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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

BY
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Cover photograph: Common bottlenose dolphin in South Carolina, July 2004.
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A process for prioritizing common bottlenose dolphin stocks for stock assessment research based on an assessment of the stressors faced by each stock and the availability and quality of basic information on stock structure, abundance and mortality for each stock

Abstract

The common bottlenose dolphin, *Tursiops truncatus,* is a well-known marine mammal widespread throughout the bays, sounds and estuaries (BSEs) of the northern Gulf of Mexico. Thirty-one stocks of common bottlenose dolphins have been delimited in the BSE environments from the Florida Keys to the Texas-Mexico border. For many of the stocks, up-to-date information necessary for accurate assessment of their status is limited. While it would be ideal to have well characterized biological data for all *T. truncatus* stocks, this is not a realistic short or medium-term goal given the limited resources that are available for the conservation and management of a single species. Thus, a method to objectively prioritize stocks relative to one other for basic stock assessment research would aid the decision making process and allow resources to be directed where they would be the most effective for meeting research and management objectives.

Here we develop a Threat Assessment Priority Scoring System, incorporating an assessment of the number and severity of threats impacting a given stock and an evaluation of the quality of data available for performing a stock assessment. To generate the priority scores, a thorough literature search is first conducted to develop a summary of the presence, severity and impact of 19 potential stressors for each stock area, and a Cumulative Threats Score (CTS) is calculated from this information. Next, the quality of available stock assessment data for a stock (*i.e*., the quality of the available information on stock structure, abundance and mortality) obtained primarily from the most recent Stock Assessment Report (SAR) is evaluated and used to generate a Data Assessment Score (DAS). Together, the CTS and DAS are used to determine whether a particular stock should be given low, medium or high priority for research. In this process, it is not simply the level of threat(s) faced nor the amount (or lack of) of data available for a stock that leads to the prioritization of one stock over another. Rather, it is the interplay of these two categories that is important; so in theory, stocks with limited amounts of data available that face a high level of threats should be prioritized above stocks with more data availability and moderate to low levels of threats. It is hoped this assessment method could be extended to coastal and pelagic cetacean stocks in the Gulf and Northwest Atlantic.

This document describes the threat assessment process and explains the rationale behind each of the scores used to produce a final assessment of the priority of a given stock. It then provides a complete summary of the literature reviews performed for each of the seven BSE stocks in Texas and the final scoring for each of these stocks. All seven BSE stocks in Texas scored a high priority. This is not unexpected because none have recent abundance estimates or information on population structure. Galveston Bay, Laguna Madre and Corpus Christ had the highest cumulative threats scores while Sabine Lake had the lowest, though this low score is partially attributed to a lack of comprehensive information on the threats in this area. It is expected that future documents will provide the literature review summaries and final CTS and DAS for the remaining BSE stocks in the Gulf of Mexico.

Introduction

The common bottlenose dolphin, *Tursiops truncatus,* is a well-known marine mammal that is common in the bays, sounds and estuaries (BSEs) of the northern Gulf of Mexico. However, little is known about the seasonal movements, gene flow, abundance and levels of mortality for the majority of the 31 BSE stocks that have been delimited in the northern Gulf [1]. This lack of information hinders the ability to effectively manage these stocks. As is the case for many other protected species [2], there are limited resources available to study the *T. truncatus* stocks in the northern Gulf of Mexico, including those in the BSEs. While it would be ideal to have well characterized biological data for all *T. truncatus* stocks, this is not a realistic short or medium-term goal given the limited resources that are available for the conservation and management of a single species. Thus, a method to objectively prioritize BSE stocks for basic stock assessment research would aid the decision making process and allow resources to be directed where they would be the most effective for meeting research and management objectives. One means to prioritize BSE stocks is to examine and evaluate the number and severity of the stressors each stock faces. Resources could then be directed to stocks that face the highest level of threat and/or are the most data deficient.

The utilization of BSE environments, which are typically heavily impacted by anthropogenic activities [3], means that these *T. truncatus* stocks are exposed to a wide variety of threats such as pollution, fisheries and industrial activities as well as environmental stressors. Nineteen threats associated with negative impacts on cetaceans in these environments and elsewhere were identified as potential stressors to BSE stocks. The identified threats include various types of pollution (oil and gas, chemical, heavy metal and marine debris), fisheries (recreational, commercial and aquaculture), industrial activities (shipping, dredging, construction, energy exploration and noise), tourism activities, environmental stressors (algal blooms, storms, hypoxia, climate change, freshwater inflow/salinity changes and disease), habitat loss and Unusual Mortality Event's (UME's) of unknown etiology (see Threat categories and Table 1). Together, these 19 threats are thought to encompass the major stressors that *T. truncatus* stocks face in the BSE environments in the northern Gulf of Mexico. Each of the 19 stressors has multiple mechanisms to impact *T. truncatus*; for example, the mechanisms of impacts from oil and gas pollution can be direct, such as through the inhalation of vapors at the surface from oil slicks and ingestion with prey, or they may be more indirect such as a shortage of prey as a result of fish kills (Table 1). Each threat can also have a number of negative impacts on *T. truncatus*, ranging from altered behavior (changes in habitat use or prey, social, feeding or reproductive behavior), reduced health, reduced fecundity, injury and/or mortality, although the extent of the impacts are sometimes unknown (Table 1). For example, fisheries (recreational or commercial) can cause mortality or injury through the mechanisms of entanglement or ingestion of fishing gear [4, 5] as well as altered behavior and reduced health through provisioning, depredation or dietary shifts if the primary prey species is overfished [6, 7].

Tursiops truncatus is a protected species under the Marine Mammal Protection Act of 1972 (MMPA), which was created to protect, restore and maintain populations of marine mammals in U.S. waters. One of the goals of the MMPA is to prevent stocks from declining below their Optimum Sustainable Population (OSP) level and to restore any stock that has been reduced below this level [8]. In order to help achieve this goal, the MMPA requires the National Marine Fisheries Service (NMFS) to assess the status of each stock with relation to OSP and prepare Stock Assessment Reports (SARs) [9]. The critical information needed for an accurate assessment of the status of a stock includes (1) an understanding of the geographic range of the stock; (2) an accurate estimate of abundance of the stock and an estimate of maximum net productivity rate; and (3) an accurate estimate of the annual human-caused mortality and serious injury incurred by the stock. Information on trends in abundance is also an important component to understanding the status of a stock, but trend data are still uncommon for BSE stocks. In addition to evaluating the number and severity of the stressors present, a second component of prioritizing stocks is to evaluate the level of information that is available on stock structure, abundance and human-caused mortality, the most basic information that is required for a SAR [1]. Stocks that are data deficient should warrant greater attention so that stock assessments can be performed based on at least a minimum level of information.

Here, we develop a Threat Assessment Priority Scoring System, which combines a cumulative score for the threats impacting a stock, a 'Cumulative Threats Score' (CTS) with a 'Data Assessment Score' (DAS) to prioritize stocks. The CTS is obtained by first performing a thorough literature search using sources such as peer-reviewed publications, technical reports, news articles, scientific records and information provided by federal and state government departments (via websites, documents or personal communications) and preparing a descriptive summary with the best available information on the physical and biological environment and the 19 potential stressors for a given stock area. Using the summary, each potential stressor is then scored independently on its presence, impact on the environment/biota and impact on cetaceans as described in the scoring scheme below. Individual threats have a maximum score of 12 and the CTS has a maximum value of 228. The DAS is an evaluation of the quality of available stock assessment data for that stock obtained primarily from the most recent SAR. Together the CTS and DAS are used to determine whether a given stock should be given low, medium or high priority for basic stock assessment research. The priority score is relative to the other stocks being scored. In this process, it is not simply the level of threat(s) faced nor the amount (or lack of) of data available for a stock that leads to the prioritization of one stock over another. Rather, it is the interplay of these two categories that is important; so in theory, stocks with limited up-to-date assessment data that face a high level of threats should be prioritized above stocks with more assessment data availability and moderate to low levels of threats.

This document describes the newly developed threat assessment process and explains the rationale behind each of the scores used to produce a final assessment of the priority of a given stock. It then provides a summary of the literature reviews performed for each of the seven BSE stocks in Texas and the final scoring for each of these stocks. The literature summaries could potentially be reviewed and updated every five years, coinciding with a five-year strategic plan. It is expected that future documents will provide the literature review summaries and final CTS and DAS for the remaining BSE stocks in the Gulf of Mexico.

Threat Categories

Each of the 19 threats that the BSE stocks will be scored against is briefly described below. Careful consideration has gone into this list of potential threats to reduce overlap so double scoring should not occur, *e.g.,* recreational fishing is not listed under tourism because it is its own category, marine debris does not include fishing gear as this is already included under the fisheries categories and boat strikes are listed under tourism and therefore are excluded under the fisheries categories (see Table 1).

Oil & gas pollution

Oil and gas pollution pose a threat to the environment and biota, including cetaceans, through oil spills and leaks during exploration and drilling activities as well as leaks from ship and boat traffic. Oil spills can create a variety of negative environmental impacts [10]. Dolphins can inhale harmful vapors associated with oil slicks at the surface or ingest oil that is on or in their prey [11]. Oil spills can also impact dolphins indirectly, via decreases in the abundance of prey as a result of fish kills that are often associated with large oil spills [11]. While the extent of the impacts of oil spills on cetaceans are not fully understood, oil spills are believed to alter their behavior, damage organs, suppress the immune system, compromise reproductive rates and result in mortality [12]. A study on pods of killer whales, *Orcinus orca,* before and after the *Exxon Valdez* oil spill in Prince William Sound, Alaska in 1989 found resident and transient pods had suffered losses of 33% and 41%, respectively, the year after the spill [13]. The resident pod had not recovered to pre-spill numbers 16 years following the oil spill and its rate of population growth was less than that of other resident pods that did not experience a decline in abundance after the spill [13]. The transient pod continued to decline after the spill and is now listed as depleted under the MMPA [13]. In another example of the impacts of oil spills on cetaceans, health assessments conducted on common bottlenose dolphins in Barataria Bay, Louisiana following the Deepwater Horizon oil spill in 2010, during which ~4.9 million barrels of oil were spilled into the northern Gulf of Mexico [14], revealed dolphins in poor body condition that were more likely to have moderate to severe lung disease than dolphins from a reference site that did not experience oiling [12]. In addition, 48% of the dolphins were given a prognosis of guarded or worse while 17% were considered poor or grave and not expected to survive [12]. The dolphins had a number of uncommon disease conditions that were consistent with the impacts of oil exposure [12].

Heavy metal pollution

Heavy metals are often found in sediment, water and biota of environments with nearby industrial activities. Species at higher trophic levels, such as common bottlenose dolphins, risk having elevated levels of heavy metals in their tissues if prey are contaminated with heavy metals, *i.e.,* through bioaccumulation [11]. In cetaceans, some heavy metals have been associated with immune system suppression and organ damage, compromised health and reproductive rates and possibly even death [15].

Chemical pollution

Chemical pollutants are often found in sediment, water and biota of environments with nearby agricultural and industrial activities and typically enter the aquatic environment through run-off and effluent containing household, industrial and agriculture chemicals. Marine mammals bioaccumulate persistent organic pollutants such as PCBs and DDTs through prey ingestion. In addition to these legacy pollutants, emerging contaminants such as perfluorinated compounds and brominated flame retardants are also of concern. In cetaceans, persistent organic pollutants have been associated with altered hormone levels [16], immunosuppression [17-19], increased susceptibility to infectious disease [18, 20], reduced reproductive rates and reproductive success [21, 22] and infectious disease mortality [18].

Marine debris
Marine debris poses a major threat to cetaceans with an increasing number of entanglements and ingestions reported each decade [23]. Marine debris includes discarded household goods, plastics and general litter found in the aquatic environment, often brought in from rivers, but also through littering. For the purposes of this threat assessment, the marine debris category does not include discarded fishing gear or ghost fishing gear as these types of debris are covered in the fisheries categories. Cetaceans can become entangled in or ingest marine debris, the latter of which can lead to internal injury, blockages and/or starvation, ultimately resulting in reduced health, injury or mortality [23, 24].

