Technical Consultation for Compliance with the Marine Mammal Protection Act in Support of the Coastal Texas Protection and Restoration Study

Final Report

EIH Final Report #18-003
October 24, 2018

Prepared by the Environmental Institute of Houston University of Houston – Clear Lake in cooperation with the Texas General Land Office

Prepared by the Environmental Institute of Houston / University of Houston-Clear Lake

Kristi Fazioli, Research Associate
George Guillen, Executive Director
Jenny Oakley, Environmental Scientist

Environmental Institute of Houston
University of Houston Clear Lake
2700 Bay Area Blvd, Box 540
Houston, Texas 77058

Prepared in cooperation with and for the Texas General Land Office

Carla Kartman, Project Manager
Texas General Land Office
1700 N. Congress Ave.
Austin, TX 78701

Table of Contents

Executive Summary

As part of the Coastal Texas Protection and Restoration Study, preliminary planning for coastal storm protection has proposed structural and non-structural modifications to the bays and estuaries of the Texas coast to reduce risk of storm surge flooding. Two current alternatives for consideration utilize a combination of Ecosystem Restoration (ER) measures throughout the Texas coast (dune/beach restoration, island and shoreline protection, oyster reef creation, marsh nourishment etc.) with Coastal Storm Risk Management (CSRM) structural and non-structural features, focused largely on the Galveston Bay (GB) estuary system. The Environmental Institute of Houston was commissioned to provide a summary report on the marine mammal protection act requirements and potential impacts to marine mammals as a result of the proposed measures. This preliminary evaluation will provide review of current knowledge, identify data gaps and provide initial recommendations for marine mammal impact assessment and monitoring related to the Coastal Texas Protection and Restoration Study. Due to time constraints for this initial review and the extent of construction and habitat modification expected for the proposed BR crossing, much of this review focuses on broad potential impacts. As specifics of planned construction activities become available, other implications on different habitats or behavioral patterns should be individually addressed in more detail.

Bays, estuaries and nearshore waters of Texas are home to the common bottlenose dolphin (*Tursiops truncatus truncatus*). No other species of marine mammal regularly inhabits these waters as part of their normal range, however, the West Indian Manatee (*ESA listed: Threatened*) is an occasional visitor within these waters as an extension of its normal range. Bottlenose dolphins inhabiting bay, sound, and estuary (BSE) habitats of the Northern Gulf of Mexico are divided by the National Marine Fisheries Service (NMFS) into geographically defined stocks for management purposes. There are six of these stocks are found in Texas waters, and a seventh straddles the Texas/Louisiana border. Bordering Texas BSE stocks is the "Gulf of Mexico Western Coastal Stock", a nearshore coastal stock inhabiting a geographically defined region from the barrier islands to the 20 m isobaths. Abundance estimates for Texas BSE stocks are mostly based on outdated aerial surveys from the early 1990's (a method now generally considered insufficient for finding dolphins in BSE environments) and are currently considered “unknown” for management purposes, with the exception of the recently updated West Bay stock currently estimated at 48 individuals. The current best population estimate for the Gulf of Mexico Western Coastal stock is 20,161, and some mixing of the BSE and coastal stocks is expected.

A variety of factors may influence dolphin abundance and distribution patterns, including environmental variables such as salinity, turbidity and temperature, water and sediment quality, prey distribution and abundance, predator avoidance, and anthropogenic disturbance. Of these, prey distribution and salinity regimes are likely the most influential factors for the GB BSE stock. Long term photo-identification projects in GB focused on the Galveston Ship Channel have estimated about 200 dolphins exhibit a high degree of site fidelity and overlap with transients moving in and out of the inlet from nearshore. Studies focused in upper GB have cataloged over 600 unique individuals since 2013 and indicate that some individuals exhibit multiyear site fidelity to that region of the bay while others may preferentially utilize different portions of the bay and only occasionally visit the upper bay. Seasonal distribution patterns are evident throughout Texas in bays, inlets and nearshore waters. The likely differential use of some habitats by multiple stocks or communities of dolphins along the coast complicate defining these patterns, and seasonal changes in GB likely reflect a combination of within bay and coastal movements.

It is widely reported along the Western Gulf Coast that high concentrations of bottlenose dolphins regularly utilize deep channels and passes where estuarine and Gulf waters meet. These areas are likely mixing zones, including dolphins from multiple adjacent stocks that may display frequent movements between bay and Gulf environments. In the Galveston Bay region, high densities of dolphins concentrate in Bolivar Roads, the Houston Ship Channel, the Galveston Ship Channel, and beaches close to inlets. This, along with other evidence from research conducted within the Galveston Bay estuarine system, along the Texas coast, and in similar estuaries around the world lead to the conclusion that the inlet to Galveston Bay at Bolivar Roads is critical dolphin foraging habitat.

Dolphins residing within industrial coastal regions carry increased toxicant loads and are subject to adverse effects on reproduction, endocrine function and immune function. These health conditions, combined with other environmental stressors such as low salinity cause immunosuppression, making dolphins more susceptible to disease. Bottlenose dolphins are physiologically adapted to inhabit brackish to oceanic coastal waters with salinities that typically range from 18 – 35 ‰. While dolphins sometimes make short forays into riverine environments, or are exposed to low salinity conditions for brief periods, a recommended threshold for Gulf of Mexico estuarine dolphins based on available data for suitable long-term dolphin habitat is ≥ 11 ‰. Due to its brackish nature, much of the inner portion of the GB estuary is likely marginal habitat for dolphins in regards to salinity, dropping below this threshold for days or weeks following heavy freshwater inflow events. Additional documented stressors to BSE dolphin stocks include chemical pollution, commercial and recreational fisheries, dredging and construction, algal blooms, hypoxia, and habitat loss.

Potential construction and operational impacts and disturbances vary based on geographical project location, seasonality and activity type. Preliminary impacts of highest concern to marine mammals are similar for each alternative, however the location, extent and stock specificity of impacts may vary dependent on the specific action. As engineering plans develop, impacts to marine mammals at each location of applied CSRM or ER measures should be specifically evaluated for severity and take potential. The proposed Bolivar Roads environmental flow and sector gates has the highest potential for impact to Galveston Bay marine mammals. Mitigation actions should be considered early in the engineering and planning phase to minimize impacts and take.

Sound plays a sizeable role in the life of marine mammal populations utilizing Galveston Bay and nearshore Gulf waters, including 1) the physiological effects of high-energy sound exposure; 2) masking of biologically important sounds, and; 3) behavioral disruptions that may result in negative effects on population vital rates (survivability and fecundity). High-energy sound exposure from pile driving or explosive detonations can cause direct physical injury to marine mammals in the form of permanent threshold shifts (PTS) or temporary threshold shifts (TTS). Development of engineering plans to include noise reduction technology will be vital to minimizing the zone of influence and reducing "take" numbers which will be instrumental to demonstrate in the Incidental Take Authorization. Potential mitigation measures to explore include: Bubble curtains, double walled piles, Hydro Sound Dampers, IHC Noise mitigation screens, cofferdams, "soft-start" operational procedures, and dolphin exclusion zones.

Noise, vessel activity, sediment suspension, release of toxic compounds and habitat modification are all concerns surrounding dredging activities with the potential to cause negative consequences to dolphin populations. Increased turbidity as a result of dredging can decrease primary productivity and bury benthic organisims causing localized disruption in dolphin prey source feeding. Studies have shown that higher intensities of dredging, even in an area of high baseline industrial activity, caused bottlenose dolphins to spend less time in important foraging areas. Dredge activities should be planned to avoid sensitive benthic communities and fish spawning seasons to reduce impacts on dolphin prey. Mitigation procedures such as proper capture and removal of sediment will reduce direct physical effects. Remaining concerns include acoustic masking due to noise of operations, short-term behavioral response and alterations to prey availability.

Vessel traffic is expected to increase temporarily during construction due to vessel-based construction activities. Additional permanent changes in vessel traffic patterns and density are expected due to a decrease in functional area for navigation as a result of permanent structures. While there are many factors that play into how vessels may affect behavior, typically smaller vessels quickly changing speed and direction have more of an immediate behavioral effect than larger vessels on a steady path such as cargo ships. Repeated vessel disturbance could lead to a change in energy budgets and/or habitat use of bottlenose dolphins. Potential mitigation options include controlling the speed of work vessels and providing additional 'safe' zones outside of the construction area with vessel speed limits.

The operational presence of the floodgate barrier across BR, even with open navigational and environmental flow gates, has the potential to act as a hindrance to dolphin movement in this area. There are documented instances of dolphins being functionally 'trapped' in areas where the only passage is through narrow or low clearance bridges. If dolphins are hesitant to pass through the vertical lift gate openings, functional passage may be restricted to the Houston Ship Channel sector gate where there is the potential for increased vessel traffic impacts. Where gates are placed at smaller bayou inlets, it may restrict movement in and out of those bayous entirely. Operational closing of the gates for emergency hurricane preparations have a potential for injury, noise disturbance, separation of social groups, effects on prey items, and disruption of foraging. The frequency and duration of maintenance and storm-related closures is currently undetermined, but will dictate the level of potential disturbance to marine mammals from these activities.

Additionally, reduced conveyance of flow through the pass is expected to create a 13-17% reduction in tidal prism within GB. Tidal flow is known to influence dolphin movements and foraging patterns. It is difficult to predict how increased flow velocities directly surrounding the gate system and an overall decrease in tidal prism will effect dolphin travel and foraging activities.

The Coastal Barrier's gate system at Bolivar Roads is expected to reduce the cross-sectional area of the pass by 27.5 percent and reduce the tidal prism by 13.5 to 16.5 percent which will increase the residence time of Galveston Bay. Increased residence time will decrease the salinity in times of freshwater inflow, and increase salinities during periods of severe drought. Additionally, reduced mixing with the Gulf of Mexico could cause the development of lower dissolved oxygen conditions upstream of barriers. Mean salinity isohaline plots indicate that some areas of the bay where dolphins frequent are already considered marginal dolphin habitat, dipping below the recommended 11 ‰ threshold for at least a portion of the year. Current dolphin habitat use and health in these zones could be affected by even a small decrease in salinity under project conditions.

Dredging, changes in tidal prism, water quality, and the effects of physical barriers could change the distribution of dolphin prey sources in Galveston Bay. Many important prey species of BSE dolphins are estuarine dependent meaning they utilize the estuary to complete their lifecycle. A large number of estuarine dependent species utilize natural passes to facilitate spawning aggregations in the near-shore GoM with access to protected nursery habitats in the bay. Current plans to include environmental flow gates in the Bolivar Roads project area placed near shore in shallow waters will facilitate ingress and egress of aquatic organisms but overall the barrier is likely to impede the migrations and movements of various life stages of nekton. Overall, a reduction of overall populations of fish and shellfish in the bay is expected which can directly affect the distribution, competition, and overall fitness of the BSE stock of bottlenose dolphin in GB. Alteration of prey sources may also indirectly increase exposure of the BSE dolphin stock to predators and other stressors depending on where dolphins shift their habitat association in order to find food sources.

Catastrophic weather events such as hurricanes may impact dolphins indirectly through critical habitat damage, decreased prey availability, and water quality changes (salinity, hypoxia and exposure to toxicants) or directly through physical injury and habitat displacement. "Out of habitat" dolphins documented after hurricanes are sometimes trapped in areas outside their normal range in locations where they are likely to perish due to surrounding environmental conditions or lack of resources. In these cases, the storm surge reductions in the bay afforded by the proposed CSRM may provide protection from "out of habitat" storm displacement for dolphins residing within the GB estuary. While the frequency and size of catastrophic weather events will likely increase with climate change these isolated events have historically affected relatively small numbers of individuals in Texas bays..

While basic life history data on dolphins in Texas documenting relative density, seasonal, distributional and stranding patterns are available, other important data necessary to establish baseline parameters for assessment of impact are lacking. The Galveston Bay stock's fine-scale population structure remains unknown and population abundance estimates are outdated. Without these data, specific calculations of estimated take for each stock affected will not be possible. Furthermore, evaluation and mapping of available dolphin habitat in the region are needed to provide managers with an understanding of where stocks may find necessary resources if they are displaced from current habitat use areas around the Bolivar Roads area. Standardized long-term monitoring efforts of dolphins within the potential impact zone of project activities are currently lacking and should be established prior to the onset of construction to create a dataset for calculation of vital rates and to provide context for distribution, habitat use and behavioral data to inform monitoring plans during and after construction. Additionally, efforts to establish baseline health and vital rates is needed prior to the onset of disturbance to adaptively manage and mitigate the effects of project activities. Live-capture health assessments have not been conducted in Galveston Bay, therefore little health data is currently available. Establishing baseline health indicators for the population prior to project activities would be highly recommended. For example remote biopsy could be utilized as long-term monitoring tool for not only toxic contaminant loads, but for measuring progesterone and cortisol hormone levels for evaluating reproductive success and stress response. Finally, sound is a critical element for any in-water project impact assessment. Investigation of how project noise will propagate above current background levels impacting dolphins in the vicinity must be modeled to create the expected zone of influence. This will inform managers about potential changes to the behavior of dolphins in the region and evaluation of the effectiveness of candidate mitigation measures.

We recommend creating an adaptive management plan to meet the mitigation, monitoring and reporting requirements of an Incidental Take Authorization (ITA) required under the Marine Mammal Protection Act. Engagement and planning should start early and aim to accomplish the below goals as outlined in the ITA application requirements. Mitigation monitoring is required to implement specific mitigation measures, and general monitoring is performed to, 1) Increase our knowledge of the species, and 2) Enhance our understanding of the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities.

Project Introduction

As part of the Coastal Texas Protection and Restoration Study, preliminary planning for coastal storm protection has proposed structural and non-structural modifications to the bays and estuaries of the Texas coast to reduce risk of storm surge flooding. The National Environmental Policy Act (NEPA) requires Federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their major proposed actions, including impacts on marine mammal populations. The Texas General Land Office (TGLO) in coordination with the U.S. Army Corps of Engineers (USACE) is preparing an Environmental Impact Statement (EIS) including a review of potential impacts on marine mammals.

Two current alternatives for consideration utilize a combination of Ecosystem Restoration (ER) measures throughout the Texas coast (dune/beach restoration, island and shoreline protection, oyster reef creation, marsh nourishment etc.) with Coastal Storm Risk Management (CSRM) structural and non-structural features, focused largely on the Galveston Bay (GB) estuary system. Major structural features include two alternate combinations of floodwall/levee systems and navigation and environmental gates across bay and bayou inlets, with the largest proposed structure spanning the 2.08 mile wide GB inlet at Bolivar Roads (BR). Construction activities are currently projected to initiate in 2025, continuing through 2035.

Alternatives currently under consideration include Alternate A, Alternate D2, and ER Measures. The specific projects that are expected to have the largest impact to marine mammals are described herein. The BR channel crossing consists of a combination of levee walls, a series of 100 ft. wide vertical lift gates with elevation over the water surface of 10 – 20 ft., one recreational vessel gate and one 2-leaf floating sector navigational gate at the Houston Ship Channel (HSC), anchored to two man-made "islands" on either side of the channel. Construction of the sector gate will require the dredging of a temporary bypass channel for navigation of the HSC. Similar, smaller-scale gate structures are under consideration for bayou inlets at Dickinson Bayou, Clear Creek, Tabbs Bay and Offatts Bayou. ER Measures, including construction of rock breakwaters, beach and dune restoration, oyster reef creation, dredge island creation, wetland and marsh restoration and hydrologic restoration are planned throughout the Texas coastline. Additional land-based construction activities are expected, but are not addressed in relation to marine mammals (the proposed upper bay rim levee in Alternative D2 is assumed in these analyses to be constructed on land). Appendix 1 includes maps of in-water activities that should be investigated to evaluate the potential for impacts to marine mammals.

Based on current information provided in the project plans, we expect that construction and operational activities related to the implementation of either alternative may result in the incidental "take" of marine mammals, defined under the Marine Mammal Protection Act (MMPA) of 1972 as "harass, hunt, capture, kill or collect, or attempt to harass, hunt, capture, kill or collect." Responsible parties conducting any activities under the selected project alternative that would result in the incidental take of marine mammals will require an Incidental Take Authorization (ITA) issued by the National Oceanic and Atmospheric Administration (NOAA). ITA applications must include detailed information regarding each discreet project activity, projected environmental impact, potentially effected marine mammal populations, mitigation of negative impacts, and a comprehensive monitoring and reporting plan.

This preliminary evaluation will provide review of current knowledge, identify data gaps and provide initial recommendations for marine mammal impact assessment and monitoring related to the Coastal Texas Study. A summary table of assessment metrics, data availability, gaps and recommendations is provided in Appendix 2: Background Data Summary – Galveston Bay. Due to time constraints for this initial review and the extent of construction and habitat modification expected for the proposed BR crossing, much of this review will focus on broad potential impacts. As specifics of planned construction activities become available, other implications on different habitats or behavioral patterns should be individually addressed in more detail as the project moves forward. An amended report that incorporates these specific activities and potential impacts to bottlenose dolphins can be provided at that time at the request of the TGLO, pending continuation of this project.

Background

Marine Mammals and Anthropogenic Disturbance

Marine mammals are particularly vulnerable from exposure to human activity (Fair and Becker 2000; Lotze et al. 2006; National Academies of Sciences 2016; Frid and Dill 2002). In addition to the threat of direct physical injury, anthropogenic disturbance can elicit physiological and behavioral responses similar to those induced by threat of predation (Frid and Dill 2002). Small, localized coastal and inshore cetacean populations may experience significant declines or displacement due to impacts of coastal development (Lusseau et al. 2009; Bejder et al. 2006; Pirotta et al. 2013; Karczmarski et al. 2016). Analysis of potential impacts from large coastal projects must include consideration of direct, indirect and cumulative effects on individual animals and the entire population on and off-site of the geographical scope of the project (Hawkins et al. 2017; Jefferson et al. 2009). Even restoration measures, which could benefit marine mammals through habitat and water quality enhancements, have potential adverse effects that may have implications under the MMPA (Lent 2015).

Direct threats to individuals from construction and operational activities include damage from noise exposure (permanent or temporary threshold shifts) and collision with increased vessel traffic and equipment. Additional consequences may initially appear less severe, but occur more frequently and are often more significant over the long-term at the population level. These include temporary or permanent abandonment of important habitat, behavioral changes to energy budgets, increased exposure to toxic contaminants, changes to physical properties or quality of estuarine waters (ie. decreased salinity), and indirect effects of habitat degradation on prey availability. The biological significance of these effects depend on links between individual behavioral response, health consequences, and overall vital rates (survivability and fecundity) of the population, (Figure 1) (New et al. 2013; Fleishman et al. 2016). Importantly, short-term behavioral response to disturbance is not necessarily indicative of long-term population level effects, as there may be no significant changes to health or vital rates, and conversely, long-term negative population trends may occur even where immediate behavioral reaction of individuals is not evident. Quantifying impact on a population is further complicated by the need to define case-specific, biologically meaningful effects and tolerable levels of change for the population in question prior to the onset of disturbance (Fleishman et al. 2016). Consequently, knowledge of population biology, health status and critical behavior patterns of the population are essential to evaluating impacts from environmental disturbance and anthropogenic activities.

