Sensitivity of Coastal Environments and Wildlife to Spilled Oil: Hawaii

INTRODUCTION

Environmental Sensitivity Index (ESI) maps have been developed for the marine and coastal areas of the Hawaiian Islands, including the islands of the northwestern chain out to Kure Atoll. The ESI maps are a compilation of information in three main categories: shoreline habitats; sensitive biological resources; and human-use resources.

The individual map pages in this atlas are divided according to the U.S. Geological Survey (USGS) topographic quadrangle index for the main islands and the National Oceanic and Atmospheric Administration (NOAA) nautical charts for the northwestern chain. Black and white scanned images of these maps are used as a backdrop for each map page in the atlas. The name and date on the bottom right of each map page refer to the corresponding USGS quandrangle or NOAA T-sheet name and its publication or latest photorevision date.

SHORELINE HABITAT MAPPING

Original ESI maps, published in 1986, were re-examined and fully updated using the sources and methods described below. The intertidal shoreline habitats of the Hawaiian Islands were mapped during overflights and ground surveys conducted by an experienced coastal geologist in August 2000. The overflights of the main island chain (Hawaii to Niihau) were conducted using fixed-wing aircraft operated by the U.S. Coast Guard Auxiliary, flying at elevations of 400-600 feet and slow air speed. During this work, the ESI ranking of observed intertidal shoreline habitats was denoted directly onto the shoreline depicted on 1:24,000-scale USGS topographic maps. Where appropriate, revisions to the existing shoreline were made and where necessary, multiple habitats were described for each shoreline segment. Classification of the Kaneohe Peninsula, Oahu, was conducted largely through the use of color vertical aerial photography due to the restricted airspace around the Marine Corps Air Station. Classification of the northwestern chain coastlines was carried out using aerial photo interpretation and local knowledge.

In addition to the ESI shoreline habitats, other coastal wetland habitat types from the 1978 National Wetlands Inventory (NWI) data for Hawaii were also depicted on the maps. These polygonal wetland types were not checked or edited extensively as part of this project. One of the polygonal wetland types, freshwater scrub/shrub wetlands, occurs mostly in inland areas, and therefore is not ranked in the ESI shoreline classification scheme, nor is it included in the shoreline habitat descriptions starting on page 13. In some cases, expert data providers and reviewers provided edits on wetland location and extent. When provided, these changes were incorporated in the atlas. Coastal wetland types from NWI depicted in this atlas include:

- Salt-Brackish Marshes
- Freshwater Marshes
- Freshwater Swamps
- Mangroves
- Freshwater Scrub/Shrub Wetlands

To determine the sensitivity of a particular intertidal shoreline habitat, the following factors are integrated:

1) Shoreline type (substrate, grain size, tidal elevation, origin)
2) Exposure to wave and tidal energy
3) Biological productivity and sensitivity
4) Ease of cleanup

Prediction of the behavior and persistence of oil in intertidal habitats is based on an understanding of the dynamics of the coastal environments, not just the substrate type and grain size. The intensity of energy expended upon a shoreline by wave action, tidal currents, and river currents directly affects the persistence of stranded oil. The need for shoreline cleanup activities is determined, in part, by the slowness of natural processes in removal of oil stranded on the shoreline. The potential for biological injury and ease of cleanup of spilled oil are also important factors in the ESI ranking. Generally speaking, areas exposed to high levels of physical energy, such as wave action and tidal currents, rank low on the scale, whereas sheltered areas with associated high biological activity have the highest ranking. The list below includes the shoreline habitats delineated for Hawaii, presented in order of increasing sensitivity to spilled oil.

1A) Exposed Rocky Cliffs
1B) Exposed, Solid Man-made Structures
2A) Exposed Wave-cut Platforms in Bedrock
2B) Exposed Scarps and Steep Slopes in Clay
3A) Fine- to Medium-grained Sand Beaches
4) Coarse-grained Sand Beaches
5) Mixed Sand and Gravel Beaches
6A) Gravel Beaches
6B) Riprap
7) Exposed Tidal Flats
8A) Sheltered Rocky Shores
8B) Sheltered, Solid Man-made Structures
8C) Sheltered Riprap
9A) Sheltered Tidal Flats
9B) Sheltered, Vegetated Low Banks
10A) Salt- and Brackish-water Marsh
10B) Freshwater Marshes
10C) Freshwater Swamps
10D) Mangroves

Each of the shoreline habitats are described on pages 13-20 in terms of their physical description, predicted oil behavior, and response considerations.

SENSITIVE BIOLOGICAL RESOURCES

Biological information presented in this atlas was collected, compiled, and reviewed with the assistance of biologists and resource managers from the Hawaii Department of Land and Natural Resources (DLNR), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries (NMFS), the University of Hawaii, and many other agencies, organizations, and groups (see the acknowledgments). The Hawaii Natural Heritage Program provided protected species information for terrestrial plant species, anchialine pools, and species associated with anchialine pools. Information collected and depicted on the maps denotes the key biological resources that are most likely at risk in the event of an oil spill. Seven major categories of biological resources are included in this atlas: marine mammals, birds, reptiles, fish, invertebrates, plants, and benthic marine habitats.

Polygons and points represent the spatial distribution of biological resources on the maps. Associated with each of these representations is an icon depicting the types of species or habitats that are present. Species have been divided into groups and subgroups based on their behavior, morphology, taxonomic classification, and spill vulnerability and sensitivity. The icons below reflect this grouping scheme. The groups are color coded, and different icons represent the subgroups:

MARINE MAMMAL
- Dolphin
- Whale
- Seal

BIRD
- Gull / Tern
- Passerine Bird
- Raptor
- Seabird
- Shorebird
- Wading Bird
- Waterfowl

REPTILE
- Turtle

FISH
- Fish

INVERTEBRATE
- Bivalve
- Crab / Other Invertebrates
- Echinoderm
- Gastropod
- Insect
- Lobster
- Octopus
- Shrimp

HABITAT

NATIVE / RARE PLANT
- Native / Rare Plant

BENTHIC MARINE HABITAT
- Algae / Seagrass
- Coral
- Anchialine Pool
- Coral Area of Special Significance

The polygon color and pattern are generally the same for all species in each major group (e.g., birds are green), and match the icon colors. Also associated with each biological polygon or point feature on the map is a resources at risk identification number (RAR#), located under each icon or group of icons. The RAR# references a table on the reverse side of the map with a complete list of species associated with the polygon or point feature, and the

state and federal protected status (T&E), concentration, seasonality, and life-history information for each species.

There are some species that are found throughout specific geographical areas or habitat types on certain maps. Displaying the polygons for these species would cover large areas or would obscure the shoreline, ESI classification, or other biological features, making the maps very difficult to read. Thus, species which occur over the majority of certain geographic areas or habitats are often identified in a small box on the maps which states that they are "Present in ..." (e.g., "Present inshore of 10 fathoms" or "Present in Pearl Harbor"). This approach informs the user of the presence of these species, while maintaining readability of the map. The use of this strategy is implemented on a map per map basis, depending on the location, size, and number of polygons present on each map.

MARINE MAMMALS

Marine mammals depicted in the Hawaii atlas include whales, dolphins, and seals. Concentration areas and highly sensitive areas for humpback whales, Hawaiian monk seals, spinner dolphins, and other cetacean species are specifically indicated on the maps. Humpback whales (federally and state endangered) are described as having "high" or "very high" concentrations within 100 fathoms of the main Hawaiian Islands, a region including all of the waters designated as part of the Hawaiian Islands Humpback Whale National Marine Sanctuary, as well as additional waters outside of these boundaries. Approximately two-thirds of the North Pacific population of humpback whales migrates to Hawaii each winter for breeding, calving, and nursing.

Known pupping and haul-out sites for the Hawaiian monk seal (federally and state endangered) are depicted on the maps as polygons or points. Areas where monk seals are frequently sighted swimming in coastal waters are designated by larger polygons within 10 fathoms. All of the northwestern Hawaiian Islands (NWHI) and waters inshore of 20 fathoms around the islands are considered "Designated Critical Habitat" for the Hawaiian monk seal under authority of the U.S. Endangered Species Act. It should be recognized that humpback whales, Hawaiian monk seals, and other whales and dolphins occur throughout nearly all marine and coastal waters of Hawaii, not just in the concentration areas depicted. We did not attempt to show the potential distribution of all species that have been sighted. For a list of species that can be found in Hawaiian waters, see table 1.

TABLE 1. Results of aerial surveys of marine mammals in the major Hawaiian Islands (Mobley et al. 1999). Species are listed in decreasing order of abundance based on observations made during surveys.

Common Name	Scientific Name	Federal/State T_E
Humpback whale	*Megaptera novaeangliae*	E/E
Spinner dolphin	*Stenella longirostris*	
Spotted dolphin	*Stenella attenuata*	
Short-finned pilot whale	*Globicephala macrorhynchus*	
Bottlenosed dolphin	*Tursiops truncatus*	
False killer whale	*Pseudorca crassidens*	
Rough-toothed dolphin	*Stena bredanensis*	
Melon-headed whale	*Peponocephala electra*	
Sperm whale	*Physeter macrocephalus*	E/E
Striped dolphin	*Stenella coeruleoalba*	
Blainville's beaked whale	*Mesoplodon densirostris*	
Cuvier's beaked whale	*Ziphius cavirostris*	
Risso's dolphin	*Grampus griseus*	
Pygmy or dwarf sperm whale	*Kogia spp.*	
Fin whale	*Balaenoptera physalus*	E/E
Hawaiian monk seal	*Monachus schauslandi*	E/E

Expert contacts for humpback whales and other marine mammals and sea turtles in Sanctuary waters include Sanctuary staff at the Maui office (800/831-4888), the Oahu office (808/541-3184), and the Kauai office (808/335-0941). Expert contacts for Hawaiian monk seals are: Bud Antonellis, (NMFS), 808/983-5710; Brad Ryon, and John Henderson, (NMFS), 808/592-8300; Margaret Dupree, (NMFS), 808/973-2937 ext. 210; and John Naughton, (NMFS), 808/973-2935 ext. 211.

Marine mammal areas are displayed on the maps as polygons with a brown-hatched pattern, or as points for some Hawaiian monk seal haul-out and pupping sites. In cases where multiple resource types occupy the same polygon (such as sea turtles and monk seals), a black-hatched, multi-group pattern is used rather than a brown-hatched pattern. A brown icon with a whale, dolphin, or seal silhouette is used to indicate the presence of marine mammals and is associated with all polygons containing these resources.

The RAR# under the icon (or icon group) on the maps references a table on the reverse side of the map. In this table, the first column gives the species name. The next column provides an estimate of the concentration of the species at the site. Concentration is usually represented as a descriptive term, such as "very high" or "high". Descriptive concentrations are based on the opinion of local resource managers or experts concerning relative concentrations within the study area. In many cases, concentration values have not been used, often at the request of data providers. Note that concentration should not be interpreted as the "level of concern" or "importance" associated with a certain site or particular resource.

The seasonality for each species or resource is shown in the next twelve columns, corresponding to the months of the year. If a species is present at a location in a particular month, an "X" is placed in the month column. The final columns list the time periods for sensitive life-history activities, such as pupping for monk seals and calving for spinner dolphins.

BIRDS

Birds in this atlas are divided into several species subgroups based on taxonomy, morphology, behavior, and oil spill vulnerability and sensitivity. The species table lists all the birds included on the maps, sorted by subgroup. These species are included either because of their likelihood of direct or indirect impact by an oil spill or similar incident, their general rarity or imperilment, or their special protection status as threatened or endangered. Endangered native wetland species, seabird nesting colonies, and migratory waterfowl and shorebirds are especially emphasized. Seabird nesting colonies shown in this atlas were based on a digital database compiled by the USGS with information provided by USFWS. Concentration areas for endangered native wetland species and migratory species were based mainly on information provided by USFWS and Hawaii DLNR refuge managers and wildlife biologists.

Expert contacts for seabirds are: Beth Flint (USFWS - Oahu), 808/541-1201; and Dave Smith, (DLNR - Oahu), 808/973-9786. Expert contacts for shorebirds, waterfowl, and endangered wetland birds are: Kevin Foster, (USFWS - Oahu), 808/541-3441; Ron Walker, (USFWS - Oahu), 808/541-2749; and Mike Silbernagle, (USFWS - Oahu), 808/637-6330 ext. 23. Expert contacts for birds on neighbor islands are Tom Alexander, (USFWS – Kauai), 808/241-6640; Tom Telfer, (DLNR – Kauai), 808/241-6670; Fern Duvall (DLNR – Maui County), 808/873-3502; and Glynnis Nakai, (USFWS – Maui), 808/875-1582.

