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# THE OIL SPILL ENVIRONMENTAL SENSITIVITY INDEX APPLIED TO THE ALASKAN COAST

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## INTRODUCTION

The oil spill Environmental Sensitivity Index (ESI) is a means of collecting and synthesizing diverse resource data onto one set of easily readable maps for use in oil spill planning and response. Types of data included in the ESI are:

a) geomorphic - relating to shoreline types,

b) biologic - indicating the location and seasonability of spill-sensitive coastal wildlife,

c) socioeconomic - indicating the sites of high socioeconomic importance, and

d) spill response - noting the location of staging sites and equipment needs.

The ESI is presented on a set of maps at the most detailed scale available (for Alaska primarily 1:63 360) accompanied by a descriptive text.

Alaska has played a key role in the development of the ESI; since major modifications have been made to the original concept over the past years, it deserves the special attention of this summary paper.

## HISTORICAL PERSPECTIVE

The potential for oil development in Alaska during the 1970's established the Outer Continental Shelf Assessment Program under the Bureau of Land Management and the National Oceanic and Atmospheric Administration. In 1975, Dr. Miles Hayes, then director of the University of South Carolina's Coastal Research Division, was asked to undertake studies to describe the geomorphic variability of the coastal zone of the northern Gulf of Alaska from Hinchenbrook Island to Dry Bay (900 km of shoreline). The request was based on Hayes' previous studies in the same area during 1969-1971 (supported by the Office of Naval Research). A concurrent study by Hayes and associates of the METULA oil spill site in Patagonia, Chile, in August 1975 (supported by the National Science Foundation) provided the basis of creating an index relating standard geomorphic shoreline types to potential oil spill longevity and damage. In this manner, an oil spill Vulnerability Index was developed as part of the shoreline classification studies in lower Cook Inlet in summer, 1976.

The Vulnerability Index included shoreline types ranked on a scale of 1 to 10 in order of increasing sensitivity to spilled oil. Because of the difficulty in placing a 1 to 10 index on large-scale (1:500 000) summary maps, many of the early projects grouped the shoreline habitats into five categories (i.e. 1-2, 3-4, 5-6, 7-8, 9-10). These studies included the northern Gulf of Alaska and lower Cook Inlet (see Figure 1 and Table 1).


FIGURE 1 LOCATION OF AREAS IN ALASKA MAPPED BY THE ENVIRONMENTAL SENSITIVITY INDEX (ESI), THE VULNERABILITY INDEX (VI) AND THE RETENTION INDEX

TABLE 1 SUMMARY OF SHORELINE SENSITIVITY MAPPING PROJECTS IN ALASKA, 1975-1982. NUMBERS CORRESPOND TO FIGURE 1.

1. BEAUFORT SEA (1978)
Pt. Barrow to Canadian Border
Field Team: Dag Nummedal, Pete Reinhart, Chris Ruby, Jeffrey Knoth, Ian Fisher
Report Submitted to: NOAA/OCSEAP, Juneau, Alaska
Map Style: a "retention index" based on coastal processes and geomorphology
Publication: Nummedal (1980)

2. KOTZEBUE SOUND (1976/1978)
Pt. Hope to Cape Prince of Wales
Field Team: Chris Ruby, Larry Ward, Pete Reinhart
Report Submitted to: NOAA/OCSEAP, Juneau, Alaska
Map Style: Vulnerability Index, 1-10 ranking on 1:250 000 scale maps
Publication: Hayes and Ruby (1979)

3. NORTON SOUND (1980)
Cape Prince of Wales to Cape Vancouver
Field Team: Erich Gundlach, Geoffrey Scott, Jim Sadd, Dave Maiero
Report Submitted to: NOAA/OCSEAP, Juneau, Alaska
Map Style: 65 ESI maps, 1:63 360 scale
Publication: Gundlach et al. (1981)

4. BRISTOL BAY (1981)
Cape Vancouver to Unimak Island
Field Team: Miles Hayes, Charles Getter, Dan Domeracki, Larry Thebeau, Jacqui Michel
Report Submitted to: NOAA/OCSEAP, Juneau, Alaska
Map Style: 105 ESI maps, mostly 1:63 360 scale
Publication: Michel et al. (1982)