Recreational fisheries
Recreational fisheries can have detrimental impacts to the environment and biota, including cetaceans, through a number of mechanisms including active and discarded fishing gear, habitat degradation, provisioning and depredation [7, 25]. Common bottlenose dolphins can become entangled in or ingest active or discarded fishing gear [4, 5]. Provisioning, depredation and scavenging released fish may change dolphin behavior and decrease wariness or increase interest in boats or fishing gear [7]. In a study examining recreational fishing gear interactions and depredation behaviors by common bottlenose dolphins in Sarasota Bay from 2000 to 2007, the number of incidents between dolphins and recreational fishers increased after 2004 (although this also included recreational boaters, which is included in the Tourism category in this threat assessment) [7]. In addition, dolphins with a history of recreational fishing gear interactions were more likely to be within 50 m of fishing line and shifted away from their natural patterns of activity [7]. Interactions with recreational fishing gear accounted for a 2% population decline in Sarasota Bay in 2006 alone [7]. For the purpose of this threat assessment, dolphin strandings involving lures and monofilament fishing line are scored in recreational fisheries rather than commercial fisheries given the prevalence of this type of line in recreational fisheries, *i.e.,* the interactions cannot be scored in both categories and they must be consistently scored in one or the other.

Although boat strikes are also a potential mechanism of impact of recreational fisheries on common bottlenose dolphins, for the purpose of this threat assessment, boat strikes are scored in the tourism category. It is unlikely that the appropriate boating sector will be known in such cases and this ensures the same event will not be scored in more than one category.

Commercial fisheries
Commercial fisheries pose a threat to cetaceans through a number of sources including active fishing gear, discarded fishing gear, ghost gear, by-catch, overfishing/declining fish stocks, provisioning and depredation [26, 27]. Dolphins can become entangled in or ingest active, discarded or ghost fishing gear [5]. As with recreational fisheries, provisioning, depredation and scavenging of released fish may change dolphin behavior and decrease wariness or increase interest in boats or fishing gear [7]. There may be retaliation or lethal deterrence from fishermen towards dolphins for depredation [27, 28]. There have also been documented changes in social structure as a result of depredation behavior on commercial fishery trawlers. For example,

bottlenose dolphins in Moreton Bay, Australia formed two distinct social groups depending on whether or not the animals foraged in association with trawlers [29]. When trawling in the area became restricted to only a small area, the two formerly distinct groups of dolphins became less differentiated and began associating with each other [29].

Commercial fisheries that common bottlenose dolphin from BSE stocks may interact with include the menhaden purse seine, shrimp, commercial hook and line (fishing charters), crab trap/pot and gillnet fisheries [1]. Common bottlenose dolphin injuries or mortalities have been documented in each of these fisheries in the Gulf of Mexico, however, data are not always stock-specific [1]. For the purpose of this threat assessment, dolphin strandings involving entanglements in fishing nets are scored as interactions with commercial fisheries rather than recreational fisheries given the prevalence of this type of gear in commercial fisheries, *i.e.,* the interactions cannot be scored in both categories and they must be consistently scored in one or the other. In addition, as with the recreational fisheries category, boat strikes are scored in the tourism category to avoid scoring the same event in more than one category.

Aquaculture

Aquaculture practices pose a threat to the environment and biota, including cetaceans, via fish farming gear in the water column, habitat loss and degradation, increased organic carbon input to the ecosystem and altered benthic communities [30, 31]. Cetaceans, such as common bottlenose dolphins, can become entangled in fish farming gear resulting in injury. Aquaculture farms can encourage depredation, which in turn, may result in retaliation by fish farm operators [30, 32, 33]. Alternatively, dolphins may avoid aquaculture farms and use alternative habitats, which may be sub-optimal [30, 34]. Aquaculture activities may also impact common bottlenose dolphins through indirect mechanisms including altering the food chain in the local area, potentially resulting in a loss of some species, which may include prey species of dolphins, and through introduction of new diseases [30].

Shipping

Activities associated with shipping such as ship traffic and port usage (*e.g.,* are ports present, how many, how much tonnage does the port process) adversely impact the environment and biota, including cetaceans. Threats of shipping activities to common bottlenose dolphins include ship strikes resulting in injuries or mortalities, habitat loss and habitat degradation resulting in a shift in habitat use, possibly the use of sub-optimal habitats [35]. Impacts of noise due to shipping are accounted for in the Noise category.

Dredging & construction

Dredging and construction activities include the deepening of channels for large vessels, construction for the oil and gas industry, construction and dredging of ports or harbors, construction of dams, levees and storm surge barriers and construction of coastal wind farms. These activities are likely to impact cetaceans through habitat loss and degradation (*e.g.,* erosion), a loss of prey species associated with a loss of seagrass beds (from dredging in particular), exposure to chemicals released from sediment during dredging or entrapment from construction activities [36]. Common bottlenose dolphins may utilize alternative habitats during dredging or construction activities, which may be sub-optimal, may feed on alternate prey species and may have decreased growth rates and nutritional condition [37].

Noise

Marine noise includes noise from activities such as shipping, boating, construction, mining, dredging, wind farms, the use of explosives during oil rig removal, sonar or seismic activity and military training activities, among others [38-40]. For the purpose of this threat assessment, all noise will be scored within this category as a means to avoid double scoring or not assigning noise to the correct source (*e.g.,* dredging or shipping). Cetaceans may attempt to avoid noise by utilizing other, sub-optimal, habitat [38, 39]. Cetaceans such as gray whales, *Eschrichtius robustus, O. orca* and harbor porpoises, *Phocoena phocoena,* have been known to avoid habitats with noise and then return when the noise ceased, even after six years [38, 41, 42]. Noise may also affect communication, prey/predator detection, and navigation or could lead to either temporary or permanent hearing loss [38, 43, 44]. Noise may also lead to mortality as sonar activity has been implicated with strandings in some cetaceans [38, 43, 45, 46].

Tourism & boat traffic

The tourism and boat traffic category includes potential impacts from recreational boaters, jet skis and ecotourism activities such as dolphin or whale watching tours. Boat traffic can disrupt natural behaviors of common bottlenose dolphins such as resting or socializing, may cause changes group composition and in travel direction [47-49]. Dolphins may learn to avoid areas with heavy boat traffic or boats targeting dolphins, leading to localized declines in abundance and shifts in habitat use (including moving to sub-optimal habitat) [47, 49]. Alternatively, if common bottlenose dolphins are fed (*i.e.,* provisioning), the association of people/boats with food can decrease their natural wariness of boats, making them more likely to be injured, create conditioning and encourage begging behaviors [50, 51]. Some dolphin watching tours as well as recreational boaters may touch, feed, swim with or harass dolphins, all of which are ultimately harmful to dolphins [52, 53]. Perhaps one of the most extreme examples of dolphin tourism is at Monkey Mia in Western Australia, where wild dolphins have been hand fed fish by tourists for over 40 years [54], although the state government now strictly regulates feeding. Between 1975 and 1995, only five of the 17 calves born to female provisioned dolphins at Monkey Mia survived [54]. As a result of this low survival rate, in 1995, the state government changed the feeding regulations and since then, only three of the 13 calves born to provisioned females have died, one of which was the result of a shark attack [55].

Boat strikes from tourism, commercial and recreational fisheries and shipping are also a mechanism of impact on common bottlenose dolphins. Because of the difficulties inherent in identifying the type of vessel that may have struck and injured or killed a dolphin, we have pooled all potential sources of boat strikes together and scored them in the tourism category. This decision was also made to avoid scoring the same event in more than one category. Boat strikes cause injuries and mortality to cetaceans [56].

Algal blooms

Harmful algal blooms (HAB), such as those caused by the dinoflagellate *Karenia brevis,* produce natural toxins and are associated with large-scale mortality events of marine species (*e.g.,* fish kills) [57]. Common bottlenose dolphins can be affected through respiratory exposure to HAB toxins at the surface and through consumption of prey [58, 59]. Sub-lethal exposure to HABs has been linked to reduced health and reproductive failure and brevetoxin exposure has specifically been linked with mortalities in common bottlenose dolphin [58, 59]. Common bottlenose dolphins could also be hypothesized to utilize alternative habitats during a HAB (especially if the bloom is contained within a bay environment), which may be sub-optimal and may also change group composition. HABs also have the potential to decrease the abundance of prey via fish kills, resulting in reduced health of dolphins. In fact, an increase in the frequency of depredation on recreational fisheries by common bottlenose dolphins was recorded when prey species were depleted in Sarasota Bay, Florida due to a HAB event [6, 7]. Depredation behavior is harmful to dolphins because it can lead to an increase in entanglements in or ingestion of fishing gear and lethal deterrence from fishermen toward the dolphin for the behavior, all of which could lead to injury or death of dolphins [6, 7].

Hypoxia

Hypoxia is a condition that occurs when the dissolved oxygen in an aquatic environment is severely reduced, often below the levels required for the survival of aerobic organisms. Mobile invertebrates and fish can move out of hypoxic waters to search for areas with higher levels of dissolved oxygen; however, if the levels of dissolved oxygen fall below critical levels, mortality of sessile or low mobility species often occurs [60]. Hypoxia is often associated with fish kills in stagnant waters with little to no mixing on a seasonal basis [61]. Common bottlenose dolphins may avoid hypoxic waters as a consequence of shifts in prey distribution [60]. If there are large fish kills associated with hypoxia, dolphins may experience dietary shifts, which could result in reduced health [60].

Adverse weather

Adverse weather such as tropical storms and hurricanes can cause large waves and storm surges that carry debris and chemicals from land into the aquatic environment. Hurricanes or tropical storms can also cause extensive habitat degradation such as damage to seagrass beds, which in turn, cause changes in the availability or abundance of prey [62]. Common bottlenose dolphins can become displaced, entrapped or stranded during storm surges or use alternative habitat such as offshore waters, during storms [62]. A ‘baby boom’ was documented in Mississippi Sound in the aftermath of Hurricane Katrina and was hypothesized to have resulted from an increase in food availability (from the loss of commercial fishing vessels) combined with the loss of calves during the event, allowing females to become reproductively active the next breeding season [63].

In addition to hurricanes and tropical storms, for the BSE’s in the Gulf of Mexico, this category also includes cold freezes, which are atypical for these environments. While dolphins have a protective layer of blubber, emaciated or young dolphins are unable to maintain their body temperatures in extremely cold waters [64]. Cold freezes can result in large fish kills and may impact dolphins through a dietary shift if prey availability is reduced via fish kills or a shift in habitat use to more suitable habitat or result in mortalities [61, 65].

Freshwater inflows

Freshwater inflows are dynamic and BSE environments may be hyper- or hypo- saline depending on freshwater inflows and the rate of evaporation, since they are typically more enclosed than the ocean. If salinities become too extreme, mobile species may move out of the area; long-term changes in freshwater inflows and, therefore, salinity regime may alter species composition. Freshwater inflows can impact cetaceans through habitat degradation (*e.g.,* seagrasses have salinity tolerances) and changes in inflows (and salinity) may cause dolphins to use alternative habitats, which may or may not be linked to a shift in prey distribution. Low salinities also increase the permeability of the skin of a dolphin, allowing easier absorption of chemicals [66] and dolphins that become trapped in low salinity waters often develop skin lesions [67]. Thus, impacts of freshwater inflows on dolphins can include altered behavior, decreased health and possibly even mortality [64, 66].

Habitat loss

Habitat loss from anthropogenic activities such as dam, levee and canal construction and oil, gas and water extraction combined with subsidence negatively impacts cetaceans. Habitat loss impacts cetaceans directly through the use of sub-optimal habitats or indirectly via potential dietary shifts if the distribution or abundance of prey species changes as a consequence of the loss or degradation of prey habitat or of nursery grounds for prey (*e.g.,* shallow wetlands) [68]. Impacts on common bottlenose dolphins include altered behavior and decreased nutritional status and growth rate from dietary changes [68].