In several cases, general terms referring to species assemblages, such as "shorebirds", "waterfowl", or "wading birds" were included along with common names of individual species, because it is possible that other species are present in addition to the most common ones that were listed. In some cases, these terms were used in place of individual species names because the exact composition of the assemblages varies at many locations. Because shorebirds in Hawaii tend to be scattered along almost all shoreline types rather than concentrated in certain areas, "present in area" boxes were used in the main Hawaiian Islands to maintain readability of the maps. Table 2. provides a list of birds that may be present in Hawaii in addition to those listed individually on the maps

TABLE 2. Bird species potentially present in coastal areas in Hawaii.

Assemblage	Species Examples
Passerine Birds	Perching birds and similar species such doves, sparrows, finches, etc.
Raptors	Falcons, osprey, owls, etc.

Seabirds, Gulls, and Terns	Albatrosses, tropicbirds, boobies, shearwaters, frigatebirds, petrels, noddies, gulls, terns, etc.
Shorebirds	Plovers, curlews, willets, turnstones, sanderlings, yellowlegs, whimbrels, tattlers, dowitchers, dunlins, snipe, etc.
Wading Birds	Herons, egrets, etc.
Waterfowl	Wigeons, shovelers, scaup, mergansers, teals, buffleheads, etc.
Landfowl	Pheasant, quail, etc.

Birds are shown on the maps as polygons with a green-hatched pattern. Seabird nesting colonies are shown as green points. The points are not necessarily in the exact location of the nesting colonies. Users should be aware that seabirds may be feeding and rafting in nearshore and offshore areas in the vicinity and up to several miles away from their nests. Rafting areas were not shown on the maps or in "present in area" boxes because they have not been extensively surveyed and documented. In the case of an actual oil spill, the seabird experts listed above should be contacted in regards to current seabird rafting locations.

In cases where multiple resource types occupy the same polygon (such as birds and reptiles), a black-hatched, multi-group pattern is used rather than a green-hatched polygon. A green icon (or icons) with the appropriate subgroup silhouette(s) is used to indicate the presence of different bird types (seabirds, waterfowl, raptors, etc.). The appropriate icons are associated with all polygons containing birds.

The RAR# under the icon (or icon group) on the maps references a table on the reverse side of the map. In this table, the first column contains the species common name. The second column indicates whether the species is listed as threatened (T) or endangered (E) on either the state (S) and/or federal (F) lists. The next column provides an estimate of the concentration of the species at the site. Concentration is usually represented as the number of nests, breeding pairs, or birds. In some cases, concentration values have not been used if information was not available. Note that concentration should not be interpreted as the "level of concern" or "importance" associated with a certain site or particular resource. The seasonality for each species or resource is shown in the next twelve columns, corresponding to the months of the year. If a species or resource is present at a location in a particular month, an "X" is placed in the month column. The last four columns denote the nesting, laying, hatching, and fledging time-periods for each species, if nesting occurs in the particular area or site in question.

REPTILES

Mapping of sea turtle nesting and basking beaches was emphasized in this atlas. Several known in-water concentrations, as well as larger, more general areas where nearshore sea turtle foraging and resting habitat exists, were also mapped. Nesting, basking, and foraging locations were determined based on expert knowledge and information provided in the Green Turtle and Hawksbill Turtle Recovery Plans published by the NMFS Pacific Sea Turtle Recovery Teams. Hawksbill sea turtles nest primarily along the southeast coast of the Big Island. Nesting occurs on a few other beaches on other islands as well. Green sea turtle nesting occurs throughout the main and northwestern Hawaiian Islands, but over 90% occurs at French Frigate Shoals (Map 89). The Natural Heritage Program provided loggerhead and olive ridley sea turtle sighting information.

Expert contacts for sea turtles are: George Balazs, (NMFS), 808/983-5733; Margaret Dupree, (NMFS), 808/973-2937 ext. 210; John Naughton, (NMFS), 808/973-2935 ext. 211; Don Heacock, (DLNR – Kauai), 808/639-7305; Larry Katahira, (NPS – Big Island), 808/985-6088; and Skippy Hau, (DLNR – Maui), 808/243-5834. Expert contacts for sea turtles in Hawaiian Islands Humpback Whale National Marine Sanctuary waters include Sanctuary staff at the Maui office (800/831-4888), the Oahu office (808/541-3184), and the Kauai office (808/335-0941).

Reptiles are depicted as polygons with a red-hatched pattern. Some nesting and basking sites and Natural Heritage Program data are shown on the maps as red points. In cases where multiple resource types occupy the same polygon, a black-hatched, multi-group pattern is used rather than a red-hatched polygon. A red icon with a turtle silhouette is used to indicate the presence of reptiles, and is associated with all polygons containing these resources.

The RAR# under the icon (or icon group) on the maps references a table on the reverse side of the map. In this table, the first column contains the species common name. The second column indicates whether the species is listed as threatened (T) or endangered (E) on either the state and/or federal lists. The next column provides an estimate of the concentration of the species at the site. Concentration is usually represented as a descriptive term, such as "very high" or "high". Descriptive concentrations are based on the opinion of local resource managers or experts concerning relative concentrations within the study area. Numerical values are used in some areas where detailed surveys have been conduced. In many cases, concentration values have not been used, often at the request of data providers. Note that concentration should not be interpreted as the "level of concern" or "importance" associated with a certain site or particular resource.

The seasonality for each species or resource is shown in the next twelve columns, corresponding to the months of the year. If a species or resource is present at a location in a particular month, an "X" is placed in the month column. The final columns denote different life-history time-periods for reptiles, such as nesting, hatching, juveniles, and adults. For sea turtles, nesting in this atlas refers to the peak time when adults construct nests and deposit eggs. Hatching refers to the peak time when young sea turtles are hatching and emerging from the nests.

FISH

Finfish depicted in this atlas include selected reef, marine, estuarine, and amphidromous species. Species of commercial, recreational, ecological, and/or conservation interest are emphasized. Fish distributions are based largely on expert opinion, and incorporate a combination of resource survey data, field experience, and habitat-based designations. Natural Heritage Program data was used to map occurrences of anchialine pool eels.

Expert contacts for finfish and invertebrates are: Frank Parrish (NMFS - Honolulu), 808/983-5391; Alan Everson (NMFS - Honolulu), 808/973-2935 ext. 212; Francis Oishi, (DLNR - Honolulu), 808/587-0094; Chris Swenson, (USFWS – Honolulu), 808/541-3441; Gordon Smith (USFWS – native stream species), 808/541-3441; Don Heacock, (DLNR – Kauai), 808/639-7305; Bill Puleloa, (DLNR – Molokai), 808/553-3778; Skippy Hau, (DLNR – Maui), 808/243-5834; Bob Nishimoto, (DLNR – Big Island, Hilo), 808/974-6201; Bill Walsh, (DLNR – Big Island, Kona), 808/328-8041; and Alan Friedlander (Oceanic Institute – NWHI expert), 808/259-3165.

Reef, estuarine, and marine fish species were mapped using broad distributions on most maps. In many cases, they are described as "present inshore of 10 fathoms", or "present in nearshore waters". Some species may utilize deeper water habitats than those described in the atlas, but due to the scale of the maps, recommendations by the resource experts, and oil spill response considerations, we chose to concentrate most of our mapping efforts in coastal marine waters, rather than offshore. Specific concentration and/or spawning areas for certain species have been designated on some maps.

A special group of "native stream" gobies are shown at several stream mouths and in some bays and estuaries. Although native gobies are only shown in certain streams in this atlas, important populations may be present in other streams as well. The amphidromous life cycle of the gobies involves adults spawning in the streams, followed by the larvae being swept out to sea, with a subsequent return of juveniles to freshwater. Adults develop in freshwater streams and spend their entire lives there. Different species of gobies spawn at different elevations in the streams, but due to the scale of the maps in the atlas, we chose to map the species together with native stream invertebrates as a group at the stream mouth with a single point. Therefore, while the life history information shows each species as "spawning" at the stream mouth, certain species may actually be spawning upstream of this point. All larvae and juveniles will pass through the stream mouths at some point during their life cycles.

Fish are shown on the maps as polygons with a blue-hatched pattern. Natural Heritage data and native stream fish occurrences are designated by a blue point at the stream mouths. In cases where multiple resource types occupy the same polygon (such as fish and invertebrates), a black-hatched, multi-group pattern is used rather than a blue-hatched polygon. When native stream fish and native stream invertebrates occupy the same point location, an orange point is used. A blue icon with a fish silhouette is used to indicate the presence of fish. This icon is associated with all polygons or point features containing fish.

The RAR# under the icon (or icon group) on the maps references a table on the reverse side of the map. In this table, the first column contains the species common name. The second column indicates whether the species is listed as threatened (T) or endangered (E) on either the state (S) and/or federal (F) lists. The next column provides an estimate of the concentration of the species at the site. Concentration is usually represented as a descriptive term, such as "very high" or "high". Descriptive

concentrations are based on the opinion of local resource managers or experts concerning relative concentrations within the study area. In many cases, concentration values have not been used, often at the request of data providers. Note that concentration should not be interpreted as the "level of concern" or "importance" associated with a certain site or particular resource.

The seasonality for each species or resource is shown in the next twelve columns, corresponding to the months of the year. If a species or resource is present at a location in a particular month, an "X" is placed in the month column. The last five columns denote different life-history time-periods for fish, including spawning, eggs, larvae, juveniles, and adults. In many cases, specific life-history information was not included, because it is not well known. Spawning information was included for some commercial, recreational, and subsistence species, especially in estuarine areas, at the request of the data providers. Spawning does also occur in additional areas, and therefore users should not interpret a lack of seasonality information on the maps as evidence that certain life-history stages do not occur in an area.

INVERTEBRATES

Invertebrates depicted in this atlas include selected marine, estuarine, amphidromous, and terrestrial species. Species of commercial, recreational, ecological, and/or conservation interest are emphasized. Invertebrate distributions are based largely on expert opinion and information gathered from the Hawaii Coral Reef Inventory (HICRI) Atlases produced for each island (see references for full citation). Natural Heritage Program data was used to map occurrences of rare terrestrial and anchialine pool species.

Expert contacts for finfish and invertebrates are: Frank Parrish (NMFS - Honolulu), 808/983-5391; Alan Everson (NMFS - Honolulu), 808/973-2935 ext. 212; Francis Oishi, (DLNR - Honolulu), 808/587-0094; Chris Swenson, (USFWS – Honolulu), 808/541-3441; Gordon Smith (USFWS – native stream species), 808/541-3441, Don Heacock, (DLNR – Kauai), 808/639-7305; Bill Puleloa, (DLNR – Molokai), 808/553-3778; Skippy Hau, (DLNR – Maui), 808/243-5834; Bob Nishimoto, (DLNR – Big Island, Hilo), 808/974-6201; and Bill Walsh, (DLNR – Big Island, Kona), 808/328-8041.

Several known invertebrate concentrations, as well as larger, more general areas where nearshore invertebrate habitat exists were mapped. Some of the information provided in the Hawaii Coral Reef Inventory (HICRI) atlases on invertebrate distributions were related to commercial, recreational, and subsistence use of certain species (i.e. limpets, octopus, lobsters, crabs), and therefore areas depicted on the maps do not necessarily represent the entire range of the species, but rather highlight concentration areas that are of social and economic, as well as ecological importance.

A special group of "native stream" shrimp and mollusks are shown at several stream mouths and in some bays and estuaries. Although native invertebrates are only shown in certain streams in this atlas, important populations may be present in other streams as well. The amphidromous life cycle of the species involves adults spawning in the streams, followed by the larvae being swept out to sea, with a subsequent return of juveniles to freshwater. Adults develop in freshwater streams and spend their entire lives there. Different invertebrate species spawn at different elevations in the streams, but due to the scale of the maps in the atlas, we chose to map the species together with native stream gobies as a group at the stream mouth with a single point. Therefore, while the life history information shows each species as "spawning" at the stream mouth, certain species may actually be spawning upstream of this point. All larvae and juveniles will pass through the stream mouths at some point during their life cycles.

Most invertebrates are shown on the maps as polygons with an orange-hatched pattern. Natural Heritage data and native stream species are shown on the maps as orange points. In cases where multiple resource types occupy the same polygon (such as fish and invertebrates), a black-hatched, multi-group pattern is used rather than an orange-hatched polygon. When native stream invertebrates and native stream fish occupy the same point location, an orange point is used. An orange icon with the appropriate silhouette is used to indicate the presence of different types of invertebrates (shrimp, crabs, lobsters, etc.). This icon (or icon group) is associated with all polygons or point features containing invertebrates.