5. PRIBILOF ISLANDS (1980)
St. Paul and St. George Islands
Field Team: Erich Gundlach, Jim Sadd, Geoffrey Scott, Dave Maiero
Report Submitted to: NOAA/OCSEAP, Juneau, Alaska
Map Style: ESI
Publication: Gundlach et al. (1981)

6. SHELIKOF STRAIT (1980)
Port Wrangel to Cape Douglas and the Strait side of Kodiak Island
Field Team: Dan Domeracki, Erich Gundlach, Larry Thebeau, Dave Maiero, Charles Getter, Jim Sadd, Geoffrey Scott, Dennis Lees
Report Submitted to: NOAA/OCSEAP, Juneau, Alaska
Map Style: 40 ESI maps, 1:63 360 scale
Publication: Domeracki et al. (1981)

7. KODIAK ISLAND ARCHIPELAGO (1978)
Kodiak, Afognak and the Trinity Islands
Field Team: Chris Ruby, Miles O. Hayes Pete Reinhart, Ken Finkelstein
Report Submitted to: NOAA/OCSEAP Juneau, Alaska
Map Style: Vulnerability Index, 1-10 ranking on 47 - 1:63 360 scale maps
Publication: Ruby and Hayes (1978)

8. LOWER COOK INLET (1976/1979)
Cape Douglas to Chugach Islands
Field Team 1: Miles Hayes, Jeff Brown, Jacqui Michel
Report Submitted to: Alaska Dept. of Fish and Game
Map Style: Vulnerability Index, five spill classes on large-scale summary maps.
Publication: Hayes et al. (1976)
Michel et al. (1978)
Field Team 2: Chris Ruby, Pete Reinhart
Report Submitted to: NOAA/OCSEAP, Juneau, Alaska
Map Style: Modified ESI, five spill classes on 1:63 360 scale maps
Publication: maps only.

9. KENAI PENINSULA AND MONTEGUE ISLAND (1979)
Field Team: Larry Ward, Tom Moslow, Ken Finkelstein
Report Submitted to: NOAA/OCSEAP, Juneau
Map Style: Vulnerability Index, 1-10 ranking on 31 - 1:63 360 scale maps
Publication: Ward et al. (1980)

10. PRINCE WILLIAM SOUND (1978/79/82)
Field Teams: Chris Ruby, Erich Gundlach, Pete Reinhart, Dave Maiero, Charles Getter
Report Submitted to: NOAA/OMPA, Boulder, Colorado
Map Style: ESI
Publication: Map atlas with introduction in progress.

11. NORTHERN GULF OF ALASKA (1975)
Field Team: Miles Hayes, Mike Stephen, Chris Ruby, Steve Wilson, Jane Zenger
Report Submitted to: NOAA/OCSEAP, Juneau, Alaska
Map Style: Vulnerability Index with five spill classes on 1:250 000 scale maps
Publication: Ruby and Hayes (1978)

A similar mapping program in the Beaufort Sea was undertaken by the USC Coastal Research Division in 1978. In this case, the shoreline index was dubbed a shoreline "retention index", based on the different environments found along this section of Alaskan coast; however, the geomorphic basis for this index remained the same.

In 1979, the Vulnerability Index was modified under the guidance of NOAA's Office of Marine Pollution Assessment and the U.S. Coast Guard to reflect additional data required for an adequate spill response. The expanded index was named the oil spill Environmental Sensitivity Index and includes wildlife resources, socioeconomic inputs and spill-response information. The ESI has been used for all spill-related mapping projects since this time. Alaskan studies utilizing the ESI include the shorelines of Norton Sound, Bristol Bay, the Pribilof Islands, Shelikof Strait and Prince William Sound (ongoing).

## DESCRIPTION OF THE ESI

The oil spill Environmental Sensitivity Index includes four different data sets: 1) geomorphic, 2) biologic, 3) socioeconomic, and 4) spill response.

### Geomorphic

Information concerning the shoreline type including grain size characteristics are denoted on ESI maps on a scale ranked 1 to 10. Each shoreline type may be color-coded or indicated directly by a number. Most of the maps in Alaska have the shoreline ranking marked in ink only (see the example provided in Figure 2). The ranking procedure is based on actual oil/shoreline interactions as observed at numerous spill sites, including AMOCO CADIZ, IXTOC I, METULA, URQUIOLA, etc. Publications summarizing oil/shoreline interactions include those by Gundlach and Hayes (1978) and Hayes et al. (1980).