Disease

Diseases from bacteria, viruses, fungi and parasites are known to affect *T. truncatus* [69-72]. Diseases can impact common bottlenose dolphins by reducing health, suppressing population growth rates and causing mortality [69-72]. However, in some cases, exposure to a disease, such as morbillivirus, could be beneficial to a common bottlenose dolphin stock since it could offer some level of resistance to future exposures at least for some time into the future [73]. How long resistance lasts in the case of morbillivirus and specifically for the Texas BSE stocks is not known [73].

Although the scoring system provides a score for disease, it does not provide a means to account for potential interactions between health and disease and the other stressors, *i.e.,* if the health of a population is poor, it may be considered more susceptible to other stressors. Therefore, after applying the scoring scheme, one should consider the possible interactive effects of health and disease and the stressors when making final rankings. Similarly, some of the other stressors, such as chemical, heavy metal and oil and gas pollutants, may weaken resistance to disease [69-72].

Climate change

Climate change encompasses changes to global climate patterns that are likely to affect sea levels, water temperatures and acidity, rainfall patterns and storm frequency and intensity [74, 75]. The impacts of global climate change on cetaceans are likely to be extensive, but are difficult to predict. A shift in the distribution of common bottlenose dolphins is possible as temperatures and habitats change, accompanied by a shift in the distribution and abundance of prey species [76]. There are also likely to be changes in the distribution of pathogens, so naïve populations may be exposed to new diseases [77]. The impacts of climate change on common bottlenose dolphin populations will depend on their ability to adapt to change and on the continued availability of suitable resources and habitat the dolphins and their prey.

Unusual mortality events of unknown etiology

The etiologies of UME's are often unknown, however it is important that these events are still considered (and therefore scored) when assessing the level of threats facing a given *T. truncatus* stock. When the cause of a particular UME is not known, the UME cannot be scored under the appropriate threat category (*e.g.,* disease or algal blooms). These events reduce the health and fecundity of common bottlenose dolphins and cause a large number of mortalities [78, 79].

Incidental research takes

There are records of mortalities of common bottlenose dolphins in the BSE's in the northern Gulf of Mexico during research activities such as dolphin health assessments, sea turtle relocations and fisheries research [1]. The stock assessment reports for the BSE *T. truncatus* stocks in the northern Gulf of Mexico indicate that the number of mortalities from this stressor for all 31 BSE stocks combined is ~10 animals since 2002 (excluding incidents believed to involve animals from coastal stocks) [1], which would not make incidental research takes a major threat at the individual stock level. However, reporting of common bottlenose dolphin mortalities in research activities is not mandatory and there has been no formal mechanism in place to report such events, *i.e.,* in the past, reporting has been done intermittently through the stranding network, through the National Marine Fisheries Service (NMFS) Southeast Regional Office (since 2011) and some mortalities or injuries have most likely not been reported at all [80]. In Texas, data compiled by NMFS Southeast Regional Office suggest that dolphin mortalities or injuries in research-related activities are occurring more frequently than previously thought, particularly in fisheries-related research in Texas [80]. Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in fishing gear (*e.g.,* gillnets) of research activities by Texas Parks and Wildlife, with four reports in 2012 alone, but none since 2012 [80]. Of these 31 incidents, 18 were from a single BSE stock area, Aransas Bay to Espiritu Santo Bay, over a 28-year span [80]. The remainder of dolphin by-catch incidents were four or five animals from a single stock area over a span of 16 to 24 years (four BSE stocks in total were impacted by research takes in Texas) [80]. It appears that outside of the Aransas Bay to Espiritu Santo Bay BSE stock, takes from research are a rare occurrence within a single BSE, although as noted above they may be under reported [1]. Because of the general rarity of incidental research takes for any given stock, this category has not been incorporated into the formal threat scoring scheme, although any known information about dolphin takes from research is included in the literature summaries. However, the high number of incidental research takes for the Aransas Bay to Espiritu Santo Bay BSE stock should be taken into consideration during the final prioritization of stocks.

Table 1. Description of the 19 potential threats, their mechanism of impact and their potential impacts on common bottlenose dolphins, *Tursiops truncatus*, in the bays, sounds and estuaries of the Gulf of Mexico. Each bay is assessed relative to each of these categories in order to identify areas where *T. truncatus* are likely to face the greatest threat.

Threat	Description	Mechanism of impacts	Impacts on *T. truncatus*
Oil & gas pollution	Spills from oil & gas exploration drilling, leaks from large vessel traffic, produce mass mortality events of marine species (*e.g.* fish kills)	Inhalation of vapors at surface with oil slicks; ingestion of oil directly on or in prey; shortage of prey as a result of fish kills; organ damage; depressed immune systems	Altered behavior, decreased nutritional status & growth rate, reduced fecundity, mortality, extent of impacts unknown, likely to be severe
Heavy metal pollution	Heavy metals in water, sediment, biota, bioaccumulation in food chain	Ingestion in prey; organ damage; some heavy metals correlated with immune system suppression	Reduced health & fecundity, mortality
Chemical pollution	Industry, agriculture & residential run-off/waste, bioaccumulation in food chain, *e.g.*, organic chemicals	Ingestion in prey; some chemicals correlated with altered hormone levels; immune system suppression	Reduced health & fecundity, mortality
Marine debris	Litter and debris in bays & estuaries, often brought in from rivers, includes household goods, plastics, garbage (not including fishing gear, see below)	Entanglement in or ingestion of marine debris; ingestion of marine debris can lead to internal injury, blockages, and/or starvation	Reduced health, injury mortality
Recreational fisheries	Fishing gear, discarded fishing gear/debris, habitat degradation, provisioning	Entanglement in or ingestion of fishing gear; provisioning; depredation; scavenging of released fish; retaliation or lethal deterrence from fishermen for depredation	Altered behavior, decreased nutritional status, injury, mortality
Commercial fisheries	Fishing gear, ghost gear, discarded fishing gear/debris, by-catch, overfishing, provisioning	Entanglement in or ingestion of fishing gear; provisioning; depredation; scavenging of released fish; retaliation or lethal deterrence from fishermen for depredation	Altered behavior, injury, decreased nutritional status, mortality
Aquaculture	Fish farming gear, habitat loss and degradation. Impacts of shellfish farming include increased organic carbon & altered benthic communities	Entanglement in fish farming gear; depredation; loss of quality habitat resulting in the use of sub-optimal habitats; avoidance of shellfish farms (*i.e.,* changes in habitat use); altered food chain; loss of prey species; introduction of new diseases	Altered behavior, decreased nutritional status & growth rate, injury, mortality

Table 1. continued

Threat	Description	Mechanism of impact	Impacts on ***T. truncatus***
Shipping	Ship traffic, port usage	Ship strikes; habitat loss & degradation resulting in a shift in habitat use; also see noise & dredging & construction impacts	Altered behavior, injury, mortality
Dredging & construction	Deepening of channels for large vessels, construction for oil & gas industry, dam and levee construction, construction of ports, harbors, storm surge barriers	Loss of quality habitat resulting in the use of sub-optimal habitats; loss of prey species associated with the loss of seagrass beds; exposure to chemicals released from sediment during dredging; entrapment from construction activities; also see noise and pollution impacts	Altered behavior, decreased nutritional status & growth rate, also see noise and pollution impacts
Noise	Noise associated with shipping, boating, construction, mining, dredging, wind farms, sonar, seismic activity	May affect communication, prey/predator detection, navigation; hearing loss; may utilize other, sub-optimal, habitats to avoid consistent noise	Altered behavior, decreased nutritional status & growth rate, could result in injury or mortality
Tourism & boat traffic	Recreational boaters, jet skis, dolphin and whale watching tour boats, some of which may operate irresponsibly. For example touching, feeding, swimming with or harassing dolphins.	Boat strikes, disrupt natural behaviors, changes to group composition; association of people/boats with food if provisioning occurs; conditioning; long-term area avoidance can lead to localized declines in abundance and shifts in habitat use (*i.e.,* use of sub-optimal habitat)	Altered behavior, decreased nutritional status & growth rate, injury, mortality
Algal blooms	Harmful algal blooms (HAB) produce natural toxins	Respiratory exposure to toxins at surface; consumption of toxic prey; exposure to HABs linked with reproductive failure; shortage of prey as a result of fish kills; increased frequency of depredation on recreational and commercial fisheries, leading to an increase in entanglements or ingestion of fishing gear and retaliation by fishermen for depredation behavior; shifts in habitat use and group composition	Altered behavior, reduced health, & fecundity, decreased nutritional status & growth rate, mortality
Hypoxia	Reduced levels of dissolved oxygen in the water, fish kills.	Change in habitat use as a result of shift in prey distribution; reduced availability of prey species if fish kills are large	Altered behavior, decreased nutritional status & growth rate, reduced fecundity

Table 1. continued

Threat	**Description**	**Mechanism of impact**	**Impacts on *T. truncatus***
Adverse weather	Hurricanes cause large waves, storm surges, the loss of seagrass beds, changes in prey availability and degradation of habitat.	Displacement, entrapment or stranding during storm surges; shift in habitat use to offshore waters	Change in fecundity, injury, mortality
Freshwater inflows	Bays, sounds or estuaries may be hyper- or hypo-saline depending on freshwater inflows and evaporation. Mobile species may move out of area if salinity is too extreme. Extreme fluctuations or changes in salinity regime may alter species composition.	Change in habitat use as a result of changes in salinity and shift in prey distribution; changes in species composition (fish and seagrasses) may degrade habitat quality; low salinity increases permeability of skin, allowing absorption of chemicals	Altered behavior, reduced health, mortality
Habitat loss	Loss and degradation of habitat from dams, levees and canals, oil and gas extraction, subsidence, wetland loss	May utilize other, sub-optimal habitat as a result of habitat loss/degradation; potential dietary shifts if the distribution or abundance of prey species changes as a result of loss of juvenile habitat (*e.g.,* shallow wetlands)	Altered behavior, decreased nutritional status & growth rate
Disease	Bacterial, viral & fungal infections, skin lesions, tumors	Affect health and cause mortality; suppress population growth rates; toxins tend to weaken disease resistance	Reduced health, mortality
Climate change	Changes in sea levels, water temperature and acidity, rainfall patterns, storm frequency/intensity	Likely to be extensive, but difficult to predict; shift in distribution as habitats & temperatures change; changes in migration routes, community structure, abundance and distribution of prey and trophic relationships; changes in pathogen distribution; impacts depend on ability to adapt & availability of suitable habitat for critical life-history stages	Altered behavior, largely unknown
Unusual mortality events of unknown etiology	Several bays and estuaries in the Gulf of Mexico have experienced common bottlenose dolphin unusual mortality events of unknown cause	Affect health; cause mortality	Reduced health and fecundity; mortality

Altered behavior: the threat is likely to have an impact on either the short or long-term 'normal' behavior of the animals; this includes changes in habitat use, social behavior, feeding behavior or reproductive behavior. Injury: the threat could result in a physical injury to the animal, for example, open wounds, skin lesions, or an injury that affects mobility. Decreased nutritional status: the impacts of the threat interfere with the availability or consumption of suitable nutrients (*i.e.* prey) and metabolic needs are not being met. Reduced health: threat may affect the health of the animal, such as the normal functioning of organs and systems (*e.g.*, immune system). Reduced fecundity: threat may affect the ability of animals to reproduce, either the inability to conceive/carry to term or produce healthy offspring. Decreased growth rate: refers to a decrease in the population growth rate; Mortality: threat may lead to the death of an animal

Development of Means to Prioritize Bay, Sound and Estuary Stocks for Research to Improve Basic Stock Assessments

This section describes the Threat Assessment Priority Scoring System and provides an explanation of how it is used and the rationale for each of its components. A score for the cumulative impacts of 19 different potential stressors on a stock, a 'Cumulative Threats Score' (CTS) is combined with a 'Data Assessment Score' (DAS), which estimates the level and quality of basic stock assessment information currently available for a stock, to yield an overall level of priority for a stock. The DAS is an evaluation of the quality of available stock assessment data for that stock (*i.e.*, the quality of the available information on stock structure, abundance and mortality) obtained primarily from the most recent SAR. The interplay of these two scores are used to determine the level of research priority a given stock should be accorded.

