
		223	Upland sandpiper	Bartramia longicauda
		234	Purple sandpiper	Calidris maritima
		237	Bairds sandpiper	Calidris bairdii
		238	White-rumped sandpiper	Calidris fusciollis
		270	Western snowy plover	Charadrius alexandrinus nivosus
		1002	Shorebirds	
	wading	54	Great blue heron	Ardea herodias
		87	Little blue heron	Egretta caerulea
		88	Great egret	Casmerodius albus
		89	Snowy egret	Egretta thula
		90	Black-crowned night heron	Nycticorax nycticorax
		91	Glossy ibis	Plegadis falcinellus
		93	Cattle egret	Bubulcus ibis
		94	Tricolor heron	Egretta tricolor
		97	Green heron	Butorides striatus
		115	White ibis	Eudocimus albus
		116	Roseate spoonbill	Ajaia ajaja
		117	Great white heron	Ardea occidentalis
		120	Yellow-crowned night heron	Nyctanassa violacea
		122	Scarlet ibis	Eudocimus ruber
		125	Clapper rail	Rallus longirostris
		132	Wood stork	Mycteria americana
		141	American avocet	Recurvirostra americana
		142	Black-necked stilt	Himantopus mexicanus
		149	White-faced ibis	Plegadis chihi
		150	Black rail	Laterallus jamaicensis
		163	Reddish egret	Egretta rufescens
		172	Sandhill crane	Grus canadensis
		178	Least bittern	Ixobrychus exilis
		184	King rail	Rallus elegans
		185	American bittern	Botaurus lentiginosus
		187	Virginia rail	Rallus limicola
		188	Sora rail	Porzana carolina
		189	Yellow rail	Coturnicops noveboracensis
		195	American woodcock	Philohela minor

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	wading	204	California clapper rail	Rallus longirostris obsoletus
		205	Light-footed clapper rail	Rallus longirostris levipes
		206	California black rail	Laterallus jamaicensis coturniculus
		242	Hawaiian stilt	Himantopus mexicanus knudseni
		265	Whooping crane	Grus americana
		271	Rails	
		1004	Wading birds	
	waterfowl	11	Whistling swan (tundra swan)	Olor columbianus
		12	Canada goose	Branta canadensis
		13	Black brant	Branta bernicla
		14	White-fronted goose	Anser albifrons
		15	Snow goose	Chen caerulescens
		16	Mallard	Anas platyrhynchos
		17	Pintail	Anas acuta
		18	Green-winged teal	Anas crecca
		19	Rock dove	Columba livia
		20	Northern shoveler	Anas clypeata
		21	Canvasback	Aythya valisineria
		22	Greater scaup	Aythya marila
		23	Lesser scaup	Aythya affinis
		24	Common goldeneye	Bucephala clangula
		25	Barrows goldeneye	Bucephala islandica
		26	Bufflehead	Bucephala albeola
		27	Oldsquaw	Clangula hyemalis
		28	Harlequin duck	Histrionicus histrionicus
		29	White-winged scoter	Melanitta deglandi
		30	Surf scoter	Melanitta perspicillata
		32	Common merganser	Mergus merganser
		33	Red-breasted merganser	Mergus serrator
		34	American coot	Fulica americana
		103	Common eider	Somateria mollissima
		124	Redhead	Aythya americana
		148	Ruddy duck	Oxyura jamaicensis
		157	Emperor goose	Philacte canagica
		158	King eider	Somateria spectabilis
		159	Stellers eider	Polysticta stelleri
		162	Gadwall	Anas strepera
		169	American wigeon	Anas americana
		170	Trumpeter swan	Olor buccinator
		171	Dusky Canada goose	Branta canadensis occidentalis
		180	Ring-necked duck	Aythya collaris
		186	Black duck	Anas rubripes

