ENVIRONMENTAL SENSITIVITY INDEX: UPPER TEXAS

INTRODUCTION

An Environmental Sensitivity Index (ESI) atlas has been developed for the marine and coastal areas of upper Texas (from Sabine Lake to East Matagorda Bay). The ESI atlas is a compilation of information from three main categories: shoreline habitats, sensitive biological resources, and human-use resources.

SHORELINE HABITAT MAPPING

The shoreline and classifications were fully updated using the sources and methods described below. The upper Texas bay shoreline was manually digitized from 2009 Texas Orthoimagery Project (TOP) half-meter imagery at a scale of 1:2000. The Gulf of Mexico shoreline was derived from a contour line 0.6 meters above local mean sea level extracted from LiDAR-derived Digital Elevation Models acquired in 2009. The intertidal shoreline habitats were classified based on the 2009 TOP imagery; 2008-2011 low-altitude oblique and orthometric aerial photography from Pictometry, Inc.; low-altitude oblique aerial photography from Red Wing Aerials; and field observations. Shoreline features of 10 meters or greater in length were classified. In addition, two wetland polygon datasets originally created by the U.S. Geological Survey National Wetlands Inventory and the Bureau of Economic Geology, The University of Texas at Austin were modified and updated to be used in conjunction with the ESI shoreline. Where necessary, multiple types were described for each shoreline segment.

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 shoreline ranking. Generally speaking, shorelines exposed to high levels of physical energy, such as wave action and tidal currents, and low biological activity rank low on the scale, whereas sheltered shorelines with associated high biological activity have the highest ranking. The list below includes the shoreline types delineated for Upper Texas, presented in order of increasing sensitivity to spilled oil.

- 1B) Exposed, Solid Man-made Structures
- 2A) Wave-cut Platforms in Clay
- 2B) Exposed Scarps and Steep Slopes in Clay
- 3A) Fine- to Medium-grained Sand Beaches
- 3B) Scarps and Steep Slopes in Sand
- 5) Mixed Sand and Gravel (Shell) Beaches
- 6A) Gravel Beaches
- 6B) Riprap
- 7) Exposed Tidal Flats
- 8A) Sheltered Scarps in Clay or Bedrock
- 8B) Sheltered, Solid Man-made Structures
- 8C) Sheltered Riprap
- 9A) Sheltered Tidal Flats
- 10A) Salt- and Brackish-water Marshes
- 10B) Freshwater Marshes
- 10C) Swamps
- 10D) Scrub-Shrub Wetlands

Each of the shoreline habitats are described on pages 9-14 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 following agencies:

- Texas Parks and Wildlife Department (TPWD)
- U.S. Fish and Wildlife Service (USFWS) – Texas Chenier Plain and Texas Mid-Coast National Wildlife Refuge Complexes
- U.S. Fish and Wildlife Service (USFWS) – Ecological Services, Coastal Program, and Migratory Bird Program
- National Park Service (NPS) – Padre Island National Seashore
- Texas Natural Diversity Database (TXNDD)
- Texas General Land Office (TGLO)
- Gulf Coast Bird Observatory (GCBO)
- Texas Colonial Waterbird Society
- Texas A&M University (TAMU)
- Texas State University
- National Marine Fisheries Service (NMFS)
- National Oceanic and Atmospheric Administration (NOAA) – Center for Coastal Monitoring and Assessment

The above agencies provided the majority of the biological information included in the atlas. Other participating agencies will be featured in the sources table and cited in the metadata accompanying the digital product.

KEY FEATURES ON ESI MAPS

1) Animal and plant species that are at risk during oil spills and/or spill response are represented on the maps by polygons and points.
2) 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.

MARINE MAMMAL
- Dolphin
- Manatee

TERRESTRIAL MAMMAL
- Small Mammal

BIRD
- Diving Bird
- Gull/Tern
- Passerine Bird/Landfowl
- Pelagic Bird
- Raptor
- Shorebird
- Wading Bird
- Waterfowl

FISH
- Fish

REPTILE
- Turtle
- Other Reptile/Amphibian

INVERTEBRATE
- Bivalve
- Cephalopod
- Crab
- Gastropod
- Shrimp

BENTHIC HABITAT
- Reef
- Seagrass (patchy)
- Seagrass (continuous)

HABITAT
- Plant

3) Polygons are color-coded on the maps based on the species composition of each feature, as shown below:

ELEMENT	COLOR
Birds/Nests	Green hatch pattern, green points
Fish	Blue hatch pattern
Invertebrates	Orange hatch pattern
Marine mammals	Brown hatch pattern
Terrestrial mammals	Brown hatch pattern
Reptiles/Amphibians	Red hatch pattern
Benthic habitats	Solid gray and purple simplified wetland patterns
Plants	Purple hatch pattern

4) There is a Resources at Risk number (RAR#) associated with each polygonal or point feature. The RAR# references a table on the reverse side of the map that contains a species list associated with each feature.
5) Also associated with each species in the table is the state (S) and federal (F) protected status as threatened (T) or endangered (E), as well as concentration, seasonality, and life-history information. Federal listings are provided by USFWS. State listings are provided by TPWD.
6) For species that are found throughout general geographical areas or habitat types on certain maps, displaying the polygons for these species would cover large areas or would obscure the shoreline and biological features, making the maps very difficult to read. In these

cases, a small box is shown on the maps which states that they are "Present in ..." (e.g., "Present in Galveston Bay" or "Present in marshes").

MARINE MAMMALS

Marine mammals depicted in the Texas atlas include the bottlenose dolphin (*Tursiops truncatus*) and West Indian manatee (*Trichechus manatus*, FE/SE).

West Indian manatees are rare visitors to the Texas coast, but they can be present in inland waters during the summer months. They are depicted in all inland waters based on anecdotal information from TPWD.

Bottlenose dolphins are ubiquitous throughout the region. Areas of consistently high concentrations were mapped based on published literature and anecdotal information from TPWD. Anecdotal information from TAMU and TPWD was used to draw the inland extent of bottlenose dolphins.

Expert contacts for upper Texas coast marine mammals* are:

Name	Agency	City	Phone	Species
Bernd Wursig	TAMU	Galveston, TX	409/740-4413	Bottlenose dolphin

***Note: this list is not meant to represent all marine mammal experts for the region.**

Major Data Sources Used: Marine Mammals

Henderson, E.E. 2004. Behavior, association patterns and habitat use of a small community of bottlenose dolphins in San Luis Pass, Texas. Dissertation. Texas A&M University.

Moreno, M.P.T. 2005. Environmental predictors of bottlenose dolphin distribution and core feeding densities in Galveston Bay, Texas. Dissertation. Texas A&M University.

BIRDS

Birds displayed in this atlas include: diving birds, gulls, terns, landfowl, passerine birds, pelagic birds, raptors, shorebirds, wading birds, and waterfowl. Species that are federally and state listed and coastal nesting, roosting, and migratory staging locations are specifically emphasized.

Bird occurrence information displayed in this atlas is based on information gathered at workshops and via phone/email correspondence with local resource experts from TPWD; USFWS – Texas Chenier Plain and Mid-Coast National Wildlife Refuge (NWR) Complexes, Ecological Services, Migratory Bird Program, and Coastal Program; Texas State University; and Audubon of Texas. Additional hardcopy and digital sources are listed below and included in the metadata.

Breeding and Wintering Birds – Survey data on locations of breeding, wintering, and resident birds were provided via shapefiles and/or tabular digital data for the following species and species groups: bald eagle, wading birds, beach nesting birds, breeding colonies, waterfowl, American oystercatcher, and piping and snowy plover. Source information is provided below and in the accompanying data tables and metadata. Point and polygon data were mostly displayed as it was received from the data providers. Processing methods for data sets that required additional processing are below. Data sets were supplemented with information provided in hardcopy documents and by local resource experts. In particular, USFWS, TPWD, and Texas State University staff provided additional insight on current species distributions and seasonalities based on their recent field observations.

Waterfowl – USFWS monthly waterfowl survey data from NWRs were displayed in individual survey areas within the NWRs. Concentrations of species were reported by order of magnitude and were taken from the maximum count of each species observed in each area. Reported seasonalities consist of the months each species was present in the study area based on the NWR survey data. TPWD goose survey data points were mapped as small buffered polygons around point locations. Goose concentrations were reported as order of magnitude of counts, where available.

Colonial waterbirds – Nesting survey data from the Texas Colonial Waterbird Society from 2002-2011 were displayed. Active colonies were mapped, and all species observed at each nest were reported. Concentrations consist of the range of pairs of each species observed at each point across all years. Some non-nesting species were opportunitistically surveyed if they occurred in the nesting area. The concentrations of these species were listed as individuals rather than pairs.