The RAR# under the icon (or icon group) on the maps references a table on the reverse side of the map. In this table, the first column contains the species common name. The second column indicates whether the species is listed as threatened (T) or endangered (E) on either the state (S) and/or federal (F) lists. The next column provides an estimate of the concentration of the species at the site. Concentration is usually represented as a descriptive term, such as "very high" or "high". Descriptive concentrations are based on the opinion of local resource managers or experts concerning relative concentrations within the study area. In many cases, concentration values have not been used, often at the request of data providers. Note that concentration should not be interpreted as the "level of concern" or "importance" associated with a certain site or particular resource.

The seasonality for each species or resource is shown in the next twelve columns, corresponding to the months of the year. If a species or resource is present at a location in a particular month, an "X" is placed in the month column. The last five columns denote different life-history time-periods for invertebrates, including spawning, eggs, larvae, juveniles, and adults. Life-history information for invertebrate species in Hawaii is generally not well known, and therefore is only included for a few species, primarily those of commercial, recreational, and subsistence importance, and native stream species.

HABITATS

NATIVE/ RARE PLANTS

Native coastal strand vegetation, and other threatened, endangered, and rare coastal plants are emphasized in this atlas. The Natural Heritage Program was the primary source for plant location information. Resource managers provided additional information on native coastal strand vegetation in some areas. Expert contacts for terrestrial plants are: the Natural Heritage Program, 808/956-3744; Vickie Caraway, (DLNR), 808/587-0165; Chris Swenson, (USFWS), 808/541-3441; and Tina Lau, (TNC – Molokai), 808/553-5236.

Plants are depicted as polygons shaded with a purple-hatched pattern and as purple points. In cases where multiple resource types occupy the same polygon (such as plants and birds), a black-hatched, multi-group pattern is used rather than a purple-hatched polygon. A purple icon with the appropriate silhouette is used to indicate the presence of plant resources. This icon (or icon group) is associated with all polygons containing plants.

The RAR# under the icon (or icon group) on the maps references a table on the reverse side of the map. In this table, the first column contains the species common name. The second column indicates whether the species is listed as threatened (T) or endangered (E) on either the state (S) and/or federal (F) lists. The next column provides an estimate of the concentration of the species at the site. Concentration is usually represented as a descriptive term, such as "very high" or "high". Descriptive concentrations are based on the opinion of local resource managers or experts concerning relative concentrations within the study area. In many cases, concentration values have not been used, often at the request of data providers. Note that concentration should not be interpreted as the "level of concern" or "importance" associated with a certain site or particular resource.

The seasonality for each species or resource is shown in the next twelve columns, corresponding to the months of the year. If a species or resource is present at a location in a particular month, an "X" is placed in the month column. All plant resources are shown as present all year in this atlas.

BENTHIC MARINE HABITATS

Three types of benthic marine habitats were mapped for Hawaii: 1) coral 2) algae, and 3) seagrass. These resources were mapped using a variety of data sources and methods. Geographic sources included Hawaii Coral Reef Inventory (HICRI) atlases, Hawaii Coral Reef Assessment and Monitoring Program (CRAMP) reports, USGS topographic quadrangles, and other sources. Where previous data or maps did not exist, biologists from DLNR, USFWS, University of Hawaii, and other groups used bathymetric features shown on USGS topographic maps and NOAA nautical charts to estimate the distribution of coral reef habitats and algae. Seagrass distributions were based largely on expert opinion.

Expert contacts for corals are: Dave Gulko, (DLNR), 808/587-0318; Jim Maragos, (USFWS), 808/541-1699 ext. 166; Paul Jokiel and Will Smith, (University of Hawaii), 808/236-7440; Eric Brown, (University of Hawaii – Maui), 808/874-3929; and Cindy Hunter, (Waikiki Aquarium), 808/923-9741. An expert contact for algae is Celia Smith, (University of Hawaii), 808/956-6947. An expert contact for seagrass is Karla McDermid-Smith, (University of Hawaii), 808/974-7650.

Major coral categories used during this project included: Coral Reef Habitat, Structural Coral Reef, and High Live Coral Cover. "Coral Reef Habitat" was used on the majority of the maps to designate general areas potentially containing live corals and structure building corals, as well as areas that may contain limestone, hard bottom and various reef associated organisms. Because this category was generally widespread containing potential coral and reef areas, areas of softbottom may have also

been inadvertently included in some places. Most benthic habitat mapping was concentrated in nearshore areas at depths of less than 10 fathoms. Coral reefs were mapped in deeper waters in some areas, such as around the Big Island and some of the northwestern Hawaiian Islands (NWHI), where nearshore waters are at greater depths. Although coral reefs and associated species may occur in deeper water habitats than those described in the atlas, we chose to concentrate most of our mapping efforts in coastal marine waters rather than offshore areas due to the scale of the maps, recommendations by the resource experts, and oil spill response considerations.

All other specific coral classifications are subsets of the "Coral Reef Habitat" group. "Structural Coral Reef" areas are those that contain structure-building hard coral species. "High Live Coral Cover" areas were designated by resource experts and the Hawaii Coral Reef Inventory Atlases as areas where live coral cover exceeded a certain percent cover of the bottom. The actual percentages varied based on the individual expert or atlas, but tended to range from > 20 to > 50%. Other less frequently used coral classifications in this atlas include: massive coral colonies, black coral, rare coral, soft coral, octocoral bed, wire coral, coralline algal apron reef, reef pinnacle, submerged barrier reef, and high coral diversity.

"Coral Areas of Special Significance", shown on the maps using yellow stars, were designated by resource experts as those areas that should be highly prioritized for protection following spills due various reasons (e.g. species diversity, rare coral, endangered/threatened marine animal species, high fish/invertebrate concentrations, sensitive habitat, etc.).

Coral reef habitats are represented on the maps as polygons using a purple-hatched pattern. A purple icon with a coral silhouette is used to indicate the presence of different types of coral reef habitats. Algae and seagrass habitats are depicted using a purple "simplified-wetland" pattern. A purple icon with a "submerged aquatic vegetation" silhouette is used to indicate the presence of different types of algae and seagrass. The RAR# under the icon (or icon group) on the maps references a table on the reverse side of the map. In this table, the first column contains the species common name or the coral reef habitat classification. The second column indicates whether the species is listed as threatened (T) or endangered (E) on either the state (S) and/or federal (F) lists. The next column provides an estimate of the concentration of the species at the site. Concentration is usually represented as a descriptive term, such as "very high" or "high". Descriptive concentrations are based on the opinion of local resource managers or experts concerning relative concentrations within the study area. In many cases, concentration values have not been used, often at the request of data providers. Note that concentration should not be interpreted as the "level of concern" or "importance" associated with a certain site or particular resource.

The seasonality for each species or resource is shown in the next twelve columns, corresponding to the months of the year. If a species or resource is present at a location in a particular month, an "X" is placed in the month column. Most benthic habitats are present year round, except for some rare algae species. The last column denotes spawning time periods for live coral.

ANCHIALINE POOLS

Anchialine pools are small, relatively shallow coastal ponds that occur singly or in groups close to the shoreline (less than a half kilometer from the ocean). They have direct connections to the ocean either through surface channels or through subsurface cracks and fissures in the lava flows, and they experience regular tidal fluctuations in water levels. Anchialine pools are found on the Big Island, Maui, Kahoolawe, Molokai, and Oahu. Anchialine pools support a highly unique group of plants and animals, including muraenid eels, shrimp, and snails which were mapped in this atlas. Because they have direct connections to the ocean, anchialine pools may be susceptible to spilled oil, especially if large volumes are stranded on beaches adjacent to the ponds. Locations of anchialine pools and associated fish and invertebrate species were provided by the Natural Heritage Program.

NATURAL HERITAGE PROGRAM DATA

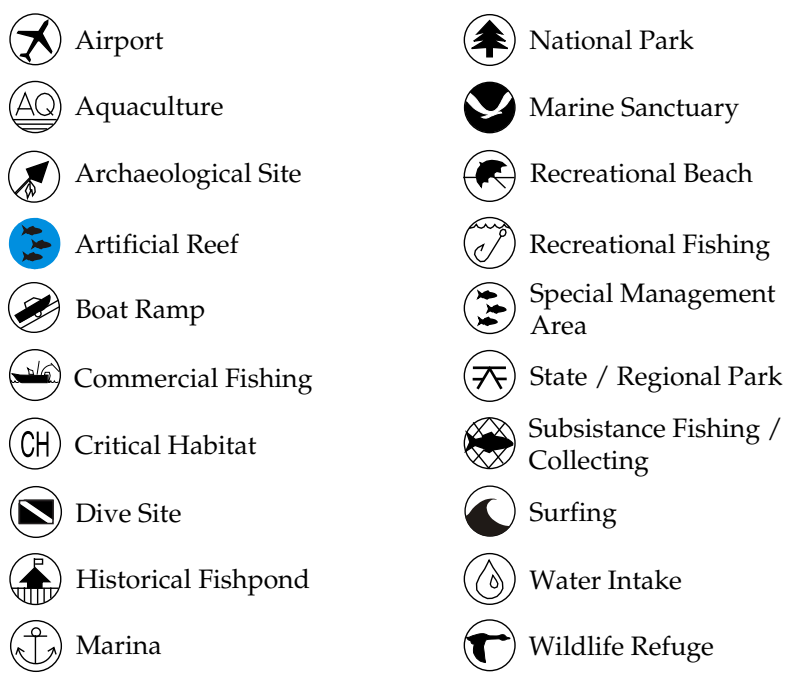
The Hawaii Natural Heritage Program, University of Hawaii, Center for Conservation Research and Training, provided a digital point coverage containing all recorded occurrences of terrestrial plants, anchialine pools, anchialine pool related fish and invertebrates, and rarely seen sea turtle species within a quarter mile on and off shore. At the request of resource managers, we only included occurrences that were most recently recorded between 1970 and 2001. Included below is a notice regarding use and distribution of this data.

Notice: The Hawaii Natural Heritage Program database is dependent on the research and observations of many scientists and individuals. In most cases this information is not the result of comprehensive site-specific field surveys, and is not confirmed by the Heritage staff. Many areas in Hawaii have never been thoroughly surveyed, and new plants and animals are still being discovered. Database information should never be regarded as final statements or substituted for on-site surveys required for environmental assessments. Data provided by the Heritage Program do not represent a position taken by The Center for Conservation Research and Training or The Nature Conservancy of Hawaii.

The Hawaii Natural Heritage Program Staff requested that they be contacted in the case of an actual spill or during planning exercises for the most updated information at 808/956-3744.

HUMAN-USE RESOURCES

Most human-use resources in this atlas are mapped as point features, indicated by a black and white icon (see legend). Management areas such as wildlife refuges, natural reserves, national parks, forests, designated critical habitats, etc. are mapped as polygons, with the boundaries indicated as a black dot-dash line with the corresponding icon placed near the center of the polygon. Where the feature is a known point location (e.g., water intake, boat ramp, marina), the exact location is shown as a small black dot and a leader line is drawn from it to the icon. Fishing sites, recreational beaches, dive sites, etc. are indicated by an icon placed in the general area, without any points or polygons, since the boundaries for these resources are not readily defined.



Airport: Locations of airports, airfields, landing strips, helipads etc., whether they are manned or unmanned.

Aquaculture: Locations of aquaculture sites. When known, the site name, owner/manager, and contact information are provided on the data tables for each map.

*** Archaeological/Historical Site:** Locations of archaeological and historical sites were not included on the maps at the request of the State Historic Preservation Office. See detailed information below.

Artificial Reef: Locations of reefs made out of man-made materials or natural materials purposely placed at a site for fishing or sport diving purposes.

Boat Ramp: Locations of boat ramps. This information was gathered from overflight observations, aerial photographs, and a digital point coverage provided by the Hawaii Statewide GIS Program.

Commercial Fishing: Nearshore areas where commercial harvest is known to occur. Fishing activities may take place throughout the study area. This information was provided by expert sources.

Designated Critical Habitat: Areas managed or regulated by the USFWS or NMFS as critical habitat for federally listed threatened and endangered species, under authority of the U.S. Endangered Species Act as amended. The Designated Critical Habitat for the federally and state endangered Hawaiian monk seal is depicted in this atlas. Designated Critical Habitat for the Hawaiian monk seal occurs in the northwestern Hawaiian Islands (NWHI) only.

Dive Site: Locations of recreational diving sites. This information was derived mainly from published guidebooks and expert sources.