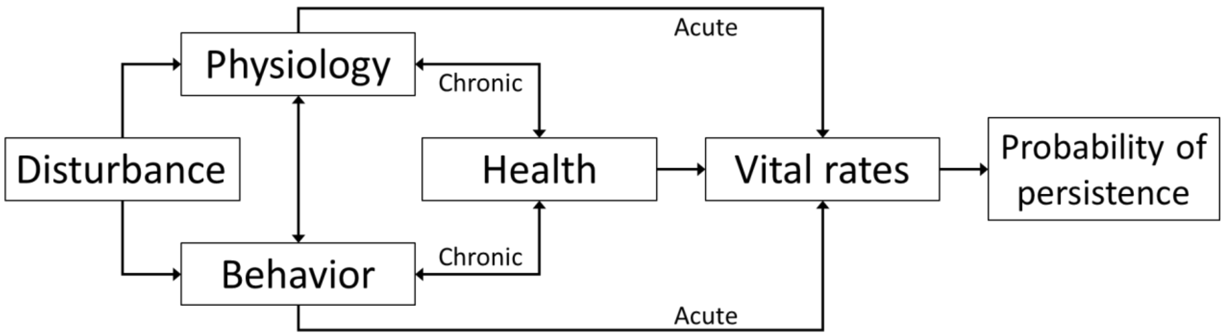


Figure 1- Adapted from Fleishman et al. (2016)– "Conceptual model of the process by which physiological or behavioral responses of individuals to disturbance might propagate to the population level, as mediated by health. Modified from New et al. 2014"

Large-scale environmental engineering projects in other, similar industrialized estuaries may serve as examples to hypothesize response and guide monitoring and management of marine mammal resources for the Coastal Texas Study. For example, decades of efforts in Hong Kong to research, monitor and protect coastal cetaceans during massive urban development provides an applicable case study of the impact assessment process (Jefferson et al. 2009). The Indo-Pacific humpback dolphin (*Sousa chinensis*) is a similar estuarine species to the bottlenose dolphin and vulnerable to impacts stemming from pile driving, dredging, vessel traffic and other in-water construction activities. Rapid development over the last few decades has threatened the survival of the Hong Kong humpback dolphin population, prompting focused research and conservation efforts to inform the environmental impact assessment process and evaluate mitigation efforts (Jefferson et al. 2009). The resulting data provides recommendations on evaluating expected impacts from land reclamation, percussive piling, dredging and dumping of soils, pipe and cable laying operations, and increased vessel traffic. Additionally, coordinating mitigation efforts were evaluated, including temporal and geographic closures, bubble curtains and jackets, monitored exclusion zones, ramping up of piling hammers, acoustic decoupling of noisy equipment, silt curtains, vessel speed limits and restrictions, no-dumping policies and cetacean density monitoring. This, and other similar environmental impact models, should serve to inform decision makers along the Texas coast.

Population Biology

Bays, sounds, estuaries and nearshore waters of Texas are home to the common bottlenose dolphin (*Tursiops truncatus truncatus*). No other species of marine mammal regularly inhabits these waters as part of their normal range, however, the West Indian Manatee (*ESA listed: Threatened*) is an occasional visitor within these waters as an extension of its normal range. Due to their rare occurrence in Texas waters, manatee are addressed only briefly in this report in regards to MMPA concerns, however further consideration may be warranted in terms of the United State Fish and Wildlife Service (USFWS) Endangered Species Act (ESA). While a total of 27 other cetacean species inhabit the Northern Gulf of Mexico, few are likely to interact with the shoreline in a way that would risk direct impact from the proposed Coastal Protection projects (Würsig et al. 2000a).

West Indian Manatee *(Trichechus manatus)*

Manatee occur primarily in Florida within the Northern Gulf of Mexico (GoM), though historically they were known to occur more often throughout the Northern GoM and were even considered common in south Texas (Gunter 1941). Minimum population estimates for the single Florida stock of manatee as of January 2011 was 4,834 and trends are considered stable or increasing (USFWS 2014), prompting a recent downlisting from 'endangered' to 'threatened' under the ESA. Fertl et al. (2005) provides a review of manatee sightings west of Florida, dating through August 2004 and attributes an increase in sightings outside of their traditional range to a combination of dispersal and increased public awareness. The authors report 66 records (53 sightings, 8 carcasses, and 5 captures) in Texas dating back to 1912. Manatee in Texas may stray from populations in either Florida or Mexico as an extension of their natural seasonal migration in warm weather or possibly in response to GoM conditions during notably active hurricane seasons (Fertl et al. 2005). They are typically found in estuarine habitats in search of seagrasses, sources of fresh water and warm water effluents in winter. Top threats to manatee include vessel collisions, cold water, and loss of seagrass foraging habitats (Runge et al. 2015).

Common Bottlenose Dolphin *(Tursiops truncatus truncatus)*

Bottlenose dolphins inhabiting bay, sound, and estuary (BSE) habitats of the Northern Gulf of Mexico are divided by the National Marine Fisheries Service (NMFS) into 31 geographically defined stocks for management purposes (Waring et al. 2016; Hayes et al. 2017). Only four of these defined BSE stocks have individual stock assessment reports (SARs) (Waring et al. 2016). Hayes et al. (2017) stated that the NMFS is in the process of writing individual SARs for each of the 31 bay, sound and estuary stocks of common bottlenose dolphins in the Gulf of Mexico. Recent communications with NOAA staff confirm that updated estimates for Galveston Bay and West Bay are in process (pers. com. Keith Mullin [NOAA Southeast Fisheries Science Center]). Until this effort is completed, basic information for Texas bay and estuary stocks will continue to be reported under the most recent published SAR for the *Common Bottlenose Dolphin Northern Gulf of Mexico Bay, Sound and Estuary Stocks*, which includes information up through 2016 (Hayes et al. 2017). The draft 2018 SAR is currently posted for public review through December 17, 2018, and can be found at
https://www.federalregister.gov/documents/2018/09/18/2018-20185/draft-2018-marine-mammal-

stock-assessment-reports (Hayes et al. 2018). Referenced information from this draft SAR should be considered preliminary until a final release is available.

The MMPA defines a stock as "a group of marine mammals of the same species or smaller taxa in a common spatial arrangement that interbreed when mature". Six of these stocks are found off Texas, and a seventh straddles the Texas/Louisiana border (Figure 2): 1) Laguna Madre, 2) Corpus Christi and Nueces Bays, 3) Redfish, Aransas, Copano, San Antonio and Espiritu Santo Bays, 4) Lavaca, Tres Palacios and Matagorda Bays, 5) West Bay, 6) Galveston Bay and 7) Sabine Lake). Abundance estimates for Texas BSE stocks are mostly based on outdated aerial surveys from the early 1990's (a method now generally considered insufficient for finding dolphins in BSE environments) and all are currently considered "unknown" for management purposes (Hayes et al. 2017). Examination of the current SAR draft document indicates that the West Bay stock is being updated with an individual SAR. According to this individual SAR the best available abundance estimate for the West Bay stock is 48, with a minimum of 46 and a calculated potential biological removal [1] (PBR) of 0.5.

Bordering Texas BSE stocks is the "Gulf of Mexico Western Coastal Stock", a nearshore coastal stock inhabiting a geographically defined region from the barrier islands to the 20 m isobath, and extending from the southern tip of Texas to the Mississippi river delta (Figure 2). This coastal region represents a management zone in which genetically distinct "offshore"[1] and "coastal/nearshore" ecotypes could potentially co-exist and where "coastal" and "BSE" populations may overlap (Waring et al. 2013). The current best population estimate for this stock, revised in 2015, is 20,161 (Hayes et al. 2017).

[1] *The Potential Biological Removal (PBR) level is defined as the maximum number of animals, not including in natural mortalities that may be removed annually from a marine mammal stock while allowing that stock to reach or maintain its optimal sustainable population level.* https://www.nefsc.noaa.gov/psb/assessment/pbr.html

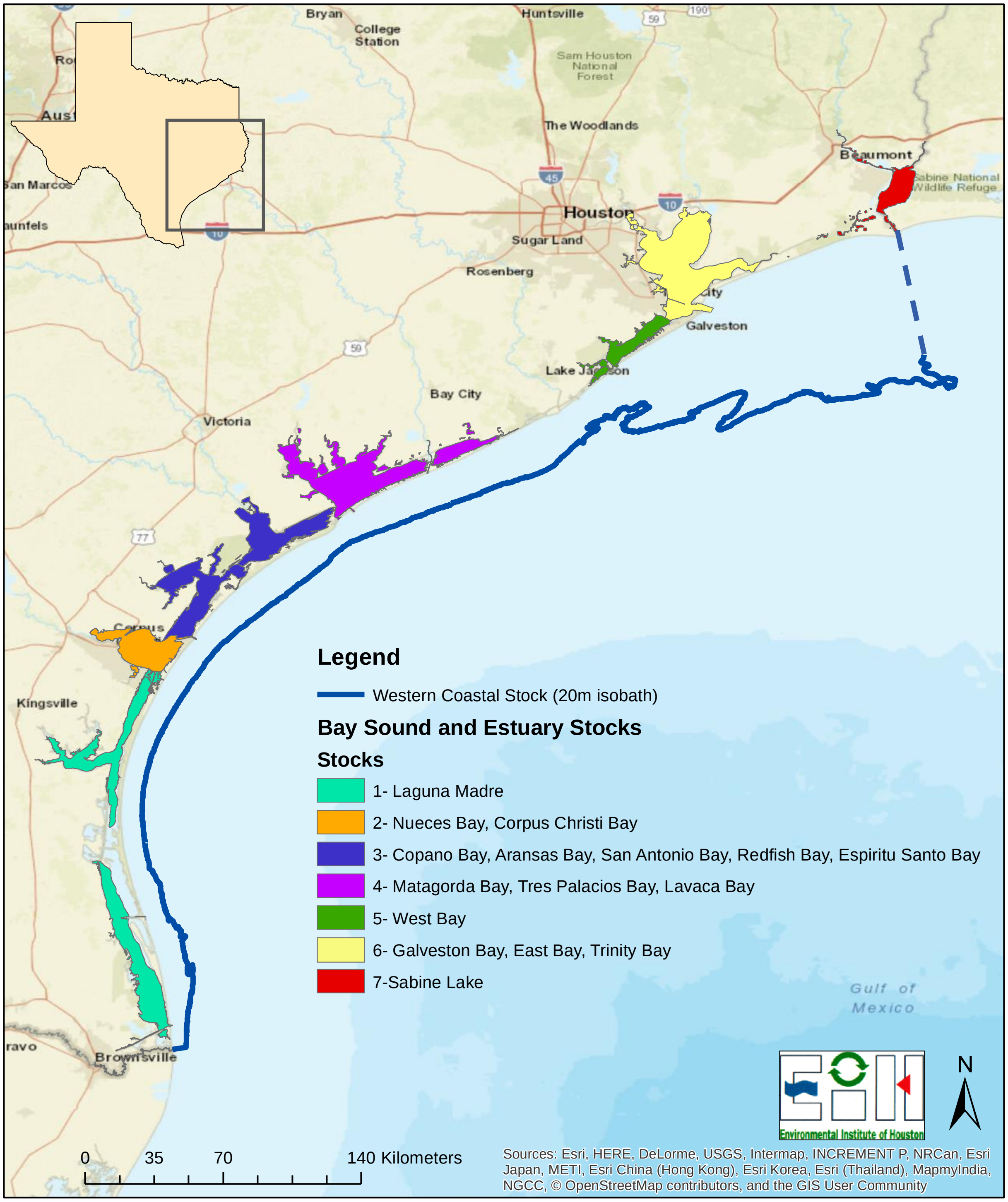


Figure 2- Map of the NMFS designated Bay Sound and Estuary (BSE) stocks and the Western Coastal Stock of Bottlenose Dolphins (*Tursiops truncatus truncatus*) that occur in Texas Waters. BSE Stock boundaries defined using Phillips and Rosel (2014).

A strategic stock is defined by the Marine Mammal Protection Act as a marine mammal stock 1) for which the level of direct human-caused mortality exceeds the PBR level; 2) which, based on best available scientific information, is declining and is likely to be listed as a threatened species under the Endangered Species Act within the foreseeable future; or 3) which is listed as a threatened or endangered species under the ESA, or is designated as depleted under the MMPA. While the Western Coastal Stock is currently not classified strategic and the West Bay stock may not be considered strategic after the 2018 SAR, all other Texas BSE stocks are considered strategic stocks due to unknown abundance estimates and evidence that most of these stocks are likely small and demographically distinct from adjacent and sometimes overlapping stocks (Waring et al. 2013; Hayes et al. 2017). Due to these factors, it is predicted that any level of human caused mortality has the potential to exceed PBR and bring populations below optimum sustainable population size (Waring et al., 2013; Hayes et al. 2017). Although geographically defined stocks have been established, delineating biologically meaningful boundaries between and within coastal and BSE bottlenose dolphin stocks is difficult due to the fluid and complex social system of the species. Research supports the division of relatively discrete "communities" of dolphins within BSEs that show long-term site fidelity, a high degree of internal social interactions and genetic differentiation from adjacent communities (Wells et al. 1987; Scott et al. 1990; Rosel et al. 2011; Hubard and Swartz 2002). Emphasis is placed on protecting stable resident communities that would be at greatest risk from localized impacts. However, fine-scale characterization of Texas stocks remains insufficient to delineate biologically significant boundaries or to determine population abundance trends (Waring et al. 2013).

Shane et al. (1982), and Vollmer and Rosel (2013) offer summary reviews of the data sets for dolphin ecology, population biology, behavior, potential threats and management considerations in the GoM, and Phillips and Rosel (2014) offers detailed review and evaluation of threats facing BSE dolphins along the Texas coast. These resources, in combination with NMFS annual stock reports, provide excellent starting points for identifying potential data gaps in this region. While much of the data summarized in these reports was collected in the 1980's through early 2000's and is considered outdated for some purposes, it provides valuable background and life history data for Texas bottlenose dolphin communities. In addition to available publications, studies by the Galveston Dolphin Research and Conservation Program (GDRCP), the Texas A&M University, Galveston (TAMUG) Marine Mammal Behavioral Ecology Group, and the NMFS Southeast Fisheries Science Center in cooperation with the Texas Marine Mammal Stranding Network (TMMSN), have all collected more recent data that will be useful for updating demographic information.

A few studies have identified individuals occasionally moving between Texas Bays (Lynn and Würsig 2002; Ronje et al. 2017), though it is unclear if these dolphins would be members of the Western Coastal stock utilizing bays and inlets as transients, or members of the BSE stocks displaying migratory behavior between bays. Despite these movements and overlapping range patterns, most studies document high levels of site fidelity and fine scale population structure within these BSE environments (Urian et al. 2009; Urian et al. 1996; Sellas et al. 2005; Litz et al. 2012). Hayes et al. 2018 suggests that it is plausible some estuarine stocks, particularly those in larger bays and estuaries such as Galveston Bay, comprise multiple demographically-independent populations. The NOAA Southeast Fisheries Science Center

(SEFSC) has conducted remote biopsy sampling and genetic testing in the central Texas region, including the coastal stock and Matagorda, Corpus Christi, and Aransas Bay, providing preliminary insight into fine-scale population structure in that region (P. Rosel, SEFSC, *unpublished data*). However, similar studies have not yet been completed for the upper Texas coast. The GDRCP collected 49 unique remote biopsy samples from dolphins within GB estuarine waters between 2015-2018. Genetic comparison of these samples to other Texas bays, in cooperation with NOAA SEFSC, is pending. In order to evaluate fine-scale structure within the GB estuary and neighboring coastal waters within the BR region, additional samples from the areas surrounding BR are necessary. These data are critical to understanding which stocks may be impacted from activities in the BR inlet and surrounding estuary system.

A variety of factors may influence dolphin abundance and distribution patterns, including environmental variables such as salinity, turbidity and temperature, water and sediment quality, prey distribution and abundance, predator avoidance, and anthropogenic disturbance (Huther 2010; Moreno 2005; Mazzoil et al. 2008; Shane 1980; Scott et al. 1990). Evaluation of how dolphins interact with their environment in relation to these factors can provide valuable data regarding critical habitat needs of the community. Prey distribution and salinity regimes may be the most likely predictors for GB stocks, given the deep channels that bring high salinity seawater and larger prey species in from the Gulf of Mexico that meets the freshwater flowing mostly from the Trinity and San Jacinto Rivers into the Bay (Moreno 2005). It is important to note that studies have suggested that dolphins do not selectively avoid areas of poor water quality and high levels of contamination (Mazzoil et al. 2008; Smultea and Würsig 1995), making it possible that this stock utilizes areas of relatively poor water quality if they meet other selection criteria.

Long term photo-identification projects in GB have documented a mixture of site fidelity patterns indicative of a resident population combined with short-term or transient visitors to the area. In lower GB, studies focused on the Galveston Ship Channel have estimated about 200 dolphins exhibit a high degree of site fidelity and overlap with transients moving in and out of the inlet from nearshore. (Bräger 1993; Henningsen and Würsig 1991; Fertl 1994a). Studies focused in upper GB have cataloged over 600 unique individuals since 2013 and indicate that some individuals exhibit multiyear site fidelity to that region of the bay while others may preferentially utilize different portions of the bay and only occasionally visit the upper bay, or be transients to the bay entirely (Fazioli et al. 2018 *unpublished data*). Preliminary site fidelity analyses identified 76 individuals that were observed year-round or in multiple non-consecutive months or seasons (ie. year-round or seasonal residents) within the upper-western portion of GB (Fazioli et al. 2017). Many of the likely GB resident dolphins identified by GDRCP have been sighted ranging throughout both upper and lower portions of the bay. In West Bay, part of the GB estuary system separated by shallow oyster reef habitats, a small distinct population of 30-40 dolphins have been identified as residents (Maze and Würsig 1999; Irwin and Würsig 2004). Overall, current evidence indicates that like other estuaries along the Gulf of Mexico (Hayes et al. 2018), the GB estuary system hosts more than one “community” of dolphins that exhibit core preferential home ranges along with extended ranges that may overlap with adjacent communities. Based on available data, GB may host two BSE communities of similar delineation to those in Mississippi Sound where two defined communities of “inshore” and “barrier island” dolphins were recently described using photo-id and satellite tagging following the Deepwater Horizon oil spill (Mullin et al. 2017; Wells et al. 2017). These GB communities would likely exhibit some overlap with each other and with both the coastal stock and the neighboring BSE stocks of West Bay and Sabine Lake, especially in areas surrounding BR inlet. Describing the complexities of site fidelity and home range of these communities will require additional focused photo-identification efforts and would be greatly enhanced by satellite tagging and genetic analysis.

Seasonal distribution patterns are evident throughout Texas in bays, inlets and nearshore waters. The likely differential use of some habitats by multiple stocks or communities of dolphins along the coast complicate defining these patterns, and seasonal changes in GB likely reflect a combination of within bay and coastal movements. Studies of lower GB near Bolivar Roads have documented seasonal increases in dolphin activity in spring and late summer through fall, with decreases in winter months (Fertl 1994a; Jones III 1988). Conversely, in the mid-coast region of Texas near tidal passes, an increase in dolphin abundance during winter months and corresponding decrease during the summer has been noted in several studies (Shane 1980; McHugh 1989; Gruber 1981). Due to the climate in Texas, it can be more biologically relevant to examine seasonal changes in terms of warmer-water months (defined as $\geq$ 20°C) and colder-water months (< 20°C), rather than using traditional calendar derived four-season designations. Some studies have used these two 'seasons', delineated for GB as "warm" (May – October), and "cold" (November – April) seasons. For BSE communities, seasonal increases in relative abundance in upper GB have been documented during "warm" months with significantly fewer dolphins sighted in upper GB during "cold" months (Fazioli et al. 2018 *unpublished data*). Similarly, in West Bay, dolphins move seasonally into the upper estuary during "warm" months and into San Luis pass and Gulf waters during "cold" months (Maze and Würsig 1999; Irwin and Würsig 2004). Seasonal changes in density have been attributed to a combination of N-S migration along the coast influenced by water temperature and more localized shifts in distribution influenced by prey movements in and out of the estuary during different times of the year (Weller 1998). Lynn and Würsig (2002) provide a review of Texas dolphin movement patterns and tentatively hypothesized that while small localized communities of Texas dolphins that exhibit high site fidelity to individual bays may be highly susceptible to anthropogenic threats, these populations may have the ability to recover due to the presence of transients and migratory individuals traveling between bays. The authors also stress the unknown aspect of genetic mixing in these communities and the need for additional research.