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	waterfowl	190	Blue-winged teal	Anas discors
		191	Wood duck	Aix sponsa
		192	Common gallinule	Gallinula chloropus
		197	Black scoter (common)	Melanitta nigra
		198	Hooded merganser	Lophodytes cucullatus
		211	Mottled duck	Anas fulrigula
		212	Purple gallinule	Porphyrula martinica
		215	Aleutian goose	Branta canadensis leucopareia
		217	Mute swan	Lygnus olor
		243	Hawaiian coot	Fulica americana alia
		244	Hawaiian duck	Anas wyvilliana
		245	Hawaiian gallinule	Gallinula chloropus sandvicensis
		246	Laysan duck	Anas laysanensis
		266	Black-bellied whistling-duck	Dendrocygna autumnalis
		267	Fulvous whistling-duck	Dendrocygna bicolor
		268	Masked duck	Oxyura dominica
		272	Teals	Anas sp.
		273	Geese	
		1003	Waterfowl	
FISH	anadromous	43	White sturgeon	Acipenser transmontanus
		44	Green sturgeon	Acipenser medirostris
		45	Cutthroat trout	Salmo clarki
		68	Chinook salmon (king)	Oncorhynchus tshawytscha
		69	Coho salmon (silver)	Oncorhynchus kisutch
		70	Pink salmon (humpy)	Oncorhynchus gorbuscha
		71	Sockeye salmon (red)	Oncorhynchus nerka
		72	Chum salmon (dog)	Oncorhynchus keta
		73	Masu salmon (cherry)	Oncorhynchus sp.
		74	Rainbow trout (steelhead)	Oncorhynchus mykiss
		83	Salmon sp.	
		86	Blueback herring	Alosa aestivalis
		87	American shad	Alosa sapidissima
		100	Brown trout	Salmo trutta
		101	Shortnose sturgeon	Acipenser brevirostrum
		102	Atlantic sturgeon	Acipenser oxyrhynchus
		104	Striped bass	Morone saxatilis
		105	Hickory shad	Alosa mediocris
		135	Dolly varden	Salvelinus malma
		144	Atlantic salmon	Salmo salar
		289	Skipjack herring	Alosa chrysochloris
		319	Gulf sturgeon	Acipenser oxyrhynchus desotoi

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	beach_sp	75	Surf smelt	Hypomesus pretiosus
		106	California grunion	Leuresthes tenuis
	kelp_sp	66	Pacific herring	Clupea harengus pallasi
	reef	253	Butterfly fish	Chaetodon sp.
		254	Surgeon fish	Acanthurus sp.
		255	Damselfish	Chromis sp.
		256	Wrasse	Thalassoma sp.
	special	1	Sablefish (blackcod)	Anoplopoma fimbria
		2	Lingcod	Ophiodon elongatus
		3	Pacific sanddab	Citharichthys sordidus
		4	Arrowtooth flounder	Atheresthes stomias
		5	Petrale sole	Eopsetta jordani
		6	Rex sole	Glyptocephalus zachirus
		7	Pacific halibut	Hippoglossus stenolepis
		8	Butter sole	Isopsetta isolepis
		9	Rock sole	Lepidopsetta bilineata
		10	Dover sole	Microstomus pacificus
		11	English sole	Parophrys vetulus
		12	Starry flounder	Platichthys stellatus
		13	C-O sole	Pleuronichthys coenosus
		14	Curlfin sole	Pleuronichthys decurrens
		15	Sand sole	Psettichthys melanostictus
		16	Flathead sole	Hippoglossoides elassodon
		17	Slender sole	Lyopsetta exilis
		18	Plainfin midshipman	Porichthys notatus
		19	Pacific cod	Gadus macrocephalus
		20	Pacific hake	Merluccius productus
		21	Pacific tomcod	Microgadus proximus
		22	Walleye pollock	Theragra chalcogramma
		23	Wolf-eel	Anarrhichthys ocellatus
		24	Pacific ocean perch	Sebastes alutus
		25	Silvergray rockfish (short spine)	Sebastes brevispinis
		26	Copper rockfish	Sebastes caurinus
		27	Puget Sound rockfish	Sebastes emphaeus
		28	Yellowtail rockfish	Sebastes flavidus
		29	Black rockfish	Sebastes melanops
		30	Bocaccio	Sebastes paucispinis
		31	Yelloweye rockfish	Sebastes ruberrimus
		32	Canary rockfish (orange)	Sebastes pinniger
		33	Chilipepper	Sebastes goodei
		34	Redbanded rockfish (flag)	Sebastes babcocki
		35	Rougheye rockfish	Sebastes aleutianus
		36	Splitnose rockfish	Sebastes diploproa
		37	Greenstriped rockfish	Sebastes elongatus
		38	Brown rockfish	Sebastes auriculatus