Piping plover – Piping plover survey data were compiled and mapped from the following sources: TXNDD element occurrences, Gulf Coast Bird Observatory monthly surveys (Jan 2008 to Jan 2009), TPWD piping plover bay surveys (2011), TGLO and TPWD priority protection areas, 2006 and 2011 International Piping Plover Censuses, and expert knowledge. The concentrations displayed on the tables and in the database for each polygon consist of the maximum number of individuals from all surveys observed in each area. Piping plover areas that had no specific count data were mapped with no concentration information. Piping plover areas that had a single occurrence of one individual in one dataset but were not corroborated as piping plover areas in any other sources, were mapped as "potential" piping plover areas. USFWS piping plover critical habitat beaches with no individuals observed in any surveys were also mapped as "potential" piping plover areas.

Please note that locations of nesting, wintering, and/or migratory sites, species composition within a given point or polygon, and particularly concentration values, are based on a compilation of observations made over a multi-year period and are not meant to accurately reflect 'current' conditions in the case of an event. Survey limitations and adjustments in protocols over numerous years, changes in shoreline geomorphology (particularly on small/ephemeral islands), weather, and numerous other ecological factors contribute to the condition of nesting colonies, solitary nest locations, and migratory or other concentrations at any given time. Also, please note that concentrations vary throughout the multi-month nesting, migratory, and wintering period listed in the seasonality table. Please contact local resource experts in the event of a spill or if data are to be used for any reason other than spill preparedness or response.

Expert contacts for upper Texas coast birds* are:

Name	Agency	City	Phone	Species
Donna Anderson	USFWS	Houston	281/286-8282	Colonial waterbirds
Clay Green	Texas State Univ.	San Marcos	512/245-8037	American oyster-catcher
Fred Roetker	USFWS	Lafayette, LA	337/291-3090	Redhead
Jennifer Wilson	USFWS	Brazoria	979/964-4011	Upper Texas coast species
Brent Ortego	TPWD	Victoria	361/576-0022	Upper Texas coast species
Mike Rezsutek	TPWD	Port Arthur	409/736-2551	Waterfowl
Patrick Walther	USFWS	Anahuac	409/267-3337	Waterfowl
Jarrett (Woody) Woodrow	USFWS – Coastal Program	Houston	281/286-8282	Upper TX coast species
Amy Turner	TPWD	Victoria	361/576-0022	Birds
Kevin Hartke	TPWD	Richmond	281/232-9707	Waterfowl
Amanda Hackney	Audubon Texas	Texas City	409/941-9114	Birds

***Note: this list is not meant to represent all bird experts for the region.**

Major Data Sources Used: Birds

eBird. 2012. eBird: An online database of bird distribution and abundance [web application]. eBird, Ithaca, NY. www.ebird.org.

Eubanks, T. L., R. A. Behrstock, and R. J. Weeks. 2006. Birdlife of Houston, Galveston, and the Upper Texas Coast. Texas A&M University Press, College Station, TX. 287 pp.

Gulf Coast Bird Observatory. 2009. Piping plover monthly observation point data: January 2008 – January 2009, vector digital data.

NOAA and Texas General Land Office (TGLO). 1996. Upper coast of Texas: Oil spill planning and response atlas.

Ortego, B. and M. Ealy. 2010. 2009 Winter Texas Gulf Coast aerial shorebird survey. Bulletin of the Texas Ornithological Society 43: 1-10.

Texas Colonial Waterbird Society and United States Fish and Wildlife Service (USFWS). 2012. Texas Colonial Waterbird Survey 2002-2011, tabular digital data.

Texas General Land Office (TGLO) and Texas Parks and Wildlife Department (TPWD). 1995. Priority protection areas, vector digital data.

Texas Natural Diversity Database. 2012. Element occurrence representation polygon data layer, vector digital data.

TPWD. 2012. BU Site 1 (Tom Jackson Marsh), vector digital data.

TPWD. 2006. Data from the 2006 International Piping Plover Census, Google Earth .kmz file.

TPWD. 2011. Data from the 2011 International Piping Plover Census, central Texas coast, Google Earth .kmz file.

TPWD. 2012. Goose survey data, central Texas coast: 2008-2012, vector digital data.

TPWD. 2011. Goose survey data, upper Texas coast: 2008-2011, vector digital data.

TPWD. 2012. JD Murphree WMA mottled duck site, vector digital data.

TPWD. 2012. Locations of upper Texas bald eagle nests, Google Earth .kmz file.

TPWD. 2011. Piping plover bay surveys 2011, Google Earth .kmz file.

TPWD. 2012. Wildlife Fact Sheets. www.tpwd.state.tx.us/huntwild/wild/species.

Texas State University. 2012. American oystercatcher nest locations 2011-2012, tabular digital data.

USFWS. 2006. Texas coastal duck survey 2000-2006, tabular digital data.

USFWS. 2010. Gulf Coast redhead survey: January 2010. 2 pp.

USFWS. Piping plover critical habitat, vector digital data.

REPTILES

Reptiles and amphibians depicted in this atlas include threatened and endangered species and coastal species of ecological concern.

Sea turtles – Green (FT/ST), hawksbill (FE/SE), Kemp's ridley (FE/SE), and loggerhead (FT/ST) sea turtles were included in this atlas. Both nesting and in-water presence polygons are displayed.

Nesting: Kemp's ridley sea turtles are the most common nesting sea turtle species on the upper Texas coast, but the number of observed nests are small compared to those recorded for the lower coast and Mexico. In particular, the nesting beach at Rancho Nuevo, Tamaulipas, Mexico is the primary nesting site for these turtles and is the only known major nesting beach for this species in the world. A secondary nesting population has been established on Padre Island National Seashore (south of the study area for this atlas). Kemp's ridley nests are mapped on Galveston Island (7-15 nests per season), Surfside Beach (3-5 nests per season), East Matagorda Bay beaches (1-2 nests), and Bolivar Peninsula (0-6 nests) and are based on observances made by the NPS and anecdotal information provided by A. Landry (retired, Texas A&M Marine Biology Department). Loggerhead sea turtles may be nesting on Bolivar Peninsula and Quintana beach (0-1 nests).

In-water:

- Non-adult and adult Kemp's ridley sea turtles commonly occur in upper Texas coast Gulf of Mexico waters from April through November. Non-adult Kemp's are also common in bays, rivers, and other saline and estuarine waters (not present in fresh waters) during April through November.
- Non-adult green turtles may be present in bays, particularly those with seagrass habitats (East Matagorda Bay and West Bay). Non-adult green turtles may also be present, occasionally, from March-November in the Gulf of Mexico.
- Loggerhead turtles (non-adults) may be present occasionally in nearshore and offshore waters of the Gulf of Mexico throughout the year.
- Non-adult hawksbills occur ocassionally in Gulf of Mexico waters of the upper Texas coast from March to October.
- Leatherback turtles may be encountered in waters offshore of the upper Texas coast study area, and therefore are not mapped in this atlas.

Other reptiles/amphibians – Diamondback terrapin, gulf salt marsh snake, and Houston toad (FE/SE) were also mapped in this atlas. Information on terrapin and snake distributions were provided by local resource experts and are mapped in general areas which are based on habitat types (estuarine waters/salt marshes). The Houston toad records were provided by the Texas Natural Diversity Database.

Expert contacts for upper Texas coast reptiles* are:

Name	Agency	City	Phone	Species
Donna Shaver	NPS	Corpus Christi	361/949 -8173 X226	Sea turtles
Andy Landry (retired)	TAMU	Galveston		Sea turtles
Jarrett (Woody) Woodrow	USFWS	Houston	281/286 -8282	Upper TX coastal species

***Note: this list is not meant to represent all reptile experts for the region.**

Major Data Sources Used: Reptiles

NPS. 2012. Sea turtle nests, Texas coast 2011-2012, Google Maps map file online.

Seney, E.E. and A.M. Landry Jr. 2011. Movement patterns of immature and adult female Kemp's ridley sea turtles in the northwestern Gulf of Mexico. Marine Ecology Progress Series 44: 241-254.

TGLO and TPWD. 1995. Priority protection areas, vector digital data.

Texas Natural Diversity Database. 2012. Element occurrence representation polygon data layer, vector digital data.

TPWD. 2012. Wildlife Fact Sheets. www.tpwd.state.tx.us/huntwild/wild/species.

TERRESTRIAL MAMMALS

The following terrestrial mammals were included in this atlas: muskrat, northern river otter, and swamp rabbit. Data were provided by TPWD, TGLO, and USFWS and consisted primarily of expert knowledge. Northern river otter were mapped throughout the atlas in freshwater and coastal marine habitats where they are likely to occur, including lakes, rivers, inland wetlands, coastal shorelines, marshes, and estuaries.

Expert contacts for upper Texas coast terrestrial mammals* are:

Name	Agency	City	Phone	Species
Jarrett (Woody) Woodrow	USFWS	Houston	281/286 -8282	Upper TX coast species
Mike Rezsutek	TPWD	Port Arthur	409/736 -2551	Upper TX coast species

***Note: this list is not meant to represent all terrestrial mammal experts for the region.**

Major Data Sources Used: Terrestrial Mammals

TGLO and TPWD. 1995. Priority protection areas, vector digital data.

TPWD. 2012. BU Site 1 (Tom Jackson Marsh), vector digital data.