Historic Fishpond: Locations of historic fishponds. Icons shown on the maps are in the general locations of the fishponds. Digital point and polygon coverages provided by the Hawaii Statewide GIS Program were used to generate the locations for icon placement. Fishponds that were classified as being in "excellent"

to "poor" condition were included on the maps. Those classified as having "no remains" were not included.

Marina: Location of marinas. This information was gathered from overflight observations, aerial photographs, and a digital point coverage provided by the Hawaii Statewide GIS Program.

Marine Sanctuary: Locations of areas managed by NOAA as National Marine Sanctuaries. The Hawaiian Islands Humpback Whale National Marine Sanctuary occurs in this atlas, and is indicated on the data table for each map on which it occurs.

National Park: Areas managed by the National Park Service, including national parks, national historic sites, national monuments, etc. Site names are provided on the data tables for each map.

Recreational Beach/Water Activities: Locations of recreational beaches used for activities such as swimming, sun-bathing, windsurfing, canoeing, kayaking, picnicking, hiking, etc. This information was gathered from published beach guides and atlases.

Recreational Fishing: Locations of recreational fishing sites. This information was provided by expert sources and public beach guides.

Special Management Area: Locations of miscellaneous resource management areas administered by state or federal agencies. These areas include the NWHI Coral Reef Ecosystem Reserve, Natural Area Reserves (NARs), Marine Life Conservation Districts (MLCDs), Fisheries Management Areas (FMAs), Public Fishing Areas (PFAs), etc. Property names are provided in the data tables for each map.

State/Regional Park: Locations of areas managed by DLNR State Parks Division as state parks, state wayside areas, state monuments, and related properties. Property names are provided in the data tables for each map.

Subsistence Fishing/Collecting: General areas where subsistence fishing and collecting take place. Fishing and collecting activities, especially harvest of lobsters, crabs, octopus, reef and estuarine fish, limpets, seaweed, etc., may take place throughout the study area. This information was provided by Hawaii Coral Reef Inventory Atlases, published beach guides, and expert sources.

Surfing: Locations of surfing sites. This information was provided by expert sources and public beach guides.

Water Intake: Locations of surface water intakes. When known, the site name, owner/manager, and telephone number are provided on the data tables for each map.

Wildlife Refuge/Natural Reserve: Areas managed by the USFWS as National Wildlife Refuges, refuges and sanctuaries managed by the DLNR, and preserves managed by the Nature Conservancy. Site names are provided on the data tables for each map.

*** Archaeological/Historical Sites**: At the request of the Hawaii State Historic Preservation Office (SHPO), archaeological and historical sites are not depicted as point locations on the maps or in the data. The rational for not showing point locations is that only 10-15% of the state has been surveyed and documented. The State Historic Preservation Office staff believes that if this incomplete data is used during oil spill response, that considerable adverse effects can occur to significant resources. Instead, an icon is shown on each map that directs the user to the brief description below (table 3.), which is a predictive model of archaeological and historic site types that are likely to be found along Hawaii's shoreline. One exception that was agreed upon by the SHPO staff is that fishponds are shown as icons on the maps.

TABLE 3. Predictive model of archaeological and historic site types found along Hawaii's shorelines

ShorelineType / Associated ESI Classifications	**Areas Where Potentially Present**	**Site Types**	**Types of Remains Present**
Low Dunes, Sandy Flats, Beaches ESI: 3A-6A, 7	Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, Hawaii	Permanent/ temporary habitations, burials, religious structures	Subsurface deposits, stone remains, food remains, broken tools, charcoal (used for dating), etc.
High Dunes ESI: 3A-6A	Hawaii, Maui, Oahu, Kauai	Permanent/ temporary habitations, burials, religious structures	Subsurface deposits, stone remains, food remains, broken tools, charcoal, etc.
Alluvial Contexts/ Floodplains ESI: 9A, 10A-10D	Pearl Harbor, Kaneohe Bay	Historically cultivated for taro; fishponds, houses, burials	Soils contain charcoal and pollen (critical for dating)
Low Rocky Shorelines/ Vegetated Low Banks ESI: 2A, 8A, 9B	Oahu, Maui, Hawaii	Densely clustered permanent/ temporary habitations, burials, religious structures	Remnants of shoreline trails and agricultural fields, stone architecture, soil deposits
Rocky Cliffs/Exposed Scarps and Steep Slopes in Clay ESI: 1A, 2B	Maui, Hawaii, Lanai, Kahoolawe	Permanent habitations	Subsurface deposits, stone remains, food remains, broken tools, charcoal, agricultural remnants
Man-Made Contexts ESI: 1B, 6B, 8B, 8C	Oahu	Burials very close to the surface layers in some beach parks	Most heavily altered shorelines do not contain archaeologic al sites

If an oil spill does occur, please contact Ross Cordy, Hawaii State Historic Preservation Office Branch Chief for Archaeology, or one of the following Island Archaeologists (table 4.) for consultation on issues regarding shoreline access, stockpiling of equipment, and cleaning of sand, as certain clean-up strategies may impact protection of archaeological/historical resources.

TABLE 4. Contact Individuals: Hawaii State Historic Preservation Office Island Archaeologists

Contact Individuals	**Islands**	**Phone: (808) area code**
Ross Cordy, Ph.D.	Branch Chief; Contact for Kaho'olawe	692-8025
Nancy McMahon, M.A.	Kaua'i & Ni'ihau	742-7033
Sara Collins, Ph.D.	O'ahu & Moloka'i	692-8026
Elaine Jourdane, B.A.	Asst. for O'ahu	692-8027
Melissa Kirkendall, Ph.D.	Maui & Lana'i	243-5169
Cathy Dagher, B.A.	Asst. for Maui & Lana'i	692-8023
Patrick McCoy, Ph.D.	Hawai'I (Big Island)	692-8029
Marc Smith, B.A.	Asst. for Hawai'I (Big Island)	933-0482

GEOGRAPHIC INFORMATION SYSTEM

The entire atlas product is stored in digital form in a Geographic Information System (GIS) as spatial data layers and associated databases. The format for the data varies depending on the type of information or features for which the data are being stored.

Under separate cover is a metadata document which details the data dictionary, processing techniques, data lineage, and other

descriptive information for the digital data sets and maps that were used to create this atlas. Below is a brief synopsis of the information contained in the digital version. Refer to the metadata file for a full explanation of the data and its structure.

SHORELINE CLASSIFICATIONS

The ESI shoreline habitat classification is stored as lines and polygons with associated attributes. In many cases, a shoreline may have two or three different classifications. These multiple classifications are represented on the maps by double and triple line patterns and in the database by ESI#1/ESI#2, where ESI#1 is the landward-most classification and ESI#2 is the seaward-most classification. In addition to the line features, exposed wave-cut platforms (ESI = 2A), tidal flats (ESI = 7, ESI = 9A), marshes (ESI=10A, ESI=10B), swamps (ESI=10C), and mangroves (ESI = 10D) are also stored as polygons.

SENSITIVE BIOLOGICAL RESOURCES

Biological resources are stored as polygons or points. Associated with each feature is a unique identification number which is linked to a series of data tables that further identify the resources. The main biological resource table consists of a list of species identification numbers for each site, the concentration of each species at each site, and identification codes for seasonality and source information. This data table is linked to other tables that describe the seasonality and life-history time-periods for each species (at month resolution) for the specified map feature. Other data tables linked to the first table include: the species identification table, which includes common and scientific names; the species status table, which gives information for state and/or federal threatened or endangered listings; and the source database, which provides source metadata at the feature-species level (specific sources are listed for each species occurring at each mapped feature in the biology coverages).

HUMAN-USE FEATURES

Human-use features are represented as lines, points, or polygons. The resource name, the owner/manager, a contact person, and phone number are included in the database for management areas, water intakes, and aquaculture sites when available. All metadata sources are documented at the feature level.

REFERENCES

Listed below are the major hardcopy reference materials used during this project. In some instances, reference materials were not directly used as source materials, but were instead used or interpreted by scientists or resource managers who provided expert knowledge or personal communication concerning resources depicted in the atlas.

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The biological and human-use data included on the maps were provided by numerous individuals, agencies, and organizations. Hawaii Department of Land and Natural Resources (DLNR), U.S. Fish and Wildlife Service (USFWS), NOAA National Marine Fisheries (NMFS), and University of Hawaii staff from several

divisions and programs contributed a vast amount of information to this effort, including first-hand expertise, publications, reports, maps, and data. Other agencies, organizations, and groups contributing to data development and review included: Hawaii Natural Heritage Program; Hawaiian Islands Humpback Whale National Marine Sanctuary; U.S. Geological Survey, National Wildlife Health Center; National Park Service; The Nature Conservancy, Molokai Chapter; U.S. Navy, Region Hawaii; U.S. Marine Corps Base Hawaii, Environmental Department; U.S. Coast Guard 14th District; Clean Islands Council; Bishop Museum; Oceanic Institute; Bubbles Below, Inc. Scuba Charters; and Hawaii Electric Company (HECO). Specific individuals and references used directly as source material for this atlas are detailed in the metadata report that accompanies the digital data set.

At Research Planning, Inc. (RPI) of Columbia, South Carolina, numerous scientific, GIS, and graphics staff were involved with different phases of the project. Jacqueline Michel was Project Manager. Shoreline habitat mapping was conducted by Colin Plank. The biological and human-use data were collected by Christine Lord. Biological and human-use data were compiled onto basemaps and edited by Christine Lord and Heidi Hinkeldey. Chris Locke (GIS Project Coordinator), Jon Whitlock, Jennifer Rainman, Zach Nixon, Vermell Simon Pyatt, Katie Born, Jessica Diimmler, Tim Ward, and David Grigg entered, processed, and produced the GIS data and hardcopy atlas under the supervision of Mark White, GIS Director. Cartographic design and graphic art production was provided by Joe Holmes. Becky Cox and Kristi Suggs prepared the final text documents and metadata.

APPROPRIATE USE OF ATLAS AND DATA

This atlas and the associated database were developed to provide summary information on sensitive natural and human-use resources for the purposes of oil and chemical spill planning and response. Although the atlas and database should be very useful for other environmental and natural resource planning purposes, it should not be used in place of data held by the Hawaii DLNR Division of Aquatic Resources (DAR), DLNR Division of Forestry and Wildlife (DOFAW), DLNR State Historic Preservation Office (SHPO), Hawaii Natural Heritage Program, USFWS, NMFS, or other agencies. Likewise, information contained in the atlas and database cannot be used in place of consultations with natural and cultural resource agencies, or in place of field surveys. Also, this atlas should not be used for navigation.

SPECIES LIST

Common Name	Species Name
MARINE MAMMALS	
DOLPHINS	
Bottlenose dolphin	*Tursiops truncatus*
Spinner dolphin	*Stenella longirostris*
Spotted dolphin	*Stenella attenuata*
SEAL	
Hawaiian monk seal	*Monachus schauinslandi*
WHALES	
False killer whale	*Pseudorca crassidens*
Humpback whale	*Megaptera novaeangliae*
Melon-headed whale	*Peponocephala electra*
Shortfin pilot whale	*Globicephala macrorhynchus*
BIRDS	
GULL/TERN	
Caspian tern	*Sterna caspia*
Great crested tern	*Sterna bergii*
Gulls	-
Laughing gull	*Larus atricilla*
Least tern	*Sterna antillarum*
Ring-billed gull	*Larus delawarensis*
Sooty tern ('Ewa 'Ewa)	*Sterna fuscata*
Terns	-
White tern (Manu o ku)	*Gygis alba*
White tern (Oahu nesting group)	*Gygis alba rothschildi*
PASSERINE	
Laysan finch	*Telespiza cantans*
Nihoa finch	*Telespiza ultima*
Nihoa millerbird	*Acrocephalus familiaris kingi*
RAPTORS	
Peregrine falcon	*Falco peregrinus*
Raptors	-
SEABIRDS	
Band-rumped storm-petrel	*Oceanodroma castro*
Black noddy (Noio)	*Anous minutus*
Black-footed albatross (Ka-upu)	*Phoebastria nigripes*
Blue-gray noddy	*Procelsterna cerulea*
Bonin petrel	*Pterodroma hypoleuca*
Brown booby ('A)	*Sula leucogaster*
Brown noddy (Noio Koha)	*Anous stolidus*
Bulwer's petrel ('Ou)	*Bulweria bulwerii*
Christmas shearwater	*Puffinus nativitatis*
Dark-rumped petrel ('Ua'u)	*Pterodroma phaeopygia sandwichensis*
Gray-backed tern	*Sterna lunata*
Great frigatebird ('Iwa)	*Fregata minor*
Laysan albatross (Moli)	*Phoebastria immutabilis*
Masked (blue-faced) booby ('A)	*Sula dactylatra*
Newell's shearwater ('A'o)	*Puffinus auricularis newelli*
Red-footed booby ('A)	*Sula sula*
Red-tailed tropicbird (Koa'e 'ula)	*Phaethon rubricauda*
Seabirds	-
Short-tailed albatross	*Phoebastria albatrus*
Tristram's storm-petrel	*Oceanodroma tristrami*
Wedge-tailed shearwater ('Ua'u kane)	*Puffinus pacificus*
White-tailed tropicbird (Koa'e-kea)	*Phaethon lepturus*
SHOREBIRDS	
American golden plover	*Pluvialis dominica*
Bar-tailed godwit	*Limosa lapponica*
Black-bellied plover	*Pluvialis squatarola*
Bristle-thighed curlew	*Numenius tahitiensis*
Common snipe	*Gallinago gallinago*
Dunlin	*Calidris alpina*