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	special	39	Redstripe rockfish	Sebastes proriger
		40	Big skate	Raja binoculata
		41	Longnose skate	Raja rhina
		42	Spotted ratfish	Hydrolagus colliei
		46	Kelp greenling	Hexagrammos decagrammus
		47	Rock greenling	Hexagrammos lagocephalus
		48	Whitespotted greenling	Hexagrammos stelleri
		49	Buffalo sculpin	Enophrys bison
		50	Red Irish lord	Hemilepidotus hemilepidotus
		51	Pacific staghorn sculpin	Leptocottus armatus
		52	Tidepool sculpin	Oligocottus maculosus
		53	Cabezon	Scorpaenichthys marmoratus
		54	Redtail surfperch	Amphistichus rhodoterus
		55	Kelp perch	Brachyistius frenatus
		56	Shiner perch	Cymatogaster aggregata
		57	Striped seaperch	Embiotoca lateralis
		58	Walleye surfperch	Hyperprosopon argenteum
		59	Pile perch	Rhacochilus vacca
		60	White seaperch	Phanerodon furcatus
		61	Penpoint gunnel	Apodichthys flavidus
		62	Saddleback gunnel	Pholis ornata
		63	Crescent gunnel	Pholis laeta
		64	Quillback rockfish	Sebastes maliger
		65	Bluefish	Pomatomus saltatrix
		67	Northern anchovy	Engraulis mordax
		77	Eulachon	Thaleichthys pacificus
		78	Capelin	Mallotus villosus
		79	White seabass	Atractoscion nobilis
		80	Pacific sand lance	Ammodytes hexapterus
		81	Spiny dogfish	Squalus acanthias
		84	Rainbow smelt	Osmerus mordax
		85	Alewife	Alosa pseudoharengus
		88	Winter flounder	Pseudopleuronectes americanus
		89	Cunner	Tautogolabrus adspersus
		90	White hake	Urophycis tenuis
		91	Threespine stickleback	Gasterosteus aculeatus
		92	Fourspine stickleback	Apeltes quadracus
		93	Striped killifish	Fundulus majalis
		94	Atlantic silverside	Menidia menidia
		95	Mummichog	Fundulus heteroclitus
		96	Sanddab	Citharichthys sp.
		97	Tautog	Tautoga onitis
		98	American eel	Anguilla rostrata

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	special	99	Atlantic tomcod	Microgadus tomcod
		103	Threadfin shad	Dorosoma petenense
		107	Spotted seatrout	Cynoscion nebulosus
		108	Summer flounder	Paralichthys dentatus
		109	Red drum	Sciaenops ocellatus
		110	Black seabass	Centropristis striata
		111	Southern flounder	Paralichthys lethostigma
		112	Gulf flounder	Paralichthys albigutta
		113	Bay anchovy	Anchoa mitchilli
		114	Florida pompano	Trachinotus carolinus
		115	Atlantic menhaden	Brevoortia tyrannus
		116	Striped mullet	Mugil cephalus
		117	Pinfish	Lagodon rhomboides
		118	Yellowfin mojarra	Gerres cinereus
		119	Silver perch	Bairdiella chrysoura
		120	Pigfish	Orthopristis chrysoptera
		121	Spot	Leiostomus xanthurus
		122	Black drum	Pogonias cromis
		123	Atlantic croaker	Micropogonias undulatus
		124	Southern kingfish (whiting)	Menticirrhus americanus
		126	King mackerel	Scomberomorus cavalla
		127	Spanish mackerel	Scomberomorus maculatus
		128	Blue runner	Caranx crysos
		129	Atlantic thread herring	Opisthonema oglinum
		130	Scaled sardine	Harengula jaguana
		131	Great barracuda	Sphyraena barracuda
		132	Grouper sp.	Epinephalus sp.
		133	Snapper sp.	Lutjanus sp.
		134	Cobia	Rachycentron canadum
		136	Dolphin	Coryphaena hippurus
		137	Sheepshead	Archosargus probatocephalus
		138	Seatrout (weakfish)	Cynoscion regalis
		139	Spanish sardine	Sardinella aurita
		140	Ladyfish	Elops saurus
		141	Snook	Centropomus undecimalis
		142	Crevalle jack	Caranx hippos
		143	Tarpon	Megalops atlanticus
		145	White perch	Morone americana
		146	Atlantic herring	Clupea harengus harengus
		147	Atlantic mackerel	Scomber scombrus
		148	Silver hake	Merluccius bilinearis
		149	Atlantic cod	Gadus morhua
		150	Porgy (scup)	Stenotomus chrysops
		151	Northern puffer	Sphoeroides maculatus
		152	Yellow perch	Perca flavescens