FISH

Fish species depicted in this atlas include selected marine, estuarine, and brackish/fresh water species. Species of conservation interest, commercial or recreational importance, or ecological importance are emphasized. Fish polygons were created based on survey information, digital data, hardcopy reports (see references), and expert opinion provided by resource experts at TPWD and TGLO.

Texas coastal waters are within the historical range of smalltooth sawfish (FE) and largetooth sawfish (FE); however, both were omitted from the ESI atlas because they are extremely rare. Smalltooth sawfish have not been recorded in TPWD's sampling programs since the 1980s, and the last recorded sighting of a largetooth sawfish in Texas waters occurred in 1961.

The major source of information used to map fish in the upper Texas coast was the fishery independent monitoring dataset provided by TPWD. Data from trawl, gill net, and bag seine surveys were provided for bays and inland waters, and data from trawl and beach seine surveys were provided for Gulf of Mexico waters. For each sampling point, TPWD provided the location, date, and catch per unit effort (CPUE) for selected species. For estuarine waters, all available years of sampling data (1975-2011) were used, and for the Gulf of Mexico, the last 10 full years of data were requested.

Sampling data were aggregated by water body to create polygons for use in the ESI fish and invertebrate layers. Water bodies were defined by TPWD to fit the scale of the project. Average CPUE by month by water body was calculated and used to derive a categorical abundance for each species in each water body. To create concentrations, species were classified into groups according to their catchability by each gear type (demersal fishes, small/shallow fishes, pelagic fishes). Within each group, maximum and average CPUE was used to define ranges for the categorical abundance. ESI concentrations used include 'RARE', 'COMMON', 'ABUNDANT' or 'HIGHLY ABUNDANT', listed in order from lowest to highest abundance. If a species was caught in more than one gear type in a water body and abundance categories conflicted, preference was given to the gear that was more likely to sample juveniles or that more adequately sampled the species.

Seasonality information was based on the TPWD sampling data where possible. To create monthly seasonality, occurrence rates were calculated for each species by water body, gear, and month. Species were marked present if they were caught in greater than 10% of the samples collected in a water body in a month. Life history information was inferred from different gear types by comparing the average lengths of animals for each species caught in each gear type to published lengths at maturity. Information on seasonality and/or life history was supplemented by anecdotal information and other sources, such as the Estuarine Living Marine Resources (ELMR) database. The ELMR database is organized by salinity zone and bay system (Sabine, Galveston, Brazos River, and Matagorda). Seasonality and concentration information based on the ELMR data was assigned to the ESI water bodies that most closely matched the spatial extent of the ELMR data. Sources for all records are documented in the sources table in the digital data.

Concentration and seasonality information was reviewed by TPWD and adjusted in some cases to be consistent with expert opinion. Please note, many species can be found in the estuary year-round but are significantly less common in the winter months. Where possible, seasonality and concentration information represents months in which a particular species is most likely to be encountered instead of all months a species could potentially be found in a location.

Shark species mapped in upper Texas coast waters include Atlantic sharpnose shark, blacktip shark, finetooth shark, bonnethead shark, bull shark, and spinner shark. NMFS Essential Fish Habitat polygons were used as a guide for mapping these species. Blacktip, bull, and bonnethead shark polygons were refined based on published information indicating salinity tolerances and the presence of nursery areas in the upper Texas coast. Life-history stages for sharks do not match the standard ESI life-history stages for fish and should be interpreted as follows: spawning = parturition; eggs = neonate; larvae = young of year.

Other game species were mapped based on information provided by TWPD. Tarpon abundance is steadily increasing along the upper Texas coast. Information on tarpon distribution was provided by TPWD and is based on data collected for the tarpon observation network. Alligator gar and striped bass are also popular game species; information on their abundance and distribution in the Trinity River system was provided by TPWD inland fisheries.

Areas of high concentration for spawning or other life stages were identified by TPWD for gray snapper, red drum, black drum, southern flounder, spot, and spotted seatrout. Seahorses and blennies were mapped to their respective habitats (seagrass and jetties) in geographic areas where they are known to exist. Striped mullet are mapped to nearshore beaches in high concentrations for specific times of the year.

Expert contacts for upper Texas coast fish* are:

Name	Agency	City	Phone	Species/ Programs
Bill Balboa	TPWD	Dickinson	281/534 -0110	Galveston Bay ecosystem
David Buckmeier	TPWD	Mountain Home	830/866 -3356	Heart of the Hills Fisheries Science Center
Jennifer Butler	TPWD	Lake Jackson	979/292 -0100	Hatchery Biologist
Winston Denton	TPWD	Dickinson	281/534 -1040	Spills and kills
Jerry Mambretti	TPWD	Port Arthur	409/983 -1104	Sabine Lake ecosystem
Art Morris	TPWD	Corpus Christi	361/ 825-3356	Coastal fisheries
Lance Robinson	TPWD	Dickinson	281/534 -0101	Coastal fisheries
Mike Stahl	TPWD	Dickinson	281-534-0110	Coastal fisheries
Terry Stelly	TPWD	Port Arthur	409-983-1104	Sabine Lake Ecosystem
Glen Sutton	TPWD	Dickinson	281-534-0105	Coastal fisheries
Jim Tolan	TPWD	Corpus Christi	361-825-3247	Coastal fisheries
Brian Van Zee	TPWD	Waco	254/ 867-7974	Inland fisheries

***Note: this list is not meant to represent all fish experts for the region.**

Major Data Sources Used: Fish

Buckmeier, D.L., N.G. Smith, and D.J. Daugherty. 2011. Alligator gar movement and microhabitat use in the lower Trinity River, Texas (draft report). TPWD, Heart of the Hills Fisheries Science Center, Mountain Home, TX.

Froeschke, J. 2010. Defining essential fish habitat: the influence of life history, biotic and abiotic factors (Doctoral dissertation). Texas A&M University, Corpus Christi, TX.

NOAA Center for Coastal Monitoring and Assessment. 2000. Estuarine Living Marine Resources Database, vector digital and tabular data.

NMFS Office of Sustainable Fisheries. 2009. Essential Fish Habitat Polygons for Highly Migratory Species, vector digital data.

Pattillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco. 1997. Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries, Vol. II: Species life history summaries. ELMR Rep. No. 11. NOAA/NOS SEA Division, Silver Spring, MD. 377 pp.

TPWD. 2012. Fishery independent sampling database – bag seine, trawl and gill net sampling data, tabular digital data.

TPWD. 1995. Intracoastal waterway trawl survey dataset, tabular digital data.

TPWD. 2012. Gulf of Mexico trawl sampling data, tabular digital data.

INVERTEBRATES

Invertebrates depicted in this atlas include selected marine and estuarine species of commercial, ecological, and/or conservation interest.

Information on shrimp, crab and squid species was compiled using the Texas fishery independent monitoring datasets described in the 'fish' section. The list of species was based on the top ten invertebrates caught in each gear type; however, some less common species were deleted. Methods used to incorporate the data into the ESI are similar to 'fish' and are summarized below.

For each gear type, sampling data points were aggregated by water body. Average CPUE by month by water body was calculated and used to derive a categorical abundance for each species in each water body. Maximum and average monthly CPUE was used to define ranges for the categorical abundance for each species. ESI concentrations used include 'RARE', 'COMMON', 'ABUNDANT' or 'HIGHLY ABUNDANT', listed in order from lowest to highest abundance. Shrimp species were grouped together when determining categories so that concentrations are comparable among shrimp species. All other species were evaluated separately. If a species was caught in more than one gear type in a water body and abundance categories conflicted, preference was given to the higher abundance.

Seasonality information was based on the TPWD sampling data where possible. To create monthly seasonality, occurrence rates were calculated for each species by water body, gear and month. Species were marked present if they were caught in greater than 10% of the samples collected in a water body in a month. Life history information was inferred from different gear types based on the life stages that would be caught by that gear type. Information on seasonality and/or life history was supplemented by anecdotal information and other sources, such as the ELMR database. The ELMR database is organized by salinity zone and bay system (Sabine, Galveston, Brazos River, and Matagorda). Seasonality and concentration information based on the ELMR data was assigned to the ESI water bodies that most closely matched the spatial extent of the ELMR data. Sources for all records are documented in the sources table in the digital data.

Concentration and seasonality information was reviewed by TPWD and adjusted in some cases to be consistent with expert opinion. Please note that seasonality and concentration information is intended to represent months in which a particular species is most likely to be encountered instead of all months a species could potentially be found in a location. Also note that blue crabs can spawn year-round; however, the majority of spawning occurs in May and July. Information on blue crab seasonality was taken from the ELMR database and adjusted to include May and July throughout the atlas.

Other areas mapped for invertebrates include beach invertebrates, which were mapped to sand beaches within the study area, and inlet polygons for brown and white shrimp, which depict periods of high concentrations of juveniles migrating to spawning grounds in the Gulf of Mexico and larvae migrating into estuarine nursery habitats.