SPECIES LIST

Common Name	Species Name
BIRDS cont.	
SHOREBIRDS (cont.)	
Greater yellowlegs	*Tringa melanoleuca*
Lesser yellowlegs	*Tringa flavipes*
Long-billed dowitcher	*Limnodromus scolopaceus*
Pacific golden plover	*Pluvialis fulva*
Pectoral sandpiper	*Calidris melanotos*
Ruddy turnstone	*Arenaria interpres*
Sanderling	*Calidris alba*
Semipalmated plover	*Charadrius semipalmatus*
Sharp-tailed sandpiper	*Calidris acuminata*
Shorebirds	-
Wandering tattler	*Heteroscelus incanus*
Whimbrel	*Numenius phaeopus*
Willet	*Catoptrophorus semipalmatus*
WADING BIRDS	
Black-crowned night-heron	*Nycticorax nycticorax*
Cattle egret	*Bubulcus ibis*
Great blue heron	*Ardea herodias*
Hawaiian stilt (Ae'o)	*Himantopus mexicanus knudseni*
Little blue heron	*Egretta caerulea*
Snowy egret	*Egretta thula*
Wading birds	-
WATERFOWL	
American wigeon	*Anas americana*
Blue-winged teal	*Anas discors*
Brant	*Branta bernicla*
Bufflehead	*Bucephala albeola*
Eurasian wigeon	*Anas penelope*
Greater scaup	*Aythya marila*
Green-winged teal	*Anas crecca*
Hawaiian common moorhen ('Alae'ula)	*Gallinula chloropus sandvicensis*
Hawaiian coot ('Alae ke'oke'o)	*Fulica alai*
Hawaiian duck (Koloa)	*Anas wyvilliana*
Hawaiian goose (Nene)	*Branta sandvicensis*
Hooded merganser	*Lophodytes cucullatus*
Laysan duck	*Anas laysanensis*
Lesser scaup	*Aythya affinis*
Mallard	*Anas platyrhynchos*
Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Waterfowl	-
REPTILES	
TURTLES	
Green sea turtle (Honu)	*Chelonia mydas*
Hawksbill sea turtle	*Eretmochelys imbricata*
Leatherback sea turtle	*Dermochelys coriacea*
Loggerhead sea turtle	Caretta caretta
Olive ridley sea turtle	*Lepidochelys olivacea*
FISH	
FISH	
Achilles surgeonfish	*Acanthurus achilles*
Anchialine muraenid eel	*Gymnothorax hilonis*
Angelfish	-
Barracuda	-
Bigeye emperor (Mu)	*Monotaxis grandoculis*
Bigeye jack (Ulua)	*Caranx sexfasciatus*
Bigeye scad (Akule)	*Selar crumenopthalmus*
Bigeyes ('Aweoweo)	
Big-scale soldierfish (U'u)	*Myripristis berndti*
Blacktip shark	*Carcharhinus limbatus*
Blennies (Pao'o)	
Bluefin trevally ('O milu)	*Caranx melampygus*

*Threatened and endangered species are designated by underlining.

SPECIES LIST

Common Name	Species Name
FISH cont.	
FISH (cont.)	
Blueline surgeonfish (Maiko)	*Acanthurus nigroris*
Bluespine unicornfish (Kala)	*Naso unicornis*
Bonefish ('O'io)	*Albula vulpes*
Boxfish (Pahu)	-
Bullethead parrotfish (Uhu)	*Scarus sordidus*
Butterflyfish	-
Cardinalfish (Upapalu)	-
Conger eels (Puhi)	-
Convict tang (Manini)	*Acanthurus triostegus*
Cornetfish (Nunu)	-
Damselfish	-
Dolphin (Mahi mahi)	*Coryphaena hippurus*
Emperors (Mu)	-
Eyestripe surgeonfish (Palani)	*Acanthurus dussumieri*
Filefish ('O'ili)	-
Flying fish	-
Galapagos shark (Mano)	*Carcharhinus galapagensis*
Giant trevally (Ulua aukea)	*Caranx ignobilis*
Goatfish (Weke, Oama, Kumu, Moano)	-
Gobies ('O'opu)	-
Golden trevally (Ulua pa'opa'o)	*Gnathanodon speciosus*
Gold-ring surgeonfish (Kole)	*Ctenochaetus strigosus*
Goldspot herring	*Herklotsichthys quadrimaculatus*
Gray mullets	-
Gray reef shark (Mano)	*Carcharhinus amblyrhynchos*
Gray snapper (Uku)	*Lutjanus griseus*
Great barracuda (Kaku)	*Sphyraena barracuda*
Greater amberjack (Kahala)	*Seriola dumerili*
Groupers	-
Halfbeak	*Hyporhamphus unifasciatus*
Hawaiian anchovy (Nehu)	*Encrasicholina purpurea*
Hawaiian black grouper (Ha pu'u)	*Epinephelus quernus*
Hawaiian domino damselfish ('Alo'ilo'i)	*Dascyllus albisella*
Hawaiian flagtail (Aholehole)	*Kuhlia sandvicensis*
Hawaiian garden eel	*Gorgasia hawaiiensis*
Hawaiian ladyfish (Awa'aua)	*Elops hawaiensis*
Hawaiian silverside (Aholehole)	*Atherinomorus insularum*
Hawkfish (Pili-ko'a)	-
Heller's barracuda (Kawele'a)	*Sphyraena helleri*
Jacks (Ulua, Papio)	-
Knifejaws	-
Leatherback (Lai)	*Scomberoides lysan*
Lizardfish	-
Longnose butterflyfish (Lau-wiliwili-nukunuku-oi'oi)	*Forcipiger longirostris*
Mackerel scad (Opelu)	*Decapterus macarellus*
Mackerels	*Scomberomorus spp.*
Manta rays (Hahalua)	-
Manybar goatfish (Moano)	*Parupeneus multfasciatus*
Marlins (A'u)	-
Masked angelfish	*Genicanthus personatus*
Milkfish (Awa)	*Chanos chanos*
Moonfish	-
Moorish idol (Kihikihi)	*Zanclus cornutus*
Moorish idols (Kihikihi)	-
Moray eels (Puhi)	-
Multiband butterflyfish	*Chaetodon multicinctus*
Native gobies	-
Needlefish ('Aha)	-
Orangeband surgeonfish (Na'ena'e)	*Acanthurus olivaceus*
Orangespine unicornfish (Umauma-lei)	*Naso lituratus*

SPECIES LIST

Common Name	Species Name
FISH cont.	

FISH (cont.)	
Ornate butterflyfish (Kikakapu)	*Chaetodon ornatissimus*
Pacific gregory	*Stegastes fasciolatus*
Parrotfish (Uhu)	-
Pink snapper (Opakapaka)	*Pristipomoides filamentosus*
Porcupinefish	-
Potter's angelfish	*Centropyge potteri*
Puffers	-
Rare fish	-
Reef fish	-
Regal parrotfish (Lauia)	*Scarus dubius*
Ringtail wrasse (Po'ou)	*Cheilinus unifasciatus*
Rudderfish (Nenue)	-
Saddle wrasse (Hinalea lau-wili)	*Thalassoma duperrey*
Scalloped hammerhead (Mano-kihikihi)	*Sphyrna lewini*
Scorpionfish (Nohu)	-
Sharks	-
Sharpnose mullet (Uouoa)	*Neomyxus leuciscus*
Sleek unicornfish (Kala holo)	*Naso hexacanthus*
Snappers	-
Soldierfish ('U'u)	-
Spectacled parrotfish (Uhu)	*Chlorus perspicillatus*
Spotted eagle ray (Hailepo)	*Aetobatus narinari*
Spotted unicornfish (Kala lolo)	*Naso brevirostris*
Sprat	-
Squirrelfish ('Ala'ihi)	-
Striped mullet ('Ama'ama)	*Mugil cephalus*
Surgeonfish	-
Swordfish (A'u)	*Xiphias gladius*
Thicklipped jack (Ulua)	*Pseudocaranx dentex*
Threadfin (Moi)	*Polydactylus sexfilis*
Threespot chromis	*Chromis verater*
Triggerfish (Humuhumu)	-
Trumpetfish (Nunu)	-
Trunkfish	-
Tunas (Ahi)	-
Wahoo (Ono)	*Acanthocybium solandri*
White ulua	*Carangoides ajax*
Whitebar surgeonfish (Maikoiko)	*Acanthurus leucopareius*
Whitespotted surgeonfish ('Api)	*Acanthurus guttatus*
White-tail damselfish	*Chromis leucurus*
Whitetip reef shark (Mano-lala-kea)	*Triaenodon obesus*
Wrasses (Hinalea)	-
Yellow tang (Lau-i-pala)	*Zebrasoma flavescens*
Yellowfin goatfish (Weke-ula)	*Mulloidicthys vanicolensis*
Yellowfin moray (Puhi)	*Gymnothorax flavimarginatus*
Yellowfin surgeonfish (Pualu)	*Acanthurus xanthopterus*
Yellowspotted jack (Ulua)	*Carangoides orthogrammus*
Yellowstripe goatfish (Weke'a)	*Mulloidicthys flavolineatus*
NATIVE STREAM SPECIES	
'O'opu akupa (goby)	*Eleotris sandwicensis*
'O'opu alamo'o (goby)	*Lentipes concolor*
'O'opu nakea (goby)	*Awaous guamensis*
'O'opu naniha (goby)	*Stenogobius hawaiiensis*
'O'opu nopili (goby)	*Sicyopterus stimpsoni*

*Threatened and endangered species are designated by underlining.

SPECIES LIST

Common Name	Species Name

INVERTEBRATES

BIVALVES (cont.)

Bivalves (Olepe)	-
Black-lipped pearl oyster (Pa)	*Pinctada margaritifera*
Eastern oyster	*Crassostrea virginica*
Endangered bivalve	-
Japanese littleneck clam	*Tapes philippinarum*
Rock oyster	*Chama iostoma*
Spiny oyster	*Spondylus nicobaricus*

CRABS

Blood-spotted swimming crab (Kuhonu)	*Portunus sanguinolentus*
Kona crab (Papa 'i kua loa)	*Ranina ranina*
Rock crabs	-
Samoan crab	*Scylla serrata*
Swimming crabs	-
Thin-shelled rock crab ('A'ama)	*Grapsus tenuicrustatus*
Xanthid crabs	-

ENCHINODERMS

Banded urchin (Wana)	*Echinothrix calamaris*
Blue-black urchin (Wana)	*Echinothrix diadema*
Collector urchin (Hawa'e maoli)	*Tripneustes gratilla*
Crown-of-thorns starfish	*Acanthaster planci*
Cushion star	*Culcita novaeguineae*
Echinoderms	-
Helmet urchin (Ha'uke'uke kaupali)	*Colobocentrotus atratus*
Long-spined urchin (Wana halula)	*Diadema paucispinum*
Needle-spined urchin	*Echinostrephus aciculatus*
Rock-boring urchin ('Ina kea)	*Echinometra mathaei*
Sea urchins	-
Ten-lined urchin (Ha'ue'ue)	*Eucidaris metularia*

GASTROPODS

Anchialine pool snail	*Neritilia hawaiiensis*
Anchialine pool snail	*Neritilia sp 1*
Anchialine pool snail	*Neritilia sp B*
Gastropods	-
Limpets ('Opihi)	-
Neretid snails	-
Sea slugs	-

INSECT

Blackburn's sphinx moth	*Manduca blackburni*

INVERTEBRATES

Bryozoans	-
Endangered invertebrate	-
Feather duster worm	*Sabellastarte sanctijosephi*
Intertidal invertebrates	-
Invertebrates	-
Molluscs	-
Rare sponges	-
Sponges (Hu'akai, 'Upi)	-
Tidepool invertebrates	-
Unique invertebrate assemblage	-
Zoanthids	-

LOBSTERS

Banded spiny lobster (Ula)	*Panulirus marginatus*
Slipper lobsters (Ula-papapa)	-
Tufted spiny lobster (Ula)	*Panulirus penicillatus*

OCTOPUS

Octopus (He'e, Tako)	-

SPECIES LIST

Common Name	Species Name

INVERTEBRATES cont.