Critical Behaviors

It is widely reported along the Western Gulf Coast that high concentrations of bottlenose dolphins regularly utilize deep channels and passes where estuarine and Gulf waters meet (Leatherwood and Reeves 1983; Würsig and Lynn 1996; McHugh 1989; Moreno 2005; Jones III 1988; Barham et al. 1980; Ronje et al. 2017; Gruber 1981). These areas are likely to be mixing zones, including dolphins from multiple adjacent stocks that may display frequent movements between bay and Gulf environments. In the GB region, high densities of dolphins concentrate in BR, the Houston Ship Channel, the Galveston Ship Channel, and just off beaches close to the inlet (Jones III 1988; Moreno 2005; Ronje et al. 2017;

Fazioli et al. 2018 *unpublished data*). Studies have shown that distinctive patterns of distribution and high density 'hot spots' are related to foraging behavior and that submarine habitat characteristics such as steep seabed gradients and deeper waters may be significant factors in foraging efficiency (Hastie et al. 2004; Moreno 2005). Moreno (2005) specifically concluded that 94% of feeding groups within the lower GB study area occurred in BR or the Galveston Ship Channel, even though these areas constituted just 20% of the survey area. This, along with other evidence from research conducted within the Galveston Bay estuarine system, along the Texas coast, and in similar estuaries around the world lead to the conclusion that the inlet to Galveston Bay at BR is critical dolphin foraging habitat.

Bottlenose dolphins exhibit a wide variety of prey preferences and have often been referred to as opportunistic feeders (Leatherwood 1975; Gaskin 1982; Shane et al. 1986); however, studies have shown that some populations exhibit selective feeding (Corkeron et al. 1990; Santos et al. 2001; Berens McCabe et al. 2010). Soniferous (sound producing) fishes from the family Sciaenidae (drums, trouts, and croakers) are important prey sources for BSE bottlenose dolphins in Florida, North Carolina, and Texas (Berens McCabe et al. 2010; Gannon and Waples 2004; Barros and Odell 1990). Dolphins may benefit energetically from passive listening to soniferous fishes to locate prey (Gannon and Waples 2004; Berens McCabe et al. 2010). Sciaenids and mullets are among the most abundant fishes in the northern Gulf inshore waters (Hoese and Moore 1977). Shrimpers in Galveston reported that dolphins feeding on discarded fish at the surface had a preference for Sciaenids (Fertl 1994b). Dominant nekton species present in stomach contents from dolphins in Texas are Atlantic croaker (*Micropogonias undulatus*), sand sea trout (*Cynoscion arenarius*), silver perch (*Bairdiella chrysoura*), brief squid (*Lolliguncula brevis*), spot (*Leiostomus xanthurus*), and striped mullet (*Mugil cephalus*) (Barros and Odell 1990; Gunter 1941). Many of these species immigrate to estuaries from the GoM through passes like BR as larvae and then return as adults during offshore spawning migrations. An analysis of GB BSE dolphin foraging ecology using observational and stable isotope data is currently underway (Sherah Loe, MSc student, University of Houston Clear Lake, Environmental Institute of Houston), though additional samples from dolphins utilizing BR, West Bay and nearshore environments are necessary for an evaluation of the entire system.

Dolphins in GB are often associated with areas of human impact and anthropogenic activities. It is likely that the advantages of utilizing foraging strategies in these areas outweigh the disadvantages of disturbance. In addition to foraging in deep shipping channels, dolphin association with shrimp trawlers is well documented in GB (Fazioli et al. 2018 *unpublished data*; Fertl 1994b; Henningsen and Würsig 1992). Tolerance of these activities is evidence of the adaptive nature of bottlenose dolphins, however, studies show that vessel activity does alter dolphin behavior and whistle vocalizations in GB (Piwetz and Würsig 2015; Candelaria-Ley 2001; Pennacchi 2013). Evidence from other similar industrial environments indicate that vessel disturbance can lead to a reduction in foraging behavior and that an increase in vessel activity can lead to an avoidance response or habitat displacement, even when dolphins are tolerant of high baseline levels of disturbance (Pirotta et al. 2013; Pirotta et al. 2015; Bejder et al. 2006).

Predator avoidance may play an important role in dolphin distribution and habitat use patterns, with studies suggesting that foraging dolphin distributions reflect a trade-off between predation risk and food availability (Heithaus and Dill 2002). Little is known about predator interactions in GB, though shark bite scars have been noted in the population (Fertl 1994a; Henningsen and Würsig 1991; Fazioli et al. 2018 *unpublished data*). Sharks in the family Carcharhinidae such as bull and tiger sharks are common in the inshore waters and coastal estuaries of the Gulf of Mexico and are known to prey on dolphin (Shane et al. 1986, Hoese and Moore 1977; Froeschke et al. 2013). Displacement, increased noise and physical barriers could reduce the ability of dolphins to detect and escape predators or force them into selecting habitat areas of increased predatory risk.

Calving in bottlenose dolphins may occur year round, but tends to show strong seasonal peaks. In Texas, evidence indicates this peak to be in March, with a smaller peak in November (Fernandez and Hohn 1998; Urian et al. 1996; Fazioli et al. 2018 *unpublished data*). Scott et al. (1990) suggests that females may select more sheltered habitats for newborn calves. While there is currently no direct data for important calving habitat in GB, known mom-calf groups tend to shift their distribution from upper GB to lower GB, often in the eastern portions removed from the HSC, during November – April (Fazioli et al. 2018). Later, upon return to upper GB in the late spring, neonate calves are typically already present. More investigation of distribution and habitat use patterns during calving season is necessary to understand which habitats may play an important role in this behavior.

Bottlenose dolphins frequently travel between important habitat areas and may, at times, move widely throughout their range. Travel in and out of estuaries may occur regularly as dolphins utilize inshore, pass and nearshore beach habitats. The frequency and importance of these movements for each stock utilizing BR is not well known, however Jones III (1988) noted apparent daily movements in and out of BR, with summer/fall movements from the pass to the beach and winter movements from the pass to the bay. Maze and Würsig (1999) documented West Bay resident dolphins moving seasonally in and out of San Luis pass, primarily using inshore estuarine waters during summer months and Gulf and pass waters during winter months. In mid-Texas bays, Lynn and Würsig (2002) found that resident dolphins left the bay system only very infrequently while McHugh (1989) found no evidence that the same dolphins utilized both inshore and offshore habitats.

Travel, rest and social behaviors are important aspects of dolphin energy budgets in addition to foraging behavior. Evaluation of energy budgets and habitat use in relation to behavior provides insight into critical needs of the population and may help to delineate between communities with overlapping ranging patterns. For example, Henderson and Würsig (2007) found distinct differences in behavior patterns indicating habitat partitioning of adjacent communities of West Bay resident dolphins and Gulf of Mexico coastal dolphins utilizing San Luis Pass.

Health and Stressors

Health data for Texas dolphins are primarily gathered through the Texas Marine Mammal Stranding Network (TMMSN) in cooperation with the NOAA Marine Mammal Health and Stranding Response Program (MMHSRP).

Under the MMPA Section 410(3), a "stranding" is defined as an event in the wild where:

(A) A marine mammal is dead and is –

(i) on a beach or shore of the United States; or

(ii) in waters under the jurisdiction of the United States (including any navigable waters); or

(B) a marine mammal is alive and is –

(i) on a beach or shore of the United States and unable to return to the water;

(ii) on a beach or shore of the United States and, although able to return to the water, is in apparent need of medical attention; or

(iii) in the waters under the jurisdiction of the United States (including any navigable waters), but is unable to return to its natural habitat under its own power or without assistance.

Reviews of stranding patterns and statistics in Texas are offered by Worthy (1998), Mullins (2008), and Litz et al. (2014) (UME"s only). "Level A data" detailing stranding activity on the Texas coast (basic data including date and location, species, condition of animal, sex of animal, length, disposition of the animal and tissues or specimens, and any personal observations) from 2005 – 2017 was requested and received from the National Stranding Database and is currently under preliminary review for inclusion in baseline data reports. According to the MMHSRP, "These data provide information necessary to detect elevated stranding rates and other trends that may have conservation implications. Recording data on gross mortalities may serve as an indicator that a particular population is impacted, threatened or at increased risk. When provided in a timely manner, this information may aid in dynamic management practices" (2017 National Stranding Database Examiners Guide). Additionally, the Marine Mammal Human Interaction Report provides consistent and detailed information on signs of human interaction in stranded marine mammals, documenting evidence of human interaction on the animal and attempting to determine whether human activities contributed to a stranding event (2017 National Stranding Database Examiners Guide). Tracking trends in stranding event data will be one way to monitor potential impacts from project activities.

Review of available literature sources indicate bimodal stranding peaks occur in late fall/early winter with a larger peak during late February to early May, coinciding with dolphin calving seasons for the region. Unusual mortality events (UME's) with increased stranding occurrences for the region have been documented in 1990, 1992, 1994, 2007, 2008 and 2012 (A review is offered by Litz et al. (2014)). Some UME's are Gulf-wide, or effect mainly offshore or coastal stocks. However, the BSE population in Matagorda Bay were effected in both the 1990 and 1992 UME's. The causes of these events remain officially undetermined. The 1990 event coincided with a larger Gulf event attributed to morbillivirus, though a hard freeze caused abnormally low sea surface temperatures in Matagorda Bay and may have contributed to deaths in this region. In 1992, record rainfall leading to low salinity combined with pesticide runoff and morbillivirus exposure are thought to be possible contributing factors (Colbert et al. 1999; Litz et al. 2014).

Mullins (2008) summarized Texas stranding data from 1980-2004, and demonstrated the importance of creating spatial designations when collecting and reviewing stranding data, as multiple factors influence stranding rates from different geographical regions. Separating Texas coastal regions in addition to categorizing stranding events as “Open Ocean” (open shorelines facing the GoM), “Intracoastal” (intra- and inter-channel waterways, passages between bays, rivers, and estuaries), and “Bay” (those reported from within major Texas bays), was key to illuminating trends for locations that did not follow trends for total events. Specifically, she found that a majority (68%) of stranding events occurred in Open Ocean locations, therefore largely influencing the total trend, and that separating stranding events occurring in Bay and Intracoastal locations revealed trends for inshore waters that varied from the overall total. It is important to keep in mind, these designations are based on the location an animal was found, which may not always be a true indication of stock origin. Additionally, due to variability in trends, Mullins (2008) found attempts to explain temporal distribution in the dataset or to forecast trends beyond 2004 to be inconclusive.

Collecting health data from dead or stranded animals, while a critical and informative piece of the life history puzzle, has many limitations. Consequently, live animal health assessments are evolving as an important tool for monitoring risk in bottlenose dolphin populations to identify problems before they become stranding events (Wells et al. 2004). In addition to collection of important demographic parameters such as age, sex and genetic profile, health metrics collected during a live capture event may include: body condition (physical examination, weight, morphometric measurements and blubber depth); core temperature; and blood, urine, milk and fecal analysis (standard chemistry, hematology, hormones, contaminants, infection and disease). Standardized methods of collection and evaluation of these metrics allow managers to grade the health of individual dolphins based on clinical assessment in comparison to established “normal” parameters and reference populations (Wells et al. 2004; Hart et al. 2013). Only one live capture health assessment has been completed in Texas, conducted in response to the 1992 UME in Matagorda Bay. During this event, 36 dolphins were examined, 35 of these were freeze-branded for easier identification and 10 were fitted with radio transmitters for tracking (Lynn and Würsig 2002). Results helped to inform analysis of the UME, provided contaminant exposure data and allowed for an analysis of the home range of this population (Litz et al. 2014; Lynn and Würsig 2002; Schwacke et al. 2002).

Evidence suggests that dolphins residing within industrial coastal regions carry increased toxicant loads and are subject to adverse effects on reproduction, endocrine function and immune function (Ross 2000; Schwacke et al. 2002; Stein et al. 2003; Wells et al. 2005). These health conditions, combined with other environmental stressors could cause immunosuppression, making dolphins more susceptible to disease (Schwacke et al. 2012; O’Shea et al. 1998; De Guise et al. 2003; Stein et al. 2003; Fair and Becker 2000). Contamination of water, sediment and biological resources within GB are a current cause for heightened concern. Galveston Bay has a history of industrial contamination, including polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins, chlorinated pesticides and heavy metals (TCEQ 2011). The Texas Department of State Health Services (TDSHS) has issued seafood consumption advisories throughout the Galveston Bay system and the Texas Commission on Environmental Quality (TCEQ) has initiated total maximum daily load (TMDL) projects for bioaccumulating pollutants including PCBs and dioxins in the Houston Ship Channel and Upper Galveston Bay (HGAC 2012). The San Jacinto River Waste Pits Superfund Site is located directly upstream and is implicated as one source of dioxins in this area (EPA 2012). Numerous other Superfund sites dot the landscape surrounding the bay (EPA 2018). Additionally, legacy contaminants have been found in sediment located near contaminant sources in Galveston Bay (Dean et al. 2009; Howell et al. 2008; Suarez et al. 2006). Redistribution of sediment from tidal activity, erosion and dredging and disposal practices may release additional toxic pollutants and heavy metals into the water column (Ohimain et al. 2008; Suarez et al. 2006). Contaminant loads are currently unknown for GB dolphins, however, the GDRCP collected remote biopsy samples from 2015-2018 from dolphins within GB. Blubber sub-samples from these sampling efforts are pending analysis for Mercury (Hg) (n=52), persistent organic pollutants (POP's) (n=48) and specific analysis for dioxins (n=44).

Bottlenose dolphins are physiologically adapted to inhabit brackish to oceanic coastal waters with salinities that typically range from 18 – 35 ‰. As such, they conserve freshwater through osmoregulation and are subject to negative health consequences and even death due to prolonged exposure to low salinity environments (less than 10 ‰) (Ewing et al. 2017; Colbert et al. 1999; Holyoake et al. 2010). Physiologic effects of freshwater exposure include significant changes in blood chemistry (elevated levels of glucose, HCO_3, total bilirubin, ALT, total protein and globulin; and lowered osmolality and alkaline phosphatase) and electrolytes (lowered Na, Cl, and Na/K ration; and elevated Na/Cl ratio) (Ewing et al. 2017) plus clouding of the eyes due to corneal edema. Additionally, several studies have documented the development of skin lesions characterized by degradation and ulceration of the epidermis accompanied by secondary infections from opportunistic pathogens (Ewing et al. 2017; Mullin et al. 2015; Colbert et al. 1999; Holyoake et al. 2010). While dolphins sometimes make short forays into riverine environments, or withstand short bouts of low salinity conditions, evidence suggests a threshold for establishing suitable long-term dolphin habitat for Gulf of Mexico estuarine dolphins to be ≥ 11 ‰ (Ewing et al. 2017; Hornsby et al. 2016; Fazioli et al. *in review*). Final establishment of habitat criteria needs to consider the current state of knowledge regarding the response of dolphin to low salinity, and utilize biologically meaningful exposure regimes (salinity level, duration) for evaluating impacts. Hornsby et al. 2016 indicated that dolphins may sometimes utilize habitat at ~8 ‰, but avoided waters with <5 ‰, and Ewing et al. 2017 suggests that water approaching freshwater values had a greater impact on the physiological response regardless of duration of exposure. Since 2015, the GDRCP has documented frequent cases of skin lesions consistent with freshwater exposure among dolphins in the GB estuary (Fazioli et al. 2016). Recent analysis of skin lesion data in the GB population after Hurricane Harvey supports that these lesions are correlated with salinity levels below 10-11 ‰, with lesion extent significantly increasing during the low salinity event associated with Harvey (Fazioli et al. *in review*). Additionally during Hurricane Harvey, dolphins evacuated the upper portion of the bay, likely favoring deep water channels and higher salinity habitats until salinity levels reached >10-11 ‰. Due to its brackish nature, much of the inner portion of the GB estuary is likely marginal habitat for dolphins in regards to salinity, possibly making them particularly sensitive to increased prolonged low salinity exposure caused by freshwater runoff and flood events and/or retention of freshwater. Access to a higher salinity environment during these events is an important management consideration.

Overall, the cumulative stressors of a heavily urbanized and industrialized watershed pose a high risk to the health of dolphins residing in GB. A threat assessment performed by Phillips and Rosel (2014) identified the highest ranked risk factors to be chemical pollution, commercial and recreational fisheries, dredging and construction, algal blooms, hypoxia, adverse weather, freshwater inflows and habitat loss. These risks combined with virtually no data available on population structure, abundance or mortality for this stock led to GB receiving a "high priority" ranking and the highest risk score for the Texas coast in the assessment. Dolphins in this region will likely continue to be exposed to these stressors into the future, with the addition of increased urbanization and potential changes to the Galveston Bay habitat caused by climate change and sea level rise. Potential effects to dolphin populations due to climate change are currently under examination through the NOAA fisheries Marine Mammal Climate Vulnerability Assessment (MMCVA) and this report can be updated when those results are released.

Potential Construction and Operational Impacts

Potential construction and operational impacts and disturbances vary based on geographical project location, seasonality and activity type. Preliminary impacts of highest concern to marine mammals from construction and operational project activities are categorized below. These impacts are similar for each alternative, however the location, extent and stock specificity of impacts may vary dependent on the specific action. As engineering plans develop, impacts to marine mammals at each location of applied CSRM or ER measures should be specifically evaluated for severity and take potential. Current assumptions are based on available data and plans provided by the TGLO and USACE and may need to be re-evaluated as project plans progress. Alternative A's proposed BR environmental flow and sector gates represent the activity with the highest potential for impact to GB marine mammals. Early involvement with NOAA's office of protected resources and local and regional experts will be critical to formulate a scientific plan for addressing impacts to marine mammal populations, including evaluation of data gaps, pre-project data collection, mitigation options, and construction and long-term operational adaptive monitoring plans. Mitigation actions should be considered early in the engineering and planning phase to minimize impacts and take. A preliminary summary of potential threats and mitigation measures are presented in Appendix 4: Potential Impact and Mitigation Summary.

Noise

Sound plays a sizeable role in the life of any marine mammal and the impacts of noise is an increasing concern in today's busy aquatic environment. Potential impacts on marine mammal populations utilizing Galveston Bay and nearshore Gulf waters, include 1) the physiological effects of high-energy sound exposure; 2) masking of biologically important sounds, and; 3) behavioral disruptions that may result in negative effects on population vital rates.

High-energy sound exposure from pile driving or explosive detonations can cause direct physical injury to marine mammals in the form of permanent threshold shifts (PTS) or temporary threshold shifts (TTS). PTS are a permanent, irreversible increase in the threshold of audibility at a specified frequency while TTS are a temporary, reversible increase in the threshold of audibility at a specified frequency. In addition to direct physiological effects of acoustic disturbance, anthropogenic noise can mask important sounds used by marine mammals (Clark et al. 2009; Jensen et al. 2009; Nowacek et al. 2007). Dolphins rely heavily on sound for communication, navigation, predator avoidance, and foraging using both active echolocation and passive listening (Allen et al. 2001; Tyack 2008; Nowacek et al. 2007). Therefore, increased noise pollution in an important habitat such as BR could have the potential to cause significant disruption to dolphin activities. Severity of behavioral disruption is often contextual to the acoustic environment and behavioral state of the animals when exposed and may result in 1) effects on energy budgets and critical behaviors such as feeding and socializing, 2) temporary or permanent habitat abandonment, and 3) increased risk of predation, injury and stranding (Ellison et al. 2012).

Due to likely extensive pile driving associated with construction of floodwall barriers, an in depth noise assessment will be necessary to map the acoustic environment and the zones of potential physical injury and behavioral disruption from these activities. Southall et al. (2008) provides scientific recommendations for structuring noise exposure assessments and NOAA provides additional guidance for applying these recommendations (NOAA 2016). Detailed Noise impact assessment requirements and a summary of noise reduction and mitigation measures can be found in Appendix 3: Marine Mammal Noise Impact Assessment Initial Recommendations and Data Gaps.