Oysters – The Eastern oyster is abundant in upper Texas coastal waters. Galveston Bay has extensive oyster reefs that have persisted for decades. Oysters were mapped based on a combination of dredge sampling data, known reef and oyster lease locations, as well as anecdotal information from TPWD. Concentrations of oysters mapped in the ESI are categorized as 'REEF', which identifies consolidated and relatively permanent oyster reef structures; 'UNCONSOLIDATED', which delineates areas with patchy but significant settlements of oyster communities; 'HIGH', for areas that have high catches of oysters in dredge sampling surveys, but where reef structure was unknown; and 'LOW', for groupings of dredge points with positive catches and where reef structure was unknown. In addition, some water bodies that are unmapped and not sampled but are known to support oysters have been added with a concentration of 'PRESENT'. Please note that oysters can be present throughout shallow estuarine areas in the upper Texas coast; not all areas with oysters can be mapped. However, every effort was made to include significant reef areas.

Delineated oyster reef polygons were available for some portions of Matagorda Bay, East Matagorda Bay, and Sabine Lake. Concentrations assigned to these polygons were based on the information provided with the dataset or anecdotal information provided by TPWD. Oyster leases and mitigation sites were mapped as oyster reefs based on anecdotal information from TPWD indicating that these sites support significant oyster populations. Other sources of reef information include the wetlands layer provided by the Harte Research Institute (HRI). Areas with 'RF2' in the habitat were selected and included as oyster reef. Some polygons were too small to show up on the map, thus a buffer was applied to make them more visible.

Dredge sampling data were provided by TPWD in the form of point observations with associated catch per unit effort (CPUE). Samples from 2000-2011 were examined to provide guidance in mapping oyster reefs in Sabine Lake, Matagorda Bay, and the Galveston Bay system (East, West, Galveston, and Trinity Bays). Areas included based on dredge sampling were assigned a concentration of 'HIGH' or 'LOW' based on the CPUE associated with the points, with 'HIGH' concentration areas having clusters of points with a CPUE greater than 5,000 and 'LOW' concentration areas having a CPUE between 0 and 5,000.

In the Galveston Bay system, information on reef and unconsolidated areas was based on the USGS (1996) dataset. Some modifications were made to update the data and make the product more aesthetically pleasing. Polygons were smoothed and small remote areas were removed to reduce clutter. Areas that no longer support oyster populations, as evidenced by samples with zero catch in the dredge data or anecdotal information by TPWD, were removed from the extent of the USGS 1996 dataset. Datasets were also clipped to exclude updated shipping channels in Galveston Bay, because the shipping lanes are too deep to support oyster populations. For the Galveston Bay system, all oyster polygons with a concentration of 'REEF' are attributed to the same source (TPWD), because the original datasets were modified by input from TPWD.

Oyster reef polygons are shown in the benthic layer in addition to the invertebrate layer. Seasonality and life-history information for eastern oyster remains in the invertebrate layer.

Expert contacts for upper Texas coast invertebrates* are:

Name	Agency	City	Phone	Species/ Program
Bill Balboa	TPWD	Dickinson	281/534 -0110	Galveston Bay ecosystem
Lance Robinson	TPWD	Dickinson	281/534 -0101	Coastal fisheries
Bill Rodney	TOWD	Dickinson	281/534 -0127	Oyster habitat

***Note: this list is not meant to represent all invert experts for the region. Several of the fish experts also contributed information on invertebrates.**

Major Data Sources Used: Invertebrates

Biowest et al. 2007. Matagorda Bay oysters from National Coastal Data Development Center, vector digital data.

NOAA Center for Coastal Monitoring and Assessment. 2000. Estuarine Living Marine Resources Database, vector digital and tabular data.

Rothchild, S.B. 2004. Beachcombers guide to Gulf Coast Marine Life. Taylor Trade Publishing. Lanham, MD.

TGLO. 2004. Oysters, Corpus Christi-Matagorda Bay, vector digital data.

TGLO. 2004. Texas oyster lease locations, vector digital data.

TPWD. 2008. Sabine Lake oyster reef and unconsolidated oyster areas, vector digital data.

TPWD. 2012. Oyster dredge sampling data, tabular digital data.

TPWD. 2012. U.S. Army Corps of Engineers mitigation reef pad sites, vector digital data.

Texas A&M University. 2011. Texas oysters 2011, vector digital data.

USGS et al. 1996. Oysters, Northern Gulf of Mexico Ecoregional Plan, U.S. Geological Survey, vector digital data.

BENTHIC HABITATS

Benthic habitats mapped in the ESI include seagrass and oyster reefs. Two concentrations of seagrass are included in the ESI. TPWD provided a layer of seagrass beds in the state, consisting of the most recent surveys, dating from 1998 to 2007. Additional information was provided from the HRI wetlands layer, from which all habitats containing 'AB3' were selected and mapped as seagrass. These sources are both depicted with a more continuous seagrass pattern on the maps, but were not assigned a concentration in the digital data. Anecdotal information from TPWD indicated that additional areas in West Bay support areas of patchy seagrass that have been expanding in recent years. These areas were added to the ESI with a concentration of 'PATCHY', and are displayed in the atlas with a less dense pattern than the 'CONTINUOUS' seagrass areas.

Oyster reefs are shown in the benthic layer with a species of 'REEF'. This information is identical to areas in the invertebrate layer with a species of 'Eastern oyster' and concentration of 'REEF'. Please note, the invertebrate layer has information on additional areas of oysters with different concentrations, and contains the corresponding seasonality for oysters.

Expert contacts for upper Texas coast benthic habitats* are:

Name	Agency	City	Phone	Species/ Program
Bill Balboa	TPWD	Dickinson	281/534 -0110	Galveston Bay eco-system
Winston Denton	TPWD	Dickinson	281/534 -1040	Spills and kills
Lance Robinson	TPWD	Dickinson	281/534 -0101	Coastal fisheries
Bill Rodney	TPWD	Dickinson	281/534 -0127	Oyster habitat
Jamie Schubert	NOAA	Galveston	409/621 -1248	Seagrass

***Note: this list is not meant to represent all benthic habitat experts for the region.**

Major Data Sources Used: Benthic Habitats

Biowest et al. 2007. Matagorda Bay oysters from National Coastal Data Development Center, vector digital data.

USGS et al. 1996. Oysters, Northern Gulf of Mexico Ecoregional Plan, U.S. Geological Survey, vector digital data.

TGLO. 2004. Oysters, Corpus Christi-Matagorda Bay, vector digital data.

TGLO. 2004. Texas oyster lease locations, vector digital data.

TPWD. 2008. Sabine Lake oyster reef and unconsolidated oyster areas, vector digital data.

TPWD. 2012. Oyster dredge sampling data, tabular digital data.

TPWD. 2012. Texas seagrass, vector digital data.

TPWD. 2012. U.S. Army Corps of Engineers mitigation reef pad sites, vector digital data.

HABITATS

Plants – An occurrence of the Texas prairie dawn (*Hymenoxys texana*, FE/SE) fell within the study area and was included on one map. Data were provided by TXNDD.

Major Data Sources Used: Habitats

Texas Natural Diversity Database. 2012. Element occurrence representation polygon data layer, vector digital data.

HUMAN-USE RESOURCES

Management areas such as wildlife refuges and state parks are mapped as polygons. Where the feature is a known point location (e.g., marinas, airports, water intakes), the specific location is displayed.

A human use number (HUN#) can be found in the accompanying data tables for each point and polygonal feature mapped. The HUN# may provide more information (i.e., name, contact) for that particular resource. The types of human use resources mapped in this atlas are depicted below.

Access	Management Area
Airport/Heliport	Marina
Aquaculture	Nature Conservancy
Artificial Reef	Park
Boat Ramp	Water Intake
Coast Guard	Wildlife Refuge
Critical Habitat	Management Area Boundary
Historical Site	State Boundary
Lock/Dam	

Access Site: Beach access sites were provided as a shapefile by TGLO.

Airport / Heliport: Information on the locations of airports and heliports was downloaded from the National Transportation Atlas Databases maintained by the FAA.

Aquaculture Site: Locations of aquaculture sites. The data were provided by TGLO and cross-referenced with more recent information from the Texas Aquaculture Association. Oyster lease locations were provided as a polygonal shapefile by TGLO and were also included in the management layer as aquaculture sites.

Artificial Reef: Locations of artificial reefs were provided by TGLO. There was only one in the upper Texas coast area mapped.

Boat Ramp: Locations of boat ramps were provided by TGLO, TPWD, and Hook-n-Line, Inc. Information was cross-referenced using Google Earth.

Coast Guard: Locations of U.S. Coast Guard Stations that fell within the area of interest were provided as a point shapefile by TGLO and updated with anecdotal information from TPWD.

Critical Habitat: USFWS Critical Habitat was mapped for piping plover. The data were downloaded from the USFWS Critical Habitat Portal.

Historical site: State historical site and national register site data were provided by the Texas Historical Commission. Only sites that could potentially be affected by a spill (adjacent to water) were mapped.