Assessing Cumulative Level of Threats – The Cumulative Threat Scoring (CTS) Scheme

The first step of the scoring scheme is to determine the level of threats faced by a particular BSE stock. The CTS is obtained by first performing a thorough literature search and summarizing the best available information on the presence, severity and impact of the 19 potential threats (Table 1) for a given stock area. A score is determined for each potential threat through summation of points earned from each of the following three categories: threat prevalence, potential for environmental impact and potential for impact on cetaceans. The scoring scheme of the CTS is asymmetrical. The two impact categories are weighted relative to the threat prevalence category through higher scores, when impacts are documented. Similarly, the impact on cetaceans category is given more weight through higher scores than the environmental impact category, although both of the impact categories have the same maximum scores. This scoring scheme allows distinct breaks in the CTS so the impact on cetaceans category appropriately corresponds to the low, medium and high threat categories (see Rational for Final CTS and DAS Bins). The maximum score possible per threat is 12. The CTS for a given stock is then the sum of the scores for each potential threat; therefore the maximum CTS possible is 228 (19 threats multiplied by a maximum score 12 per threat).

Threat prevalence:

- 0 = threat not present in this stock area
- 1 = threat is present, but data deficient[1] in this stock area
- 2 = threat is present and a characterized problem in this stock area

Potential for environmental impact[2]:

- 0 = threat present, but environmental impact unknown[3]
- 2 = impact is likely based on data from other locations, but data deficient in this location
- 3 = moderate impact documented at this location
- 5 = severe impact documented at this location (*e.g.* large fish kills, measureable change in environment or ecosystem function)

[1] A Threat score of 1 indicates that this stressor may be impacting the geographic area and/or the stock, *i.e.*, it is present in the stock's geographic area and it is known to negatively impact other stocks, but there is limited information available about the level of this threat on the stock being assessed. For example, we know a fishery that interacts with cetaceans operates in an area, but have insufficient information on total effort, gear characteristics etc. to assess impacts to the stock.

[2] This category covers all impacts on the environment and non-cetacean biota.

[3] 'Environmental impact unknown' means that the environmental impact of a threat is unknown for any location, not only a given stock area. The environmental impact may be negligible or there may not be any information on such impacts for any location, globally.

Potential for impact on cetaceans:

- 0 = no mortality or sub-lethal impacts documented for this stressor at this location or elsewhere
- 3 = no mortality documented for this stressor at this location, but threat has been associated with mortality elsewhere OR sub-lethal effects documented in cetaceans for this stressor elsewhere
- 4 = mortalities and/or sub-lethal impacts documented for this stressor at this location[4]
- 5 = mass mortality event(s) documented for this stressor at this location

The *threat prevalence* category is relatively straightforward; the threat is either present or not present, as documented in literature such as peer-reviewed publications, technical reports, news articles, scientific records or information provided by federal and state government departments. If the threat is present, it is either data deficient or it has been characterized as a problem in the area under consideration. The *potential for environmental impact* category encompasses all impacts on the environment and non-cetacean biota, but excludes impacts on cetaceans. A score of '0' in this category means that the environmental impact of a threat is unknown for any location, not only a given stock area. The environmental impacts may also be data deficient in the particular location (but impacts are likely based on data from other locations), moderate or severe. A severe impact is one that causes large die-offs of biota (*e.g.,* fish kills in the millions), or a substantial change in the environment or ecosystem function (*e.g.* loss of a wetland, complete loss of seagrass beds). The *potential for impact on cetaceans* category is based on mortality and sub-lethal impacts on cetaceans. In this context, sub-lethal refers to any impact that could adversely affect the health and fitness (ability to survive and reproduce) of cetaceans. Examples of sub-lethal impacts include, but are not limited to, reduced fecundity, immune system suppression, behavioral changes, and changes in growth and development.

UME's of unknown etiology have been identified as a stressor and are scored like the other 18 threats (Table 1; N.B. UME's of known cause are scored under the relevant threat categories, *e.g.*, disease). For example, an UME of unknown etiology with stranded dolphins in the BSE would score a '2' for the threat prevalence, a '2' for the potential environmental impact (because the cause of the UME is unknown and to err on the side of caution we score a '2' rather than a '0') and a '5' for the potential for cetacean impact, for a total score of 9. An UME with stranded dolphins in coastal areas adjacent to the bay (but no stranded dolphins in the BSE) would score a '1' for threat prevalence, a '2' for the potential environmental impact and a '3' for the potential cetacean impact, for a total score of 6. This difference in scoring is designed to capture some of the uncertainty in UME impacts on a BSE stock when all the mortalities are recorded only from coastal areas and not from inshore waters.

Assessing the Level of Basic Information Available for Stock Assessment- The Data Assessment Score (DAS)

The second step of the scoring scheme is to determine the quality of available stock assessment data for a particular BSE stock. The DAS is the sum of three values that estimate the level of information available on stock structure, abundance and human-cause mortality for a stock, the most basic information required for the SARs. The maximum DAS possible is 20. However, the

[4] Mortality in this category does not include rare, single events, *e.g.*, one mortality in 1950.

scoring scheme of the DAS is asymmetrical with maximum scores of 10, 5 and 5 for the levels of information available on stock structure (genetics), abundance and human-caused mortality, respectively. More weight has been given to information on stock structure because without such data, estimates of abundance and mortality are difficult to apply appropriately to groups of individuals, *e.g.,* the ‘stocks’ to which the estimates apply are unknown, and so data on abundance and mortality are of limited use. Similarly, stocks with some genetic data, but small sample sizes or results that are not statistically robust (*i.e.,* based on a small number of genetic markers) are only awarded 1 point because the data are of limited value. Obtaining additional genetic data on stock structure would still be a high research priority in such cases because small sample sizes and/or an insufficient number of genetic markers can lead to incorrect conclusions about the stock structure of a species and, therefore, abundance and mortality estimates may be applied to inappropriately grouped individuals. For example, groups of individuals may appear to be genetically homogenous when in reality there is stock structure that is not detected because of low power of the data, *e.g.,* [81-83]. Thus, data on stock structure are considered 'good' and score a ‘10’ in this category when a minimum of 40 samples [84] have been collected via random sampling within the BSE during the season when permanent residents dominate the area (rather than seasonal residents or transients), excluding boundary areas and inlets where adjacent stocks may be mixing with residents.

Information on stock structure:

- 0 = No genetic data available on the stock structure of *T. truncatus* in the stock area
- 1 = Some genetic data available on the stock structure, but sample sizes may be small and/or results not statistically robust
- 10 = Good genetic data on stock structure available with sufficient sample sizes and appropriate temporal sampling regime

Information on abundance:

- 0 = No information on abundance or data are more than 5 years old
- 2 = Well designed abundance surveys conducted for part of the area within the last 5 years
- 3 = Well designed abundance surveys conducted for the majority of area within the last 5 years
- 5 = Abundance surveys conducted for majority of area and with sufficient regularity to assess trends with good precision

Information on mortality

- 0 = No data or only anecdotal reports available on human induced mortalities
- 3 = Minimum and maximum mortality and serious injuries based on counts from stranding data and other reports OR an imprecise estimate of mortality based on observer data
- 5 = Robust estimate of mortality and serious injury available (through observer data)

For the information on abundance category, having no estimate of abundance or having data from surveys greater than 5 years old (based on the Stock Assessment Improvement Plan benchmark) is awarded a ‘0’. ‘Well designed’ abundance surveys means that the surveys were suitable for the habitat type and used appropriate statistical analyses to calculate total abundance from mark/recapture studies, or line-transect or aerial survey data where appropriate. ‘Well designed’ abundance surveys in the last 5 years are awarded either 2 or 3 points based on the coverage area of the survey. The only difference between scoring a '2' or a '3' in this category is if the majority of the geographic range of the stock was not covered in a survey, a '2' would be scored, whereas if the majority of the range was covered in a survey a '3' would be scored. If surveys were conducted regularly enough over the majority of the stock area such that data on trends were available, then this would score a '5' and these data would have good precision, *i.e.,* the power to detect a 50% change over 10 years, have adequate sampling frequency and reasonable CV, *e.g.* 0.3 [85]. Overall, for the information on abundance score, a score of '3' is considered very good information and '5' is considered excellent information.

For the information on mortality category, a score of '0' means no data, or only anecdotal reports, are available on human-induced mortality. A score of '3' in this category means that estimates of serious injury and mortality are available as counts from stranding data, self-reported takes, research mortalities and data from un-expandable observer data, or that there is an expanded mortality estimate from an observer program but it has problems, *i.e*., the CV is large or there are known biases and uncertainties in the estimate. A score of '5' implies that a robust estimate (CV less than 0.3 [85]) of serious injury and mortality is available. For this purpose serious injury in the information on mortality section refers to any serious injury that is more likely than not to lead to mortality of the animal [86]. Overall, for the information on mortality score, a score of '3' is considered very good information and a score of '5' is considered excellent information. For many Gulf of Mexico BSE *T. truncatus* stocks, data availability for mortality will often score a '0'. However, for some of these stocks a score of '3' might be possible.

Rational for Final CTS and DAS Bins

The overall priority score is based on the interplay of the CTS and the DAS (Figure 1). The CTS and DAS scores are each described in detail below.

<u>Cumulative threat score (CTS)</u>

The CTS can range from 0 to 228, with scores between 0 and 95 representing low levels of threats, scores greater than 95 and less than 152 representing medium levels of threats and scores between 152 and 228 representing high levels of threats faced by stocks. Thresholds for each category (low, medium high) were determined first for a single threat (*i.e.,* maximum of 12) and then multiplied by 19 for the total number of identified threats that may impact a stock (Table 1).

CTS scores between 0 and 95 are considered very low threat scores and arise from an average score between 0 and 5 for each threat (out of a maximum of 12 per threat). These scores typically result from threats not being present in the location, present and either data deficient or a characterized problem, an environmental impact likely, but data deficient for the specific location, or a moderate environmental impact documented (but never severe), but with no cetacean mortality associated with the threat at the location or elsewhere, *e.g.,* the potential for impact on cetaceans category is always a '0'.

CTS scores greater than 95 but less than 152 are considered medium level threat scores and arise generally from an average score of 6 or 7 per threat (out of a maximum of 12 per threat). These scores result from threats that are present, although information on the threats and their impacts on the environment may be data deficient, and the threat has been associated with cetacean mortality or sub-lethal affects elsewhere, *e.g.,* the potential for impact on cetaceans category is at least a ‘3’. Although considered unlikely, it is also possible to get scores within this range when threats are present and characterized problems, with a severe impact on the environment, but there are no cetacean mortalities associated with the stressor in any location.

CTS scores between 152 and 228 are considered very high threat scores and arise from an average score between 8 and 12 per threat (out of a maximum of 12 per threat). These scores result from threats that are present and characterized problems, environmental impacts are generally documented to be moderate to severe (although sometimes an impact may be data deficient) and mortality has at least been associated with the stressor in cetaceans elsewhere or sub-lethal affects have been documented in cetaceans for stressor. Often, however, this CTS is associated with mortality or sub-lethal impacts of cetaceans at a specific location, *e.g.,* the potential for impact on cetaceans category is at least a ‘3’, often a ‘4’ or ‘5’.