Marine mammals are placed into functional hearing groups for determining noise response thresholds based on their hearing frequency range. Bottlenose dolphins are considered “mid-frequency cetaceans”, hearing in the range of 150 Hz to 160 kHz. Underwater noise injury thresholds (PTS) for impact pile driving are 230db peak SPL (sound pressure level) and 185db SEL (cumulative sound level, accounting for duration of exposure over a 24hr period); and for vibratory pile driving PTS threshold is 198db SEL. Determination of behavioral disturbance thresholds will depend on establishing levels of background noise in the construction zone. Noise reduction measures are necessary where unmitigated sound levels exceed desired thresholds. The effectiveness of noise mitigation measures are highly site specific and must be chosen carefully and validated based on real time conditions. Attainable noise reduction levels range from 6 – 20 db peak sound pressure at a range of frequencies. Development of engineering plans to include noise reduction technology will be vital to minimizing the zone of influence and reducing “take” numbers. Potential mitigation measures to explore include: Bubble curtains (Würsig et al. 2000b), double walled piles (Reinhall et al. 2016), Hydro Sound Dampers (Elmer and Savery 2014), IHC Noise mitigation screens, cofferdams (Stokes et al. 2010), “soft-start” operational procedures, and dolphin exclusion zones.

Dredging

Noise, vessel activity, sediment suspension, release of toxic compounds and habitat modification are all concerns surrounding dredging activities with the potential to cause negative consequences to dolphin populations. In addition to dredging activities for ER measures throughout the estuary, construction of a bypass channel for the HSC in BR will require deep dredging. High levels of toxic legacy contaminants and heavy metals absorbed into Galveston Bay sediment will be at risk for re-suspension into the water column (Suarez et al. 2006, Dean et al. 2009, Howell et al. 2008, Ohimain et al. 2008), putting dolphins at risk for increased exposure and bioaccumulation through prey. These substances have the potential to cause adverse effects on immune function and reproduction and increase incidence of disease, as outlined in the background information above. Increased turbidity as a result of dredging can decrease primary productivity and burry benthic organisims causing localized disruption in dolphin prey source feeling and distribution. In addition it can cause stress to nekton by reducing respiration rates by coating gills with sediment (USACE and TGLO 2018, Clarke and Wilber, 2000). See section: prey source for descriptions of how impacts to BSE dolphin stocks can be impacted by reductions in their prey source.

Pirotta et al. (2013) found that higher intensities of dredging, even in an area of high baseline industrial activity, caused bottlenose dolphins to spend less time in the important foraging site of Aberdeen harbor (Scotland). While few studies have focused on the effects of dredging on marine mammals, Todd et al. (2015) provides a review of available data, and concludes that effects are likely to vary by location and equipment type. Furthermore, the authors suggest that management procedures such as proper capture and removal of sediment will reduce direct physical effects, with remaining concerns including acoustic masking due to noise of operations, short-term behavioral response and alterations to prey availability. Dredge activities should be planned to avoid sensitive benthic communities and fish spawning seasons to reduce fisheries impacts that would indirectly affect dolphins.

Increased Vessel Traffic

Vessel traffic is expected to increase temporarily during construction due to vessel-based construction activities. Additional permanent changes in vessel traffic patterns and density are expected due to a decrease in functional area for navigation as a result of permanent structures. Dolphins are known to change their behavior in response to vessel traffic (Nowacek et al. 2001; Bejder et al. 2006; Piwetz and Würsig 2015; Allen and Read 2000). While there are many factors that play into how vessels may affect behavior, a common trend implies that smaller vessels quickly changing speed and direction have more of an immediate behavioral effect than larger vessels on a steady path such as cargo ships. Short-term responses to vessels can range from attraction (bow riding) to changes in behavioral state, dive patterns and orientation. Repeated vessel disturbance could lead to a change in energy budgets and/or habitat use. Reactions to vessel traffic appear to be highly contextual to the environment and dolphin behavior, necessitating site-specific observations to validate assumptions made from other studies. Potential mitigation options include controlling the speed of work vessels and providing additional 'safe' zones outside of the construction area with vessel speed limits.

Physical Barrier

The operational presence of the floodgate barrier across BR, even with open navigational and environmental flow gates, has the potential to act as a hindrance to dolphin movements in this area. There are documented instances of dolphins being functionally 'trapped' in areas where the only passage is through narrow or low clearance bridges (Mullin et al. 2015). If dolphins are hesitant to pass through the vertical lift gate openings, functional passage may be restricted to the Houston Ship Channel sector gate where there is the potential for increased vessel traffic impacts. Where gates are placed at smaller bayou inlets, it may restrict movement in and out of those bayous entirely.

Operational closing of the gates for emergency hurricane preparations and maintenance purposes would entirely close off the pass. These closures have a potential for injury, noise disturbance, separation of social groups, effects on prey items, and disruption of foraging. The frequency and duration of maintenance and storm-related closures is currently undetermined, but will dictate the level of potential disturbance to marine mammals from these activities. The Engineer Research and Development Center, Coastal and Hydraulics Laboratory performed estuarine hydraulic and salinity modeling using the 3D Adaptive Hydraulics (AdH) model (McAlpin et al. 2018). The hydrodynamics at gate locations show "high velocity magnitudes, eddy formations, and large water surface elevation changes across the structures" McAlpin et al. (2018). Additionally, reduced conveyance of flow through the pass is expected to create a 13-17% reduction in tidal prism within GB. Tidal flow is known to influence dolphin movements and foraging patterns. It is difficult to predict how increased flow velocities directly surrounding the gate system and an overall decrease in tidal prism will effect dolphin travel and foraging activities.

Water Quality

The Coastal Barrier's gate system at Bolivar Roads will reduce the cross-sectional area of the pass by 27.5 percent and reduce the tidal prism by 13.5 to 16.5 percent reducing the tidal amplitude by 9 to 22 percent (USACE and TGLO, 2018). Velocities may increase by up to 6.6 feet per second at the gate (USACE and TGLO 2018). The narrowing of the cross-sectional opening and decreased tidal prism will cause reduced circulation in Galveston Bay which will increase residence time in the bay. Increased residence time will decrease the salinity in times of freshwater inflow, and increase salinities during periods of severe drought. Additionally, reduced mixing with the Gulf of Mexico could cause the development of lower dissolved oxygen conditions upstream of barriers (USACE and TGLO, 2018).

Increased holding time of freshwater in the bay following rain events, which are known to carry additional pollutants, will increase the exposure of BSE dolphin stocks to harmful waterborne pollutants and may indirectly enhance exposure to bio accumulating contaminants via the food web (USEPA 1983; Soller et al. 2005). According to McAlpin et al. (2018) "The salinity was analyzed at 23 locations along the HSC and in the surrounding bays. On average, the salinity did not vary by more than 2 ‰ between with and without project conditions at any location." This modeling includes the assumption of a 12 percent decrease in freshwater flow into the Galveston Bay estuary over the next 50 years based on projected increasing water demands of the growing Houston population (McAlpin et al. 2018; Guthrie et al. 2010). The majority of sites exhibited declines in salinity in comparison to no project alternatives for the same time periods (e.g. present 2035 and future 2085). Mean salinity isohaline plots indicate that some areas of the bay where dolphins frequent are already considered marginal dolphin habitat, dipping below the 11 ‰ threshold for at least a portion of the year. Dolphin habitat use and health in these zones could be affected by even a small decrease in salinity under project conditions. The current model does not explicitly consider the closing of Rollover Pass in East Bay or the proposed deepening and widening of the Houston Ship Channel (Das 2018), both of which have the potential to further impact salinity regimes in portions of the estuary. Furthermore, intensification of the hydrological cycle associated with global climate change may cause increased heavy precipitation and flood events

(Easterling et al., 2000; Knutson et al., 2010). How these events would be altered by increased holding times in the bay would need to be modeled for evaluation of impacts to available dolphin habitat.

Prey Source

Dredging, changes in tidal prism, water quality, and the effects of physical barriers can all impact fishery recruitment through passes, indirectly impacting BSE dolphin stocks by reducing available prey. Modeling of fisheries impacts will be vital to determining foraging efficiency for the dolphin population under project conditions. Many important prey species of BSE dolphins are estuarine dependent meaning they utilize the estuary to complete their lifecycle. A large number of estuarine dependent species utilize natural passes to facilitate spawning aggregations in the near-shore GoM with access to protected nursery habitats in the bay. Little is understood about the current ingress and egress of the essential prey sources of BSE dolphins.

The draft Environmental Impact Statement for the CSRM System, section 5.4.2 (Ecological and Biological Resources; Aquatic Communities) mentions that environmental flow gates placed near shore in shallow waters will facilitate ingress and egress of aquatic organisms but overall the barrier is likely to impede the migrations and movements of various life stages of nekton (USACE and TGLO, 2018). The secondary in-bay barriers at Dickinson Bayou, Clear Lake, and Offatts Bayou could also inhibit movement of nekton past the barriers (USACE and TGLO, 2018). Galveston Bay supports a diverse nekton population that is influenced by salinity, habitat availability, fishing pressures, and in many cases recruitment through tidal passes. The potential changes to physical and water quality attributes could change the distribution of dolphin prey sources in Galveston Bay. Overall, a reduction of overall populations of fish and shellfish in the bay is expected with the CSRM System (USACE and TGLO, 2018). The reduction in available prey source can directly affect the distribution, competition, and overall fitness of the BSE stock of bottlenose dolphin in GB. Alteration of prey sources may also indirectly increase exposure of the BSE dolphin stock to predators and other stressors depending on where dolphins shift their habitat association in order to find food sources.

Storm Protection

Catastrophic weather events such as hurricanes may impact dolphins indirectly through critical habitat damage, decreased prey availability, and water quality changes (salinity, hypoxia and exposure to toxins) or directly through physical injury and habitat displacement (Rosel and Watts 2007; Bassos-Hull and Wells 2007). “Out of habitat” dolphins documented after hurricanes are sometimes trapped in areas outside their normal range in locations where they are likely to perish due to surrounding environmental conditions or lack of resources (Rosel and Watts 2007). After Hurricane Rita’s landfall in Louisiana, seven bottlenose dolphins were found in various locations including flooded roadside ditches, borrow pits, larger canals, shallow flooded field and natural creeks. These locations were located 2.5 to 11 km inland where salinities ranged from 10 to 15 ‰ (Rosel and Watts 2007). The displaced animals were carried inland by the 4.6 m storm surge accompanying the hurricane and were left stranded in areas that retained water longest as waters receded. Between 2005 and 2017, a total of nine bottlenose dolphins were reported as "out of habitat" in Texas. Of these, four were reported as likely to be caused by storm surge (Tropical Storm Eduardo (2008) n=1, Hurricane Ike (2008) n=1, Hurricane Harvey (2017) n=2) (NOAA Level A Stranding Data[2]). Observations indicate that dolphins may change distribution patterns in response to hurricanes. Dolphins were displaced from their habitat in upper Galveston Bay for weeks following freshwater flooding associated with Hurricane Harvey, returning when salinity levels rose above 10-11‰ (Fazioli et al. *in review*). One population in the Bahamas exhibited long-term post-hurricane changes to population structure (Elliser and Herzing 2011), while Bassos-Hull and Wells (2007) found no long-term impacts to the dolphin population in Charlotte Harbor, FL after Hurricane Charley devastated the shoreline.

The storm surge reductions in the bay afforded by the proposed Alternative A may provide protection from "out of habitat" storm displacement for dolphins residing within the GB estuary. Given the greater probability of stronger storms with global climate change, it is highly likely that storm surges will increase as well. Under future sea level rise scenarios and a Hurricane Ike-type storm making landfall southeast of Galveston Island the maximum surge in Galveston Bay could reach 21 feet (6.6 m) (Arcadis 2011), a full 2 meters higher than the Hurricane Rita scenario detailed above. However, as isolated events, historically effecting relatively small numbers of individuals, these benefits are unlikely to affect long-term population vital rates.

Additional Considerations – West Indian Manatee

While the number of manatee migrating into Texas is small, construction activities or the presence of a physical floodgate barrier may discourage migrant or stray individuals from taking refuge in GB due to similar disturbance concerns outlined above for bottlenose dolphin. In the event of a manatee sighting near the construction zone, mitigation measures should include a plan to immediately report the sighting to the USFWS and TMMSN and to follow the USFWS guidelines, "Standard Manatee Conditions for In-Water Work" (Appendix 5).

Knowledge Gaps

While life history data on dolphins in Texas documenting relative density, seasonal, distributional and stranding patterns are available, other important data necessary to establish baseline parameters for assessment of impact are lacking. Refer to Appendix 2 for a specific outline of baseline knowledge and data gaps for each preliminarily recommended impact assessment metric.

---

[2] *Note: These data may contain errors or may be missing records. These data are from the NOAA National Marine Mammal Health and Stranding Response Database and the NOAA SER Marine Mammal Stranding Database. We acknowledge the Southeast US Marine Mammal Stranding Network for the collection of these data.*

For the upper coast region of Texas, where the majority of impacts are expected in Galveston and surrounding bays, fine-scale population structure remains unknown and population abundance estimates are outdated. We hypothesize that BR and surrounding waters are potentially used by up to four currently designated stocks of bottlenose dolphin (Western Coastal, Galveston BSE, West Bay BSE, and Sabine Lake BSE). Specific calculations of estimated take per stock affected will not be possible without additional fine-scale demographic data. Furthermore, evaluation and mapping of available dolphin habitat in the region is needed to provide managers with a better understanding of where stocks may find necessary resources if they are displaced from current habitat. A full evaluation of Level A stranding data 2005 - present needs to be completed to establish baseline conditions and attempt to predict trends under no-project conditions for comparison to stranding data during and after project activities. A summary of available data prior to 2005 is available from Mullins (2008).

Standardized long-term monitoring efforts of dolphins within the potential impact zone of project activities are currently lacking and should be established prior to the onset of construction to create a dataset for calculation of vital rates and to provide context for distribution, habitat use and behavioral data to inform monitoring plans during and after construction. Additionally, health is a key factor for establishing the link between observed behavioral patterns and the biological significance of those patterns on overall vital rates of the population. Therefore, estimating both baseline health status and vital rates, which are currently lacking in the GB region, prior to the onset of disturbance would be necessary to evaluate any links with project activities and, if needed, adaptively manage and mitigate negative effects associated with the project. Live-capture health assessments have not been conducted in Galveston Bay, therefore little health data is currently available. Establishing baseline health indicators for the population prior to project activities is highly recommended. Analysis of previously collected (2013-2018) remote biopsy samples from within Galveston Bay, plus sampling of areas within and surrounding BR would provide baseline information for POP's, heavy metals and delineation of dolphin communities utilizing genetic and stable isotope analysis. Additionally, remote biopsy sampling could be utilized as long-term monitoring tool for not only tissue contaminant loads, but also for measuring progesterone and cortisol hormone levels for evaluating reproductive success and stress response (Kellar et al. 2006; Kellar et al. 2015; Pérez et al. 2011). Other important health metrics including blood chemistry, body condition, disease pathology, adrenal function, hearing loss and diagnostic ultrasound can only be provided through live-capture health assessment (Wells et al. 2004; Schwacke et al. 2013).

Sound is a critical element for any in-water project impact assessment. Investigation of how project noise will propagate above current background levels and be received by dolphins in the vicinity must be modeled to create the expected zone of influence and behavior of dolphins in the region understood for context of potential disruptions and evaluation of the effectiveness of mitigation measures. To accomplish this task, baseline sound surveys are needed to describe the typical acoustic background profile of areas of interest in GB, specifically areas with planned in-water work, especially the BR area. This baseline work should encompass diurnal, day-of-the-week, and seasonal scales. In addition, physical parameters including sediment type, bathymetry, water chemistry, and detailed construction activities and materials are needed to model noise propagation in order to assess the potential for impact to dolphins in the vicinity of the proposed in-water construction efforts.

Mitigation and Monitoring

While mitigation and monitoring plans are outside of the scope of this initial report, initial broad suggestions can be found by referring to Appendix 2 and Appendix 4. Additionally, we recommend creating an adaptive management plan to meet the mitigation, monitoring and reporting requirements of an ITA under the MMPA. To complete this plan, we suggest the creation of an adaptive management team consisting of marine mammal experts and managers that can review specific project activities and make recommendations in coordination with project managers. In this way, minimization and monitoring of marine mammal takes can be proactive and integrated with other plans for the overall project. Engagement and planning should start early and aim to accomplish the below goals as outlined in the ITA application requirements:
An ITA requires both "mitigation monitoring", required to implement specific mitigation measures, and "general monitoring", performed to, 1) Increase our knowledge of the species, and 2) Enhance our understanding of the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities.

Monitoring should improve our understanding of one or more of the following:

- Occurrence of marine mammal species in the area of the action (e.g., presence, abundance, distribution, and/or density of species)
- Nature, scope, or context of the likely exposure of marine mammals to potential stressor(s) (e.g., sound or visual stimuli), through better understanding of one or more of the following: o Action or environment (e.g., sound source characterization, propagation, ambient noise levels)
    - Affected species (e.g., life history or dive patterns)
    - Co-occurrence of marine mammals with the action (in whole or part)
    - Biological or behavioral context of exposure to the stressor(s) (e.g., age of exposed animals or known pupping, calving or feeding areas)
- Response to stressors (behaviorally or physiologically) associated with the action (in specific contexts when possible, e.g., at what distance or received level)
- How anticipated individual responses, to individual stressors or anticipated combinations of stressors, may impact either the long-term fitness and survival of:
    - An individual, or
    - The population, species, or stock (e.g., through effects on annual rates of recruitment or survival)
- Effectiveness of mitigation and monitoring measures

Literature Cited

Allen, M. , and A. Read. 2000. 'Habitat Selection of Foraging Bottlenose Dolphins in Relation to Boat Density near Clearwater, Florida', *Marine Mammal Science*, 16: 815-24.

Allen, M. , A. Read, J. Gaudet, and L. Sayigh. 2001. 'Fine-scale habitat selection of foraging bottlenose dolphins Tursiops truncatus near Clearwater, Florida', *Marine Ecology Progress Series*, 222: 253-64.

Arcadis. 2011. ADCIRC Based Storm Surge: Analysis of Sea Level Rise in the Galveston Bay and Jefferson County Area in Texa. Arcadis U.S. Inc. Highlands Ranch, CO.

Barham, E. G., J. C. Sweeney, S. Leatherwood, R.K. Beggs, and C. L. Barham. 1980. 'Aerial census of the bottlenose dolphin, Tursiops truncatus, in a region of the Texas coast', *Fish Bulletin*, 77: 585-95.

Barros, N., and D. K. Odell. 1990. 'Food Habits of Bottlenose Dolphins in the Southeastern United States', *The bottlenose dolphin*: 309-28.

Bassos-Hull, K. M., and R. S. Wells. 2007. "Investigating potential hurricane and red tide related impacts on bottlenose dolphin (Tursiops truncatus) abundance, reproductive rates, distribution, and site fidelity in Charlotte Harbor and Pine Island Sound, Florida. Final technical report." In, 1-43. Florida: Harbor Branch Oceanographic Institution.

Bejder, L., A. Samuels, H. Whitehead, and N. Gales. 2006. 'Interpreting short-term behavioural responses to disturbance within a longitudinal perspective', *Animal Behaviour*, 72: 1149-58.

Bejder, L., A. Samuels, H. Whitehead, N. Gales, J. Mann, R. Connor, M. Heithaus, J. Watson-Capps, C. Flaherty, and M. Kruetzen. 2006. 'Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance', *Conservation Biology*, 20: 1791-98.

Berens McCabe, E. J., D. P. Gannon, N. B. Barros, and R. S. Wells. 2010. 'Prey selection by resident common bottlenose dolphins (tursiops truncatus) in Sarasota Bay, Florida', *Marine Biology*, 157: 931-42.

Bräger, S. 1993. 'Diurnal and seasonal behavior patterns of bottlenose dolphins (Tursiops truncatus)', *Marine Mammal Science*, 9: 434-38.

Candelaria-Ley, R. I. 2001. 'Frequency and amplitude shifts in the whistle vocalizations of bottlenose dolphins in response to anthropogenic noise', Masters, Texas A&M University.

Clark, C. W., W. T. Ellison, B. L. Southall, L. Hatch, S. M. Van Parijs, A. Frankel, and D. Ponirakis. 2009. 'Acoustic masking in marine ecosystems: intuitions, analysis, and implication', *Marine Ecology Progress Series*, 395: 201-22.