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	special	153	Northern kingfish	Menticirrhus saxatilis
		154	Pollock	Pollachius virens
		155	Squirrel (red) hake (ling)	Urophycis chuss
		156	American sand lance	Ammodytes americanus
		157	Goosefish	Lophius americanus
		158	Butterfish	Peprilus triacanthus
		159	Banded killifish	Fundulus diaphanus
		160	Windowpane (flounder)	Scophthalmus aquosus
		161	Lake sturgeon	Acipenser fulvescens
		162	Carp	Cyprinus carpio
		163	Gizzard shad	Dorosoma cepedianum
		164	Cisco sp.	Coregonus sp.
		165	Lake whitefish	Coregonus clupeaformis
		166	Brook trout	Salvelinus fontinalis
		167	Lake trout	Salvelinus namaycush
		168	Spottail shiner	Notropis hudsonius
		169	Blackchin shiner	Notropis heterodon
		170	Blacknose shiner	Notropis heterolepis
		171	Fathead minnow	Pimephales promelas
		172	Longfin smelt	Spirinchus thaleichthys
		173	White mullet	Mugil curema
		174	Longnose sucker	Catostomus catostomus
		175	White sucker	Catostomus commersoni
		176	Yellow bullhead	Ictalurus natalis
		178	Rock bass	Ambloplites rupestris
		179	Largemouth bass	Micropterus salmoides
		180	Smallmouth bass	Micropterus dolomieui
		181	Black crappie	Pomoxis nigromaculatus
		182	Bluegill	Lepomis macrochirus
		183	Green sunfish	Lepomis cyanellus
		184	Grass pickeral	Esox americanus
		185	Northern pike	Esox lucius
		186	Muskellunge	Esox masquinongy
		187	Sauger	Stizostedion canadense
		188	Walleye	Stizostedion vitreum vitreum
		189	Arctic char	Salvelinus alpinus
		190	White bass	Morone chrysops
		191	Shorthead redhorse	Moxostoma macrolepidotum
		192	Topsmelt	Atherinops affinis
		193	Jacksmelt	Atherinopsis californiensis
		194	White baitsmelt	Allosmerus elongatus
		195	Silver surfperch	Hyperprosopon ellipticum
		196	Blue rockfish	Sebastes mystinus
		197	Grass rockfish	Sebastes rastrelliger
		198	Brown Irish lord	Hemilepidotus spinosus

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	special	199	Rock gunnel	Pholis gunnellus
		200	Blue catfish	Ictalurus furcatus
		201	Channel catfish	Ictalurus punctatus
		202	White crappie	Pomoxis annylaris
		203	Warmouth	Chaenobryttus gulosus
		204	Redear sunfish	Lepomis microlophus
		205	Freshwater drum	Aplodinotus grunnieus
		206	Spotted sunfish	Lepomis punctatus miniatus
		207	Sea catfish	Galeichthyes felis
		208	Northern squawfish	Ptychocheilus oregonensis
		209	Peamouth	Mylocheilus caurinus
		210	Largescale sucker	Catostomus macrocheilus
		211	Brown bullhead	Ictalarus nebulosus
		212	Pumpkinseed	Lepomis gibbosus
		213	Gulf menhaden	Brevoortia patronus
		214	Gulf kingfish	Menticirrhus littoralis
		215	Sand seatrout	Cynoscion arenarius
		217	Gafftopsail catfish	Bagre marinus
		219	Pacific lamprey	Entosphenus tridentatus
		220	Sandroller	Percopsis transmontana
		221	Chiselmouth	Acrocheilus alutaceus
		222	Mottled sculpin	Cottus bairdi
		223	Rockfish	Sebastes spp.
		224	Surfperch	Embiotocidae
		225	California halibut	Paralichthys californicus
		226	Tidewater goby	Eucyclogobius newberryi
		227	Prickly sculpin	Cottus asper
		228	Night smelt	Spirinchus starksi
		229	River redhorse	Moxostoma carinatum
		230	Pygmy whitefish	Prosopium coulteri
		231	Tadpole madtom	Noturus gyrinus
		232	Trout perch	Percopsis omiscomaycus
		233	Ninespine stickleback	Pungitius pungitius
		234	Johnny darter	Etheostoma nigrum
		235	Lake herring	Coregonus artedii
		237	Burbot	Lota lota
		238	Round whitefish (menomonee)	Prosopium clindraceum
		239	Splake	Salvelinus namaycush + fontinalis
		240	Greater redhorse	Moxostoma valenciennesi
		241	Striped shiner	Notropis chrysocephalus
		242	Redfin shiner	Notropis umbratilis
		243	Longear sunfish	Lepomis megalotis
		244	Golden redhorse	Moxostoma erythrurum
		245	Silver redhorse	Moxostoma anisurum
		246	Black bullhead	Ictaluras melas