The shoreline index applied to most of the Alaskan coast is as follows and is in the order of increasing sensitivity:

1) exposed rock headlands,
2) wave-cut platforms,
3) fine-grained sand beaches,
4) coarse-grained sand beaches,
5) exposed tidal flats (low biomass),
6) exposed, mixed sand and gravel beaches,
7A) gravel beaches,
7B) exposed tidal flats (high biomass),
7C) Basalt boulder beaches,
8) sheltered rocky shores,
9) sheltered tidal flats,
10) marshes.

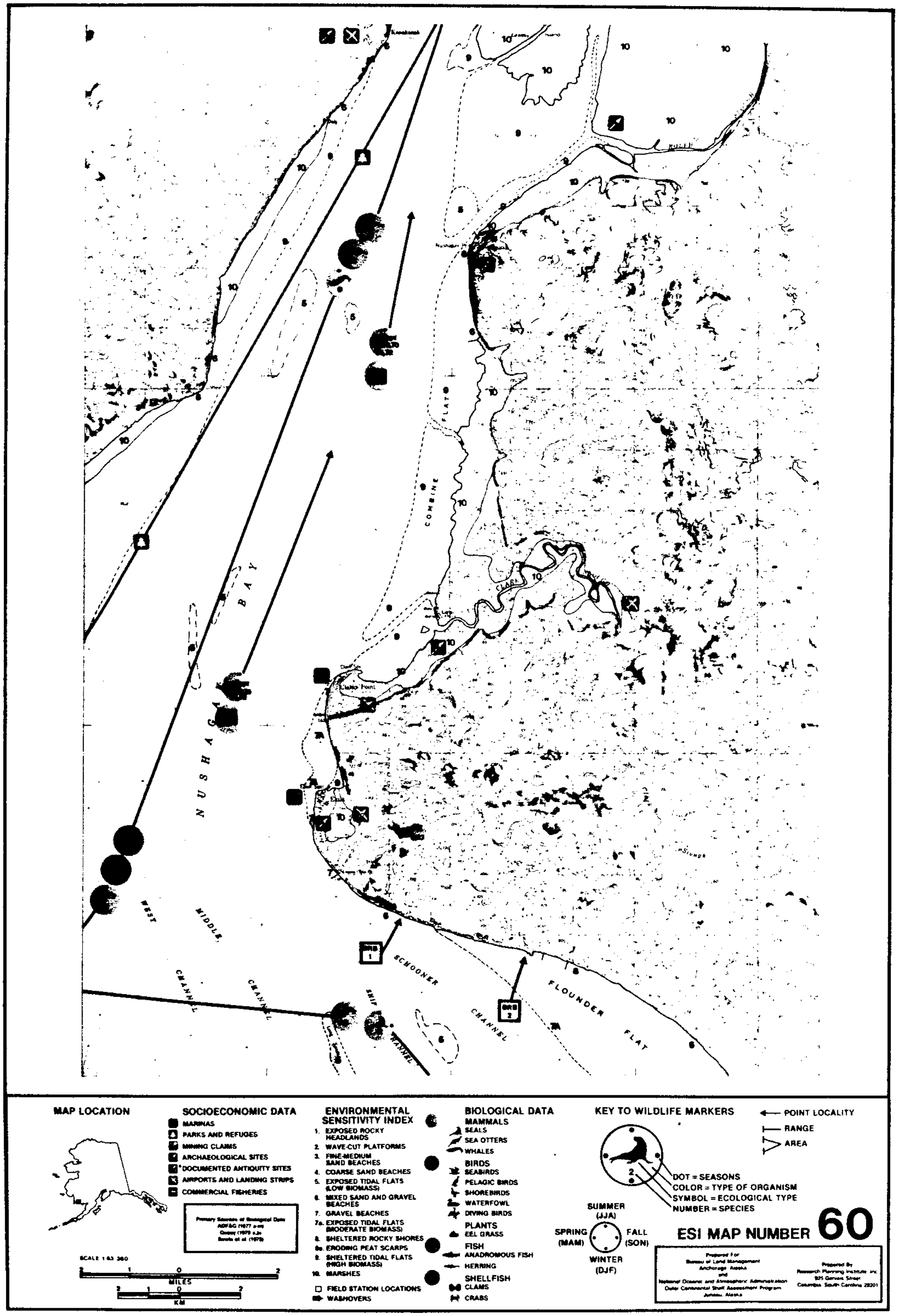


FIGURE 2 EXAMPLE OF A PHOTO-REDUCED BLACK AND WHITE COPY OF AN ESI MAP FOR NUSHAGAK BAY IN BRISTOL BAY, ALASKA

7) GRAVEL BEACHES

Description

- Physical
  - Sediments may be either dominantly mobile or stable, dependent on location of beach with respect to wind and wave activity
  - Composed mostly of gravel, cobbles, and boulders (<10% sand)
  - Well-sorted gravel commonly located on upper beach face
  - Sediments range from angular to well-rounded
- Plants
  - Dominantly mobile substrate:
    - Beaches generally devoid of vegetation
    - Green filamentous algae observed on small boulders
  - Dominantly stable substrate:
    - Rockweed is dominant algae - Gigartina, Odonthalia, and Rhodemela comprising other algae
    - Kelp grows at low intertidal waterline
    - Density is moderate to high (surface coverage $\bar{X}$ = 73.3%)
- Animals
  - Dominantly mobile substrate:
    - Beaches devoid of fauna
  - Dominantly stable substrate:
    - Faunal densities are moderate to high: mussels ($\bar{X}$ = 6,738/m$^2$), barnacles ($\bar{X}$ = 12,252/m$^2$), and littorine snails ($\bar{X}$ = 1,741/m$^2$)
    - Two distinct faunal communities occur: (1) barnacle community at supralittoral to upper intertidal zones, and (2) mussel community at mid to lower intertidal zones
    - Other common species: littorina (moderate to high densities), hermit crabs, and limpets

Predicted Oil Behavior

- Oil would be deposited primarily on the upper beach face
- Oil would percolate easily into the sediments
- Burial may be exceptionally deep along berm

Potential Biological Damages

- Dominantly mobile substrate:
  - Damages would be minimal
- Dominantly stable substrate:
  - Barnacle community would be most highly impacted due to long-term persistence of oil
  - Mid and lower intertidal zones would have short-term, moderate impact because of natural cleaning processes
  - Oil would percolate between rocks, and "underrock" organisms would be impacted

Recommended Cleanup Activity

- High pressure spraying may be required
- Mechanical reworking of sediment into the surf zone may be effective if oil accumulation is enough to require it
- Removal of sediment should be restricted

SKF-46
31 MAY, 1980

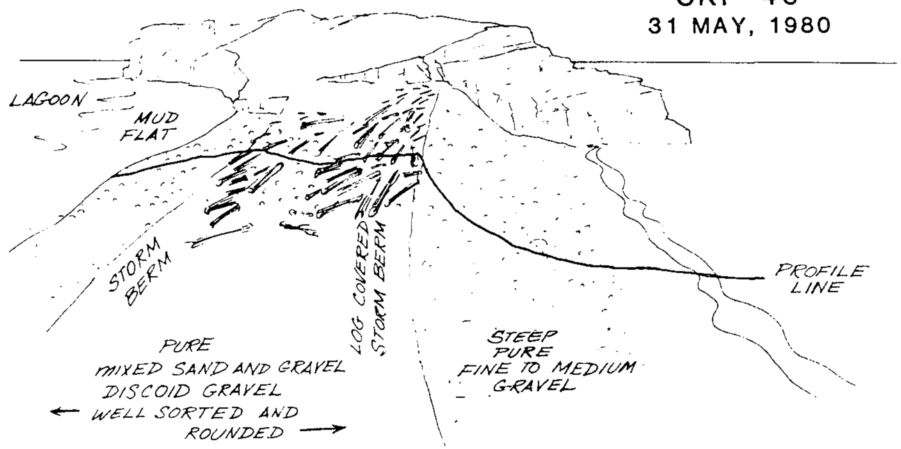


FIGURE 30. Ground view of SKF-46 showing a virtually pure gravel beach. Oil would percolate deeply into sediments making cleanup extremely difficult.