Clarke, D.G., and D.H. Wilber. 2000. Assessment of potential impacts of dredging operations due to sediment resuspension. DOER Technical Notes Collection. ERDCTN-DOER-E9. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Colbert, A. A., G. I. Scott, M. H. Fulton, E. F. Wirth, J. W. Daugomah, P. B. Key, E. D. Strozier, and S. B. Galloway. 1999. "Investigation of unusual mortalities of bottlenose dolphins along the mid-Texas coastal bay ecosystem during 1992." In *NOAA Technical Report*, 25 pp. Seattle, Washington

Corkeron, P. J., M. M. Bryden, and K. E. Hedstrom. 1990. 'Feeding by bottlenose dolphins in association with trawling operations in Moreton Bay, Australia.' in, *The bottlenose dolphin* (Elsevier).

Das, H.S. 2018. Coastal Storm Risk Management and Ecosystem Restoration Projects along the Texas Coast: Environmental Impact (Tide, Salinity, and Velocity). Presentation 6/7/18. Galveston, Texas.

De Guise, S., K. B. Beckmen, and S. D. Holladay. 2003. 'Contaminants and marine mammal immunotoxicology and pathology', *Toxicology of marine mammals*: 38-54.

Dean, K. E., M. P. Suarez, H. S. Rifai, R. M. Palachek, and L. Koenig. 2009. 'Bioaccumulation of polychlorinated dibenzodioxins and dibenzofurans in catfish and crabs along an estuarine salinity and contamination gradient', *Environmental Toxicology and Chemistry*, 28: 2307-17.

Easterling, D.R., Meehl, G.A., Parmesan, C., Changnon, S.A., Thomas R.K., and L.O. Mearns. 2000. Climate Extremes: Observations, Modeling, and Impacts. Science 289: 2068-74.

Elliser, C. R., and D. L. Herzing. 2011. 'Replacement dolphins? Social restructuring of a resident pod of Atlantic bottlenose dolphins, Tursiops truncatus, after two major hurricanes', *Marine Mammal Science*, 27: 39-59.

Ellison, W. T., B. L. Southall, W. Clark, and A. S. Frankel. 2012. 'A New Context-Based Approach to Assess Marine Mammal Behavioral Responses to Anthropogenic Sounds', *Conservation Biology*, 26: 21-28.

Elmer, K., and J. Savery. 2014. "New Hydro Sound Dampers to reduce piling underwater noise." In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*, 5551-60. Institute of Noise Control Engineering.

EPA. 2012. "Site Update: San Jacinto River Waste Pits Superfund Site." In.: United States Environmental Protection Agency. .

Ewing, R. Y., B. Mase-Guthrie, W. McFee, F. Townsend, C. A. Manire, M. Walsh, R. Borkowski, G. D. Bossart, and A. M. Schaefer. 2017. 'Evaluation of Serum for Pathophysiological Effects of Prolonged Low Salinity Water Exposure in Displaced Bottlenose Dolphins (Tursiops truncatus)', *Frontiers in Veterinary Science*, 4.

Fair, P. A., and P. R. Becker. 2000. 'Review of stress in marine mammals', *Journal of Aquatic Ecosystem Stress and Recovery*, 7: 335-54.

Fazioli, K., V. Mintzer, and G. J. Guillen. *in review*. 'Short-term Effects of Hurricane Harvey on Bottlenose Dolphins (*Tursiops truncatus*) in the Upper Galveston Bay Estuary', *Estuaries and Coasts*. Submitted September 2018.

Fazioli, K., V. Mintzer, G. J. Guillen, and S Loe. 2016. " Texas' estuarine bottlenose dolphins: addressing knowledge gaps in Galveston Bay." In *Restore America's Estuaries*, poster. New Orleans, LA.

Fazioli, Kristi , Vanessa Mintzer, and George J. Guillen. 2018. Galveston Dolphin Research and Conservation Program. *Unpublished Data 2013-2018*.

Fazioli, K., V. Mintzer, and G. J. Guillen. 2017. Site fidelity of bottlenose dolphins (Tursiops truncatus) in a highly-industrialized estuary. In *Society for Marine Mammalogy, 22nd Biennial Conference on the Biology of Marine Mammals*. Halifax, Canada.

Fernandez, S., and A. A. Hohn. 1998. 'Age, growth, and calving season of bottlenose dolphins, Tursiops truncatus, off coastal Texas', *Fishery Bulletin*, 96: 357-65.

Fertl, D. 1994a. 'Occurrence patterns and behavior of bottlenose dolphins (Tursiops truncatus) in the Galveston ship channel, Texas', *Texas Journal of Science*, 46: 299-318.

Fertl, D. C. 1994b. 'Occurrence, movements, and behavior of bottlenose dolphins(Tursiops truncatus) in association with the shrimp fishery in Galveston Bay, Texas', Masters, Texas A&M University.

Fertl, D., A. J. Schiro, G. T. Regan, C. A. Beck, N. Adimey, L. Price-May, A. Amos, G. A. J. Worthy, and R. Crossland. 2005. 'Manatee occurrence in the northern Gulf of Mexico, west of Florida', *Gulf and Caribbean Research*, 17: 69-94.

Fleishman, E., D. P. Costa, J. Harwood, S. Kraus, D. Moretti, L. F. New, R. S. Schick, L. K. Schwarz, S. E. Simmons, L. Thomas, and R. S. Wells. 2016. 'Monitoring population-level responses of marine mammals to human activities', *Marine Mammal Science*, 32: 1004-21.

Frid, A., and L. M. Dill. 2002. 'Human-caused disturbance stimuli as a form of predation risk', *Conservation Ecology*, 6: 11.

Gannon, D. P., and D. M. Waples. 2004. 'Diets of coastal bottlenose dolphins from the US mid-Atlantic coast differ by habitat', *Marine Mammal Science*, 20: 527-45.

Gaskin, D. E. 1982. *Ecology of whales and dolphins* (Heinemann).

Gruber, J. A. 1981. 'Ecology of the Atlantic bottlenosed dolphin(Tursiops truncatus) in the Pass Cavallo area of Matagorda Bay, Texas', Masters, Texas A&M University.

Gunter, G. 1941. 'Occurrence of the Manatee in the United States, with Records from Texas', *Journal of Mammalogy*, 22: 60-64.

Guthrie, C.G., R.S. Solis, and J. Matsumoto. 2012. Analysis of the influence of water plan strategies on inflows and salinity in Galveston Bay. TWDB. Austin, TX.

Hart, L., R. Wells, and L. Schwacke. 2013. 'Reference ranges for body condition in wild bottlenose dolphins Tursiops truncatus', *Aquatic Biology*, 18: 63-68.

Hastie, G. D., B. Wilson, L. J. Wilson, K. M. Parsons, and P. M. Thompson. 2004. 'Functional mechanisms underlying cetacean distribution patterns: hotspots for bottlenose dolphins are linked to foraging', *Marine Biology*, 144: 397-403.

Hawkins, E. R., R. Harcourt, L. Bejder, L. O. Brooks, A. Grech, F. Christiansen, H. Marsh, and P. L. Harrison. 2017. 'Best Practice Framework and Principles for Monitoring the Effect of Coastal Development on Marine Mammals', *Frontiers in Marine Science*, 4.

Hayes, S.A., K. Josephson, K Maze-Foley, and P. Rosel. 2017. "US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2016." In, 282.

Heithaus, M. R., and L. M. Dill. 2002. 'Food availability and tiger shark predation risk influence bottlenose dolphin habitat use ', *Ecology*, 83: 480-91.

Henderson, E., and B. Würsig. 2007. 'Behavior patterns of bottlenose dolphins in San Luis Pass, Texas', *Gulf of Mexico Science*, 2: 153-61.

Henningsen, T. , and B. Würsig. 1992. "Interactions between humans and dolphins in Galveston Bay, Texas." In *Symposium Whales: Biology – Threats – Conservation*, edited by Royal Academy of Overseas Sciences J. J. Symoens, 135-40.

Henningsen, T. , and B. Würsig. 1991. "Bottlenosed Dolhpins in Galveston Bay, Texas: Numbers and Activities." In *Fifth Annual Conference of the European Cetacean Society*, edited by P.G.H. Evans. Sandefjord, Norway.

HGAC. 2012. 'TMDL Project for Dioxin and Polychlorinated Biphenyls (PCBs) in Fish Tissue', Houston-Galveston Area Council. http://www.h-gac.com/community/water/tmdl/houston-ship-channel-galveston-bay.aspx.

Hoese, H. D., and R. H. Moore. 1977. *Fishes of the Gulf of Mexico, Texas, Louisiana, and adjacent waters* (Texas A&M University.).

Holyoake, C., H. Finn, N. Stephens, P. Duignan, C. Salgado, H.C. Smith, L Bejder, T Linke, C Daniel, N.L. Hong, S. H. Gin, K Moiler, S. Allen, K Bryant, and D. McElligott. 2010. "Technical report on the bottlenose dolphin (Tursiops aduncus) unusual mortality event within the Swan Canning Riverpark, June-October 2009." In, 190. Murdoch University.

Hornsby, F. E., T. L. McDonald, B. C. Balmer, T. R. Speakman, K. D. Mullin, P. E. Rosel, R. S. Wells, A. C. Telander, P. W. Marcy, and L. H. Schwacke. 2016. 'Using salinity to identify common bottlenose dolphin habitat in Barataria Bay, Louisiana, USA', *Endangered Species Research*, 33: 181-92.

Howell, N. L., M. P. Suarez, H. S. Rifai, and L. Koenig. 2008. 'Concentrations of polychlorinated biphenyls (PCBs) in water, sediment, and aquatic biota in the Houston Ship Channel, Texas', *Chemosphere*, 70: 593-606.

Hubard, C. W., and S. L. Swartz. 2002. "Gulf of Mexico Bottlenose Dolphin Stock Identification Workshop." In *NOAA Technical Memorandum NMFS-SEFSC-473*, 33.

Huther, K. D. . 2010. 'An Examination of Bottlenose Dolphin (Tursiops truncatus) Abundances in Relation to Environmental Factors and Risks', Masters Graduate School of the College of Charleston.

Irwin, L. J., and B. Würsig. 2004. 'A small resident community of bottlenose dolphins, Tursiops truncatus, in Texas: monitoring recommendations', *Gulf of Mexico Science*, 22: 13-21.

Jefferson, T. A., S. K. Hung, and B. Würsig. 2009. 'Protecting small cetaceans from coastal development: Impact assessment and mitigation experience in Hong Kong', *Marine Policy*, 33: 305-11.

Jensen, F. H., L. Bejder, M. Wahlberg, N. Aguilar De Soto, M. P. Johnson, and P. T. Madsen. 2009. 'Vessel noise effects on delphinid communication', *Marine Ecology Progress Series*, 395: 161-75.

Jones III, S. C. 1988. 'Survey of the Atlantic bottlenose dolphin (Tursiops truncatus) population near Galveston, Texas', Masters, Texas A&M University.

Karczmarski, L., S. Huang, C. K. M. Or, D. Gui, S. C. Y. Chan, W. Lin, L. Porter, W. Wong, R. Zheng, and Y. Ho. 2016. 'Humpback dolphins in Hong Kong and the Pearl River Delta: status, threats and conservation challenges.' in, *Advances in marine biology* (Elsevier).

Kellar, Nicholas M., Krista N. Catelani, Michelle N. Robbins, Marisa L. Trego, Camryn D. Allen, Kerri Danil, and Susan J. Chivers. 2015. Blubber Cortisol: A Potential Tool for Assessing Stress Response in Free-Ranging Dolphins without Effects due to Sampling. *Plos One* 10 (2):e0115257. doi:10.1371/journal.pone.0115257.

Kellar, Nicholas M., Marisa L. Trego, Corina I. Marks, and Andrew E. Dizon. 2006. Determining Pregnancy from Blubber in Three Species of Delphinids. *Marine Mammal Science* 22 (1):1-16. doi:doi:10.1111/j.1748-7692.2006.00001.x.

Knutson, T.R., McBride, J.L., Chan, J., Emanuel, K., Holland, G., Landsea, C., Held, I., Kossin, J.P., Srivastava, A.K., and M. Sugi. 2010. Tropical cyclones and climate change. Nature Geoscience, 3: 157.

Leatherwood, S. 1975. 'Some observations of feeding behavior of bottle-nosed dolphins (Tursiops truncatus) in the northern Gulf of Mexico and (Tursiops cf. T. gilli) off southern California, Baja California, and Nayarit, Mexico', *Marine Fisheries Review*, 37: 10-16.

Leatherwood, S., and R. R. Reeves. 1983. 'Abundance of bottlenose dolphins in Corpus Christi Bay and coastal southern Texas', *Marine Science*, 26: 179-99.

Lent, R. 2015. "Comments on Draft Funded Priorities List." In.: Marine Mammal Commission.

Litz, J. A., M. A. Baran, S. R. Bowen-Stevens, R. H. Carmichael, K. M. Colegrove, L. P. Garrison, S. E. Fire, E. M. Fougeres, R. Hardy, and S. Holmes. 2014. 'Review of historical unusual mortality events (UMEs) in the Gulf of Mexico (1990-2009): providing context for the multi-year northern Gulf of Mexico cetacean UME declared in 2010', *Diseases of aquatic organisms*, 112: 161-75.

Litz, J. A., C. R. Hughes, L. P. Garrison, L. A. Fieber, and P. E. Rosel. 2012. 'Genetic structure of common bottlenose dolphins (Tursiops truncatus) inhabiting adjacent South Florida estuaries-Biscayne Bay and Florida Bay', *J. Cetacean Res. Manage*, 12: 107-17.

Lotze, H. K., H. S. Lenihan, B. J. Bourque, R. H. Bradbury, R. G. Cooke, M. C. Kay, S. M. Kidwell, M. X. Kirby, C. H. Peterson, and J. B. C. Jackson. 2006. 'Depletion, degradation, and recovery potential of estuaries and coastal seas', *Science*, 312: 1806-09.

Lusseau, D., D. E. Bain, R. Williams, and J. C. Smith. 2009. 'Vessel traffic disrupts the foraging behavior of southern resident killer whales Orcinus orca', *Endangered Species Research*, 6: 211-21.

Lynn, S. K., and B. Würsig. 2002. 'Summer movement patterns of bottlenose dolphins in a Texas bay', *Gulf of Mexico Science*, 20: 25-37.

Maze, K. S., and B. Würsig. 1999. 'Bottlenosed dolphins of San Luis Pass, Texas: Occurrence patterns, site-fidelity, and habitat use', *Aquatic Mammals*, 25: 91-104.

Mazzoil, M., J. S. Reif, M. Youngbluth, M. E. Murdoch, S. E. Bechdel, E. Howells, S. D. McCulloch, L. J. Hansen, and G. D. Bossart. 2008. 'Home Ranges of Bottlenose Dolphins (Tursiops truncatus) in the Indian River Lagoon, Florida: Environmental Correlates and Implications for Management Strategies', *Ecohealth*, 5: 278-88.

McAlpin, J., C. Ross, and J. McKnight. 2018. Draft Coastal Texas Region 1 (CTR1) Estuarine Numerical Modeling Report. ERDC/CHL TR-18-XX. USACE Engineer Research and Development Center, Coastal and Hydraulics Laboratory. Vicksburg, Mississippi. 278 pp.

McHugh, M. B. 1989. 'Population numbers and feeding behavior of the Atlantic bottlenose dolphin (Tursiops truncatus) near Aransas Pass, Texas', Masters, University of Texas at Austin.

Moreno, M. P. T. 2005. 'Environmental Predictors of Bottlenose Dolphin Distribution and Core Feeding Densities in Galveston Bay, Texas', Doctor Texas A&M University.

Mullin, K. D., K. P. Barry, C. Sinclair, J. Litz, K. S. Maze, E. Fougeres, B. Mase-Guthrie, R. Ewing, A. M. Gorgone, J. Adams, and M. Tumlin. 2015. "Common Bottlenose Dolphins (Tursiops truncatus) in Lake Pontchartrain, Louisiana: 2007 to mid-2014." In, 53.

Mullin, K. D., T. McDonald, R. S. Wells, B. C. Balmer, T. Speakman, C. Sinclair, E. S. Zolman, F. Hornsby, S. M. McBride, K. A. Wilkinson, and L. H. Schwacke. 2017. 'Density, abundance, survival, and ranging patterns of common bottlenose dolphins (Tursiops truncatus) in Mississippi Sound following the Deepwater Horizon oil spill', *Plos One*, 12: e0186265.

Mullins, R. L. 2008. 'Characterizing marine mammal stranding events along the Texas coast', Masters of Science Texas A&M University.

National Academies of Sciences, Engineering, and Medicine. 2016. "Approaches to Understanding the Cumulative Effects of Stressors on Marine Mammals." In, 146. Washington, D.C.: The National Academies Press.

New, L. F., J. Harwood, L. Thomas, C. Donovan, C. W. Clark, G. D. Hastie, P. M. Thompson, B. Cheney, L. Scott-Hayward, D. Lusseau, and D. Costa. 2013. 'Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance', *Functional Ecology*, 27: 314-22.

NOAA. 2016. *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing; Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts.* U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-55, 178 p.

Nowacek, D. P., L. H. Thorne, D.W. Johnston, and P. L. Tyack. 2007. 'Responses of cetaceans to anthropogenic noise', *Mammal Review*, 37: 81-115.

Nowacek, S. M., R. S. Wells, and A. R. Solow. 2001. 'Short-Term Effects of Boat Traffic on Bottlenose Dolphins, Tursiops truncatus, in Sarasota Bay, Florida', *Marine Mammal Science*, 17: 673-88.

O'Shea, T. J., R. R. Reeves, and A. K. Long. 1998. "Marine mammals and persistent ocean contaminants." In *Proceedings of the Marine Mammal Commission Workshop. Keystone, Colorado*, 12-15.

Ohimain, E. I., G. Jonathan, and S. O. Abah. 2008. 'Variations in heavy metal concentrations following the dredging of an oil well access canal in the Niger Delta', *Advances in Biological Research*, 2: 97-103.

Pennacchi, A. M. 2013. 'Behavior of Bottlenose dolphins (Tursiops truncatus) relative to boat traffic in the galveston ship channel, Texas\', Undergraduate Research Scholars Thesis, Texas A&M University Galveston.

Pérez, Sergi, Ángel García-López, Renaud De Stephanis, Joan Giménez, Susana García-Tiscar, Philippe Verborgh, Juan Miguel Mancera, and Gonzalo Martínez-Rodriguez. 2011. Use of blubber levels of progesterone to determine pregnancy in free-ranging live cetaceans. *Marine Biology* 158 (7):1677-1680. doi:10.1007/s00227-011-1676-9.

Phillips, N. M., and P. E. Rosel. 2014. "A Method for Prioritizing Research on Common Bottlenose Dolphin Stocks Through Evaluating Threats and Data Availability: Development and Application to Bay, Sound and Estuary Stocks in Texas." In *NOAA Technical Memorandum NMFS-SEFSC-665* 154.

Pirotta, E., B. E. Laesser, A. Hardaker, N. Riddoch, M. Marcoux, and D. Lusseau. 2013. 'Dredging displaces bottlenose dolphins from an urbanised foraging patch', *Mar Pollut Bull*, 74: 396-402.

Pirotta, E., N. D. Merchant, P. M. Thompson, T. R. Barton, and D. Lusseau. 2015. 'Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity', *Biological Conservation*, 181: 82-89.

Piwetz, S., and B. Würsig. 2015. *Dolphins modify behaviors due to human activity in an important foraging habitat*.

Reinhall, P.G., J. Hampden, and T. Dardis. 2016. "Underwater noise reduction of marine pile driving using a double pile; Vashon Ferry Termuinal Test " In.

Reyff, J. 2005. 'Underwater sound pressure levels associated with marine pile driving: Assessment of impacts and evaluation of control measures', *Transportation Research Record: Journal of the Transportation Research Board*: 481-90.

Ronje, E. I., H. R. Whitehead, S. Piwetz, K. P. Barry, C. Sinclair, and K. D. Mullin. 2017. "Seasonal Distribution and Inter-Bay Movements of Common Bottlenose Dolphins in Bays and Adjacent Coastal Waters of Texas." In *SMM 21st Biennial Conference*. Halifax, Nova Scotia, Canada.