Locks and dams: Information on lock and dam locations was obtained from the USGS National Hydrography Dataset and supplemented by anecdotal knowledge from U.S. Army Corps of Engineers staff.

Management Area: Locations of coastal preserves, wildlife management areas, Audubon preserves, and other management area boundaries. This information was provided as multiple digital polygon shapefiles from TPWD and TGLO.

Marina: Locations of marinas. This information was provided as a point shapefile from TGLO and supplemented with information from Hook-n-Line fishing maps and Google Earth. Efforts were made to eliminate marinas that are no longer in service.

Nature Conservancy: Boundaries of The Nature Conservancy properties. The data were provided by The Nature Conservancy through TGLO.

State Parks: Locations of State Park lands. These data were provided by TPWD.

Water Intake: Locations of surface water intakes. This information was provided as a point shapefile from TCEQ.

Wildlife Refuge: Locations of National Wildlife Refuges. These data were provided by the USFWS.

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 that details the data dictionary, processing techniques, data lineage, and other descriptive information for the digital datasets 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 or colored lines on the shoreline. These multiple classifications are represented 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, marshes (ESI=10A, ESI=10B), swamps (ESI=10C), and scrub-shrub wetlands (ESI=10D) are also stored as polygons.

SENSITIVE BIOLOGICAL RESOURCES

Biological resources are stored as points and polygons. Associated with each feature is a unique identification number that 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 points or polygons. The resource name, the owner/manager, a contact person, and phone number are included in the database for management areas, and socio-economic points when available. All metadata sources are documented at the feature level.

ACKNOWLEDGMENTS

This project was funded by the NOAA Office of Response and Restoration, Emergency Response Division and Texas General Land Office. Steve Buschang (TGLO), and Andy Tirpak (TPWD) assisted greatly in all aspects of the project's completion.

The biological and human-use data included on the maps were provided by numerous individuals and agencies, including: TPWD, TGLO, USFWS, NPS, TXNDD, USGS, NMFS, NOAA, TAMU, and Texas State University. Staff at these agencies contributed a vast amount of information to this effort, including first-hand expertise, publications, maps, and digital data. Shoreline habitat mapping was conducted by James Gibeaut, Alistair Lord, Karen Meinstein, William Nichols, and Boris Radosavljevic of the Texas A&M University – Corpus Christi, Harte Research Institute for Gulf of Mexico Studies.

At Research Planning, Inc. (RPI) of Columbia, South Carolina, numerous scientific, GIS, and graphic staff were involved with different phases of the project. Mark White, GIS Director, was Project Manager. The biological and human-use data were collected and compiled onto base maps by Christine Boring, Jennifer Weaver, Lauren Szathmary, and Lincoln Smith. Lee Diveley, Katy Beckham, Jeff Dahlin, Bryan Thom, and Chris Locke entered, processed, and produced the GIS data. Joe Holmes and Wendy Early produced the final documents.

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 <u>not</u> be used in place of data held by TPWD, TGLO, USFWS, NPS, TXNDD, USGS, NMFS, TAMU, Texas State University 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

BIRDS

Common Name*	Scientific Name*
DIVING	
American white pelican	*Pelecanus erythrorhynchos*
Anhinga	*Anhinga anhinga*
Brown pelican	*Pelecanus occidentalis*
Common loon	*Gavia immer*
Cormorants	*Phalacrocorax* spp.
Diving birds	-
Double-crested cormorant	*Phalacrocorax auritus*
Grebes	-
Loons	*Gavia* spp.
Neotropic cormorant	*Phalacrocorax brasilianus*
Pelicans	*Pelecanus* spp.
GULL/TERN	
Black skimmer	*Rynchops niger*
Caspian tern	*Hydroprogne caspia*
Forster's tern	*Sterna forsteri*
Gull-billed tern	*Gelochelidon nilotica*
Gulls	-
Laughing gull	*Larus atricilla*
Least tern	*Sternula antillarum*
Royal tern	*Thalasseus maximus*
Sandwich tern	*Thalasseus sandvicensis*
Terns	-
LANDFOWL	
Attwater's greater prairie chicken	*Tympanuchus cupido attwateri*
PASSERINE	
Migratory songbirds	-
Seaside sparrow	*Ammodramus maritimus*
Swamp sparrow	*Melospiza georgiana*
PELAGIC	
Magnificent frigatebird	*Fregata magnificens*
Masked booby	*Sula dactylatra*
Northern gannet	*Morus bassanus*
Shearwaters	-
Storm-petrels	*Oceanodroma* spp.
RAPTOR	
Aplomado falcon	*Falco femoralis*
Bald eagle	*Haliaeetus leucocephalus*
Merlin	*Falco columbarius*
Northern harrier	*Circus cyaneus*
Osprey	*Pandion haliaetus*
Peregrine falcon	*Falco peregrinus*
Raptors	-
White-tailed hawk	*Buteo albicaudatus*
White-tailed kite	*Elanus leucurus*
SHOREBIRD	
American avocet	*Recurvirostra americana*
American oystercatcher	*Haematopus palliatus*
Black-bellied plover	*Pluvialis squatarola*
Black-necked stilt	*Himantopus mexicanus*
Dowitchers	*Limnodromus* spp.
Dunlin	*Calidris alpina*
Killdeer	*Charadrius vociferus*
Long-billed curlew	*Numenius americanus*
Marbled godwit	*Limosa fedoa*
Piping plover	*Charadrius melodus*
Plovers	*Charadrius* spp.
Red knot	*Calidris canutus*
Ruddy turnstone	*Arenaria interpres*
Sanderling	*Calidris alba*
Shorebirds	-
Short-billed dowitcher	*Limnodromus griseus*
Snowy plover	*Charadrius alexandrinus*
Western sandpiper	*Calidris mauri*
Whimbrel	*Numenius phaeopus*
Willet	*Catoptrophorus semipalmatus*
Wilson's plover	*Charadrius wilsonia*
Yellowlegs	*Tringa* spp.
WADING	
American bittern	*Botaurus lentiginosus*
Black rail	*Laterallus jamaicensis*
Black-crowned night-heron	*Nycticorax nycticorax*
Cattle egret	*Bubulcus ibis*
Clapper rail	*Rallus longirostris*
Egrets	-
Great blue heron	*Ardea herodias*
Great egret	*Ardea alba*
Green heron	*Butorides virescens*
Herons	-
King rail	*Rallus elegans*
Little blue heron	*Egretta caerulea*
Marsh birds	-
Rails	-
Reddish egret	*Egretta rufescens*

BIRDS, cont.

Common Name*	Scientific Name*
WADING, cont.	
Reddish egret (white morph)	*Egretta rufescens*
Roseate spoonbill	*Ajaia ajaja*
Sandhill crane	*Grus canadensis*
Snowy egret	*Egretta thula*
Sora	*Porzana carolina*
Tricolored heron	*Egretta tricolor*
Wading birds	-
White ibis	*Eudocimus albus*
White-faced ibis	*Plegadis chihi*
Wood stork	*Mycteria americana*
Yellow rail	*Coturnicops noveboracensis*
Yellow-crowned night-heron	*Nyctanassa violacea*
WATERFOWL	
American coot	*Fulica americana*
American wigeon	*Anas americana*
Black-bellied whistling-duck	*Dendrocygna autumnalis*
Blue-winged teal	*Anas discors*
Bufflehead	*Bucephala albeola*
Canada goose	*Branta canadensis*
Canvasback	*Aythya valisineria*
Common goldeneye	*Bucephala clangula*
Common moorhen	*Gallinula chloropus*
Dabbling ducks	-
Diving ducks	-
Ducks	-
Fulvous whistling-duck	*Dendrocygna bicolor*
Gadwall	*Anas strepera*
Geese	-
Greater scaup	*Aythya marila*
Greater white-fronted goose	*Anser albifrons*
Green-winged teal	*Anas crecca*
Lesser scaup	*Aythya affinis*
Mallard	*Anas platyrhynchos*
Mottled duck	*Anas fulvigula*
Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Purple gallinule	*Porphyrula martinica*
Redhead	*Aythya americana*
Ring-necked duck	*Aythya collaris*
Ross's goose	*Chen rossii*
Ruddy duck	*Oxyura jamaicensis*
Scaup	*Aythya* spp.
Scoters	*Melanitta* spp.
Snow goose	*Chen caerulescens*
Waterfowl	-
Wood duck	*Aix sponsa*