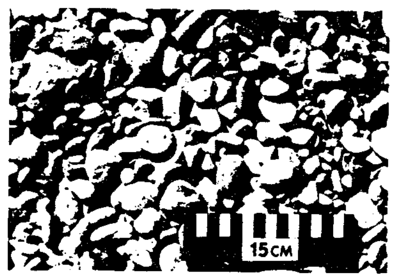


FIGURE 31. Close-up of pure gravel sediments. These high-energy environments respond rapidly to changing wave and tidal conditions. Burial of oil would be especially deep along developing berms.

FIGURE 3 EXAMPLES OF DESCRIPTIVE MATERIAL CONCERNING EACH SHORELINE TYPE (from Domeracki et al., 1981). This is a description of ESI = 7, gravel beaches.

## Biologic

In addition to characterizing the shoreline, areas of special biological importance are identified, primarily from previous studies. Localities of oil-sensitive, protected, or commercial species and communities are noted on each map by colored circles. The information is on circles as illustrated in Figure 4. On the full-scale maps, the color of the circle indicates rapid identification of the type of organism present: yellow = mammals; green = birds; blue = fishes; and orange = shellfish. The silhouette in the center of the marker refers to the ecological groups listed in Figure 5. The number refers to a species or species group as listed in a special appendix. Seasonality data, presented on the outer perimeter of the marker, are shown to indicate the seasons of the year that a particular species or group of species (i.e. mixed bird colonies) are most likely present. Consideration is given to such factors as reproduction, migration, and feeding behavior.