Rosel, P. E., and H. Watts. 2007. 'Hurricane impacts on bottlenose dolphins in the northern Gulf of Mexico', *Gulf of Mexico Science*, 25: 88.

Rosel, P., K. Mullin, L. Garrison, L. Schwacke, J. Adams, B. Balmer, P. B. Conn, M. Conroy, T. Eguchi, and A. Gorgone. 2011. "Photo-identification capture-mark-recapture techniques for estimating abundance of bay, sound and estuary populations of bottlenose dolphins along the US East Coast and Gulf of Mexico: A workshop report." In *NOAA Technical Memorandum NMFS-SEFSC-621*, 38.

Ross, P. S. 2000. 'Marine Mammals as Sentinels in Ecological Risk Assessment', *Human and Ecological Risk Assessment: An International Journal*, 6: 29-46.

Runge, M. C., C. A. Langtimm, J. Martin, and C. J. Fonnesbeck. 2015. "Status and threats analysis for the Florida manatee (Trichechus manatus latirostris), 2012." In *Open-File Report*, 33. Reston, VA.

Santos, M. B., G. J. Pierce, R. J. Reid, I. A. P. Patterson, H. M. Ross, and E. Mente. 2001. 'Stomach contents of bottlenose dolphins (Tursiops truncatus) in Scottish waters', *Journal of the Marine Biological Association of the United Kingdom*, 81: 873-78.

Schwacke, L. H., E. O. Voit, L. J. Hansen, R. S. Wells, G. B. Mitchum, A. A. Hohn, and P. A. Fair. 2002. 'Probabilistic risk assessment of reproductive effects of polychlorinated biphenyls on bottlenose dolphins (Tursiops truncatus) from the southeast United States coast', *Environmental Toxicology and Chemistry*, 21: 2752-64.

Schwacke, L. H., E. S. Zolman, B. C. Balmer, S. De Guise, R. C. George, J. Hoguet, A. A. Hohn, J. R. Kucklick, S. Lamb, M. Levin, J. A. Litz, W. E. McFee, N. J. Place, F. I. Townsend, R. S. Wells, and T. K. Rowles. 2012. 'Anaemia, hypothyroidism and immune suppression associated with polychlorinated biphenyl exposure in bottlenose dolphins (Tursiops truncatus)', *Proc Biol Sci*, 279: 48-57.

Scott, M. D., R. S. Wells, and A. B. Irvine. 1990. 'A Long-Term Study of Bottlenose Dolphins on the West Coast of Florida 11', *The bottlenose dolphin*: 235.

Sellas, A. B., R. S. Wells, and P. E. Rosel. 2005. 'Mitochondrial and nuclear DNA analyses reveal fine scale geographic structure in bottlenose dolphins (Tursiops truncatus) in the Gulf of Mexico', *Conservation Genetics*, 6: 715-28.

Service, National Marine Fisheries. 2016. "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts." In, 189.

Shane, S. H., R. S. Wells, Würsig B., and D. K. Odell. 1982. "A review of the ecology, behavior life history of the bottlenose dolphin." In, 72 U.S. Dept of the Interior, Minerals Management Service, Gulf of Mexico OCS Region.

Shane, S. H., R. S. Wells, and B. Würsig. 1986. 'Ecology, behavior and social organization of the bottlenose dolphin: a review', *Marine Mammal Science*, 2: 34-63.

Shane, S.H. 1980. 'Occurrence, movements, and distribution of bottlenose dolphin, Tursiops truncatus, in southern Texas', *Fishery Bulletin*, 78.

Smultea, M. A., and B. Würsig. 1995. 'Behavioral reactions of bottlenose dolphins to the Mega Borg oil spill, Gulf of Mexico 1990', *Aquatic Mammals*, 21: 171-81.

Soller, J., J. Stephenson, K. Olivieri, J. Downing, and A.W. Olivieri. 2005. Evaluation of seasonal scale first flush pollutant loading and implications for urban runoff management, *Journal of Environmental Management*, 76,4:309-318.

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene Jr, D. Kastak, D. R. Ketten, J. H. Miller, and P. E. Nachtigall. 2008. "Marine mammal noise-exposure criteria: initial scientific recommendations." In *Bioacoustics*, 273-75.

Stein, John E, Karen L Tilbury, James P Meador, Jay Gorzelany, Graham AJ Worthy, and Margaret M Krahn. 2003. '17 Ecotoxicological investigations of bottlenose dolphin (Tursiops truncatus) strandings: Accumulation of persistent organic chemicals and metals', *Toxicology of marine mammals*: 458.

Stokes, A., K. Cockrell, J. Wilson, D. Davis, and D. Warwick. 2010. 'Mitigation of underwater pile driving noise during offshore construction', *Applied Physical Science*.

Suarez, M. P., H. S. Rifai, R. Palachek, K. Dean, and L. Koenig. 2006. 'Distribution of polychlorinated dibenzo-p-dioxins and dibenzofurans in suspended sediments, dissolved phase and bottom sediment in the Houston Ship Channel', *Chemosphere*, 22: 417-29.

TCEQ. 2011. The State of the Bay: A Characterization of the Galveston Bay Ecosystem, Third Edition: Texas Commission on Environmental Quality. 356 pp.

Todd, Victoria L. G., Ian B. Todd, Jane C. Gardiner, Erica C. N. Morrin, Nicola A. MacPherson, Nancy A. DiMarzio, and Frank Thomsen. 2015. 'A review of impacts of marine dredging activities on marine mammals', *ICES Journal of Marine Science*, 72: 328-40.

Tyack, P. L. 2008. 'Implications for Marine Mammals of Large-Scale Changes in the Marine Acoustic Environment', *Journal of Mammalogy*, 89: 549-58.

Urian, K. W., D. A. Duffield, A. J. Read, R. S. Wells, and E. D. Shell. 1996. 'Seasonality of reproduction in bottlenose dolphins, Tursiops truncatus', *Journal of Mammalogy*, 77: 394-403.

Urian, K. W., S. Hofmann, R. S. Wells, and A. J. Read. 2009. 'Fine-scale population structure of bottlenose dolphins (Tursiops truncatus) in Tampa Bay, Florida', *Marine Mammal Science*, 25: 619-38.

United States Army Corps of Engineers and Texas Genearl Land Office (USACE and TGLO). 2018. Coastal Texas Protection and Restoration Feasibility Study. Draft Integrated Feasibility Report and Environmental Impact Statement. Pp 442

US EPA (U.S. Environmental Protection Agency), 1983. Results of the Nationwide Urban Runoff Program,Volume I – Final Report. U.S. Environmental Protection Agency, Water Planning Division, Washington DC.

Vollmer, N. L., and P. E. Rosel. 2013. 'A Review of Common Bottlenose Dolphins (Tursiops truncatus truncatus) in the Northern Gulf of Mexico: Population Biology, Potential Threats, and Management', *Southeastern Naturalist*, 13: 1-43.

Waring, G. T., E. Josephson, K. Maze-Foley, and P. E. Rosel. 2013. "US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments--2012." In *NOAA Technical Memorandum NMFS-NE-223*.

Weller, D.W. 1998. 'Global and Regional Variation in the Biology and Behavior of Bottlenose Dolphins', Texas A&M University.

Wells, R. S., H. L. Rhinehart, L. J. Hansen, J. C. Sweeney, F. I. Townsend, R. Stone, D. R. Casper, M. D. Scott, A. A. Hohn, and T. K. Rowles. 2004. 'Bottlenose dolphins as marine ecosystem sentinels: developing a health monitoring system', *Ecohealth*, 1: 246-54.

Wells, R. S., L. H. Schwacke, T. K. Rowles, B. C. Balmer, E. Zolman, T. Speakman, F. I. Townsend, M. C. Tumlin, A. Barleycorn, and K. A. Wilkinson. 2017. 'Ranging patterns of common bottlenose dolphins Tursiops truncatus in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill', *Endangered Species Research*, 33: 159-80.

Wells, R. S., M. D. Scott, and A. B. Irvine. 1987. 'The social structure of free-ranging bottlenose dolphins.' in, *Current mammalogy* (Springer).

Wells, R. S., V. Tornero, A. Borrell, A. Aguilar, T. K. Rowles, H. L. Rhinehart, S. Hofmann, W. M. Jarman, A. A. Hohn, and J. C. Sweeney. 2005. Integrating life-history and reproductive success data to examine potential relationships with organochlorine compounds for bottlenose dolphins (Tursiops truncatus) in Sarasota Bay, Florida. *Sci Total Environ* 349 (1-3):106.

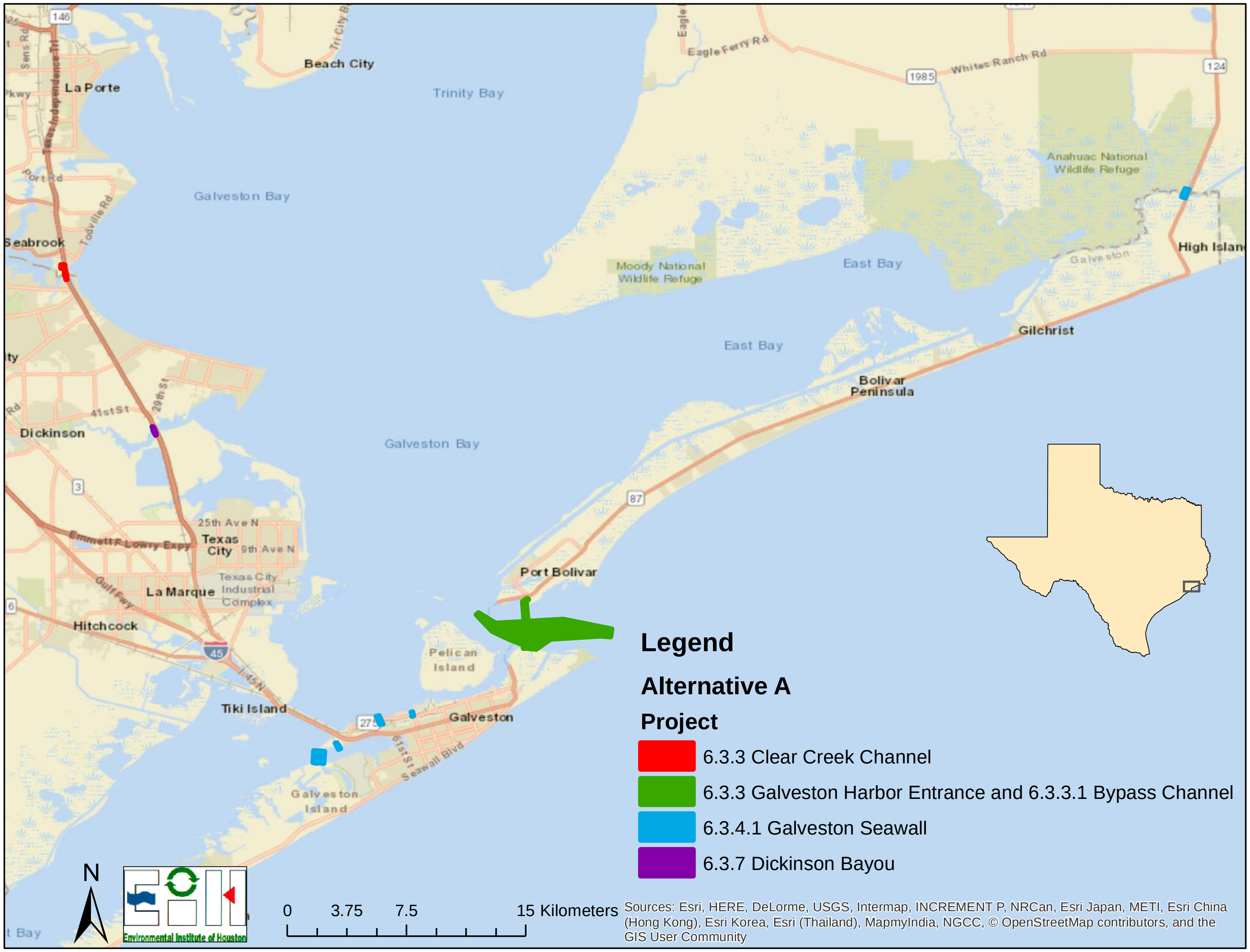
Worthy, Graham AJ. 1998. 'Patterns of bottlenose dolphin, Tursiops truncatus, strandings in Texas', *NOAA Technical Report NMFS*: 47-56.

Würsig, B.G., Jefferson, T.A., Schmidly, D.J., and L. Foster. 2000a. The Marine Mammals of the Gulf of Mexico. Texas A&M University Press, College Station.

Würsig, B., C. R. Greene, and T. A. Jefferson. 2000b. 'Development of an air bubble curtain to reduce underwater noise of percussive piling', *Mar Environ Res*, 49: 79-93.

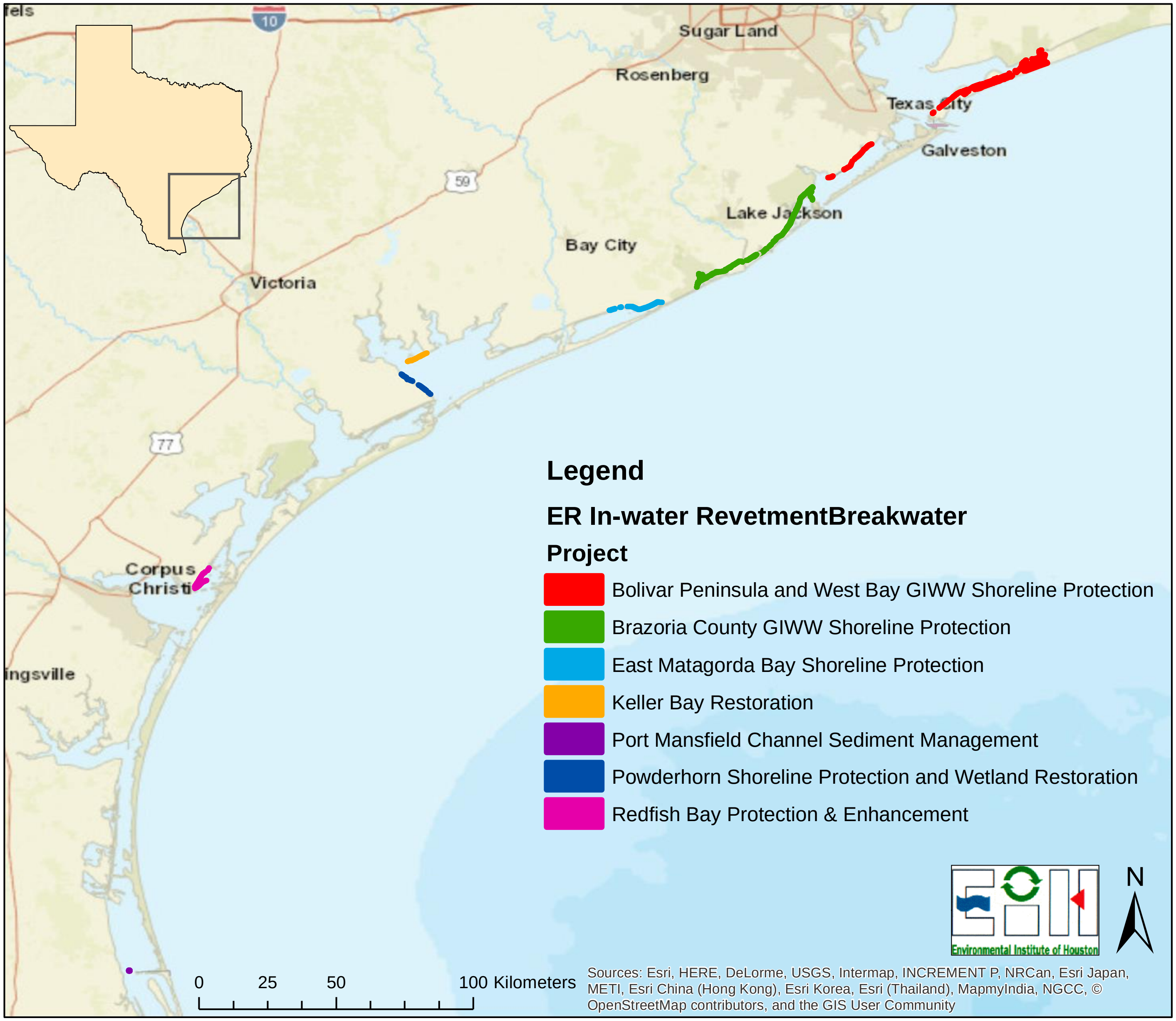
Würsig, B., and S. K. Lynn. 1996. "Movements, Site Fidelity, and Respiration Patterns of Bottlenose Dolphins on the Central Texas Coast." In *NOAA Technical Memorandum NMFS-SEFSC-383*, 128.

Appendix 1: Maps of in-water activities that have the potential for marine mammal impacts.

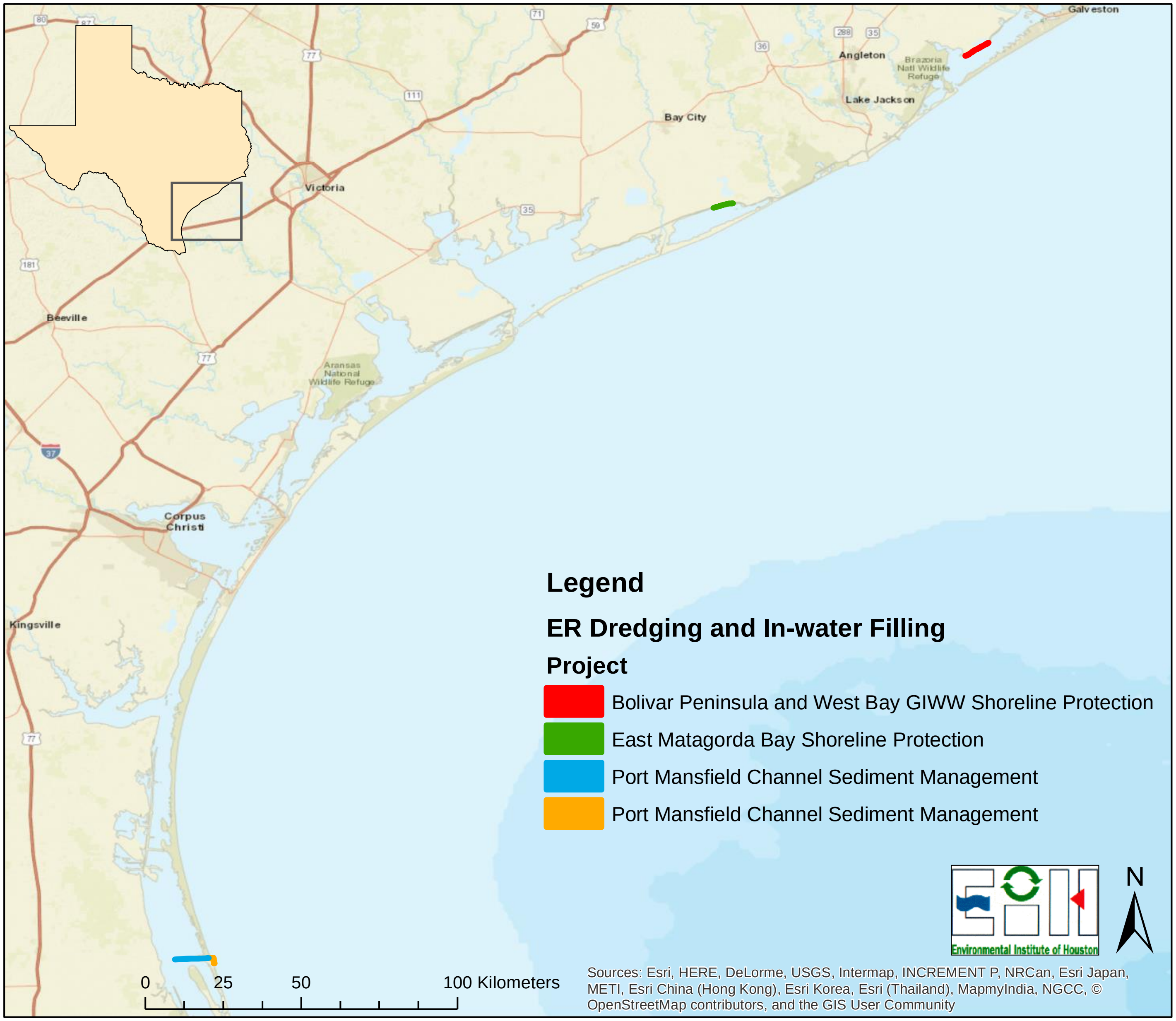


Appendix 1, Figure 1: Map of Alternative A projects that have the potential for marine mammal impacts.