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	special	247	Emerald shiner	Notropis atherinoides
		248	Common shiner	Notropis cornutus
		249	Logperch	Percina caprodes
		250	Ruffe	Gymnocephalus cernuus
		251	Tiger musky	Esox masquinongy + lucius
		252	Yellow bass	Morone mississippiensis
		258	Hawaiian anchovy	Stolephorus purpurens
		259	Freshwater goby	Awaous sp.
		260	Barred sand bass	Paralabrax nebulifer
		261	Spotted sand bass	Paralabrax maculatofasciatus
		262	California corbina	Menticirrhus undulatus
		263	Shortfin corvina	Cynoscion parvipinnis
		264	Yellowfin croaker	Umbrina roncador
		265	Spotfin croaker	Roncador stearnsii
		266	Kelp bass	Paralabrax clathratus
		267	Opaleye	Girella nigricans
		268	Silver seatrout	Cynoscion nothus
		269	Gulf killifish	Fundulus grandis
		270	Longnose killifish	Fundulus similis
		271	Inland silverside	Menidia beryllina
		272	Rainbow runner	Elegatis bipinnulata
		273	Star drum	Stellifer lanceolatus
		274	Sheepshead minnow	Cyprinodon variegatus
		275	Least puffer	Sphoeroides parvus
		276	Red shiner	Notropis lutrensis
		277	Paddlefish	Polyodon spathula
		278	Little tunny	Euthynnus alletteratus
		279	Blue sucker	Cycleptus elongatus
		280	Sunfish	Lepomis sp.
		281	Seatrout	Cynoscion sp.
		282	Mullet	Mugil sp.
		283	Killifish	Fundulus sp.
		284	Flounder	Paralichthys sp.
		285	California barracuda	Sphyraena argentea
		286	Sole	
		287	Hardhead catfish	Arius felis
		288	Tripletail	Lobotes surinamensis
		290	Striped anchovy	Anchoa hepsetus
		291	Shiners	Notropis spp.
		292	Chain pickerel	Esox niger
		293	Southern hake	Urophycis floridanus
		294	Spotted hake	Urophycis regius
		295	Halfbeak	Hyporhamphus unifasciatus
		296	Diamond killifish	Adenia xenica
		297	Marsh killifish	Fundulus confluentus

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	special	298	Saltmarsh topminnow	Fundulus jenkinsi
		299	Rainwater killifish	Lucania parva
		300	Sailfin molly	Poecilia latipinnaa
		301	Rough silverside	Membras martinica
		302	Gag grouper	Mycteroperca microlepis
		303	Permit	Trachinotus falcatus
		304	Rough scad	Trachurus lathami
		305	Red snapper	Lutjanus campechanus
		306	Gray snapper	Lutjanus griseus
		307	Lane snapper	Lutjanus synagris
		308	Rock sea bass	Centropristis philadelphica
		309	Spotfin mojarra	Eucinostomus argenteus
		310	Atlantic spadefish	Chaetodipterus faber
		311	Atlantic bonito	Sarda sarda
		312	Harvestfish	Peprilus alepidotus
		313	Gulf butterfish	Peprilus burti
		314	Broad flounder	Paralichthys squamilentus
		315	Blacktip shark	Carcharhinus limbatus
		316	Spinner shark	Carcharhinus brevipinna
		317	Bull shark	Carcharhinus leucas
		318	Atlantic sharpnose shark	Rhizoprionodon terraenovae
		320	Atlantic bumper	Chloroscombrus chrysurus
		321	Atlantic cutlassfish	Trichiurus lepturus
		322	Atlantic spadefish	Chaetodipterus faber
		323	Atlantic stingray (stingaree)	Dasyatis sabina
		324	Bighead searobin	Prionotus gibbesii
		325	Blackcheek tonguefish	Symphurus plagiusa
		326	Bonnethead shark	Sphyrna tiburo
		327	Dwarf seahorse	Hippocampus zosterae
		328	Gar	Lepisosteidae
		329	Grass carp	Ctenopharyngodon idella
		330	Hammerhead	Sphyrna lewini
		331	Sharks	
		332	Tiger shark	Galeocerdo cuvieri
HABITAT	marsh	77	Intermittent coastal wetlands	
	sav	1	Eelgrass	Zostera marina
		2	Bull kelp	Nereocystis luetkeana
		7	Surfgrass	Phyllospadix sp.
		9	Giant kelp	Macrocystis pyrifera
		78	Turtle grass	Thalassia testudinum
		79	Shoal grass	Halodule wrightii
		80	Widgeon grass	Ruppia maritima
		81	Manatee grass	Syringodium filiforme
		82	Southern naiad	Najas sp.

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	sav	83	Water celery	Vallisneria americana
		84	Dwarf seagrass	Halophila engelmannii
		85	Seagrass	
		86	Alligatorweed	Alternanthera philoxeroides
	plant	3	Menzies wallflower	Erysimum menziesii
		4	Beach layia	Layia carnosa
		5	Salt marsh birds-beak	Cordylantus maritimus maritimus
		6	Western lily	Lilium occidentale
		8	Clover lupine	Lupinus tidestromii tidestromii
		10	Coastal dunes milkvetch	Astragalus tener titi
		11	Sand (Monterey) gilia	Gilia tenuiflora arenaria
		12	Pitchers thistle (Dune thistle)	Cirsium pitcheri
		13	Clustered broomrape	Orobanche fasciculata
		14	Smartweed	Polygonum careyi
		15	Spurge	Euphorbia polygonifolia
		16	Rock Sandwort	Arenaria stricta
		17	Bald-rush	Psilocarys scirpoides
		18	Clubmoss	Lycopodium appressum
		19	Rose mallow	Hibiscus palustris
		20	Wild bean	Strophostyles helvola
		21	Sea rocket	Cakile edentula
		22	Ginseng	Panax quinquefolius
		23	Sedge	Carex platphylla
		24	Thickspike wheatgrass	Agropyron dasystachyum
		25	Moonwort	Botrychium lunaria
		26	Sand reed	Calamovilfa longifolia
		27	Garbers sedge (Elk sedge)	Carex garberi
		28	Chestnut sedge	Fimbristylis puberula
		29	Northern comandra	Geocaulon lividum
		30	Pale false foxglove	Gerardia skinneriana
		31	Dwarf lake iris	Iris lacustris
		32	Smooth phlox	Phlox glaberrima
		33	Seaside crowfoot	Ranunculus cymbalaria
		34	Sand dune willow	Salix cordata
		35	Lake Huron tansy	Tanacetum huronense
		36	False asphodel	Tofieldia glutinosa
		37	Houghtons goldenrod	Solidago houghtonii
		38	Beach peavine	Lathyrus maritimus var glaber
		39	Small floating manna-grass	Glyceria borealis
		40	Silverweed	Potentilla anserina
		41	Scirpus-like rush	Juncus scirpoides
		42	Sand-heather	Hudsonia tomentosa