FISH

FISH	
Alligator gar	*Lepisosteus spatula*
Atlantic bumper	*Chloroscombrus chrysurus*
Atlantic croaker	*Micropogonias undulatus*
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*
Atlantic spadefish	*Chaetodipterus faber*
Atlantic tripletail	*Lobotes surinamensis*
Banded drum	*Larimus fasciatus*
Bay anchovy	*Anchoa mitchilli*
Bay whiff	*Citharichthys spilopterus*
Black drum	*Pogonias cromis*
Blackfin tuna	*Thunnus atlanticus*
Blacktip shark	*Carcharhinus limbatus*
Blennies	-
Blue catfish	*Ictalurus furcatus*
Bonnethead shark	*Sphyrna tiburo*
Bull shark	*Carcharhinus leucas*
Cobia	*Rachycentron canadum*
Common snook	*Centropomus undecimalis*
Crevalle jack	*Caranx hippos*
Dwarf seahorse	*Hippocampus zosterae*
Finetooth shark	*Carcharhinus isodon*
Florida pompano	*Trachinotus carolinus*
Gafftopsail catfish	*Bagre marinus*
Gizzard shad	*Dorosoma cepedianum*
Gray snapper	*Lutjanus griseus*
Gray triggerfish	*Balistes capriscus*
Greater amberjack	*Seriola dumerili*
Gulf butterfish	*Peprilus burti*
Gulf killifish	*Fundulus grandis*
Gulf menhaden	*Brevoortia patronus*
Hardhead catfish	*Arius felis*
King mackerel	*Scomberomorus cavalla*
Lane snapper	*Lutjanus synagris*
Longnose gar	*Lepisosteus osseus*
Pinfish	*Lagodon rhomboides*
Rainwater killifish	*Lucania parva*
Red drum	*Sciaenops ocellatus*
Red snapper	*Lutjanus campechanus*
Sailfin molly	*Poecilia latipinna*
Sand seatrout	*Cynoscion arenarius*
Sheepshead	*Archosargus probatocephalus*

Common Name*	Scientific Name*

FISH, cont.

FISH, cont.	
Silver perch	*Bairdiella chrysoura*
Silver seatrout	*Cynoscion nothus*
Silversides	-
Smallmouth buffalo	*Ictiobus bubalus*
Southern flounder	*Paralichthys lethostigma*
Southern kingfish	*Menticirrhus americanus*
Spanish mackerel	*Scomberomorus maculatus*
Spinner shark	*Carcharhinus brevipinna*
Spot	*Leiostomus xanthurus*
Spotfin mojarra	*Eucinostomus argenteus*
Spotted gar	*Lepisosteus oculatus*
Spotted seatrout	*Cynoscion nebulosus*
Star drum	*Stellifer lanceolatus*
Striped bass	*Morone saxatilis*
Striped mullet	*Mugil cephalus*
Tarpon	*Megalops atlanticus*
White mullet	*Mugil curema*

HABITATS

PLANT	
Texas prairie dawn	*Hymenoxys texana*
SAV	
Seagrass	-

INVERTEBRATES

BIVALVE	
Atlantic rangia	*Rangia cuneata*
Atlantic surfclam	*Spisula solidissima*
Eastern oyster	*Crassostrea virginica*
CEPHALOPOD	
Brief squid	*Lolliguncula brevis*
CRAB	
Atlantic ghost crab	*Ocypode quadrata*
Blue crab	*Callinectes sapidus*
Gulf stone crab	*Menippe adina*
Lesser blue crab	*Callinectes similis*
Mole crab	*Emerita portoricensis*
Speckled swimming crab	*Arenaeus cribrarius*
GASTROPOD	
Lettered olive	*Oliva sayana*
SHRIMP	
Atlantic seabob shrimp	*Xiphopenaeus kroyeri*
Brown shrimp	*Farfantepenaeus aztecus*
Grass shrimp	*Palaemonetes* spp.
White shrimp	*Litopenaeus setiferus*

MARINE MAMMALS

DOLPHIN	
Bottlenose dolphin	*Tursiops truncatus*
MANATEE	
West Indian manatee	*Trichechus manatus*

REPTILE

AMPHIBIAN	
Houston toad	*Anaxyrus houstonensis*
SNAKE	
Gulf salt marsh snake	*Nerodia clarkii clarkii*
TURTLE	
Diamondback terrapin	*Malaclemys terrapin*
Green sea turtle	*Chelonia mydas*
Hawksbill sea turtle	*Eretmochelys imbricata*
Kemp's ridley sea turtle	*Lepidochelys kempii*
Loggerhead sea turtle	*Caretta caretta*

TERRESTRIAL MAMMALS

SMALL MAMMAL	
Muskrat	*Ondatra zibethicus*
Northern river otter	*Lontra canadensis*
Swamp rabbit	*Sylvilagus aquaticus*

* Threatened and endangered species are designated by underlining

SHORELINE DESCRIPTIONS

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

DESCRIPTION

- These structures are solid, man-made structures such as seawalls, jetties, breakwaters, groins, revetments, piers, and port facilities
- Many structures are constructed of concrete, wood, or metal
- Often there is no exposed substrate at low tide, but multiple habitats are indicated if present
- They are built to protect the shore from erosion by waves, boat wakes, and currents, and thus are exposed to relatively high-energy processes
- Attached animals and plants are sparse to dense
- Present in highly developed industrial and port areas and scattered along residential waterfronts; Present along 95.8 miles, comprising 2.3% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Oil is held offshore by waves reflecting off the steep, hard surface in exposed settings
- Oil readily adheres to the dry, rough surfaces, but it does not adhere to wet substrates
- The most resistant oil would remain as a band at or above the high-tide line

RESPONSE CONSIDERATIONS

- Cleanup is usually not required
- High-pressure water spraying may be conducted to:
  - remove persistent oil in crevices;
  - minimize aesthetic damage; and
  - prevent chronic leaching of oil from the structure

EXPOSED SCARPS AND STEEP SLOPES IN CLAY — ESI = 2B

DESCRIPTION

- These habitats commonly are created by eroding bluffs that slump and are undercut by waves generated by both waves and boat wakes
- They may represent natural shoreline features or they may form along mounds and embankments of dredged material
- May be fronted by a narrow beach of fine- to medium-grained sand and/or shell fragments. Rapidly eroding bluffs have no beach and those where a major slump occurs may temporarily form a beach reworked from the slump material
- Low biological utilization because of strong currents and steep slopes
- Normally occur downwind of the prevailing winds where fetch across the bay and wave energy are greatest; Present along 240 miles, comprising 5.8% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Oil is not expected to adhere to the wet, impermeable, and vertical sediment surface
- There may be a thin band of oil left at or above the high water line

RESPONSE CONSIDERATIONS

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

- Access may be difficult
- The muddy substrate cannot support heavy equipment, and even foot traffic could disrupt the sediments and mix oil deeper.

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

DESCRIPTION

- These beaches are flat to moderately sloping and relatively hard packed; along the Gulf shore they are 50-100 m wide, whereas along bay shores they are ~15 m wide
- They are composed of predominantly quartz sand but also contain a small percentage of shell or shell hash
- There can be heavy accumulations of wrack present
- They are utilized by birds and turtles
- Upper beach fauna include ghost crabs and amphipods; lower beach fauna can be moderate, but highly variable
- They are generally areas of heavy recreational use
- They occur along most of the barrier islands and peninsulas on the Gulf shore, and are common along South Galveston Bay, East Bay, and large spoil islands of the Houston Ship Channel; Present along 124 miles, comprising 3.6% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Light oil accumulations will be deposited as oily swashes or bands along the upper intertidal zone
- Heavy oil accumulations will cover the entire beach surface; oil will be lifted off the lower beach with the rising tide
- Maximum penetration of oil into fine- to medium-grained sand is about 10-15 cm
- Burial of oiled layers by clean sand within the first week after a spill typically will be less than 30 cm along the upper beach face

- Organisms living in the beach sediment may be killed by smothering or lethal oil concentrations in the interstitial water
- Biological impacts include temporary declines in infauna, which can affect important shorebird foraging areas

RESPONSE CONSIDERATIONS

- These beaches are among the easiest shoreline types to clean
- Cleanup should concentrate on removing oil and oily debris from the upper swash zone once oil has come ashore

- Traffic through dune areas should be limited to prevent contamination of clean areas and disturbance of habitat and birds
- Manual cleanup is advised to minimize the volume of sand removed from the shore and requiring disposal, particularly for non-amenity beaches
- Mechanical sand sifters may be effective on oil in the form of tarballs and patties
- All efforts should focus on preventing the mixing of oil deeper into the sediments by vehicular and foot traffic
- Mechanical reworking of lightly oiled sediments from the high-tide line to the middle intertidal zone can be effective along outer beaches

SCARPS AND STEEP SLOPES IN SAND **ESI = 3B**

DESCRIPTION

- This shoreline type occurs where sandy bluffs are undercut by waves or currents and slump
- They normally form along embankments of sandy dredge-spoil material
- Some scarps are fronted by narrow beaches, if the erosion rates are moderate and episodic
- Trees growing at the top of these slopes are eventually undercut and logs can accumulate at the base of the scarp
- Biological utilization by birds and infauna is low
- Uncommon; Present along 27 miles, comprising 0.7% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Any stranded oil will concentrate at the high-water line and may penetrate sandy sediments
- Oil will also adhere to the dry surfaces of any woody debris that has accumulated at the base of the scarp
- Burial risk is low except when slumping of the bluff occurs
- Active erosion of the scarp will remove the oil