SHRIMP

Anchialine pool shrimp	*Antecaridina lauensis*
Anchialine pool shrimp	*Calliasmata pholidota*
Anchialine pool shrimp	*Halocaridina palahemo*
Anchialine pool shrimp	*Metabetaeus lohena*
Anchialine pool shrimp	*Palaemonella burnsi*
Anchialine pool shrimp	*Procaris hawaiana*
Anchialine pool shrimp	*Vetericaris chaceorum*
Banded coral shrimp	*Stenopus hispidus*
Mantis shrimp	*Gonadactylus falcatus*
Tahitian prawn	*Macrobrachium lar*

NATIVE STREAM SPECIES

Hapawai (snail)	*Neritina vespertina*
Hihiwai (snail)	*Neritina granosa*
Newcomb's snail	*Errina newcombi*
Pipiwai (snail)	*Theodoxus cariosus*
'O'pae 'oeha'a (prawn)	*Macrobrachium grandimanus*
'O'pae kala'ole (shrimp)	*Atyoida bisulcata*

HABITATS

NATIVE/RARE PLANTS

Abutilon menziesii (Ko'oloa'ula)	*Abutilon menziesii*
Acacia koaia (Koai'a)	*Acacia koaia*
Achyranthes splendens rotundata	*Achyranthes splendens rotundata*
Alectryon macrococcus macrococcus ('Ala'alahua)	*Alectryon macrococcus macrococcus*
Amaranthus brownii	*Amaranthus brownii*
Bidens molokaiensis (Ko'oko'olau)	*Bidens molokaiensis*
Bobea sandwicensis ('Ahakea)	*Bobea sandwicensis*
Bonamia menziesii	*Bonamia menziesii*
Brighamia insignis (Alula)	*Brighamia insignis*
Brighamia rockii (Alula)	*Brighamia rockii*
Canavalia molokaiensis ('Awikiwiki)	*Canavalia molokaiensis*
Canavalia napaliensis ('Awikiwiki)	*Canavalia napaliensis*
Canavalia pubescens ('Awikiwiki)	*Canavalia pubescens*
Capparis sandwichiana (Pua pilo)	*Capparis sandwichiana*
Centaurium sebaeoides ('Awiwi)	*Centaurium sebaeoides*
Chamaesyce celastroides kaenana ('Akoko)	*Chamaesyce celastroides kaenana*
Chamaesyce celastroides laehiensis ('Akoko)	*Chamaesyce celastroides laehiensis*
Chamaesyce celastroides stokesii ('Akoko)	*Chamaesyce celastroides stokesii*
Chamaesyce celastroides tomentella ('Akoko)	*Chamaesyce celastroides tomentella*
Chamaesyce kuwaleana ('Akoko)	*Chamaesyce kuwaleana*
Chamaesyce skottsbergii skottsbergii ('Akoko)	*Chamaesyce skottsbergii skottsbergii*
Chamaesyce skottsbergii vaccinioides ('Akoko)	*Chamaesyce skottsbergii vaccinioides*
Charpentiera densiflora (Papala)	*Charpentiera densiflora*
Cyperus trachysanthos	*Cyperus trachysanthos*
Fimbristylis hawaiiensis	*Fimbristylis hawaiiensis*
Gardenia brighamii (Nanu)	*Gardenia brighamii*
Gnaphalium sandwicensium molokaiense ('Ena' Ena)	*Gnaphalium sandwicensium molokaiense*
Hedyotis elatior	*Hedyotis elatior*
Hedyotis fluviatilis	*Hedyotis fluviatilis*
Hedyotis littoralis	*Hedyotis littoralis*
Hedyotis st.-johnii	*Hedyotis st.-johnii*

*Threatened and endangered species are designated by underlining.

SPECIES LIST

Common Name	Species Name
HABITATS cont.	
NATIVE/RARE PLANTS (cont.)	
Hibiscus arnottianus immaculatus (Koki'o ke'oke'o)	*Hibiscus arnottianus immaculatus*
Hibiscus brackenridgei brackenridgei (Ma'o hau hele)	*Hibiscus brackenridgei brackenridgei*
Hibiscus kokio kokio (Koki'o 'ula'ula)	*Hibiscus kokio kokio*
Hibiscus kokio saintjohnianus (Koki'o 'ula'ula)	*Hibiscus kokio saintjohnianus*
Hibiscus waimeae hannerae (Koki'o ke'oke'o)	*Hibiscus waimeae hannerae*
Ischaemum byrone	*Ischaemum byrone*
Kanaloa kahoolawensis	*Kanaloa kahoolawensis*
Labordia helleri (Kamakahala)	*Labordia helleri*
Lepidium arbuscula ('Anaunau)	*Lepidium arbuscula*
Lepidium bidentatum o-waihiense ('Ananunau)	*Lepidium bidentatum o-waihiense*
Lepidium serra ('Anaunau)	*Lepidium serra*
Lipochaeta lobata lobata (Nehe)	*Lipochaeta lobata lobata*
Lipochaeta tenuifolia (Nehe)	*Lipochaeta tenuifolia*
Lobelia niihauensis ('Oha)	*Lobelia niihauensis*
Mariscus pennatiformis pennatiformis	*Mariscus pennatiformis pennatiformis*
Marsilea villosa ('Ihi 'ihi)	*Marsilea villosa*
Munroidendron racemosum	*Munroidendron racemosum*
Native coastal strand vegetation	-
Nothocestrum breviflorum ('Aiea)	*Nothocestrum breviflorum*
Nototrichium humile (Kulu'I)	*Nototrichium humile*
Ochrosia haleakalae (Holei)	*Ochrosia haleakalae*
Ochrosia kauaiensis (Holei)	*Ochrosia kauaiensis*
Ophioglossum concinnum (Pololei)	*Ophioglossum concinnum*
Panicum beecheyi	*Panicum beecheyi*
Panicum fauriei carteri	*Panicum fauriei carteri*
Panicum lineale	*Panicum lineale*
Panicum niihauense (Lau'ehu)	*Panicum niihauense*
Peucedanum sandwicense (Makou)	*Peucedanum sandwicense*
Pittosporum napaliense (Ho'awa)	*Pittosporum napaliense*
Portulaca molokiniensis ('Ihi)	*Portulaca molokiniensis*
Portulaca sclerocarpa ('Ihi)	*Portulaca sclerocarpa*
Portulaca villosa ('Ihi)	*Portulaca villosa*
Pritchardia affinis (Loulu)	*Pritchardia affinis*
Pritchardia lowreyana	*Pritchardia lowreyana*
Pritchardia remota	*Pritchardia remota*
Pseudognaphalium sandwicensium molokaiense	*Pseudognaphalium sandwicensium molokaiense*
Pteralyxia kauaiensis (Kaulu)	*Pteralyxia kauaiensis*
Scaevola coriacea (Naupaka)	*Scaevola coriacea*
Schiedea apokremnos	*Schiedea apokremnos*
Schiedea globosa	*Schiedea globosa*
Schiedea kealiae	*Schiedea kealiae*
Schiedea ligustrina	*Schiedea ligustrina*
Schiedea lydgatei	*Schiedea lydgatei*
Schiedea menziesii	*Schiedea menziesii*
Schiedea stellarioides (Ma'oli'oli)	*Schiedea stellarioides*
Schiedea verticillata	*Schiedea verticillata*
Sesbania tomentosa ('Ohai)	*Sesbania tomentosa*
Solanum nelsonii	*Solanum nelsonii*
Tetramolopium rockii calcisabulorum	*Tetramolopium rockii calcisabulorum*
Tetramolopium rockii rockii	*Tetramolopium rockii rockii*

SPECIES LIST

Common Name	Species Name
HABITATS cont.	

NATIVE/RARE PLANTS (cont.)	
Tetramolopium sylvae	*Tetramolopium sylvae*
Vigna o-wahuensis	*Vigna o-wahuensis*
Wilkesia hobdyi (Iliau)	*Wilkesia hobdyi*
BENTHIC MARINE HABITATS	
ALGAE/SEAGRASSES	
Algae	-
Algal reef	-
Rare algae	-
Red algae	-
Seagrass	-
CORALS	
Black coral	*Antipathes spp.*
Coral reef habitat	-
Coralline algal apron reef	-
High coral diversity	-
High live coral cover	-
Massive coral colonies	-
Octocoral bed	-
Rare coral	-
Reef pinnacle	-
Sinularia molokaiensis (soft coral)	*Sinularia molokaiensis*
Soft coral	-
Structural coral reef	-
Submerged barrier reef	-
Wire coral	*Cirrhipathes anguina*

*Threatened and endangered species are designated by underlining.

SHORELINE DESCRIPTIONS

EXPOSED ROCKY CLIFFS **ESI = 1A**

DESCRIPTION

- Steep intertidal zone (usually greater than 30 degree slope) with very little width
- Regularly exposed to high wave energy, with strong wave reflection patterns
- Sediment accumulations are uncommon and usually ephemeral, because waves quickly remove debris slumped from eroding cliffs
- Attached organisms are hardy and accustomed to strong hydraulic impacts and pressures
- Impermeable substrate with no potential for subsurface penetration
- Seldom found in combination with another shoreline type, however they are often interspersed along the shore with wave-cut platforms and gravel beaches
- Very common throughout the study area, being particularly abundant along southern and eastern shoreline of Hawaii and Maui, as well as the eastern shore of Oahu

PREDICTED OIL BEHAVIOR

- Oil is held offshore by waves reflecting off the steep cliffs
- Any oil that is deposited is rapidly removed from exposed faces by wave action

- Most resistant oil remains as a patchy band at or above the high-tide line
- Impacts to intertidal communities are often short term, an exception being where heavy concentrations of a light refined product comes ashore very quickly

RESPONSE CONSIDERATIONS

- Cleanup usually not required
- Access can be difficult and dangerous

EXPOSED, SOLID MAN-MADE STRUCTURES **ESI = 1B**

DESCRIPTION

- Typically composed of concrete or metal bulkheads
- Organisms, such as barnacles and algae, may be common on the lower levels, whereas biota along the upper intertidal zone is sparse
- Attached organisms are hardy and accustomed to strong hydraulic impacts and pressures
- Occur throughout the islands to provide protection to residential and industrial developments where these structures are threatened by beach erosion

PREDICTED OIL BEHAVIOR

- Much of the oil will be held offshore by wave reflection
- Oil could percolate between the joints of the structures
- Under heavy accumulations, oil may coat the intertidal area and biota present would be impacted

RESPONSE CONSIDERATIONS

- High-pressure spraying may be required in order to:
  - remove oil

  - prepare substrate for re-colonization of epifaunal communities
  - minimize aesthetic damage
  - prevent the chronic leaching of oil from the structure

EXPOSED WAVE-CUT PLATFORMS IN BEDROCK **ESI = 2A**

DESCRIPTION

- Regular exposure to high wave energy, with strong wave reflection patterns
- Intertidal zone is a flat rock bench of variable width
- Rock can consist of both bedrock and calcareous beach rock. Many are low-relief lava flows that have been further modified through wave energy
- Attached organisms are hardy and used to strong hydraulic impacts and pressures
- May be backed by a steep scarp or low bluff
- Perched beach of sand- to boulder-sized sediments may be present at base of the scarp
- Substrate is impermeable with no potential for subsurface penetration over much of intertidal zone, except in the ephemeral beach sediments
- Surface is irregular and tidal pools may be present
- Small accumulations of gravel, shells, or coral rubble can be found in the tidal pools and crevices in the platform
- May support large populations of encrusting animals and plants, with rich tidal pool communities
- Common throughout the more exposed shorelines of all the islands, typically interspersed along the shore with rocky cliffs and gravel beaches

PREDICTED OIL BEHAVIOR

- Oil will not adhere to the rock platform, but rather be transported across the platform and accumulate along the high-tide line, where it can penetrate in beach sediments, if present

- Persistence of oiled sediments is usually short-term, except in wave shadows or larger sediment accumulations at the landward edge of the platform, where oil can persist for up to several weeks to months
- Biological impacts can be immediate and severe, particularly if fresh oil slicks cover tidal pool communities