Data assessment score (DAS)

The DAS can take one of 19 values (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20), with the lowest scores (≤ 13) representing assessment data poor stocks, medium scores (15-17) representing stocks for which some assessment data are available, and the highest scores (18-20) representing assessment data rich stocks. The score ranges for poor, medium and high were determined based on the overall quality of data possible with each of these scores in the three data categories, *i.e.,* stock structure, abundance and mortality. Stocks with a DAS of 13 or less are considered data poor because these are stocks for which minimal information on stock structure, abundance and/or mortality are available. Data in any one of these categories may be excellent (or excellent in the abundance and mortality categories with no or poor genetic data); however, the trade-off is often that data in another category will be very poor or non-existent. For example, we could have good genetic data, and no information on abundance or mortality, for a total DAS score of 10; or some genetic data, abundance data for part of the range and no information on mortality for a total DAS score of 3.

Stocks with DAS scores between 15 and 17 are stocks that we have good data on stock structure and some data on abundance and mortality estimates. However, in almost all cases there is a trade-off in data availability/quality between abundance and mortality; if there are excellent data on abundance with trends (*e.g.,* a ‘5’), then there is no available information on mortality. The one exception is the score of 16, which can only be achieved with a stock structure score of ‘10’, an abundance score of ‘3’ and a mortality score of ‘3’. Under this circumstance, this stock would actually be considered a low priority unless combined with a high threat score, because scores of ‘3’ in the latter two categories are quite good, particularly for Gulf of Mexico BSE *T. truncatus* stocks. However, when combined with a high threat score, these stocks should be considered for additional abundance surveys to obtain trend data to determine whether or not the abundance is declining.

Stocks with DAS of 18 or greater are stocks for which we have good genetic data on stock structure, recent abundance data for the majority of the stock’s range, potentially with data on trends, and at least minimum and maximum mortality (*i.e.*, genetic data score is a ‘10’ and abundance and mortality scores are at least a '3', but must be a combination of a '3' and a '5'). DAS scores within this range are considered very good.

Final Priority Score for Individual Stocks
To determine a stock's priority level, the final CTS and DAS scores generated for a stock are placed into a 3x3 matrix that was created based on the bins described above.

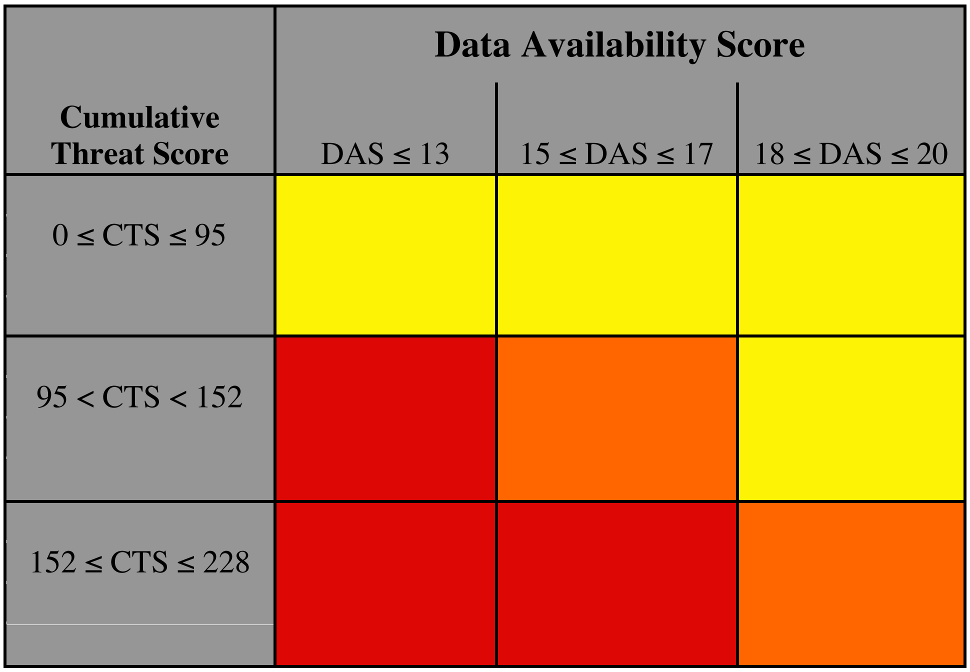

Figure 1. Overall priority-scoring matrix designed for *Tursiops truncatus* stocks in the bays, sounds and estuaries (BSE's) of the northern Gulf of Mexico. CTS and DAS come from steps 1 and 2 of the Threat Assessment Priority Scoring Scheme, respectively. Yellow squares indicate low priority, orange squares indicate medium priority and red squares indicate high priority stocks.

<u>Low priority stocks (yellow squares)</u>
There are four different DAS and CTS combinations that will prioritize a stock as low. Two of these combinations (*i.e.,* two of the squares) apply to stocks with very high quality data assessment information (DAS of 18 or greater) and CTS scores between 0 and 152 (see Figure 1). These are *T. truncatus* stocks for which good genetic data on stock structure, recent abundance data for the majority of the stock's range, potentially with data on trends and at least minimum and maximum mortality estimates are available. In reality, the level of data available for stocks in this category are very good, so regardless of the level of threat (low or medium), there will be other stocks that should be a higher priority due to data deficiencies, *e.g.,* DAS < 18.

The other two combinations of DAS and CTS scores that will give a stock a low priority rating involve CTSs that are considered very low (0 ≤ DAS ≤ 17 and 0 ≤ CTS ≤ 95; see Figure 1). *Tursiops truncatus* stocks that fall within these categories have either poor (DAS ≤ 13) or medium (15 ≤ DAS ≤ 17) levels of assessment data available, which would usually make these stocks a high and medium priority, respectively. However, the CTS scores indicate that the threats/stressors generally have not been associated with sub-lethal impacts or mortalities to cetaceans in any location (see CTS explanations for additional details). Therefore, *T. truncatus* stocks that fall within this category in a particular location should be considered a low priority.

Once the data deficiencies of stocks within the high and medium priority categories have been addressed, then it may be worth prioritizing the stocks within the 'low priority' category.

Medium priority stocks (orange squares)

There are two different DAS and CTS combinations that will create a medium priority designation for a stock. In one circumstance (15 ≤ DAS ≤ 17 and 95 < CTS < 152), the stock would have good data on stock structure and some data on abundance and/or mortality. However, in almost all cases there is a trade-off in data availability between abundance and mortality; if there are excellent data on abundance with trends (*e.g*., a '5'), then there is no information available on mortality or *vice versa* (see DAS explanations for additional details). The CTS between 96 and 152 indicate that a number of the threats have been associated with sub-lethal impacts on cetaceans or have been associated with cetacean mortality in other locations. Medium priority stocks should always be prioritized after high priority stocks and before low priority stocks.

The other situation where a stock can be considered of medium priority is when excellent data are available for the stock, but the stock is known to also face a high level of threat (DAS = 18 or 20 and 152 ≤ CTS ≤ 228). These are stocks for which we have good data available on stock structure, recent abundance data for the majority of the stock's range, potentially with data on trends and at least minimum and maximum mortality estimates. The level of data available for stocks in this category is very good, so even though the level of threat is high, there will be other stocks that should be a higher priority for stock assessment research due to data deficiencies, *e.g.,* DAS < 18. However, stocks in this category are considered a medium priority given that they face high levels of threats. Other research to decrease the known threats may be needed.

High priority stocks (red squares)

There are three different DAS and CTS combinations that will prioritize a stock as high. Two of these combinations (*i.e.,* two of the squares) involve a DAS of 13 or less (DAS ≤ 13 and 95 < CTS ≤ 228). These are stocks for which minimal information is available for stock structure, abundance and mortality. Alternatively, data in any one of the data categories may be excellent (or excellent in the abundance and mortality categories with no or poor genetic data); however, the trade-off is that data availability in another category will be poor or non-existent. When poor data availability on stocks is combined with a medium to high CTS, these stocks are considered to be a high priority. This is because these categories are generally characterized by threats that have at least been associated with sub-lethal impacts or mortality of cetaceans in other locations (see CTS explanations for additional details). High levels of threat are often associated with mortality or sub-lethal impacts of cetaceans at the specific location (see CTS explanations for additional details).

The other combination of DAS and CTS that will prioritize a stock as high is 15 ≤ DAS ≤ 17 and 152 ≤ CTS ≤ 228. These stocks have good genetic data on stock structure and some data on abundance and/or mortality estimates. However, in almost all cases there is a trade-off in data availability between abundance and mortality; if there are excellent data on abundance (*e.g.,* a '5'), then there is no information available on mortality (see DAS explanations for additional details). High levels of threats suggest that the threats have at least been associated with sub-lethal impacts on cetaceans or have been associated with cetacean mortality in other locations. Often, however, this CTS is associated with mortality or sub-lethal impacts of cetaceans at a specific location (see CTS explanations for additional details).

Scoring Scheme in Practice

A literature review of Corpus Christi Bay is available (see BSE: Corpus Christi Bay area). When the Threat Assessment Priority Scoring Scheme is used to score Corpus Christi Bay, the CTS is 136 and the DAS score is 0 (Tables 2 and 3). Using the overall priority-scoring matrix in step 3 of the scoring scheme (Figure 1), this places the Corpus Christi Bay *T. truncatus* stock in a high priority category.

Table 2. Threat assessment for *Tursiops truncatus* in the Corpus Christi Bay area of Texas. Citations are included where supporting data are available. The maximum number of points per threat is 12 and the maximum total number of points possible is 228

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Oil & gas pollution	2[87-89]	3[61, 90]	3[13]	8
Heavy metal pollution	2[91, 92]	3[91, 93]	3	8
Chemical pollution	2[91, 92, 94]	3[91]	3[66, 95]	8
Marine debris	2[96, 97]	2	3	7
Recreational fisheries	1[94, 98]	2	4[4, 35, 72, 99]	7
Commercial fisheries	1[94, 100, 101]	2	3[26, 102, 103]	6
Aquaculture	1[104]†	2	3[30]	6
Shipping	1[101, 105]	2	3[35]	6

Table 2. continued

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Dredging & construction	2[94]	3[92, 93]	3[106]	8
Noise	2[94, 101]	3[61]	3[38, 43]	8
Tourism	1[107, 108]	2	4[54]	7
Algal blooms	2[109, 110]	3[110]	3[109]	8
Hypoxia	2[61, 101, 111]	3[61]	3[60]	8
Adverse weather	1[112]	2[113]	3[62]	6
Freshwater inflows	2[66, 94, 101]	2[94, 101]	3[66]	7
Habitat loss	2[101, 114]	2	3	7
Disease	1	0	5*[69-72]	6
Climate change	1[74, 75, 114, 115]	2	3[76]	6
UME of unknown etiology	2[116]	2	5*[116]	9
Total				136

*mortality event was along the Texas coast that included animals from this BSE, not contained solely within this BSE; † oyster farms operated in Nueces Bay until 1995

Table 3. Assessment of data available on common bottlenose dolphins, *Tursiops truncatus* in the Corpus Christi Bay area of Texas. Citations are included where reliable supporting data are available

	Score
Information on stock structure	0
Information on abundance	0
Information on mortality	0
Total	0

Some Considerations for the Process

The developed scoring scheme has attempted to make the decision-making process of prioritizing BSE *T. truncatus* stocks in the northern Gulf of Mexico for stock assessment research relatively objective. However, there is still some level of judgment in the scoring scheme. For example, when assigning scores for the environmental 'impact' category of the CTS there is some level of subjectivity involved as to what constitutes a moderate *versus* severe impact on the environment. Therefore, there could be slight variations in CTS between scorers. To alleviate this, one individual could score all stocks or, if this is not possible, it may be worthwhile to have multiple scorers score all stocks in order to ensure that the level of subjectivity does not change the overall priority ranking of the stocks.