RESPONSE CONSIDERATIONS

- In most cases, cleanup is not necessary because of the short residence time of the oil; sorbents can be deployed to recover oil being mobilized from the shore
- The need for removal of oiled sediments and debris should be carefully evaluated because of the potential for increased erosion
- Closely supervised manual labor should be used so that the minimal amount of material is removed during cleanup

MIXED SAND AND GRAVEL (SHELL) BEACHES **ESI = 5**

DESCRIPTION

- Moderately sloping beach composed of a mixture of sand and gravel (shell or limestone fragments)
- There can be large-scale changes in the sediment distribution patterns along the Gulf shore depending upon season, because of the transport of the sand fraction offshore during storms
- Because of sediment desiccation and mobility on exposed beaches, densities of animals and plants are lower than sand beaches
- Occur on the Bolivar Peninsula, between High Island and Sea River State Park, and along spoil islands in East and West Bays and Galveston Bay; Present along 124 miles, comprising 3% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- During small spills, oil will be deposited along and above the high-tide swash
- Large spills will 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 oil behavior is much like on a sand beach if the sand fraction exceeds about 40 percent
- Burial of oil may be deep at and above the high-tide line, where oil tends to persist, particularly where beaches are only intermittently exposed to waves
- In sheltered pockets on the beach, pavements of asphalted sediments can form if there is no removal of heavy oil accumulations because most of the oil remains on the surface
- Once formed, these asphalt pavements can persist for years

RESPONSE CONSIDERATIONS

- Remove heavy accumulations of pooled oil as soon as possible
- All oiled debris should be removed
- Sediment removal should be limited as much as possible
- Low-pressure flushing can be used to float oil away from the sediments for recovery by skimmers or sorbents. High-pressure spraying should be avoided because of potential for transporting contaminated finer sediments (sand) to the lower intertidal or subtidal zones
- Mechanical reworking of lightly oiled sediments from the high-tide zone to the middle intertidal zone can be effective in areas regularly exposed to wave activity (as evidenced by storm berms)
- In-place tilling/excavation may be used to reach deeply buried oil in layers in the middle zone on exposed beaches

GRAVEL (SHELL) BEACHES ESI = 6A

DESCRIPTION

- The gravel fraction is composed of shell fragments; they occur as lag deposits where the finer-grained sediments have been eroded away
- The shells tend to form steep, narrow berms or washover deposits
- Shell beaches are common in bays near oyster reefs and along spoil islands where the spoil is reworked by waves into steep shell berms; Along the Gulf shore, gravel (shell) beaches are found at Sargent Beach, San Luis Pass, and east of High Island
- Present along 51.4 miles, comprising 1.2% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Deep penetration of stranded oil is likely on shell beaches because of their high permeability
- Long-term persistence will be controlled by the depth of routine reworking by waves or boat wakes
- Deeply penetrated oil can leach out for long periods, thick oil layers can harden into asphalt pavements

RESPONSE CONSIDERATIONS

- Heavy accumulations of pooled oil should be removed quickly from the upper beachface
- All oiled debris should be removed
- Sediment removal should be limited as much as possible

- Low-pressure flushing can be used to float fresh oil away from the sediments for recovery by skimmers or sorbents
- Heavily oiled shells may have to be removed and replaced with clean shells

RIPRAP ESI = 6B

DESCRIPTION

- Riprap structures are composed of cobble- to boulder-sized blocks of granite, limestone, or concrete
- Riprap structures are used for shoreline protection and inlet stabilization
- Attached biota are highly variable in cover
- These structures are highly utilized for shore-based fishing
- Common along highly developed commercial waterfronts, residential areas, and inlets; Present along 238 miles, comprising 5.8% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Oil adheres readily to the rough surfaces of the blocks
- Deep penetration of oil between the blocks is likely
- Uncleaned oil can cause chronic leaching until the oil hardens

RESPONSE CONSIDERATIONS

- When the oil is fresh and liquid, high-pressure spraying and/or water flooding may be effective, making sure to recover all mobilized oil

- Heavy and weathered oils are more difficult to remove, requiring scraping and/or hot-water spraying
- It may be necessary to remove and replace heavily oiled blocks in high-use areas

EXPOSED TIDAL FLATS ESI = 7

DESCRIPTION

- Exposed tidal flats are broad, flat, intertidal areas composed primarily of sand and minor amounts of shell
- The presence of sand indicates that tidal currents and waves are strong enough to mobilize the sediments
- Flats on the Gulf shore can support vehicular and foot traffic, whereas those along bays are usually too soft
- They are often associated with another shoreline type on the landward side of the flat, though they can occur as separate shoals; they are commonly associated with tidal inlets
- Biological utilization can be very high, with large numbers of infauna, heavy use by birds for roosting and foraging and by foraging fish
- They are also highly utilized for recreational fishing
- Uncommon; they are mapped along 26.8 miles, comprising 0.65% of the upper Texas coast

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 penetrate water-saturated sediments
- Biological damage may be severe, primarily to infauna, thereby reducing food sources for birds and other predators

RESPONSE CONSIDERATIONS

- Currents and waves can be very effective in natural removal of the oil
- Cleanup is very difficult (and possible only during low tides)
- The use of machinery should be restricted to prevent mixing of oil into the sediments

SHELTERED SCARPS IN CLAY OR BEDROCK **ESI = 8A**

DESCRIPTION

- Sheltered scarps can be composed of clay formed by dredge-spoil deposits in man-made waterways or steep slopes composed of either clay or sand and covered with terrestrial vegetation
- There may be some fringing marsh along the water's edge
- They are very common along bay shorelines; Present along 321 miles, comprising 7.8% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Oil will not adhere to the wet sediment surface, but could penetrate the burrows if present and dry
- Stranded oil will persist because of low energy setting

RESPONSE CONSIDERATIONS

- Low-pressure flushing at ambient temperatures is most effective when the oil is fresh and still liquid
- Where the high-tide area is accessible, it may be feasible to remove heavy oil accumulations and oiled debris

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SHELTERED, SOLID MAN-MADE STRUCTURES **ESI = 8B**

DESCRIPTION

- These structures are solid man-made structures such as seawalls, groins, revetments, piers, and port facilities
- Most of the structures are designed to protect a single lot, thus their composition, design, and condition are highly variable
- Most structures are constructed of concrete, wood, or metal
- Often there is no exposed beach at low tide, but multiple habitats are indicated if present
- Attached animal and plant life can be sparse
- They can have high recreational use, particularly in public areas
- Common in highly developed commercial and residential waterfront areas; Present along 290 miles, comprising 7% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Oil will adhere readily to rough surfaces, particularly along the high-tide line, forming a distinct oil band
- If the oil is not removed, it may cause chronic leaching until the oil hardens
- The lower intertidal zone usually stays wet (particularly if algae-covered), preventing oil from adhering to the surface

RESPONSE CONSIDERATIONS

- Cleanup of seawalls is usually conducted for aesthetic reasons or to prevent leaching of oil
- Low- to high-pressure spraying at ambient water temperatures is most effective when the oil is fresh

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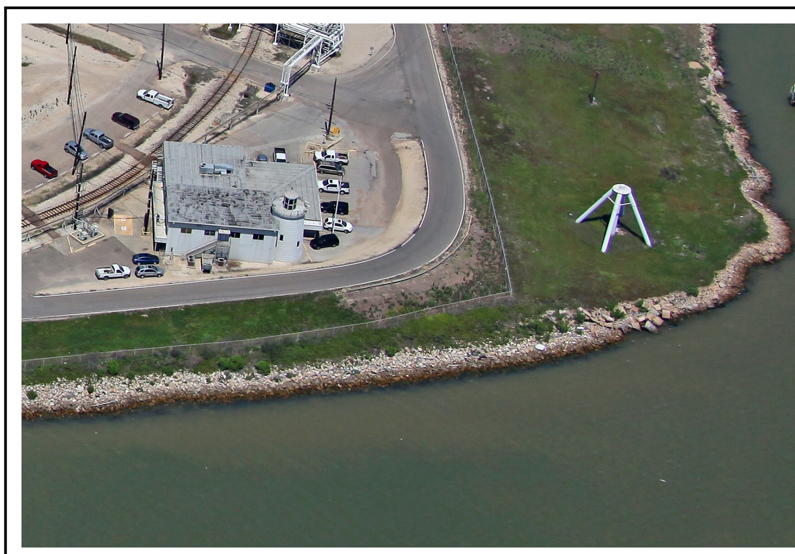
SHELTERED RIPRAP **ESI = 8C**



DESCRIPTION

- Riprap structures are composed of cobble- to boulder-sized blocks of granite, limestone, or concrete
- These structures are found inside harbors and bays in developed areas, sheltered from direct exposure to waves
- High densities of attached biota may be present at lower tidal elevations
- Common in highly developed commercial and residential waterfront areas; Present along 76 miles, comprising 1.8% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Oil adheres readily to the rough surfaces
- Deep penetration of oil between the blocks is likely
- If oil is left uncleaned, it may cause chronic leaching until the oil hardens