RESPONSE CONSIDERATIONS

- Cleanup is usually not required, because oil is quickly removed by wave action
- Access may be difficult and dangerous
- Where the high-tide area is accessible, it may be feasible to remove heavy oil accumulations and oiled debris in areas of high recreational use or in order to protect a nearshore marine resource, such as marine birds

EXPOSED SCARPS AND STEEP SLOPES IN CLAY ESI = 2B

DESCRIPTION

- Regular exposure to high wave energy, with moderate to weak wave reflection patterns
- Scarp heights vary from about 1 to 3 feet and usually consist of a heavily rooted, loamy soil with a highly irregular, moderately permeable surface
- May be accompanied by an extremely narrow beach of fine to medium-grained sand
- Typically backed by scrub-shrub vegetation
- Uncommon in study area. Found primarily on the eastern shores of Lanai. May develop on any erosional coast line

PREDICTED OIL BEHAVIOR

- Oil may adhere to roots or become entrapped in depressions or irregularities on the scarp surface near the high tide line. Oil in such irregularities could persist in small amounts, despite high wave energy
- Biological impacts can be immediate and severe, particularly if oil is left to pool on the landward side of scarp

RESPONSE CONSIDERATIONS

- Cleanup is usually not required, because oil is quickly removed by wave action

- Access may be difficult and dangerous
- Where the high-tide area is accessible, it may be feasible to remove heavy oil accumulations and oiled debris in order to protect a nearshore marine resource, such as marine birds

FINE- TO MEDIUM-GRAINED SAND BEACHES ESI = 3A

DESCRIPTION

- Generally flat, wide, and hard-packed
- Rate of sediment mobility is relatively low, thus rapid, dramatic changes in the beach profile are not common
- Surface sediments subject to regular reworking by waves
- Beach fauna can vary in type and density; mobile surface, burrowing, and interstitial forms are typical
- Sea turtle nesting, eggs, and hatchlings can be expected on nearly all outer coast sand beaches
- Extensive medium-grained sand beaches are found on southwestern shores of Kauai, as pocket beaches on the eastern shores of Oahu, and at the upper intertidal zone on wave-cut platforms

PREDICTED OIL BEHAVIOR

- Light oil accumulations deposited as oily swashes or bands along the upper intertidal zone
- Heavy oil accumulations cover entire beach surface; the oil will be lifted off the lower beach with the rising tide
- Maximum penetration of oil is about 10 cm into fine-grained sand and 15 cm into medium-grained sand
- Burial of oiled layers by clean sand can occur within hours on these microtidal beaches, but the maximum burial will typically occur along the upper beach face to depths less than 30 cm
- Organisms living in the beach may be killed by smothering or lethal oil concentrations in interstitial water
- Direct and indirect impacts to sea turtle nests, eggs, and hatchlings can be severe

RESPONSE CONSIDERATIONS

- The easiest beach type to clean, because hard substrate can support vehicular and foot traffic and depths of oil burial and penetration are minimal

- After all oil has come ashore, cleanup activities should concentrate at first on the removal of oil from the upper swash zone
- Vehicular traffic and walking through oiled areas and dunes should be limited, to prevent contamination of clean areas and disturbance of dune vegetation
- Vehicular and foot traffic, and mechanical or manual beach cleanup, should be carefully planned and monitored in sea turtle nesting areas to avoid disturbance and destruction of nesting turtles, eggs, and young
- Manual cleanup, rather than road graders and front-end loaders, is advised where feasible to minimize the volume of sand removed from the shore
- Prevent the mixture of oil deeper into the sediments by vehicular and foot traffic

COARSE-GRAINED SAND BEACHES ESI = 4

DESCRIPTION

- Moderate to steep beachface slopes. Sediments are soft and permeable with low trafficability
- The rate of sediment mobility is relatively high, with the vertical accumulation of up to 20 cm of sediments possible within a single tidal cycle
- Beach fauna can vary in type and density; mobile surface, burrowing, and interstitial forms are typical
- Sea turtle nesting, eggs, and hatchlings can be expected on nearly all sand beaches
- Not quite as common as fine-to-medium grained sand beaches, they are found along exposed volcanic coastlines of Hawaii and on the north and southwestern shores of Oahu where they consist largely of shell fragments
- In places, they occur at the upper intertidal zone on wave-cut platforms

PREDICTED OIL BEHAVIOR

- During small spills, oil is deposited primarily as a band along the high-tide line
- Under very heavy accumulations, oil may spread across the entire intertidal zone, though it will be lifted off the lower part of the beach during the rising tide
- Penetration up to 25 cm possible
- Burial of oiled layers by clean sand can be rapid, to depths of 1 m or more if the oil comes ashore at the start of a depositional period
- Organisms living in the beach may be killed by smothering or lethal oil concentrations in interstitial water
- Direct and indirect impacts to sea turtle nests, eggs, and hatchlings can be severe

RESPONSE CONSIDERATIONS

- Cleanup more difficult than for finer-grained beaches, because equipment tends to grind oil into the substrate due to the loosely packed and permeable nature of these coarser-grained sediments; therefore, special care must be exercised at all times while using heavy equipment in order to prevent mixing oil deeper into the beach sediment
- Use of heavy equipment for oil/sand removal may also result in the export of excessive amounts of sand; therefore, where feasible and for smaller amounts of oil, manual cleanup may be desirable
- Vehicular traffic and walking through oiled areas and dunes should be limited, to prevent contamination of clean areas and disturbance of dune vegetation
- Vehicular and foot traffic, and mechanical or manual beach cleanup, should be carefully planned and monitored in sea turtle nesting areas to avoid disturbance and destruction of nesting turtles, eggs, and young
- Removal of sediment should be limited as much as possible to avoid erosion problems on the beach in the future; however, the common occurrence of multiple buried oil layers in these types of beaches increases the amount of sediment to be handled and disposed of
- Mechanical reworking of the sand into the surf zone (surf washing) may be used under optimal conditions to release the oil without sediment removal

MIXED SAND AND GRAVEL BEACHES — ESI = 5

DESCRIPTION

- Moderately sloping beach (8-15 degrees) composed of a mixture of sand and at least 20 percent gravel
- Soft sediments with low trafficability
- Sediment mobility is very high during storms, but considerably less than sand beaches during normal conditions
- Spatial variations in the distribution of grain sizes may be significant, with separate zones of pure sand, pebbles, or cobbles, in addition to the mixed zones
- Gravel can be composed of a variety of materials, including volcanic bedrock, beach-rock rubble , coral rubble, shells, and other calcium carbonate materials
- Substrate has medium-to-high permeability
- Beach fauna can vary in type and density; mobile surface, burrowing, and interstitial forms are typical
- Sea turtle nesting, eggs, and hatchlings can be expected on outer coast mixed sand and gravel beaches, particularly those dominated by sand and smaller-sized gravel
- Occur on almost all of the islands, most typically in transition zones between rocky/gravel areas and sand beaches

PREDICTED OIL BEHAVIOR

- During small spills, oil will be deposited along the high-tide swash line
- During large spills, oil will be spread across the entire intertidal area
- Oil penetration into the beach sediments may be up to 50 cm; however, the sand fraction can be quite mobile, and if the sand fraction exceeds about 40 percent, oil behavior is similar to that described for sand beaches
- Significant amounts of oil can be eroded away during storms
- Burial of oil may be deep (up to 1 m) if oil comes ashore while the beach is recovering from storm conditions
- In sheltered pockets on the beach, such as in the lee of large boulders, pavements of asphalted sediments can form if there is no removal of heavy oil accumulations, and, once formed, these pavements can persist for many years
- Organisms living in the beach may be killed by smothering or lethal oil concentrations in interstitial water

RESPONSE CONSIDERATIONS

- Remove heavy accumulations of pooled oil as quickly as possible
- All oiled debris should be removed
- Vehicular traffic and walking through oiled areas should be limited, to prevent contamination of clean areas
- Vehicular and foot traffic, and mechanical or manual beach cleanup, should be carefully planned and monitored in sea turtle nesting areas to avoid disturbance and destruction of nesting turtles, eggs, and young
- Sediment removal should be limited as much as possible, because of potential beach erosion problems in the future
- Low-pressure flushing can be used to remove heavy oil where collection of the flushed oil is feasible, but high-pressure flushing should be avoided, because of the potential for transporting contaminated finer sediments (sand) to the lower intertidal or subtidal zones
- Mechanical reworking of oiled sediments from the high-tide zone to the upper intertidal zone for wave reworking (berm relocation) can be effective in areas subject to significant wave action
- In-place tilling may be used to expose deeply buried oil layers to wave reworking in areas subject to significant wave action

GRAVEL BEACHES — ESI = 6A

DESCRIPTION

- Composed of sediments larger than 2 mm (granules, pebbles, cobbles and boulders) that may be made up of bedrock fragments, coral rubble, and
- Most permeable of all beach sediments
- Lowest trafficability of all beach types
- Slope is intermediate to steep with multiple, wave-built berms usually forming the upper beach
- Sediment replenishment rates are lowest of all beach types
- Attached animals and plants are usually restricted to lowest parts of the beach, where the sediments are less mobile
- Common throughout the islands as reworked alluvial fans adjacent to cliffs and as perched berms atop wave-cut rock platforms, less commonly found as a storm berm in conjunction with fine- to medium-grained sand beaches

PREDICTED OIL BEHAVIOR

- Deep penetration and rapid burial of stranded oil is likely; penetration of 10's of cm (over 1 m possible) can extend oil to depths below where it cannot be reworked by any natural process except extreme storms
- Therefore, long-term persistence will be controlled by the depth of penetration versus the depth of routine reworking by storm waves
- Oil may be carried over the normal high-tide line and storm berms during high-water events, where it can pool and persist above the normal zone of wave wash
- In the more sheltered areas, formation of asphalt pavements is likely if oil accumulations are heavy

RESPONSE CONSIDERATIONS

- Because of the low trafficability, and the rapid rates of burial and deep penetration of the oil, this is the most difficult of all the beach types to clean
- Heavy accumulations of pooled oil should be removed quickly
- All oiled debris should be removed
- Because of slow sediment replenishment rates, sediment removal should be limited as much as possible
- Flushing with ambient water can be used to remove some of the oil from the sediments, provided adequate oil recovery is possible
- Mechanical reworking of oiled sediments from the high-tide line to the upper intertidal zone (berm relocation) can be effective in areas regularly exposed to wave activity (as evidenced by storm berms)
- In-place tilling may be used to expose deeply buried oil layers to wave reworking on beaches with high wave activity

RIPRAP **ESI = 6B**

DESCRIPTION

- Composed of cobble- to boulder-sized rock fragments
- Used for shoreline protection and inlet stabilization
- Attached mid- and low-intertidal zone biota may be plentiful and varied
- Relatively common in all the developed areas of the islands

PREDICTED OIL BEHAVIOR

- Deep penetration of oil because of the high permeability of the riprap
- Oil adheres readily to the rough rock surfaces
- If left uncleaned, oil may cause chronic leaching (weeks to months) until it hardens
- Resident fauna and flora may be killed by the oil

RESPONSE CONSIDERATIONS

- Flushing can be effective for removing mobile oil, but large amounts of residue can remain after flushing, particularly for heavy oil
- Scrapping and/or hot-water spraying of residual heavy oils may be required in areas of high recreational value

EXPOSED TIDAL FLATS **ESI = 7**

DESCRIPTION

- Flat intertidal areas, composed primarily of sand and mud (sand dominant), that vary in width from a few to hundreds of meters
- The presence of sand indicates that tidal or wind-driven currents and waves are strong enough to mobilize the sediments
- Usually associated with another shoreline type on the landward side of the flat
- Sediments usually remain water-saturated, with only the topographically higher ridges drying out during low tide
- Sediments are generally too soft for vehicular traffic
- Biological utilization can be very high, with large numbers of infauna, and heavy use by birds for roosting and foraging
- Not common in the study area, found in the vicinity of Pearl Harbor, Oahu, and on the southern shores of Molokai

PREDICTED OIL BEHAVIOR

- Oil does not usually adhere to the surface of exposed tidal flats, but rather moves across the flat and accumulates at the high-tide line
- Deposition of oil on the flat may occur on a falling tide if concentrations are heavy
- Oil does not typically penetrate these water-saturated sediments, except on the top of sand bars and into animal burrows if they dry out at low tide; thus, oil penetration is limited to a maximum of a few cm
- Because of the high biological use, impacts can be significant to benthic invertebrates that are smothered or exposed to the water-accommodated fraction of the oil