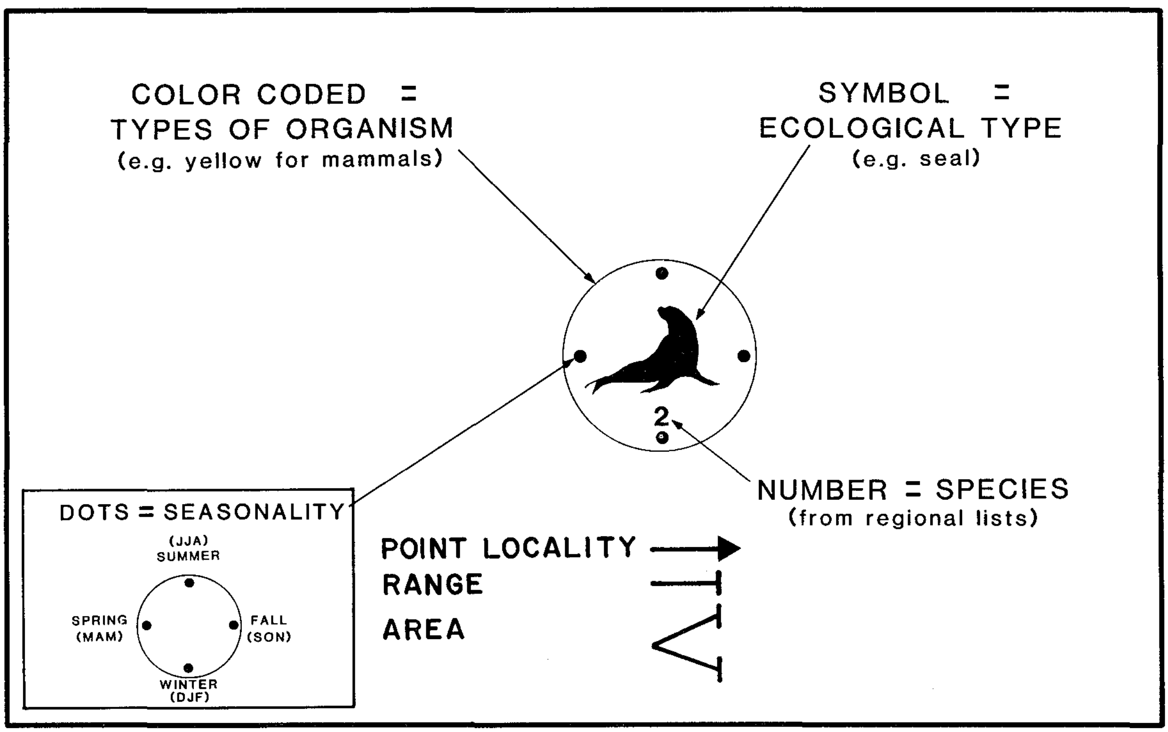


FIGURE 4 KEY FOR BIOLOGICAL INFORMATION CONTAINED ON THE ESI MAPS

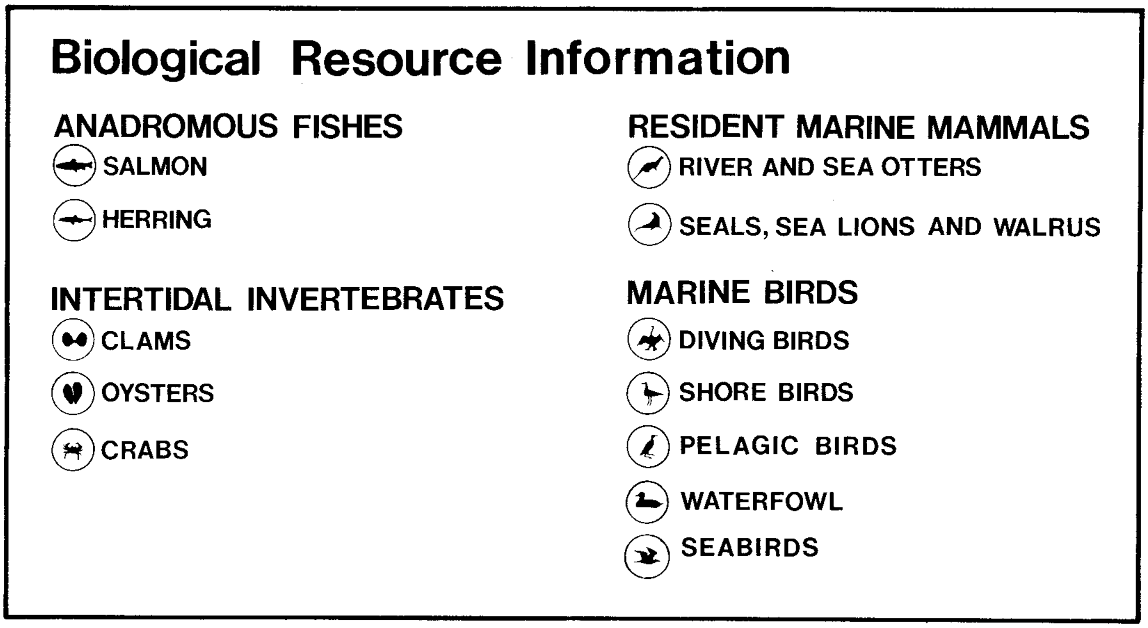


FIGURE 5 EXAMPLE OF "BIO-SYMBOLS" USED ON THE ESI MAPS TO REPRESENT SPILL-SENSITIVE WILDLIFE

In the text accompanying the ESI maps, a summary is provided of the major ecological groups in terms of species present, pertinent protection laws, probable oil effects and mitigation measures. Typical examples of this summary are provided in Figure 6.

During a spill, the presence of a "bio-symbol" elevates the particular shoreline type over the adjacent shores of similar value. The symbol also designates that an appropriate response (e.g. bird hazing and cleanup centers) will be necessary. Although attempts have been made to rank bird types in terms of oil sensitivity (see Manuwal et al., 1979), there is insufficient scientific evidence to rank all ecological groups and species.

MARINE MAMMALS

Resident Populations

| | | |
|---|---|---|
| • Harbor seals | (*Phoca vitulina*) | - Year-round; 16 major haulout and pupping areas. |
| • Northern sea lions | (*Eumatopias jubatus*) | - Year-round; five major haulout and pupping areas. |
| • *Sea otters | (*Enhydra lutris*) | - Year-round; scattered. |

Visitors

| | | |
|---|---|---|
| • Harbor porpoises | (*Phocoena phocoena*) | - Year-round; shallow bays and estuaries. |
| • Dall porpoises | (*Phocoenoides dalli*) | - April-September; deep bays. |
| • Minke whales | (*Balaenoptera acutorostrata*) | - Occasional. |
| • *Humpback whales | (*Megaptera novaeangliae*) | - Occasional. |
| • Gray whales | (*Eschrichtius robustus*) | - Occasional. |
| • Killer whales | (*Orcinus orca*) | - April to June; nearshore bays and coastal waters. |