RESPONSE CONSIDERATIONS

- 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
- It may be necessary to remove and replace heavily oiled riprap in high-use areas

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, and are usually backed by marshes
- They also include wind-tidal flats that are subject to inundation only by wind-generated tides
- The sediments are very soft and cannot support even light foot traffic in many areas
- Large concentrations of shellfish, worms, and snails can be found on and in the sediments
- They are heavily utilized by birds and fish for feeding
- Common; Present along 337 miles, comprising 8.2% of the upper Texas coast

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 or other crevices in muddy sediments
- In areas of high suspended sediments, sorption of oil can result in deposition of contaminated sediments on the flats
- Biological damage may be severe

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
- Low-pressure flushing, vacuum, and deployment of sorbents from shallow-draft boats may be appropriate for use under heavy oiling

SALT- AND BRACKISH-WATER MARSHES **ESI = 10A**

DESCRIPTION

- These are grassy intertidal wetlands containing emergent, herbaceous vegetation
- Width of the marsh can vary widely, from a narrow fringe to extensive areas; many have been extensively ditched
- Sediments are composed of organic muds except on the margins of islands where sand is abundant
- Exposed areas are located along bays with wide fetches and along heavily trafficked waterways
- Sheltered areas are not exposed to significant wave or boat wake activity
- Resident flora and fauna are abundant and diverse, with high utilization by birds, fish, and shellfish
- Very common; Present along 1,881 miles, comprising 45.5% of the upper Texas coast

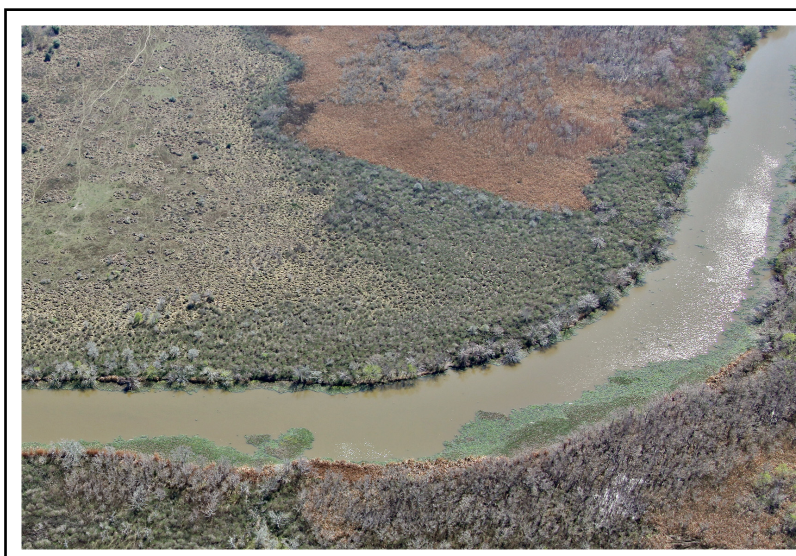
PREDICTED OIL BEHAVIOR

- Oil adheres readily to intertidal vegetation
- The band of coating will vary widely, depending upon the water level at the time oil slicks are in the vegetation; there may be multiple bands
- Large slicks will persist through multiple tidal cycles and coat the entire stem from the high-tide line to the base
- If the vegetation is thick, heavy oil coating will be restricted to the outer fringe, although lighter oils can penetrate deeper, to the limit of tidal influence
- Medium to heavy oils do not readily adhere to or penetrate the fine sediments, but can pool on the surface or in burrows
- Light oils can penetrate the top few centimeters of sediment and deeply into burrows and cracks (up to one meter); heavy oils will thickly cover or pool on the sediment surface

RESPONSE CONSIDERATIONS

- Under light oiling, the best practice is natural recovery; natural removal processes and rates should be evaluated prior to conducting cleanup
- 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 activities should be carefully supervised to avoid 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 are at great risk from leaving the oiled vegetation in place

FRESHWATER MARSHES **ESI = 10B**



DESCRIPTION

- These are grassy wetlands composed of emergent herbaceous vegetation
- They occur upstream of brackish vegetation along major rivers and tributary bayous and creeks
- Those along major channels are exposed to strong currents and boat wakes; smaller channels tend to be sheltered
- The sediment substrate is seldom exposed because daily water level changes are low; greater changes result from floods and wind-generated tides
- Resident flora and fauna are abundant with numerous species, with high utilization by birds and fish
- Present on the Sabine River delta, along the Neches River, and inland of the Trinity River delta with 137 miles, comprising 3.3% of the Upper Texas shoreline

PREDICTED OIL BEHAVIOR

- Oil adheres readily to the vegetation
- The band of coating will vary widely, depending upon the water level at the time oil slicks are in the vegetation; there may be multiple bands
- Most of the time, there will be a narrow band because of the small tidal range; the band can be very large during high-water events
- If the vegetation is thick, heavy oil coating will be restricted to the outer fringe, although lighter oils can penetrate deeper
- Medium to heavy oils do not readily adhere to or penetrate the fine sediments, but can pool on the surface or in burrows

RESPONSE CONSIDERATIONS

- Under light oiling, the best practice is natural recovery; natural removal processes and rates should be evaluated prior to conducting cleanup
- Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing
- Cleanup activities should be carefully supervised to avoid 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 are at great risk from leaving the oiled vegetation in place

SWAMPS — ESI = 10C

DESCRIPTION

- Swamps consist of shrubs and hardwood forested wetlands, essentially flooded forests; vegetation is taller, on average, than 6 meters
- The sediment tends to be silty clay with large amounts of organic debris
- They are seasonally flooded, though there are many low, permanently flooded areas
- Resident flora and fauna are abundant with numerous species
- They are common along major river valleys, such as the Sabine, Neches, Trinity, and San Jacinto; Present along 163 miles, comprising 3.9% of the Upper Texas shoreline

PREDICTED OIL BEHAVIOR

- Oil behavior depends on whether the swamp is flooded or not
- During floods, most of the oil passes through the forest, coating the vegetation at the waterline, which changes levels throughout the flood event
- Woody vegetation is less sensitive than grasses to oil coating
- Some oil can be trapped and pooled on the swamp floodplain as water levels drop
- Penetration into the floodplain soils is usually limited because of high water levels, saturated soils, muddy composition, surface organic debris, and vegetation cover
- Large amounts of oily debris can remain
- During dry periods, terrestrial spills flow downhill and accumulate in depressions or reach water bodies

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
- Live woody vegetation should not be cut

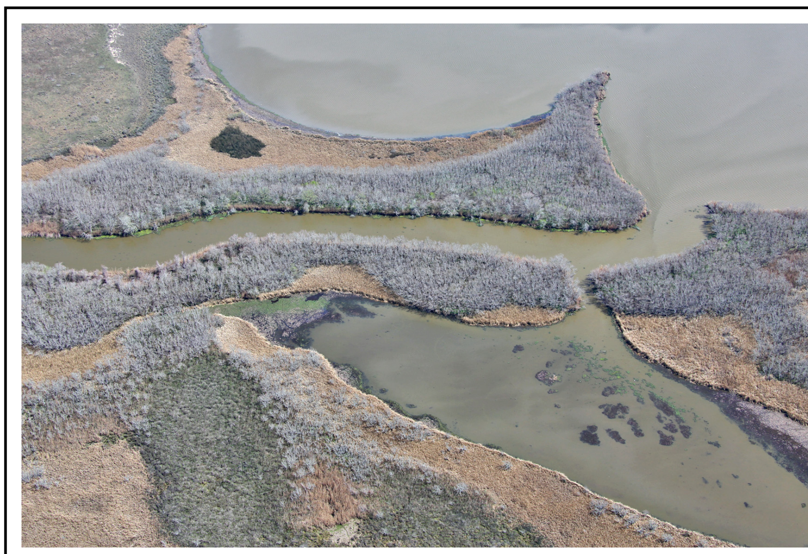
SCRUB-SHRUB WETLANDS — ESI = 10D

DESCRIPTION

- Scrub-shrub wetlands consist of woody vegetation less than 6 meters tall including true shrubs, small trees, and trees and shrubs that are stunted due to environmental conditions
- The sediments are silty clay mixed with organic debris
- They are seasonally flooded, though there are many low, permanently flooded areas
- Resident flora and fauna are abundant
- Uncommon, occurring along much less than 0.1% of the upper Texas coast

PREDICTED OIL BEHAVIOR

- Oil behavior depends on water level
- During high water, most of the oil passes through the wetland, coating the vegetation above the waterline
- Woody vegetation is less sensitive than grasses to oil
- Some oil can be trapped and pooled on the surface as water levels drop
- Penetration into the soils is usually limited because of high water levels, muddy composition, surface organic debris, and vegetation cover
- Large amounts of oily debris can remain in the wetland
- During dry periods, terrestrial spills flow downhill and accumulate in depressions or reach water bodies



RESPONSE CONSIDERATIONS

- Under light oiling, the best practice is natural recovery
- Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing
- 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
- Live woody vegetation should not be cut