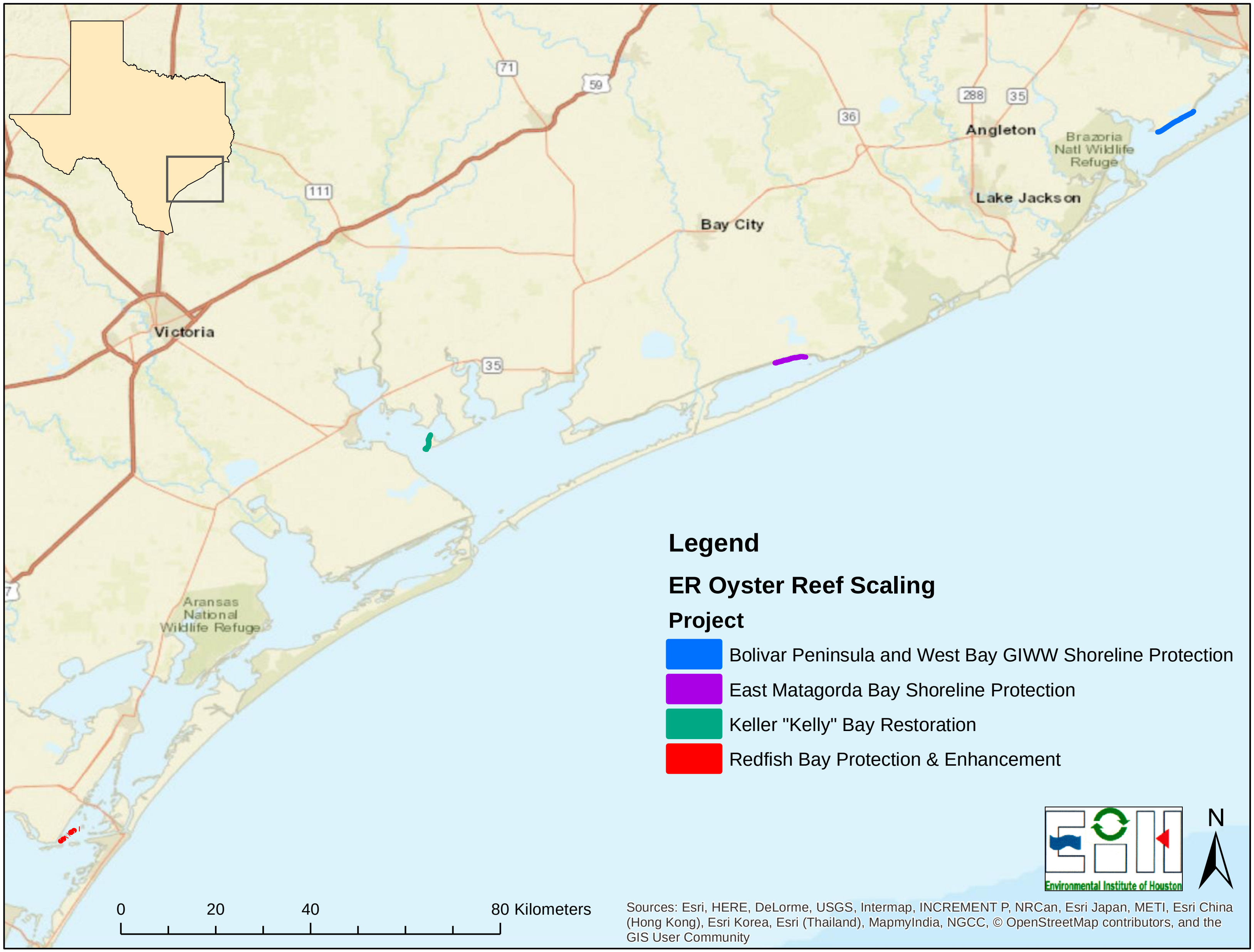
Appendix 1, Figure 2: Map of Alternative D2 projects that have the potential for marine mammal impacts.



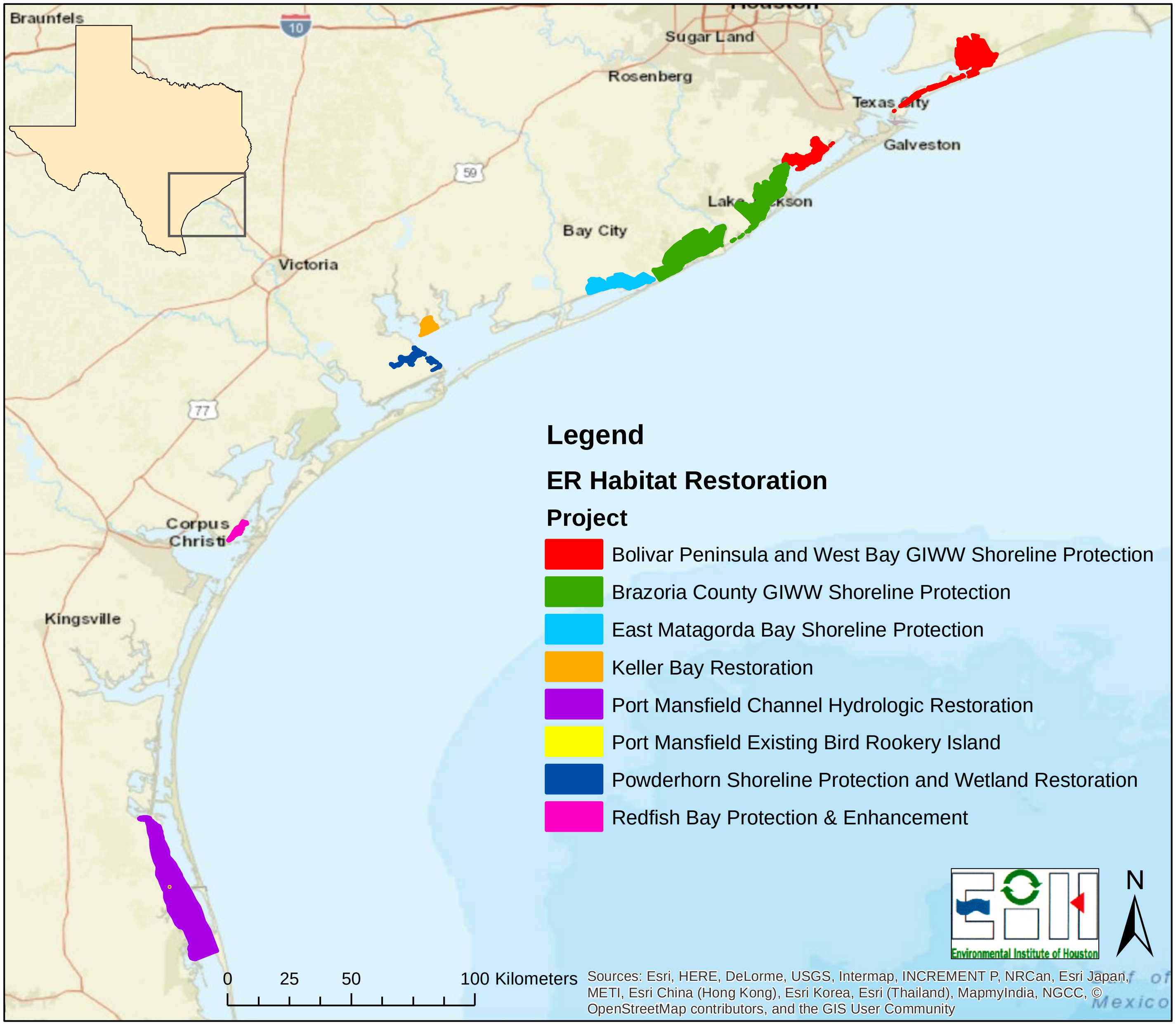
Appendix 1, Figure 3: Map of Ecological Restoration Revetment and Breakwater projects that have the potential for marine mammal impacts.



Appendix 1, Figure 4: Map of Ecological Restoration Dredging and In-water Filling projects that have the potential for marine mammal impacts.



Appendix 1, Figure 5: Map of Ecological Restoration Oyster Reef Scaling projects that have the potential for marine mammal impacts.



Appendix 1, Figure 6: Map of Ecological Restoration Habitat Restoration projects that have the potential for marine mammal impacts.

Appendix 2: Background Data Summary – Galveston Bay

Assessment Metric	**Current Data Sources**	**Data Gaps/Recommendations**
Population Abundance	NMFS Stock assessments; Ronje et al. (pending analysis);	Updated abundance estimate and population trend for GB, West Bay, and Sabine Lake
Fine Scale Population Structure	GDRCP skin samples (pending analysis) and photo-id catalog (2014 – present) *GoMDIS; TMMSN samples and photo-id catalog; TAMUG long term/historical photo-id catalog; SEFSC photo-id catalog (mid-Texas bays and coastal) *GoMDIS; other photo-id catalogs for TX coast (Linda Price-May, Will McGlaun); Henderson and Würsig 2007 (West Bay)	Historical and current catalogs for TX coast digitized and entered into GoMDIS for comprehensive comparison; Continued sampling in GB, BR, West Bay, Sabine Lake and upper Texas coast for genetic analysis
Vital Rates (Survivability and Fecundity)	TMMSN/MMHSRP stranding database; GDRCP long term monitoring data (upper bay); TAMUG long term monitoring data (Galveston Ship Channel)	Establish pre-project vital rates –Year-round survey monitoring effort encompassing GB, BR and adjacent waters to create a dataset robust enough to calculate survivability and fecundity; Blubber samples to evaluate hormone levels for reproductive success
Spatial and Temporal Distribution Patterns	Jones 1988; Henderson and Würsig 2007 (West Bay); Lynn and Würsig 2002 (1992 radio tracking); GDRCP data 2014 – present; Rivard 2016 – BR ferry passage; <u>Manatee</u>- Fertl et al 2005 (Sightings through 2004)	Satellite tagging to establish range patterns and community overlap; continued and expanded photo-id and distance sampling efforts in GB, BR, West Bay, Sabine Lake and adjacent coastal waters; model suitable dolphin habitat based on salinity/temperature regimes and fishery migrations; <u>Manatee</u> – updated sighting summary
Behavioral and Habitat Use Patterns	Moreno 2009; Brager 1993; Henderson and Würsig 2007 (West Bay); Piwetz (vessel disturbance, *in press*); Rivard 2016 (BR ferry passage)	Investigate important calving habitat; Energy Budgets; Habitat partitioning in BR

Appendix 2-continued: Background Data Summary – Galveston Bay

Assessment Metric	Current Data Sources	Data Gaps/Recommendations
Baseline Health	TMMSN/MMHSRP stranding database; GDRCP skin lesion data (pending analysis); July 1992 Health assessment Matagorda/Espiritu Santo bays	No Health Assessment has been conducted for GB; Baseline health assessment for the GB BSE population would provide valuable data for impact assessment; Remote blubber samples could provide evaluation of stress response utilizing cortisol levels
Strandings	TMMSN/MMHSP stranding database; Miller 1992 (1990 Matagorda); Colbert et al. 1999 (1992 UME); Worthy 1998; Mullins 2008 thesis (data summary - 2004); Litz et al. 2014 (UME's)	Summarize and evaluate available Level A data 2005 – present to establish baseline stranding patterns;
Contaminant Loads	GDRCP blubber samples (pending analysis); TMMSN samples	Establish baseline levels – analyze current GB subsamples and collect and analyze samples from BR and adjacent coastal waters
Background Sound	Site specific data currently unavailable	Establish baseline acoustic environment
Sound Propagation	Site specific data currently unavailable	Map sound propagation and use sound source levels to create zone of influence with and without mitigation measures for PTS, TTS and behavioral thresholds (above background)
Sound Source Levels	Estimates based on other projects (WSDOT, Reyff 2005)	Identify appropriate comparable data (pile type, size, sediment type, pile driver equipment) to estimate source levels; measure and verify source levels at start of project

Appendix 3: Marine Mammal Noise Impact Assessment Initial Recommendations and Data Gaps

Initial recommendations and needs for Marine Mammal Noise Impact Assessment

Due to the sizeable role of sound in the daily life of marine mammals, determination of potential effects of noise from construction activities is a substantial portion of any impact assessment. Meeting the requirements of the MMPA for CSRM Alternatives will require detailed acoustic mapping and calculations to examine impacts on marine mammal populations utilizing Galveston Bay and nearshore Gulf waters, including 1) the physiological effects of high-energy sound exposure; 2) masking of biologically important sounds, and; 3) behavioral disruptions that may result in a negative effect on population vital rates. The first step in this process is to address actions known to cause direct physical injury to marine mammals, including pile driving and explosive detonations. Consideration of these actions will need to follow specific formulas for calculating injury when estimating takes for ITA applications. Due to time constraints in preparation of the Draft EIS, we suggest using comparable projects and published data to calculate initial preliminary estimates of the level of impact for each region where pile driving or explosives will be utilized**. We highly recommend using measured site specific data for calculations moving forward beyond the Draft EIS.** Once physical thresholds are determined, behavioral disturbance zones need to be evaluated.

The NOAA-NMFS has provided recent guidance for assessing impacts of sound on marine mammals. Utilizing this guidance in combination with other recommended best practices and comparable projects *(See Resources)* we have developed a preliminary plan for noise assessment associated with the Coastal Texas CSRM Alternatives.

Sound Metrics

It is helpful to define the metrics used to describe and measure underwater sound for the purposes of impact assessment.

- Marine Mammals are placed into **Frequency Hearing Groups** based on their generalized range of hearing. **Bottlenose dolphins, considered in this assessment are Mid-frequency cetaceans (MF) hearing at a range of 150 Hz to 160 kHz.**
- To reflect higher hearing sensitivity at particular frequencies, sounds are often weighted. **Auditory Weighting Functions** for each marine mammal hearing group are derived using data on hearing ability (composite audiograms), effects of noise on hearing, and data on equal latency. They are used within the context of assessment to reflect risk of **noise induced hearing loss (NIHL)**. NMFS recommends calculating appropriate auditory weighting functions for each action proponent associated with an acoustic assessment, but recognizes that the implementation of marine mammal weighting functions may extend beyond the capabilities of some action proponents. Thus, NMFS has developed simple **weighting factor adjustments (WFA)** for those who cannot fully apply auditory weighting functions.
    - **The use of WFA include multiple conservative assumptions and therefore would be expected to typically result in higher estimates of instances of hearing impairment. The larger the scale of the activity, the more these conservative overestimates would be compounded with the use of WFA. We therefore recommend the use of WFA during initial draft EIS preparation followed by a more thorough calculation using project specific auditory weighting functions.**

- Sound is divided into two general categories for analysis:
    - **Impulsive sound:** Sound sources that produce sounds that are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay. They can occur in repetition or as a single event. Examples of impulsive sound sources include: explosives, seismic airguns, and impact pile drivers.
    - **Non-impulsive sound**: Sound sources that produce sounds that can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent) and typically do not have a high peak sound pressure with rapid rise time that impulsive sounds do. Examples of non-impulsive sound sources include: marine vessels, machinery operations/construction (e.g., drilling), certain active sonar (e.g. tactical), and vibratory pile drivers.
- **Peak sound pressure level (PK; re: 1 µPa):** The greatest absolute instantaneous sound pressure within a specified time interval and frequency band
- **Permanent threshold shift (PTS):** A permanent, irreversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above a previously established reference level.
- **Temporary threshold shift (TTS):** A temporary, reversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above a previously established reference level.
- The **RMS** level is the square root of the energy divided by the impulse duration. This level is the mean square pressure level of the pulse. It has been used by NMFS to describe disturbance-related effects (i.e., harassment) to marine mammals from underwater impulse-type noises.
- **Sound Exposure Level (SEL)** is a metric for acoustic events and is often used as an indication of the energy dose. SEL is calculated by summing the cumulative pressure squared (p2), integrating over time, and normalizing to 1 second.
- **Cumulative Sound Exposure Level (SELcum)**: The SELcum metric takes into account both received level and duration of exposure, both factors that contribute to NIHL. Often this metric is normalized to a single sound exposure of one second. NMFS intends for the SELcum metric to account for the accumulated exposure (i.e., **SELcum = cumulative exposure over the duration of the activity within a 24-h period**).
- **Transmission loss (TL)** underwater is the accumulated decrease in acoustic intensity as an acoustic pressure wave propagates outward from a source. The intensity of the noise is reduced with increasing distance due to spreading.

Impact Assessment Requirements

Calculating the impact of pile driving on marine mammals is dependent on several factors described below. The most imperative information needs to complete an impact assessment include 1.a-d, 2.a-d, and 2.e.i. from the list below.

**If alternative methods of installation are under consideration, details of each method will be needed for comparison.*

1. Detailed information on construction activities
    a. Type of piles used
    b. Size of piles
    c. Method of installation
        i. **Vibratory Pile Driving** is considered a non-impulsive sound source
        ii. **Impact Hammer Pile Driving** is considered an impulsive sound source and generally more likely to cause injury due to high peak pressure.

d. Extent and duration of piling
    i. Number of **strikes per hour (for a single pile)**
    ii. Average number of **hours per day** spent pile driving
    iii. Average number of **piles per day** being driven
    iv. Expected **total number of piles** and **number of days spent pile driving**

2. Properties of the impacted area and calculated "zone of influence"
    a. Seabed bathymetry
    b. Bottom substrate
    c. Acoustic properties of the water (depth variations, salinity, temperature)
    d. Background noise levels – Existing underwater sound levels serve as a baseline from which to measure potential disturbance associated with project activities.
        i. Average daytime noise levels pre-project – If current levels are not known, we recommend this as part of a pre-project study
    e. Model of site specific sound propagation
        i. Sound source levels: Unmitigated sound source levels can be estimated from comparable projects for the draft EIS, but should be measured at start of project to validate assumptions. (*See Appendix 3 – Table 1: WSDOT Impact Pile Noise*)
        ii. Calculate transmission loss (TL) from source levels to surrounding areas
            1. TL is in dB as a function of distance from the source, which is as follows: TL = B * log10 (R1/R2) + C * (R1-R2), where B = logarithmic (predominantly spreading) loss; C = linear (scattering and absorption) loss; R1 = receiver distance; R2 = range at which the source measurement was made (usually 10 m [33 ft] for pile driving). The B term has a value of 10 for cylindrical spreading and 20 for spherical spreading. An intermediate "practical spreading" value of 15 is generally accepted by NOAA for use in pile driving applications. The C term is dependent on frequency, temperature, and depth, but is small and will conservatively be assumed to equal zero for pile driving. If we use the practical spreading loss equation, with the conservative assumption that C = 0, it simplifies to **TL = 15 log (R1/R2). This simplified equation may be used for preliminary estimates, though exploration of a site specific value is recommended.**
        iii. Use estimated source levels along with sound propagation models to predict zones where project noise will:
            1. Run into a land mass
            2. Attenuate to below background noise levels
            3. Attenuate to below injury and behavioral threshold levels for MF cetaceans

3. PTS, TTS and behavioral response thresholds
    a. NOAA provides guidance on estimated thresholds and a worksheet (Appendix 3 – Table 2) to estimate distance from a sound source for PTS. Acoustic thresholds are presented using dual metrics of cumulative sound exposure level (SELcum) and peak sound level (PK) for impulsive sounds and SELcum for non-impulsive sounds.