Once all stocks are prioritized using the developed scoring scheme, there will most likely be multiple stocks within a single box of the overall priority matrix (Figure 1). If desired, stocks within a single box (*e.g.* the medium category) could be further prioritized. This could be done in a number of ways. To start, stocks within a single overall priority level could be ranked by CTS. One step further would be to identify the 'high level' threats each stock faces in order to determine if any of the stressors can be more easily managed or mitigated. 'High level' threats are threats with individual threat scores of eight or more and are typically threats that are associated with mortality or sub-lethal impacts of cetaceans at a specific location (although they sometimes may only have mortality or sub-lethal affects associated with a stressor in cetaceans in other locations; see threat scoring scheme and CTS explanation). For example, in one box there may be two stocks, stock A and stock B; if stock A's biggest stressor is harmful algal blooms and stock B's largest stressor is chemical pollution from industrial effluent, then stock B could be prioritized before stock A because at least, in theory, pollution is somewhat easier to manage and control than algal blooms. Stressors that would be considered easier to manage or mitigate would be those that are controllable through the enforcement of laws and regulations to reduce the presence of the stressor in the first place (*e.g.* restrictions on dumping some toxins/chemicals, reducing marine debris through cleanup efforts and fines for littering). Stressors that would be considered more difficult to manage would be those stressors which cannot be controlled by bringing in new legislation or enforcing already existing regulations, although arguably, some of these stressors may be made worse by anthropogenic activities (*e.g.*, adverse weather, algal blooms, disease). If one or two extremely lethal stressors are apparent for a given stock (and all other stressors are low and medium, which should place the stock in an overall 'medium threat' category), further investigation may be warranted, and ultimately, prioritization could depend on the severity and manageability of the lethal threat(s). In addition to further prioritizing stocks within a single overall priority level using CTS or the manageability of high-level threats, population size could also be considered. When data availability (DAS) and threat levels (CTS) are similar between stocks, smaller stocks should be prioritized over larger stocks. The *T. truncatus* BSE stocks in the northern Gulf of Mexico are likely to be relatively small (when compared to coastal or offshore stocks), so any mortality or serious injury will have a proportionately larger impact on the population. However, when comparing *T. truncatus* BSE stocks to one another, many probably have similar population sizes. Finally, it should be noted that the failure to identify an individual threat as 'high-level' could be due to data deficiencies in the impact categories of the CTS scheme rather than the stressors not being important or 'high-level'. Identification of data deficiencies for stocks is another useful outcome of the process.

The first step in scoring the BSE *T. truncatus* stocks is to perform a thorough literature search to: 1) provide a description of the BSE environment; and 2) summarize, as best possible, the level of potential impact each of the 19 stressors might have on common bottlenose dolphins and the environment. The following section provides summaries of the seven BSE areas in Texas.

Summary of Characteristics and Anthropogenic Activities for Bay, Sound and Estuary areas of Texas

The seven BSE *T. truncatus* stocks currently delineated in Texas are: Laguna Madre, Corpus Christi Bay, Aransas Bay to Espiritu Santo Bay, Matagorda Bay, West Bay, Galveston Bay and Sabine Lake (Figure 2). The remainder of this document summarizes physical and biological characteristics and threats facing *T. truncatus* stocks in each of these areas. The majority of the sources used in the literature searches for the Texas BSE stocks are dated from the 1970's to the present (*i.e.,* 2014), although some of the information dates back to the 1920's. A brief description of each of the threat categories and the impacts on *T. truncatus* is summarized under the Threat categories section of the Introduction of this document.

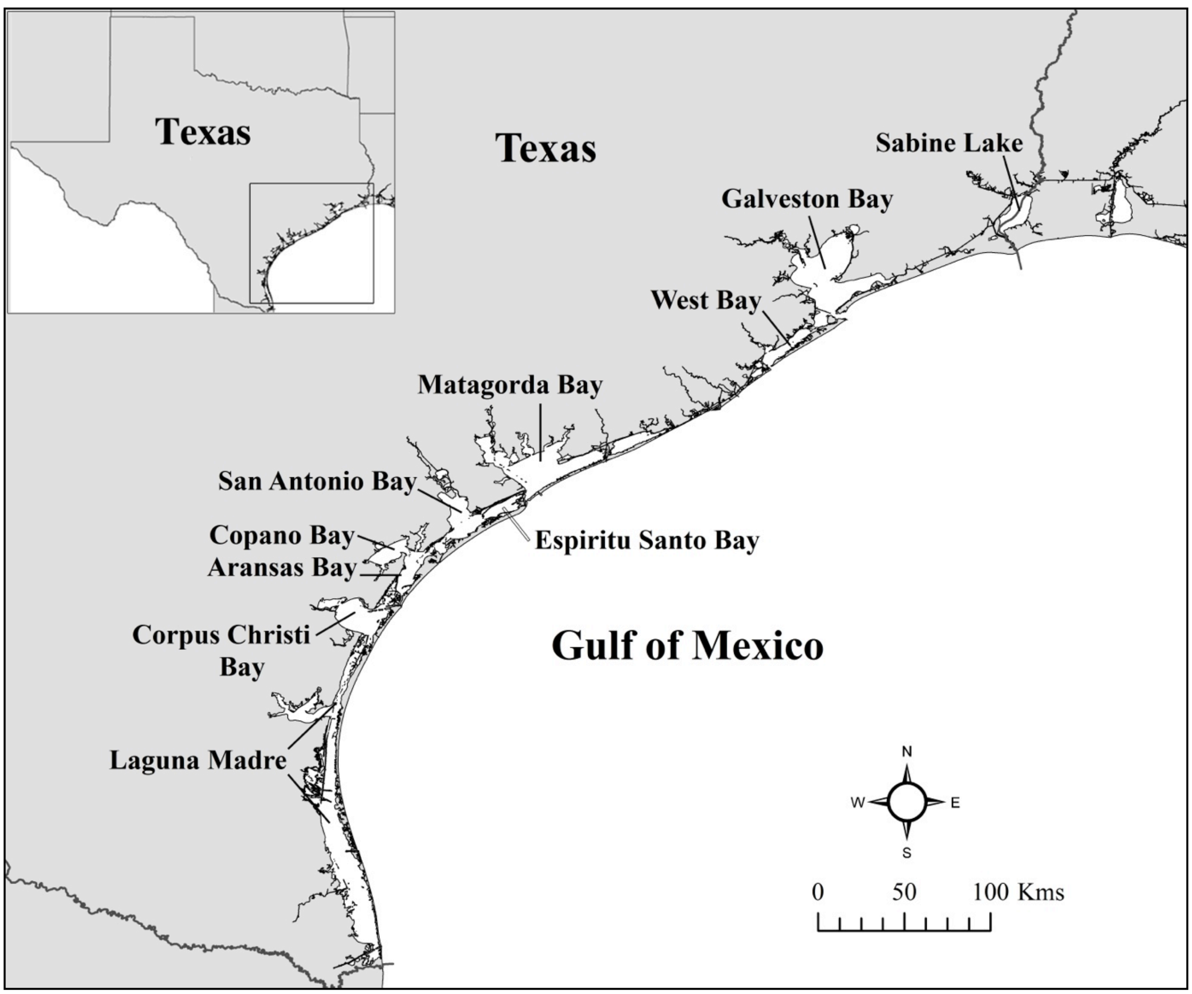

Figure 2. The bays, sounds and estuaries (BSE's) of the Texas coast

BSE: Laguna Madre

The Laguna Madre (LM) system formally includes Baffin Bay in the upper LM and South Bay in lower LM (see Figure 3). The LM system is a long backwater bay separated from the Gulf of Mexico by Padre Island [117, 118]. The bay stretches from Texas, just south of Corpus Christi, to Mexico and is the largest bay in Texas based on surface area [117, 119]. Excluding Baffin Bay, LM makes up approximately 20% of Texas' protected coastal waters [118].

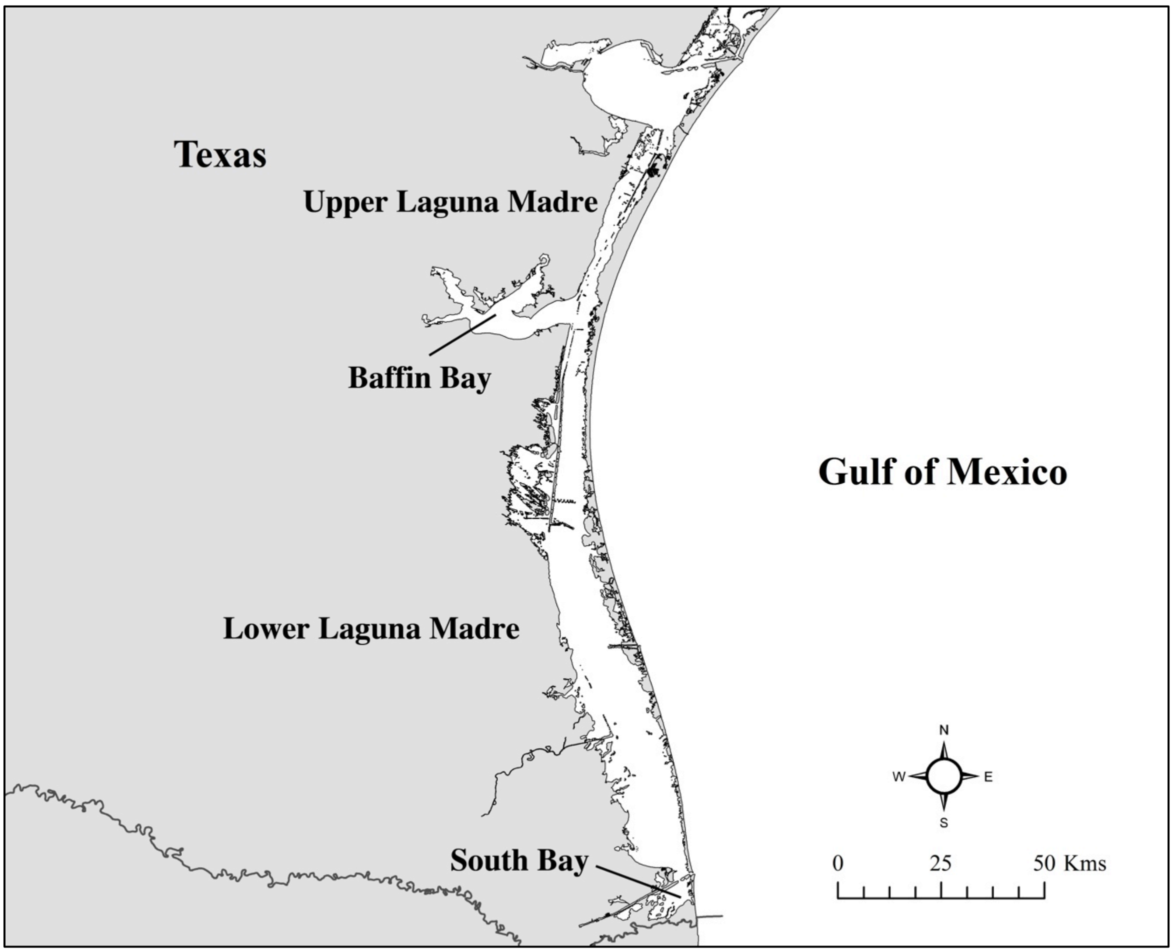

Figure 3. Laguna Madre estuary, Texas

Physical attributes

LM is a long, narrow bay extending roughly 443 km along the shores of Texas [117]. LM covers an area of approximately 3,658 km^2 with an average depth of 1.1 m, although the maximum depth is 4 m where it is dredged [105]. The LM system is naturally separated into two parts, the upper LM and lower LM, isolated by sand and mudflats roughly 20 km long, the Saltillo Flats, [118] located south of Baffin Bay in Kenedy County. Dolphins are unlikely to be able to move across this 20 km shallows except through the Gulf Intracoastal Waterway (GICW), which was completed in 1949, connecting the two bodies of water and runs the entire length of the LM system [120]. The upper LM is approximately 80 km long and 3 to 6 km wide while the lower

LM is roughly 95 km in length and ranges from 3 to 12 km in width [118]. LM is hypersaline with salinities typically around 36 parts per thousand (ppt), although prior to the construction of the GICW it was not uncommon for the salinity in lower LM to be double that of the Gulf of Mexico in lower LM while salinities of upper LM could be triple that of the Gulf [117-119]. However, the connection of LM to the Gulf of Mexico as well as the upper and lower sections of LM via the GICW has enhanced water exchange and salinities typically do not exceed 50 ppt [118]. LM receives approximately 74.4 cm of precipitation each year, but loses about 158.3 cm/year through evaporation for a net loss of about 83.9 cm/year, further contributing to the hypersaline environment [119]. LM is separated from the Gulf of Mexico for almost its entire length by Padre Island [117, 118]. Exchange with Gulf waters occurs via Brazos-Santiago Pass and the Mansfield Channel, constructed in 1938 and 1957, respectively [65]. The tidal ranges in upper and lower LM are 0.2 m and 0.3 m, respectively [94]. The average air temperatures of LM range from highs of 29°C (84°F) to lows of 16°C (61°F), with an overall average temperature of 23°C (74°F), based on data for 107 years from Brownsville, Texas [94]. The average water temperature of LM is 26.1°C (79.0°F), based on temperature data from 1984-1987 [121].