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	plant	43	Reticulated nutrush	Scleria reticularis
		44	Prairie fame-flower	Talinum rugospermum
		45	Leafy northern green orchis	Platanthera hyperborea
		46	Horned bladderwort	Utricularia cornuta
		47	Zigzag bladderwort	Utricularia subulata
		48	Whorled water-milfoil	Myriophyllum verticillatum
		49	Variegated horsetail	Equisetum variegatum
		50	Sticky goldenrod	Solidago simplex var gillmanii
		51	Spotted pondweed	Potamogeton pulcher
		52	Beach sumac	Rhus aromatica var arenaria
		53	Black-fruit mountain-ricegrass	Oryzopsis racemosa
		54	Chamomile grape-fern	Botrychium matricariifolium
		55	Flatleaf pondweed	Potamogeton robbinsii
		56	Clinton lily	Clintonia borealis
		57	Brown-fruited rush	Juncus pelocarpus
		58	Capitate spike-rush	Eleocharis geniculata
		59	Plant (E)	
		60	Plant (T)	
		61	Butterwort	Pinguicula vulgaris
		62	Beautiful sedge	Carex concinna
		63	Lenticular sedge	Carex lenticularis
		64	Spike trisetum	Trisetum spicatum
		65	Grass-of-parnassus	Parnassia palustris
		66	Coast sedge	Carex exilis
		67	Michauxs sedge	Carex michauxiana
		68	Lake cress	
		69	Marin bent grass	Agrostis blasdalei marinensis
		70	Pt. Reyes blennosperma	Blennosperma nanum robustum
		71	Howells spineflower	Chorizanthe howellii
		72	Soft birds-beak	Cordylantus mollis mollis
		73	Tamarack Swamp natural community	
		74	Surf thistle	Cirsium rhothophilum
		75	Beach spectacle pod	Dithyrea maritima
		87	Arrowhead	Sagittaria sp.
		88	Bald cypress	Taxodium distichum
		89	Banana water lily	Nymphaea mexicana
		90	Black needlerush	Juncus roemerianus
		91	Bull-tongue	Sagittaria lancifolia
		92	Bulrush	Scirpus sp.
		93	California bulrush	Scirpus californicus
		94	Cattail	Typha sp.
		95	Chinese tallow tree	

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	plant	96	Common reed	Phragmites australis
		97	Cordgrass	Spartina sp.
		98	Cutgrass	Leersia oryzoides
		99	Dwarf spike-rush	Eleocharis parvula
		100	Glasswort	Salicornia sp.
		101	High-tide bush	Iva frutescens
		102	Maliciae	Maliciae
		103	Olneys three-square	Scirpus americanus
		104	Palmetto	Sabal minor
		105	Pondweed	Potamogeton sp.
		106	Rushes	Juncus sp.
		107	Salt grass	Distichlis spicata
		108	Salt marsh bulrush	Scirpus robustus
		109	Salt meadow cord-grass (wiregrass)	Spartina patens
		110	Saltwort	Batis maritima
		111	Seashore paspalum	Paspalum vaginatum
		112	Smooth cordgrass	Spartina alterniflora
		113	Spike-rushes	Eleocharis sp.
		114	Sundews	Drosera
		115	Tupelo	Nyssa sp.
		116	Water lotus	Nelumbo lutea
		117	Water oak	Quercus nigra
		118	White water lily	Nymphaea odorata
		119	Giant cutgrass (Southern wild rice)	Zizaniopsis miliacea
M_MAMMAL	dolphin	6	Harbor porpoise	Phocoena phocoena
		17	Bottlenose dolphin	Tursiops truncatus
		20	Northern right-whale dolphin	Lissodelphis borealis
		21	Atlantic spotted dolphin	Stenella plagiodon
		45	Pacific white-sided dolphin	Lagenorhynchus obliquidens
		46	Rissos dolphin	Grampus griseus
		47	Dalls porpoise	Phocoenoides dalli dalli
		49	Spotted dolphin	Stenella attenuata
		50	Spinner dolphin	Stenella longirostris
		60	Common dolphin	Delphinus delphis
		61	Stenellid dolphin	Stenella sp.
	manatee	10	Manatee	Trichechus manatus
	sea_lion	1	Northern (Steller) sea lion	Eumetopias jubatus
		3	Northern fur seal	Callorhinus ursinus
		22	California sea lion	Zalophus californianus
		23	Guadalupe fur seal	Arctocephalus townsendi
	sea_otter	7	Sea otter	Enhydra lutris