Protection Status

- All protected by Marine Mammal Act of 1972
- *Protected by Endangered Species Act of 1973

Predicted Impact

- Seals
  - Eye irritation (Geraci and Smith, 1976)
  - Already stressed seals (e.g., emaciated, late molting, captivity) may die from additional stress of oil contamination (Geraci and Smith, 1976)
  - Preweaned pups, which have not yet developed insulating fat layers, may have thermoregulatory stress
  - Greatest impact may occur during pupping season, when stress is high and preweaned pups are present
- Sea Otters
  - Totally dependent on fur for thermal protection
  - Any contamination may cause thermoregulatory stress, which can lead to death
- Whales
  - Stress may occur through ingestion of oil-contaminated food, oil intake through blowholes, eye irritation, and skin absorption
  - Baleen whales may have decreased feeding efficiency caused by matting of hairs on baleen plates, reducing filtering capacity (OSIR, 1980)

Recommended Response Measures

- Seals
  - Hazing from haulout areas during nonbreeding status
  - Boom protection of pupping areas with minimal human disturbance
- Sea Otters
  - Trapping and physical removal
- Whales
  - Hazing to change swimming pattern

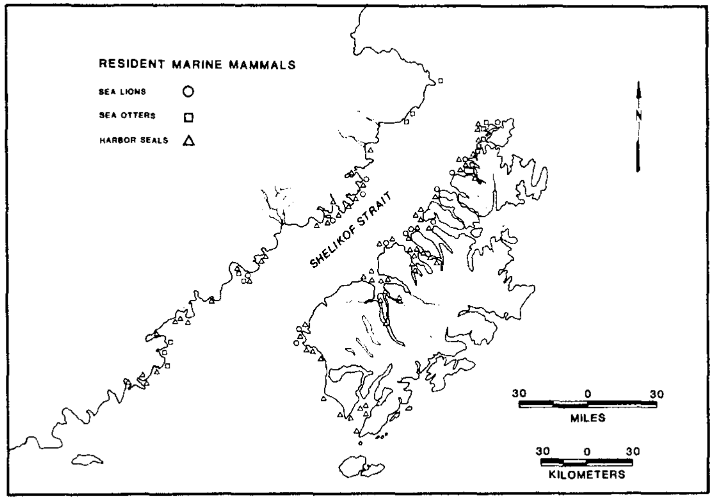


FIGURE 51. Diagram showing the distribution of resident marine mammals in the study area of Shelikof Strait.

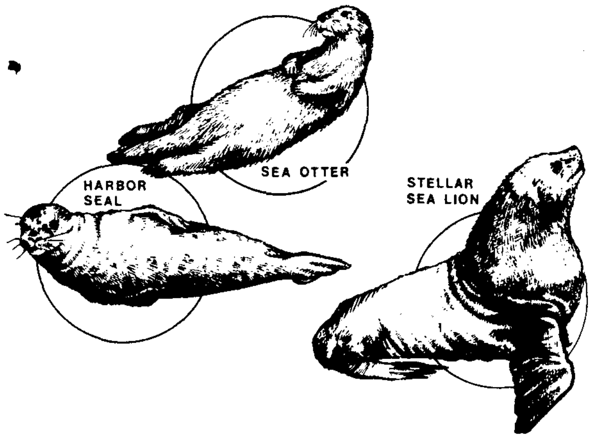


FIGURE 52. Sketches of resident marine mammals which are found in the Shelikof Strait area.

FIGURE 6 EXAMPLE OF DESCRIPTIVE MATERIAL CONCERNING EACH MAJOR ECOLOGICAL GROUP THAT IS INCLUDED IN AN ESI REPORT (from Domeracki et al., 1981)

Primary sources for this baseline information include the principal investigator's reports for Alaska OCSEAP (1976-1981), Alaska Department of Fish and Game resource maps, Sowls et al. (1978) and other publications (e.g. Gusey, 1979).