Biota

Seagrass

There are extensive seagrass beds in LM, with meadows covering ~65% of LM and accounting for roughly 80% of the remaining seagrass habitat in Texas [118, 119]. These seagrass beds are important nursery areas for juvenile fish and invertebrates and they also provide shelter and feeding areas for adult fish including spotted seatrout, *Cynoscion nebulosus,* and red drum, *Sciaenops ocellatus*. For the LM system as a whole, seagrass beds decreased by about 4% (29 km^2) from the mid-1960's to 1998 with a shift in species composition from predominantly (64%) the shoal grass, *Halodule wrightii,* to 40% *H. wrightii*, 11% turtle grass, *Thalassia testudinum,* and 14% manatee grass, *Syringodium filiforme* [118]. The species composition and distribution within each of upper and lower LM, however, is somewhat different.

In upper LM, *H. wrightii* is the most abundant species of seagrass, with some *S. filiforme* and small patches of star grass, *Halophila engelmanni,* and widgeon grass, *Ruppia maritima* [118]. Seagrass bed coverage in upper LM increased by 64% (79 km^2) from the mid-1960's to the mid-1970's and again by 13% (26 km^2) by 1988, followed by a 2% decrease (11 km^2) by 1998 [118]. *Halodule wrightii* beds increased in coverage by 76% from the 1960's to 1988, and then suddenly decreased by 10% by 1998 [118]. *Syringodium filiforme,* which was virtually absent from surveys in 1988, dominated 15 km^2 of upper LM by 1998 [118]. The marked increase in seagrass beds from the 1960's to 1988 is likely due to the more tolerable (*e.g.,* lower) salinity regime of upper LM after the construction of the GICW and the slow process of seagrass bed establishment through propagation from remote source populations from lower LM or Corpus Christi Bay [118]. From 1989 to 1997, a brown tide was continually present (see Algal blooms below), reducing light at 1 m, resulting in dieback of some seagrass beds [118, 122].

In lower LM, the dominant species of seagrass are *S. filiforme*, *H. wrightii*, and *T. testudinum*, although the species composition and seagrass bed distribution has been dynamic since the 1960's [118]. For example, from the mid-1960's to the mid-1970's, seagrass bed area decreased by roughly 21% (~126 km^2), then increased by 0.1% (0.66 km^2) by 1988 and again decreased by 1% (4.5 km^2) by 1998 [118]. In addition, the species composition has shifted dramatically; in

1965, over 89% of the seagrass beds were dominated by *H. wrightii,* which were gradually replaced by *S. filiforme* and *T. testudinum*, with *H. wrightii* comprising only 46% of the beds by 1998 [118]. The decrease in seagrass beds and shift in species composition in the 1960's and 1970's have largely been attributed to the maintenance dredging of the GICW, which increased turbidity [118]. *Halodule wrightii* is a rapid colonizer with a high salinity tolerance, and therefore, was likely to be more widespread prior to the construction of the GICW when there was a higher salinity regime in lower LM bay [118]. Once the salinity of lower LM decreased, the greater competitive abilities of *S. filiforme* (but slower rate of colonization) likely led to a gradual shift in species composition [118, 123].

Birds

LM is one of the most important and undisturbed wetlands on the Gulf coast [124]. LM is an important winter habitat for redhead ducks, *Aythya americana* [118]. Over 75% of the world's population of *A. americana* utilize this area in the winter, feeding on rhizomes of the seagrass, *H. wrightii* [118]. Other bird species found in LM include the piping plover, *Charadrius melodus*, snowy plover, *Charadrius alexandrinus*, Wilson's plover, *Charadrius wilsonia,* willet, *Tringa semipalmata,* American oystercatcher, *Haematopus palliatus,* black-bellied plover, *Pluvialis squatarola,* American avocet, *Recurvirostra americana,* roseate spoonbill, *Ajaja ajaja,* long-billed curlew, *Numenius americanus,* brown pelican, *Pelecanus occidentalis,* and peregrine falcon, *Falco peregrinus* [124-127].

Fish & invertebrates

The most common fish and invertebrate species in LM are: pinfish*, Lagodon rhomboides,* bay anchovy, *Anchoa mitchilli,* blue crab, *Callinectes sapidus,* Gulf toadfish, *Opsanus beta,* spot, *Leiostomus xanthurus,* striped mullet, *Mugil cephalus,* mud crab, *Dyspanopeus texana,* inland silverside, *Menidia beryllina*, and Atlantic croaker, *Micropogonias undulatus* [119]. Species that are economically important in LM are *C. nebulosus, S. ocellatus*, black drum, *Pogonias cromis,* white shrimp, *Litopenaeus setiferus* and brown shrimp, *Farfantepenaeus aztecus* [119, 128]. Other species found in upper LM are: the lesser blue crab or dwarf crab, *Callinectes similis*, bay squid, *Lolliguncula brevis*, mantis shrimp, *Squilla empusa*, southern flounder, *Paralichthys lethostigma*, sand trout, *Cynoscion arenarius*, Gulf menhaden, *Brevoortia patronus*, sea catfish, *Arius felis*, sheepshead, *Archosargus probatocephalus*, gafftopsail catfish, *Bagre marinus*, and blackcheek tonguefish, *Symphurus plagiusa* [119]. The fish and invertebrate composition of upper and lower LM is similar except that lower LM does not have *L. brevis*, *D. texana*, *S. ocellatus*, *B. marinus* or *P. cromis* [119]. Lower LM also has oysters and the star drum, *Stellifer lanceolatus* [119]. Oysters are only found in lower LM where salinities are more moderate [129]. The oyster population in South Bay has a higher salinity tolerance than oysters found on the Atlantic or Gulf coasts and is genetically distinct from other populations [65, 130].

As is the case for all the Texas bays, LM is an important nursery habitat for a number of fish and invertebrates. The occurrence of *L. setiferus* in LM is highly seasonal; larvae use estuarine waters for development and growth while adults migrate to deeper waters in the Gulf of Mexico to spawn. The abundance of *L. setiferus* in LM peaks in late spring and summer. *Sciaenops ocellatus* uses LM as nursery habitat for juveniles, however after reaching maturity around three to five years, juveniles migrate to Gulf waters where they spend their adult lives [131, 132]. *Mugil cephalus* depend on the estuarine environments such as LM for development, but are euryhaline as adults, migrating to the Gulf of Mexico to spawn and returning to food-rich estuarine waters [133].

Common bottlenose dolphins

Data assessments

There has been little research on dolphins in the LM area. There are no studies regarding the population genetic structure of *T. truncatus* assemblage(s) in this area and there has not been an estimate of abundance of the dolphins in LM in the last five years.

An aerial abundance study conducted by Leatherwood and Reeves in 1979 from Aransas Pass to Brownsville found that *T. truncatus* in LM were rare and typically found only in ship channels and passes [134]. During this survey, a total of three *T. truncatus* groups, each comprised of between three and eight individuals, were sighted in LM, all within the GICW near Port Isabel and Port Mansfield, *e.g.,* near passes [134]. However, the authors state that these results should be interpreted with a note of caution because of the potential bias of using aerial surveys to estimate population size (*e.g.*, sightings of only large groups, availability bias when animals are submerged and planes quickly pass by, visibility bias from obstructed views from the aircraft, turbid water, poor weather, which underestimate the number of animals [135-137]) and because the survey was conducted in September, when the abundances may have been well below their peak. Leatherwood and Reeves [134] report that of the ~528 km of habitat surveyed in LM proper (not including the GICW survey), ~37.6% of LM was 'acceptable' dolphin habitat, based on water depth (at least 0.2 m at mean low tide and accessible).

Unusual Mortality Events

Since 1990, at least four UME's as well as a large die-off prior to the start of the UME program (in 1991) have occurred along the Texas coast involving *T. truncatus*. In 1990, a mortality event of *T. truncatus* occurred from January through May along the entire northern Gulf of Mexico coast from Florida through Texas with 46% of the 344 carcasses being collected in Texas [78]. However, at this time, the Texas Marine Mammal Stranding Network (TMMSN) was more developed than some of the stranding networks in other Gulf states, which may have led to a higher proportion of stranding reports from Texas [78]. For the LM area, during this event, one *T. truncatus* stranded in LM proper and 15 stranded on the barrier islands, Padre Island and South Padre Island (Figure 4). Whether the stranded *T. truncatus* on the barrier islands of LM were residents of the estuarine stock or a coastal stock remains unknown. The winter of 1989-1990 was colder than normal throughout most of the Gulf [78] and the influence of the cold weather on the UME is unclear. Chemical contaminant levels (PCB's) were measured in 10 male dolphins that stranded in Matagorda Bay during the 1990 event [138] and in 26 dolphins collected during the event from both coastal and estuarine waters from LM to Galveston Bay, including one female from South Padre Island [95]. While PCB levels were relatively low in the majority of the dolphins, PCB levels in a few animals were high enough to potentially negatively impact reproductive success in females [21, 138]. However, contaminant levels were not ultimately considered the cause of this mortality event [78]. Retrospectively, it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this large die-off was not confirmed [78].

Figure 4. Locations of stranded *Tursiops truncatus* during the 1990 mortality event. For Texas, 159 stranded *T. truncatus* are shown of the total 344 *T. truncatus* stranded in the Gulf of Mexico during this event. Some locations are approximate as latitude and longitude coordinates were not available and had to be estimated based on the location descriptions. Not all strandings are plotted as coordinates were not available for all strandings and location descriptions were not precise enough to be estimated for some cases.

An UME was declared for Texas from December 1993 through May 1994, with a total of 236 *T. truncatus* and four unidentified dolphin strandings in Texas [79]. Of these strandings reported in Texas, three were recovered in LM near inlets and passes, one was recovered from the bay side of Padre Island and 12 were recovered on the gulf-side beaches of Padre Island (Figure 5). Whether the strandings from LM proper and the barrier island were from the estuarine stock or a coastal stock remains unknown, especially since they were found in inlets and passes. The confirmed cause of this UME was morbillivirus [70, 71, 139].