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	seal	2	Harbor seal	Phoca vitulina
		14	Gray seal	Halichoerus grypus
		15	Bearded seal	Erignathus barbatus
		16	Walrus	Odobenus rosmarus
		24	Northern elephant seal	Mirounga angustirostris
		51	Hawaiian monk seal	Monachus schauinslandi
	whale	4	Killer whale	Orcinus orca
		5	Little (Pacific) blackfish	Peponocephala electra
		9	Beluga whale	Delphinapterus leucas
		11	Fin whale	Balaenoptera physalus
		12	Minke whale	Baleonoptera acutorostrata
		13	Humpback whale	Megaptera novaeangliae
		18	Pygmy sperm whale	Kogia breviceps
		19	Shortfin pilot whale	Globicephala macrorhynchus
		26	Gray whale	Eschrichtius robustus
		27	Sei whale	Balaenoptera borealis
		29	Blue whale	Balaenoptera musculus
		48	Sperm whale	Physeter catodon
REPTILE	alligator	1	American crocodile	Crocodylus acutus
		3	American alligator	Alligator mississippiensis
	snake	11	Atlantic salt marsh snake	Nerodia fasciata taeniata
		12	Gulf salt marsh snake	Nerodia clarkii
	turtle	2	Atlantic green sea turtle	Chelonia mydas mydas
		4	Kemps (Atlantic) ridley sea turtle	Lepidochelys kempii
		5	Leatherback sea turtle	Dermochelys coriacea
		6	Atlantic loggerhead sea turtle	Caretta caretta
		7	Diamondback terrapin	Malaclemys terrapin
		8	Pacific green sea turtle	Chelonia mydas agassizi
		9	Atlantic hawksbill sea turtle	Eretmochelys imbricata imbricata
		10	Pacific hawksbill sea turtle	Eretmochelys imbricata bissa
		13	Turtles	
SHELLFISH	abalone	31	Japanese abalone	Haliotis kamtschatkana
		60	Abalone	Haliotis sp.
		61	Red abalone	Haliotis rufescens
		62	Black abalone	Haliotis cracherodii
		63	Green abalone	Haliotis fulgens
		64	White abalone	Haliotis sorenseni
		65	Pink abalone	Haliotis corrugata

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	cephalopod	30	Octopus	Octopus sp.
		37	Pacific Coast squid	Loligo opalescens
		73	Squid	Loligo sp.
	clam	18	Pismo clam	Tivela stultorum
		21	Washington butter clam	Saxidomus giganteus
		21.1	Washington clam	Saxidomus nuttallii
		22	Common egg cockel	Laevicardium laevigatum
		23	Horse clam	Tresus capax
		24	Gaper clam	Tresus nuttallii
		25	Soft-shell clam	Mya arenaria
		26	Japanese littleneck clam	Venerupis japonica
		27	Flat-tipped piddock (rock)	Penitella penita
		28	Pacific razor clam	Siliqua patula
		29	Common Pacific littleneck clam	Protothaca staminea
		32	Geoduck	Panope generosa
		42	Quahog (hard clam)	Mercenaria mercenaria
		48	Surf clam	Spisula polynyma
		52	Bean clam	Donax gouldii
		56	Wart-necked piddock	
		58	Sunset clam	Gari californica
		59	Rough-sided little-necked clam	Palphia staminea
		66	California jackknife clam	Tagelus californianus
		68	Clipped semele clam	Semele sp.
		77	Razor clam (eastern)	Ensis directus
		82	Brackishwater clam	Rangia cuneata
		94	Southern quahog	Mercenaria campechiensis
		95	Dwarf surf clam	Mulinia lateralis
		100	Quahog	Mercenaria spp.
	crab	13	Flame-streaked box crab	Calappa flammea
		14	Dungeness crab	Cancer magister
		15	Red rock crab	Pachygrapsus crassipes
		16	Puget Sound king crab	Paralithodes sp.
		17	Shield-backed kelp crab	Pugettia producta
		39	Red king crab	Paralithodes camtschatica
		40	Tanner crab	Chionoecetes bairde
		44	Horseshoe crab	Limulus polyphemus
		49	Blue crab	Callinectes sapidus
		70	Purple shore crab	Hemigrapsus nudus
		74	Stone crab	Menippe mercenaria
		75	Brown king crab	Lithodes acquispina
		88	Samoan crab	Scylla serrata