## Socioeconomic

Socioeconomic resource information is presented to provide specialized data relevant to OCS lease sales and to augment the decision-making processes in the event of an oil spill. The socioeconomic information appearing on the base maps does not affect the ESI numerical rating and is designed to be used in the same manner as the biological resource information - to highlight areas of special attention or response. Figure 7 contains some of the socioeconomic symbols used in Alaska. Typical sources for this information include:

a) the 1977 Alaska Coastal Land Status and Land Use Atlas,
b) the Bureau of Land Management - Alaska (land status records current through 1980),
c) the Draft Environmental Impact Statements prepared by BLM Alaska Outer Continental Shelf Office,
d) the map file housed as public record by the Alaska Resource Library, Anchorage.

## Spill Response

In Alaska, spill-response information includes the locations of landing strips, boom placements, inlet closure and washovers (see Figure 6).

## USE OF THE ESI AND FIELD TESTING

The ESI was developed to be specifically used by the Scientific Support Coordinator (SSC) or the On-Scene Coordinator (OSC) to provide the maximum amount of information concerning resources at risk within a minimum amount of time. This concept was field-tested during two spill incidents, IXTOC I and the BURMAH AGATE; in each case it provided extremely useful and pertinent information to the SSC and OSC.

The ESI maps are currently part of the federal spill response program and are extensively used in "spill drill" circumstances throughout the country. In the lower 48 states, ESI maps have been prepared for the Puget Sound region, southern California, most of Texas, Alabama, Florida, South Carolina, North Carolina (in progress), Virginia (in progress), Maryland (in progress), and Massachusetts.

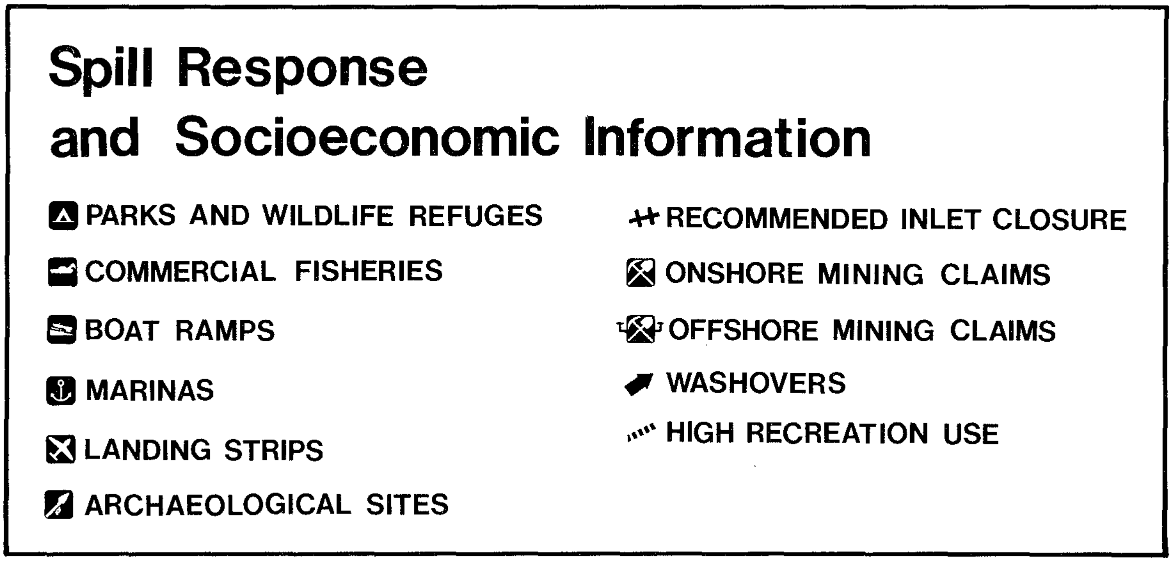


FIGURE 7 EXAMPLES OF TYPICAL SPILL-RESPONSE AND SOCIOECONOMIC INFORMATION APPLIED TO ESI MAPS IN ALASKA

Internationally, New Zealand has used the VI concept, while France and Germany are planning to use the expanded ESI. It is hoped that in the next two years most of the lower 48 states and much of Alaska will have been mapped according to the ESI. As a result, spill-response organizations will be better prepared to handle an actual oil spill incident.

## ACKNOWLEDGEMENTS

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