RESPONSE CONSIDERATIONS

- In most cases, the best response is to let the oil, which is primarily on the surface of the flat, be removed naturally
- Natural removal tends to happen rather quickly in this habitat, because of its exposure to waves and tidal currents
- Cleanup is very difficult, because of the potential for mixing the oil deeper into the sediments
- If cleanup is attempted, the use of heavy machinery should be restricted in order to prevent contamination of the subsurface sediments, with manual removal being preferred; however, heavy foot traffic can also result in oiling of the deeper sediments

SHELTERED ROCKY SHORES — ESI = 8A

DESCRIPTION

- Bedrock shores of variable slope (from vertical cliffs to wide, rocky ledges) that are sheltered from exposure to most wave and tidal energy
- Attached biota may be plentiful and varied, especially in lower and mid-intertidal zones
- Sheltered rocky shores are rare on the islands, occurring in only a few bays and coves

PREDICTED OIL BEHAVIOR

- Oil will adhere readily to the rough rocky surface, particularly along the high-tide line, forming a distinct oil band
- Oil can remain for a long time (months to years) because of the low energy setting
- Where surface sediments are abundant, oil will penetrate into the crevices formed by the surface rubble and pool at the contact of the sediments and the rock surface
- Where the rubble is loosely packed, oil will penetrate deeply, causing long-term contamination of the subsurface
- Impacts to attached organisms can be severe
- Asphalt pavements can form in the cracks and cervices

RESPONSE CONSIDERATIONS

- Cleanup is often required because natural removal rates are slow

- Water flushing at ambient water temperatures is most effective when the oil is fresh
- All pooled oil and oiled debris should be removed as soon as possible
- Weathered asphalt pavements can be removed manually

SHELTERED, MAN-MADE STRUCTURES — ESI = 8B

DESCRIPTION

- Include revetments, seawalls, piers, and docks typically constructed of impermeable materials such as concrete and wood
- Commonly found inside harbors and bays in highly developed areas sheltered from direct exposure to waves
- Attached biota may be plentiful and varied, especially in lower and mid-intertidal zones

PREDICTED OIL BEHAVIOR

- On impermeable surfaces, the oil will form a band at the high-tide line
- If the oil is not removed, it may cause chronic leaching until the oil hardens
- Impacts to attached organisms can be severe

RESPONSE CONSIDERATIONS

- Cleanup is frequently required, because natural removal rates are slow and these features are located in populated areas
- High-pressure spraying may be required to remove oil for aesthetic reasons and to prevent leaching of oil from the structure

- Cleanup crews should make sure to recover all released oil
- All pooled oil and oiled debris should be removed as soon as possible

SHELTERED RIPRAP — ESI = 8C

DESCRIPTION

- Composed of cobble- to boulder-sized basaltic rock fragments, similar to exposed riprap but sheltered from wave energy
- Commonly found inside harbors and bays in highly developed areas sheltered from direct exposure to waves
- Attached biota may be plentiful and varied, especially in lower and mid-intertidal zones

PREDICTED OIL BEHAVIOR

- On impermeable surfaces, the oil will form a band at the high-tide line, oil will adhere readily to the rough rock surfaces
- Deep penetration of oil possible because of the high permeability of the riprap
- If the oil is not removed, it may cause chronic leaching (weeks to months) until the oil hardens
- Impacts to attached organisms can be severe

RESPONSE CONSIDERATIONS

- Cleanup is frequently required, because natural removal rates are slow and these features are located in populated areas
- Flushing can be effective for removing mobile oil, but large amounts of residue can remain after flushing, particularly for heavy oil. Clean up if often difficult and intrusive

- High-pressure spraying and/or scraping may be required to remove oil for aesthetic reasons and to prevent leaching of oil from the structure
- Cleanup crews should make sure to recover all released oil
- All pooled oil and oiled debris should be removed as soon as possible

SHELTERED TIDAL FLATS — ESI = 9A

DESCRIPTION

- Sheltered tidal flats are composed primarily of mud with minor amounts of sand and shell
- They are present in calm-water habitats, sheltered from major wave activity, frequently in unvegetated areas within mangrove forests and in salt ponds
- The sediments are very soft and cannot support even light foot traffic in many areas
- They can be sparsely to heavily covered with algae
- They can have very heavy wrack deposits along the upper fringe
- There can be large concentrations of invertebrates on and in the sediments

PREDICTED OIL BEHAVIOR

- Oil does not usually adhere to the surface of sheltered tidal flats, but rather moves across the flat and accumulates at the high-tide line
- Deposition of oil on the flat may occur on a falling tide if concentrations are heavy
- Oil will not penetrate the water-saturated sediments, but could penetrate burrows and desiccation cracks or other crevices in muddy sediments

RESPONSE CONSIDERATIONS

- These are high-priority areas necessitating the use of spill protection devices to limit oil-spill impact; deflection or sorbent booms and open water skimmers should be used

- Cleanup of the flat surface is very difficult because of the soft substrate; many methods may be restricted
- Care should be taken to limit foot traffic during any cleanup operations, to avoid mixing oil into the sediments
- Low-pressure flushing and deployment of sorbents from shallow-draft boats may be helpful

SHELTERED, VEGETATED LOW BANKS — ESI = 9B

DESCRIPTION

- Sheltered banks of stream channels, canals and other waterways
- Calm-water habitats that are typically muddy, soft and highly vegetated
- Wave energy is very low, although there may be some tidal and/or riverine currents along the banks
- Present but not abundant throughout the islands along the most oceanward parts of stream outlets, minor estuarine systems, and canals

PREDICTED OIL BEHAVIOR

- Natural removal rates very slow because of low energy and dense vegetation
- Oil adheres readily to vegetation
- The band of oil coating on the vegetation will vary widely, depending upon the tidal stage at the time of oiling; there may be multiple bands
- If the vegetation is thick, heavy oil coating will be restricted to the outer fringe, with penetration and lighter oiling to the limit of tidal influence
- In areas of high suspended sediments, sorption of oil can result in deposition of contaminated sediments on the channel banks and bottoms

RESPONSE CONSIDERATIONS

- These are high-priority areas necessitating the use of spill protection devices to limit oil-spill impact; most are along channels that have a opening to the open ocean close by; therefore, deflection booming should be used to prevent the oil from entering the channel mouth

- Cleanup of the banks is very difficult because of the soft substrate
- Manual operations and deployment of sorbents from shallow-draft boats may be helpful
- Under light oiling, the best practice is to let the area recover naturally
- Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing
- Any cleanup activity must not mix the oil deeper into the sediments; trampling of the plant roots must be minimized
- Cutting of oiled vegetation should only be considered when other resources present (such as birds) are at great risk from leaving the oiled vegetation in place

SALT- AND BRACKISH – WATER MARSHES — ESI = 10A

DESCRIPTION

- Intertidal wetlands consisting of emergent, herbaceous vegetation
- Marshes vary in extent from extensive areas to narrow fringes
- Sediments in the substrate range from fine sands to silts and organically rich muds

PREDICTED OIL BEHAVIOR

- Oil adheres readily to intertidal vegetation
- Oil coating typically takes the form of a band of varying width. Multiple bands are possible
- Large slicks will persist through multiple tidal cycles and coat vegetation from high tide line to the base of the stem
- If the vegetation is thick, the heaviest oil coating will be restricted to the outer fringe of the marsh. However, the lighter the oil, the further into the marsh it may penetrate

- Medium to heavy oils do not readily adhere to or penetrate the fine sediments, but can pool in surface depressions or collect in burrows
- Light oils can penetrate the top few centimeters of sediment and deeply into burrows and cracks (up to one meter)

RESPONSE CONSIDERATIONS

- Extent of oiling, natural removal processes and rates should be evaluated prior to conducting cleanup
- Under light oiling, the best practice is to allow the area time to recover naturally

- Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing. During flushing care must be taken to prevent transporting oil to sensitive areas down slope or along shore
- Cleanup crews and activities must be carefully monitored to avoid unnecessary vegetation damage
- Any cleanup activity must not mix the oil deeper into the sediments. Trampling of the roots must be minimized
- Cutting of oiled vegetation should only be considered when other resources present (such as birds) are at great risk from leaving the oiled vegetation in place

FRESH WATER MARSHES **ESI = 10B**

DESCRIPTION

- Wetlands consisting of emergent, herbaceous freshwater vegetation
- Marshes vary in extent from extensive areas to narrow fringes
- Sediments in the substrate range from fine sands to silts and organically rich muds and potentially thick accumulations of peat

PREDICTED OIL BEHAVIOR

- Oil adheres readily to vegetation
- Oil coating typically takes the form of a band of varying width. Multiple bands are possible
- If the vegetation is thick, the heaviest oil coating will be restricted to the outer fringe of the marsh. However, the lighter the oil, the further into the marsh it may penetrate
- Medium to heavy oils do not readily adhere to or penetrate the fine sediments, but can pool in surface depressions or collect in burrows
- Light oils can penetrate the top few centimeters of sediment and deeply into burrows and cracks (up to one meter)

RESPONSE CONSIDERATIONS

- Extent of oiling, natural removal processes and rates should be evaluated prior to conducting cleanup
- Under light oiling, the best practice is to allow the area time to recover naturally

- Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing. During flushing care must be taken to prevent transporting oil to sensitive areas down slope or along shore
- Cleanup crews and activities must be carefully monitored to avoid unnecessary vegetation damage
- Any cleanup activity must not mix the oil deeper into the sediments. Trampling of the roots must be minimized
- Cutting of oiled vegetation should only be considered when other resources present (such as birds) are at great risk from leaving the oiled vegetation in place

FRESHWATER SWAMPS **ESI = 10C**

DESCRIPTION

- Freshwater swamps consist of shrubs and forested wetlands
- The sediment tends to be silty clay with large amounts of organic debris
- They may be seasonally flooded, though there are many low, permanently flooded areas
- Resident flora and fauna are abundant with numerous species
- They occur along freshwater drainage, often adjacent to freshwater marshes

PREDICTED OIL BEHAVIOR

- Oiled woody vegetation is less sensitive than marshes to oil coating
- Some oil can be trapped and pooled on the swamp flood plain as water levels drop
- Penetration into the floodplain soils is usually limited because of high water levels, muddy composition, surface organic debris, and vegetation cover
- Large amounts of oily debris can be sources of chronic sheening
- During dry periods, terrestrial spills flow downhill and accumulate in depressions or reach waterbodies

RESPONSE CONSIDERATIONS

- Under light oiling, the best practice is to let the area recover naturally
- Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing. During flushing, care must be taken to prevent transporting oil to sensitive areas down slope or along shore

- Under stagnant water conditions, herding of oil with water spray may be needed to push oil to collection areas
- Oily debris can be removed where there is access
- Any cleanup activity must not mix the oil deeper into the sediments. Trampling of the roots must be minimized
- Cutting of oiled vegetation should only be considered when other resources present are at great risk from leaving the oiled vegetation in place

MANGROVES **ESI = 10D**

DESCRIPTION

- Mangrove species include red, white, and black mangroves; red mangroves usually, but not always, occupy the most seaward fringe or zone
- Roots and trunks are intertidal, with only the lowest leaves inundated at high tide
- Relatively sheltered from waves and strong tidal currents
- The width of the forest can range from one tree to a many miles
- The substrate ranges from mud to shell to coral rubble
- Mangroves are important nursery habitats for fish and invertebrates, and feeding and nesting areas for wildlife (such as birds)
- Occur along sheltered shorelines and estuarine areas throughout the islands

PREDICTED OIL BEHAVIOR

- Oil can wash through mangroves if it comes ashore at high tide
- If there is a berm present, oil tends to concentrate and penetrate into the berm sediments or the wrack/litter that has accumulated there
- Heavy and emulsified oil can be trapped in and adhere to thickets of mangrove prop roots or pneumatophores
- Re-oiling from resuspended or released oil residues may cause additional injury over time
- Oiled trees may start to show evidence of effects (leaf yellowing) days to weeks after oiling; tree mortality may take months, especially for heavy oils
- Oil that penetrates the substrate or gets mixed into the sediments can cause long-term contamination of sediments and severe mangrove injury and mortality

RESPONSE CONSIDERATIONS

- Wrack may protect the trees from oiling, so wait until the threat of oiling has passed before removing it
- Sorbent boom can be placed in front of oiled forests to recover oil released naturally
- In most cases, no other cleanup activities are recommended
- Where thick oil accumulations are not being naturally removed, low-pressure flushing or vacuum may be attempted at the outer fringe
- No attempt should be made to clean interior mangroves, except where access to the oil is possible from terrestrial areas
- It is extremely important to prevent disturbance of soft substrates by foot traffic, which can mix oil into the sediments