**

Functional Hearing Group	Underwater Noise Thresholds				
	Impulsive Sound Impact Pile Driving			Non- Impulsive Sound Vibratory Pile Driving	
	Auditory Injury Threshold (PTS)		Behavioral Disturbance Threshold	Auditory Injury Threshold (PTS)	Behavioral Disturbance Threshold
	Peak SPL	dB SELcum	dB RMS	dB SELcum	dB RMS
Mid-frequency Cetaceans	230	185 MF, 24h	160**	198	120**

Some studies use these generalized behavioral thresholds for marine mammals, while other determine behavioral disturbance to be possible at any point where project noise has not dissipated below background noise

Spatial and temporal density of animals – The number of takes by noise for injury and disturbance will be estimated based on the expected number of animals within the zone of influence during operations.

   b. NMFS Stock Abundance Estimates
   c. Pre-project study

4. Acoustic masking and behavioral response (Ellison et al. 2012)
   a. Severity of behavioral disruption is often contextual to the acoustic environment and behavioral state of the animals when exposed. Pre-project and during construction behavioral studies will be necessary to guide the assessment of behavioral reactions.
   b. Potential behavioral impacts:
      i. Effects on energy budgets and critical behaviors such as feeding and socializing
      ii. Temporary or permanent habitat abandonment
      iii. Increased risk of predation, injury and stranding

Noise Reduction and Mitigation Measures

Noise reduction measures are necessary where unmitigated sound levels exceed desired thresholds. The effectiveness of noise mitigation measures are highly site specific and must be chosen carefully and validated based on real time conditions. Attainable noise reduction levels range from 6 – 20 db peak sound pressure at a range of frequencies. There are several new technologies in development for pile driving noise mitigation, however many of these are driven by the offshore wind energy industry and therefore are applied in different conditions than those proposed in this project (Bellman 2014 – overview of noise mitigation systems). The Washington State Department of Transportation (WSDOT) provides applicable research and development for consideration under inshore environmental conditions.

Once details of installation methods are confirmed and sound source modeling is complete we will have a better starting point for exploration of mitigation measures.

1. **Bubble curtains.** Bubble curtains have demonstrated some success in sound attenuation within 1 km of pile driving activity at frequency ranges sensitive to bottlenose dolphins during similar construction projects

(Würsig et al. 2000b). However, their effectiveness is sensitive to environmental conditions. In areas with high tidal currents, such as passes, bubble curtains may not be an effective method of noise mitigation and the use of other types of devices should be investigated.

2. **Double Walled Pile (WSDOT) (Reinhall, Hampden, and Dardis 2016); http://www.marinecontech.com/technology/** "The double-walled pile consists of two concentric steel pipe piles flexibly connected by a special driving shoe, allowing for an air gap between the two tubes. The double-walled pile is driven into the sediment by using traditional equipment that strikes the inner pile only. The air gap between the inner and outer pile and the flexible coupling prevent the radial deformation wave produced by the pile hammer from interacting with the water and the sediment. In one embodiment of the double-pile design the inner tube can be removed and repeatedly reused." Tests show reduction of peak sound pressure over 20db at 8m in contrast to a 3-6 db reduction for bubble curtains. Unlike bubble curtains and cofferdams, double piles attenuate noise transmitted through the sediment into the water, increasing their effectiveness over these methods.
3. **Hydro Sound Dampers (Elmer and Savery 2014), Australia** "HSD systems use nets with air filled elastic balloons and special PE-foam elements with high dissipative effects to reduce continuous and impact noise. The resonance frequency of the HSD-elements, the optimum damping rate for impact noise, the distribution and the effective frequency range can be fully controlled." "The effectiveness of HSD is not affected by tidal currents and the attenuation provided by HSD is not dependent upon maintaining a given separation distance between the HSD net and the pile under strong tidal current conditions." May achieve reductions of more than 10 db.
4. **Noise Mitigation Screen (IHC).** The IHC-NMS system consists of a double-wall steel screen (tube). The pile will be inserted into this system. The space between the two screens is filled with air; additionally, air bubbles can be fed in between pile and NMS system (water-air-composite). The radiated sound crosses the internal bubble curtain as well as the air-filled double-wall steel screen and will be reduced due to reflection (impedance gap).
5. **Cofferdam.** The cofferdam system consists of a single-wall steel tube. The pile will be inserted into this system. Near the seabed a gasket (seal ring) is installed so that the space between pile and cofferdam can be evacuated from water by pumps. In principal the pile can be installed "in air" and not in water so the pile radiates the sound into air and will cross the steel tube thereafter. Due to the different impedances the pile-driving noise will be reduced by reflection. However, sound may travel through the substrate in some cases.
6. **"Soft start" of pile driving hammers** – gradual ramp up of operations intended to warn animals in the vicinity so they can vacate the area before maximum hammer energy is reached.
7. **Dolphin exclusion zones –** Observers are posted in the area during pile driving operations and report dolphins entering calculated injury zones, at which time operations must pause until dolphins have moved out of the zone.

Unmitigated sound pressure levels associated with pile types during impact pile driving. All sound levels are measured at 10 m from the pile unless otherwise stated.

Pile Type	Sound Level (single strike)		
12-inch timber pile:[1]	180 dB_{peak}	170 dB_{RMS}	160 dB SEL
18-inch concrete pile:[2]	185 dB_{peak}	166 dB_{RMS}	155 dB SEL
24-inch concrete pile:[2]	188 dB_{peak}	176 dB_{RMS}	166 dB SEL
36-inch concrete pile:[3]	192 dB_{peak}	176 dB_{RMS}	174 dB SEL
12-inch steel H-type – thin[2]	190 dB_{peak}	175 dB_{RMS}	160 dB SEL
12-inch steel H-type – thick[2]	200 dB_{peak}	183 dB_{RMS}	170 dB SEL
24-inch AZ steel sheet[2]	205 dB_{peak}	190 dB_{RMS}	180 dB SEL
13-inch plastic pile[2]	177 dB_{peak}	153 dB_{RMS}	
12-inch steel pipe pile:[4]	207 dB_{peak}	189 dB_{RMS}	173 dB SEL
14-inch steel pipe pile:[2]	200 dB_{peak}	184 dB_{RMS}	174 dB SEL
16-inch steel pipe pile:[5]	200 dB_{peak}@ 9 m	187 dB_{RMS} @ 9 m	
24-inch steel pipe pile:[6]	207 dB_{peak}	194 dB_{RMS}	178 dB SEL
30-inch steel pipe pile:[2]	210 dB_{peak}	190 dB_{RMS}	177 dB SEL
36-inch steel pipe pile:[2]	210 dB_{peak}	193 dB_{RMS}	183 dB SEL
60-inch steel pipe pile:[2]	210 dB_{peak}	195 dB_{RMS}	185 dB SEL
66-inch steel pipe pile: [6]	210 dB_{peak}	195 dB_{RMS}	
72-inch steel pipe pile:[7]	214 dB_{peak}	189 dB_{RMS}	182 dB SEL
96-inch steel pipe pile:[2]	220 dB_{peak}	205 dB_{RMS}	195 dB SEL
126-inch steel pipe pile:[6]	213 dB_{peak} @ 11 m	202 dB_{RMS} @ 11 m	
150-inch steel pipe pile: [8]	200 dB_{peak} @ 100 m	185 dB_{RMS} @ 100 m	

Sound pressure levels associated with pile types during vibratory pile driving/removal. All sound levels are measured at 10 m from the pile unless otherwise stated.[2]

Pile Type	Sound Level (single strike)		
12-inch steel H-type	165 dB_{peak}	150 dB_{RMS}	150 dB SEL
24-inch AZ steel sheet	182 dB_{peak}	165 dB_{RMS}	165 dB SEL
12-inch steel pipe pile:	171 dB_{peak}	155 dB_{RMS}	155 dB SEL
36-inch steel pipe pile:	185 dB_{peak}	175 dB_{RMS}	175 dB SEL
72-inch steel pipe pile:	195 dB_{peak}	180 dB_{RMS}	180 dB SEL

[1]. Timber piles, 12-inches in diameter, have been measured underwater by Illingworth and Rodkin and are published in the 2015 Compendium of Pile Driving Sound Data. Illingworth and Rodkin (2004) have compared the shape of the sound wave between steel piles and timber piles and found that a timber pile produced a more 'rounded' wave than a steel pile. Although the peak sound levels may be similar, the waveform appears more stretched out for a timber pile than for a steel pile and the rise time is relatively slower. A slower rise time means that the shock wave produced with each pile strike is not as severe presumably resulting in less damage to fish. The effect is similar to the difference between a push and a punch.

[2] CalTrans. 2015. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish.

[3] MacGillivray et al. 2007. While there have been no documented fish kills with the installation of concrete piles, the Services may require sound mitigation strategies or monitoring because of the lack of formally documented effects

[4] Laughlin (2006)

[5] Laughlin, Jim. 2004. Underwater Sound Levels Associated with the Construction of the SR 240 Bridge on the Yakima River at Richland. WSDOT, Office of Air Quality and Noise, Seattle, WA. September 2004. 33 pp.

[6] Laughlin (2005b)

[7] Laughlin, Jim. 2011. Underwater sound levels associated with driving 72-inchsteel piles at the SR 529 Ebey Slough Bridge Replacement project. WSDOT Office of Air Quality and Noise, Seattle WA.

[8] Thorson and Reyff (2003)

E.1: IMPACT PILE DRIVING (STATIONARY SOURCE: Impulsive, Intermittent)

VERSION: 1.1 (Aug-16)

KEY	
(green)	Action Proponent Provided Information
(pink)	NMFS Provided Information (Acoustic Guidance)
(blue)	Resultant Isopleth

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	
PROJECT/SOURCE INFORMATION	
Please include any assumptions	
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT — Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

Weighting Factor Adjustment (kHz)[¥]	2	default

[¥] Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab

† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 64), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

*** BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)**

STEP 3: SOURCE-SPECIFIC INFORMATION

NOTE: Choose either E1-1 OR E.1-2 method to calculate isopleths (not required to fill in sage boxes for both)

E.1-1: METHOD USING RMS SPL SOURCE LEVEL

Source Level (RMS SPL)	
a) Activity Duration (h) within 24-h period OR b) Number of piles per day[•]	
Pulse Duration[Δ] (seconds)	
a) Number of strikes in 1 h OR b) Number of strikes per pile[•]	
Activity Duration (seconds)	0
10 Log (duration)	#NUM!
Propagation (xLogR)	
Distance of source level measurement (meters)[+]	

Marine Mammal Hearing Group
Low-frequency (LF) cetaceans: baleen whales
Mid-frequency (MF) cetaceans: dolphins, toothed whales, beaked whales, bottlenose whales
High-frequency (HF) cetaceans: true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* & *L. australis*
Phocid pinnipeds (PW): true seals
Otariid pinnipeds (OW): sea lions and fur seals

[Δ] Window that makes up 90% of total cumulative energy (5%-95%) based on Madsen 2005

• For cells B27 & B29 users should supply information for both cells as either a) OR b); Don't mix-n-match.

[+] Unless otherwise specified, source levels are referenced 1 m from the source.

RESULTANT ISOPLETHS* — *Note: For impulsive sounds, action proponent must also consider isopleths peak sound pressure level (PK) thresholds (dual thresholds).

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	183	185	155	185	203
PTS Isopleth to threshold (meters)	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!

E.1-2: ALTERNATIVE METHOD (SINGLE STRIKE EQUIVALENT)

Unweighted $SEL_{cum\ (at\ measured\ distance)} = SEL_{ss}$ + 10 Log (# strikes)	#NUM!

Source Level (Single Strike/shot SEL)	
a) Number of strikes in 1 h OR b) Number of strikes per pile[•]	
a) Activity Duration (h) within 24-h period OR b) Number of piles per day[•]	
Propagation (xLogR)	
Distance of single strike SEL measurement (meters)[+]	

Marine Mammal Hearing Group
Low-frequency (LF) cetaceans: baleen whales
Mid-frequency (MF) cetaceans: dolphins, toothed whales, beaked whales, bottlenose whales
High-frequency (HF) cetaceans: true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* & *L. australis*
Phocid pinnipeds (PW): true seals
Otariid pinnipeds (OW): sea lions and fur seals

• For cells B47 & B48 users should supply information for both cells as either a) OR b); Don't mix-n-match.

[+] Unless otherwise specified, source levels are referenced 1 m from the source.

RESULTANT ISOPLETHS* — *Note: For impulsive sounds, action proponent must also consider isopleths peak sound pressure level (PK) thresholds (dual thresholds).

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	183	185	155	185	203
PTS Isopleth to threshold (meters)	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
a	1	1.6	1.8	1	2
b	2	2	2	2	2
f_1	0.2	8.8	12	1.9	0.94
f_2	19	110	140	30	25
C	0.13	1.2	1.36	0.75	0.64
Adjustment (dB)†	-0.01	-19.74	-26.87	-2.08	-1.15

$$W(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a\,[1+(f/f_2)^2]^b}\right\}$$

Appendix 3 – Noise Assessment Resources

BOEM (2018). Summary Report: Best Management Practices Workshop for Atlantic Offshore Wind Facilities and Marine Protected Species, US Dept of the Interior Bureau of Ocean Energy Management.

Dahl, P. H., et al. (2015). The underwater sound field from impact pile driving and its potential effects on marine life. Acoustics Today 11(2): 18-25.

Ellison, W. T., B. L. Southall, W. Clark and A. S. Frankel. 2012. A New Context-Based Approach to Assess Marine Mammal Behavioral Responses to Anthropogenic Sounds. Conservation Biology 26(1): 21-28.

NOAA. 2016. *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing; Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts.* U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-55, 178 p.

Reinhall, P. G., J. Hampden and T. Dardis (2016). UNDERWATER NOISE REDUCTION OF MARINE PILE DRIVING USING A DOUBLE PILE; Vashon Ferry Terminal Test.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals 33:411-521.

Teilmann, J. 2015. *Impact Assessments for Pile Driving – What are the Requirements for a Proper EIA for Marine Mammals?*. Dept. of Bioscience, Aarhus University, Frederiksborgvej 399, 4000 Roskiide, Denmark.

Washington State Department of Transportation (WSDOT*).* 2018. *Biological Assessment Preparation Advanced Training Manual Version 1-2018*

Würsig, B., C. Greene Jr and T. Jefferson 2000. "Development of an air bubble curtain to reduce underwater noise of percussive piling." Marine environmental research 49(1): 79-93.

Appendix 4: Potential Impact and Mitigation Summary

Action	Potential Threat(s)	Possible Mitigation Measures

Pile Driving	• Sound induced permanent threshold shifts/temporary threshold shifts
	• Acoustic masking and behavioral disturbance
	  ○ Habitat abandonment, (*including critical foraging habitat in Bolivar Roads)
	  ○ Effects on energy budgets
	  ○ Increased risk of predation, injury and stranding
		• Sound mitigation technology
		  ○ Bubble curtains
		  ○ Double walled piles
		  ○ Noise mitigation screen
		  ○ Cofferdams
		  ○ Hydro Sound Dampers
		• Dolphin exclusion zones
		• "Soft start" procedures
		• Seasonal and/or diurnal timing in some locations

Dredging	• Sediment disruption
	  ○ Increased exposure to contaminants
	  ○ Effects on prey
	• Acoustic masking and behavioral disturbance
	  ○ Habitat abandonment, (*including potentially critical foraging habitat in Bolivar Roads)
	  ○ Effects on energy budgets
	  ○ Increased risk of predation, injury and stranding
		• Silt curtains
		• Seasonal and/or diurnal timing in some locations

Vessel Traffic	• Collision, physical injury
	• Acoustic masking and behavioral disturbance
	  ○ Habitat abandonment, *including critical foraging habitat in Bolivar Roads
	  ○ Effects on energy budgets
	  ○ Increased risk of predation, injury and stranding
		• Vessel speed limits
		• 'Safe' zones

Physical Barrier	• Hindrance or prevention of travel in and out of (*pass) and bayou inlets by bottlenose dolphin
	• *Water quality consequences
	  ○ Increased exposure to contaminants
	  ○ Loss of optimal habitat greater than 11 ‰ or increased exposure to low salinity water
	• Habitat modification and displacement
	• *Increased tidal flow velocity at gates and decreased overall tidal prism in bay
	• Indirect impacts to primary prey species (e.g. shrimp, drum, flounder) during spawning migrations as adults to the Gulf and as larvae/juveniles immigrating back into estuaries
		• Currently unknown; construction and operational measures to minimize impacts should be explored and addressed in engineering plans

In-water ER measures	• Acoustic masking and behavioral disturbance
	  ○ Habitat abandonment
	  ○ Effects on energy budgets
	  ○ Increased risk of predation, injury and stranding
	• Sediment disruption
	  ○ Increased exposure to contaminants
	  ○ Effects on prey
	• Habitat modification/land reclamation
		• Vessel speed limits
		• 'Safe' zones
		• Seasonal and/or diurnal timing in some locations
		• Silt curtains

*** Potential Threat only included in Alternative 1**

Appendix 5: Manatee Guidance Document

STANDARD MANATEE CONDITIONS FOR IN-WATER WORK

2011

Provided by Donna Anderson, USFWS

The permittee shall comply with the following conditions intended to protect manatees from direct project effects:

a. All personnel associated with the project shall be instructed about the presence of manatees and manatee speed zones, and the need to avoid collisions with and injury to manatees. The permittee shall advise all construction personnel that there are civil and criminal penalties for harming, harassing, or killing manatees which are protected under the Marine Mammal Protection Act, the Endangered Species Act, and the Florida Manatee Sanctuary Act.

b. All vessels associated with the construction project shall operate at "Idle Speed/No Wake" at all times while in the immediate area and while in water where the draft of the vessel provides less than a four-foot clearance from the bottom. All vessels will follow routes of deep water whenever possible.

c. Siltation or turbidity barriers shall be made of material in which manatees cannot become entangled, shall be properly secured, and shall be regularly monitored to avoid manatee entanglement or entrapment. Barriers must not impede manatee movement.

d. All on-site project personnel are responsible for observing water-related activities for the presence of manatee(s). All in-water operations, including vessels, must be shut down if a manatee(s) comes within 50 feet of the operation. Activities will not resume until the manatee(s) has moved beyond the 50-foot radius of the project operation, or until 30 minutes elapses if the manatee(s) has not reappeared within 50 feet of the operation. Animals must not be herded away or harassed into leaving.

e. Any collision with or injury to a manatee shall be reported immediately to the Texas Marine Mammal Stranding Network (TMMSN) Hotline at 1-888-9-MAMMAL. Collision and/or injury should also be reported to the U.S. Fish and Wildlife Service in Houston (1-281-286-8282).

f. Temporary signs concerning manatees shall be posted prior to and during all in-water project activities. All signs are to be removed by the permittee upon completion of the project. Temporary signs that have already been approved for this use by the FWC must be used. One sign which reads *Caution: Boaters* must be posted. A second sign measuring at least 8 ½" by 11" explaining the requirements for "Idle Speed/No Wake" and the shutdown of in-water operations must be posted in a location prominently visible to all personnel engaged in water-related activities..

Appendix 6: List of Acronyms

BR	Bolivar Roads
BSE	Bay, Sound and Estuary
CSRM	Coastal Storm Risk Management
EIS	Environmental Impact Statement
ER	Ecosystem Restoration
ESA	Endangered Species Act
GB	Galveston Bay
GDRCP	Galveston Dolphin Research and Conservation Program
GoM	Gulf of Mexico
HSC	Houston Ship Channel
ITA	Incidental Take Authorization
MMHSRP	Marine Mammal Health and Stranding Response Program
MMPA	Marine Mammal Protection Act
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PBR	Potential biological removal
PCB	Polychlorinated biphenyls
PTS	Permanent threshold shifts
SAR	Stock Assessment Report
SEFSC	Southeast Fisheries Science Center
TAMUG	Texas A&M University, Galveston
TGLO	Texas General Land Office
TMMSN	Texas Marine Mammal Stranding Network
TTS	Temporary threshold shifts
UME	Unusual mortality event
USACE	U.S. Army Corps of Engineers
USFWS	United State Fish and Wildlife Service