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	crab	91	Rock crabs	Cancer sp.
		93	Crustacean	
		96	Ghost crab	Ocypode quadrata
		99	Surf crab	Arenaeus cribrarius
		1001	Crabs	
	echinoderm	86	Red sea urchin	Strongylocentrotus franciscanus
	gastropod	46	Channeled whelk	Busycon canaliculatum
		47	Knobbed whelk	Busycon carica
		55	Wavy top snail	Astraea undosa
		67	Spiny cockle	Cardium quadrigenarium
		76	Nuttalls cockle (basket	heart)
		87	California brackish water snail	Tryonia imitator
		90	Lightning whelk	Busycon contrarium
	lobster	45	Northern lobster	Homarus americanus
		54	California spiny lobster	Panulirus interruptus
		72	Spiny lobster	Panulirus argus
		78	Western Pacific crayfish	Pacifastacus leniusculus
		83	River crayfish	Procambrus acutus
		84	Red swamp crayfish	Procambrus clarkil
		85	Pacific river crayfish	Pacifistacus trowbridgil
	mussel	19	Blue mussel	Mytilus edulis
		20	California mussel	Mytilus californianus
		80	Ribbed mussel	Volsella demissa
		81	Horse mussel	Volsella modiolus
		98	Mussels	Lithophaga
	oyster	38	Native Pacific oyster	Ostrea lurida
		43	American oyster (eastern)	Crassostrea virginica
		79	Pacific oyster	Crassostrea gigas
	scallop	33	Pacific pink scallop	Chlamys hastata
		34	Atlantic deep-sea scallop	Placopecten magellanicus
		35	Rock scallop	Hinnites multirugosus
		36	Hinds scallop	Chlamys hindsi
		41	Atlantic bay scallop	Argopecten irradians
		89	Speckled scallop	Argopectin circularis
	shrimp	4	Pink shrimp	Penaeus duorarum
		5	Ocean pink shrimp	Pandalus jordani
		6	Maine shrimp	Pandalus borealis
		7	Sidestripe shrimp	Pandalopsis dispar
		8	Spot shrimp	Pandalus platyceros
		10	Humpy shrimp	Pandalus goniurus
		11	Coon-stripe shrimp (dock)	Pandalus danae

ELEMENT	SUB-ELEMENT	SPECIES NO.	COMMON NAME	SCIENTIFIC NAME
	shrimp	12	Broken-back shrimp	Heptacarpus sp.
		50	White shrimp	Penaeus setiferus
		51	Brown shrimp	Penaeus aztecus
		69	Bay ghost shrimp	Callianassa californiensis
		71	Rock shrimp	Sicyonia sp.
		92	Shrimp	Penaeus
		97	Grass shrimp	Palaemonetes sp.
T_MAMMAL	bear	55	Brown bear	Ursus arctos horribilis
		56	Black bear	Ursus americanus
	canine	54	Gray wolf	Canis lupus
		57	Red fox	Vulpes vulpes
		63	Coyote	Canis latrans
		64	Gray fox	Urocyon cinereoargenteus
		67	Red wolf	Canis rufus
	deer	25	Florida key deer	Odocoileus virginianus clavium
		30	Columbia white-tailed deer	Odocoileus virginianus leucurus
		31	White-tailed deer	Odocoileus virginianus
		32	Mule deer	Odocoileus hemionus
		33	Black-tailed deer	Odocoileus hemionus columbianus
		34	Elk	Cervus canadensis
		35	Roosevelt elk	Cervus canadensis roosevelti
	feline	62	Bobcat	Lynx rufus
		65	Mountain lion	Felis concolor
		66	Ocelot	Felis pardalis
	mustelid	8	River otter	Lutra canadensis
		38	Mink	Mustela vison
		39	Shorttail weasel	Mustela erminea
		40	Longtail weasel	Mustela frenata
		44	Northern raccoon	Procyon lotor
		52	Striped skunk	Mephitis mephitis
		53	Long tailed weasel	Mustel frenata
	rodent	36	Beaver	Castor canadensis
		37	Muskrat	Ondatra zibethicus
		41	Saltmarsh harvest mouse	Reithrodontomys naviventris
		42	Santa Cruz harvest mouse	Reithrodontomys megalotis santacruzae
		43	Nutria	Myocastor coypus
		58	Meadow vole	Microtus pennsylvanicus
		59	Morro Bay kangaroo rat	Dipodomys heermanni morroensis