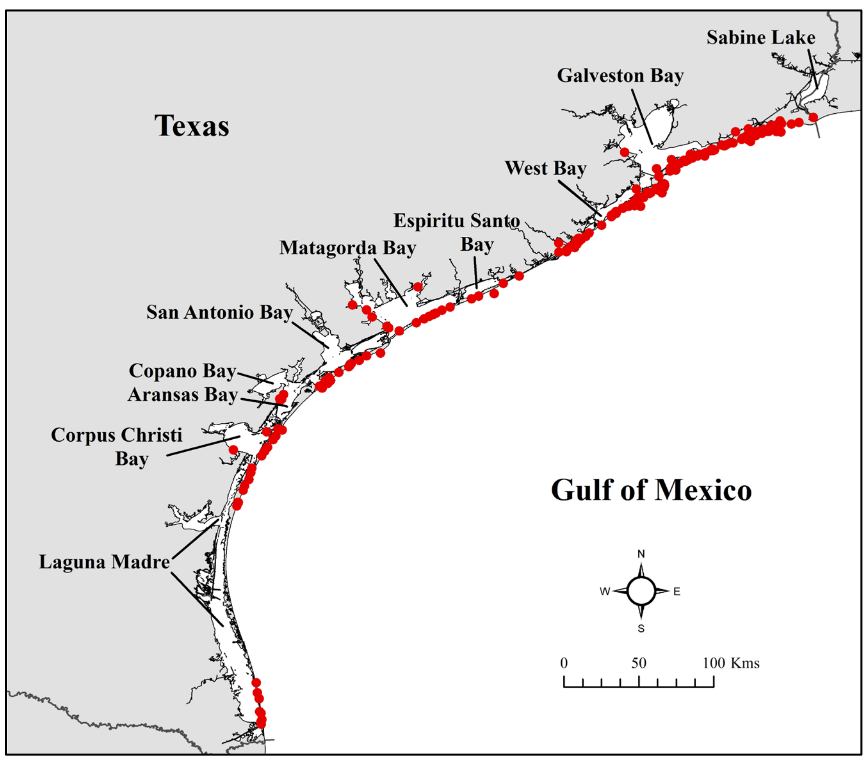

Figure 5. Locations of 224 out of the total 236 stranded *Tursiops truncatus* during the 1993-1994 unusual mortality event. Some locations are approximate as latitude and longitude coordinates were not available and had to be estimated based on the location descriptions. Not all strandings are plotted as coordinates were not available for all strandings and location descriptions were not precise enough to be estimated for some cases.

In 2008, an UME was declared in Texas for February and March, during which 111 *T. truncatus* stranded primarily on the Gulf-side beaches [79]. This UME had a high proportion of perinate strandings, which suggests an infectious agent that can cause late term abortions or early neonatal loss, such as the bacterium *Brucella*, may have been involved in this event; transmission of this bacteria is often through placental tissues and maternal feeding, resulting in aborted fetuses [79, 140]. In the LM area, 12 animals were recovered on beaches on the barrier islands, Padre Island and South Padre Island, only one of which was recovered from the bay side (although there were two additional strandings in the LM area that did not have coordinates available) (Figure 6). Whether the strandings were from the estuarine stock or a coastal stock is unknown. An analysis of gastrointestinal contents from stranded animals, including those from Padre Island, revealed the presence of harmful algal bloom (HAB) toxins domoic acid and okadaic acid (associated with a *Dinophysis* spp. and *Prorocentrum* spp. toxic algae bloom occurring at the time) [109]. Low levels of brevetoxin were also found despite an absence of an associated *K. brevis* bloom [109]. The levels of each HAB toxin were low relative to levels associated with acute mortality and the levels of okadaic acid were at levels of unknown effects; however the impact of multiple toxins (*e.g.,* okadaic acid, domoic acid and brevetoxin) on marine mammal health is unknown [109]. The toxicity of okadaic acid has been shown to increase in the presence of a toxin (gymnodimine) produced by *K. brevis* [141]. However, no definitive cause for the 2008 event has been determined [116].

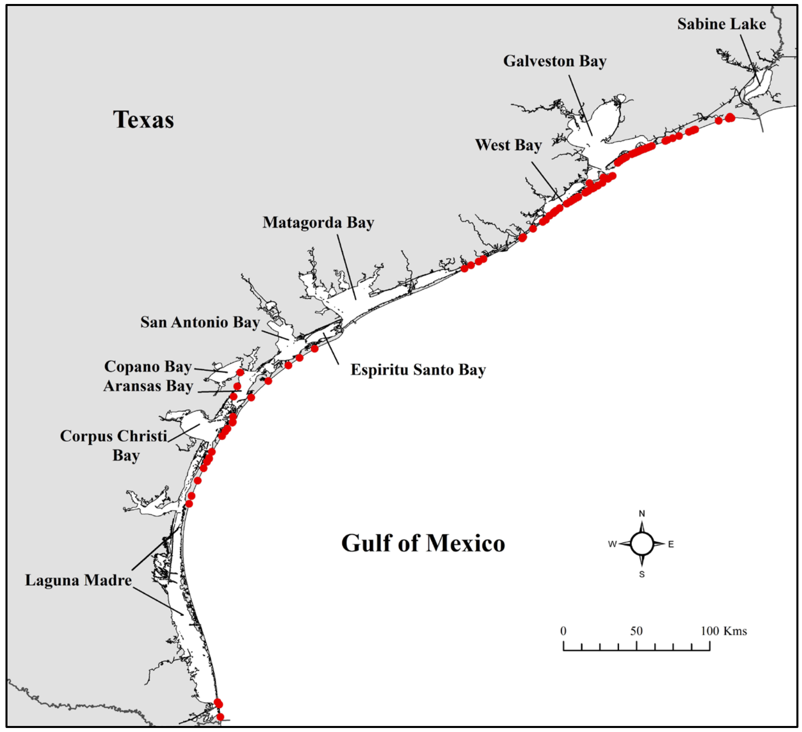

Figure 6. Locations of 108 out of the 111 of the stranded *Tursiops truncatus* during the 2008 unusual mortality event. Some locations are approximate as latitude and longitude coordinates were not available and had to be estimated based on the location descriptions. Not all strandings are plotted as coordinates were not available for all strandings and location descriptions were not precise enough to be estimated for some cases.

More recently, an UME was declared from November 2011 to March 2012 involving 126 stranded *T. truncatus*. Of the 126 common bottlenose dolphin strandings, 20 were recovered from the barrier islands of LM; 18 from the Gulf side of the islands and two from the bay side of the islands. Whether the animals recovered along the coastal beaches adjacent to LM were residents of the estuarine stock or a coastal stock are unknown (Figure 7). A preliminary analysis indicated some animals had discolored teeth or a mud-like substance in their stomachs but the cause of the event remains unknown and the investigation is ongoing [142].

Potential threats

Mining oil and natural gas, petroleum and petrochemical refineries, shipping, ranching, agriculture (beef cotton, grain, citrus fruit), commercial fisheries and tourism are all economically important to the LM area [94, 119, 128]. There are also ~248 mineral production sites in Nueces County, 34 in Kenedy, 84 in Kleberg, 115 in Willacy and ~20 in Cameron County, for a total of ~501 sites surrounding LM [94]. These anthropogenic activities pose a number of threats to the LM system and the biota that utilize this environment.

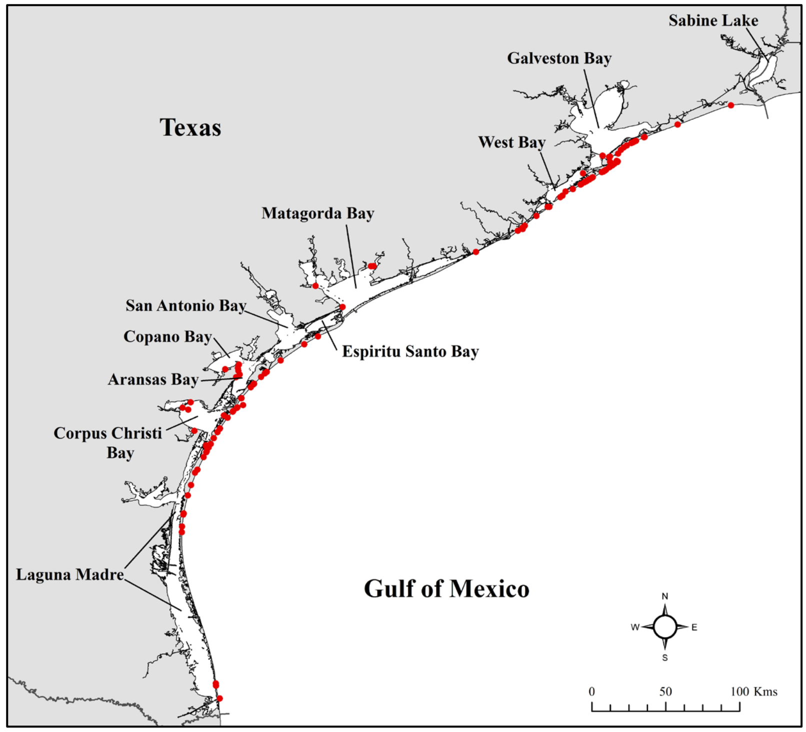

Figure 7. Locations of 126 out of the 126 of the stranded *Tursiops truncatus* during the 2011-2012 unusual mortality event. Some locations are approximate as latitude and longitude coordinates were not available and had to be estimated based on the location descriptions.

Oil & gas pollution

There are no records of major oil spills in LM in the recent past. However, given that ships and barges regularly use the GICW and the ports in LM, as well as the presence of pipelines and wells, smaller spills have occurred via leaks or minor collisions or accidents [143]. For example, in 2009 an oil slick formed around Port Isabel and tar balls washed up on beaches, with no known source of an oil spill [144].

Heavy metal & chemical pollution

LM receives agricultural and industrial run-off contaminated with pesticides from the Arroyo Colorado, which serves as a major drainage of the irrigated Lower Rio Grande Agricultural District [143, 145]. Chemicals, such as arsenic, were used until 1970 on cotton fields and lead was widely used in fuels and other agricultural chemicals until 1990 [146]. The continual run-off of pesticides into LM has created concern over the health of the bay and has prompted a number of studies into the levels of pollution in the sediments, water and biota of LM. New wastewater treatment plants have also been built on the Arroyo Colorado to accommodate the growing population of Brownsville [146].

Heavy metal & chemical pollution in water & sediment samples

In an assessment of estuarine health, the condition of both water and sediment quality in upper LM was determined to be good to poor [147]. Both water and sediment samples in LM have a history of chemical and heavy metal contamination. Sediment testing has revealed both PCB's and PAH's in the sediments of the turning basin of the Brownsville Ship channel, suspected to be from spilled petroleum products [65, 148]. From 1972 to 1978, cadmium, cobalt, lead, manganese and zinc were detected in sediment samples from Port Mansfield and in LM below the Arroyo Colorado, with sediment from the latter location also containing arsenic [65]. Testing of water samples in the 1970's found high levels of arsenic, cadmium, copper, chromium, lead, mercury, manganese, silver and zinc in the water at the Brownsville Ship Channel turning basin and high levels of copper, oil and grease in the water at the Brownsville fishing harbor [65]. High levels of iron, copper and zinc were found in water samples and zinc and arsenic in sediment samples collected from Port Isabel in the 1980's [65]. More recently, in an environmental monitoring study of sediment condition, the quality of 14.3% of the area of upper LM was rated as poor, with 21.5% and 26% of the sediments of upper and lower LM considered toxic, respectively [149]. In the same monitoring study, upper LM was found to have high levels of PCB's and DDT in the sediments; in fact, LM was amongst the highest of the Texas Bays [149]. In contrast, the levels of heavy metals in the sediments in upper and lower LM were low, at times amongst the lowest of the Texas Bays [149].

Heavy metal & chemical pollution in biota

In an assessment of estuarine health, the condition of fish tissue contaminants was determined to be good to poor in upper LM [147]. DDT (contributed by the Arroyo) has been suspected as a cause for a decline in *C. nebulosus* in lower LM [65, 150]. In the 1960's, concentrations of DDT in the gonads of *C. nebulosus* were very high and breeding was believed to have stopped for at least a couple years as a result [150]. More recently, in 2010, fishes (*S. ocellatus*, *P. cromis*, *C. nebulosus*) collected from LM had levels of mercury that were detectable and near the safety threshold [151]. Levels of PCB's were measured as a part of the same study and were found to be almost undetectable in fishes from upper LM (fishes from lower LM were not sampled) [151].

A study investigating the levels of heavy metals and chemical contaminants in the redhead duck, *A. americana,* in the Port Mansfield area of LM in 1988 found that heavy metals were within background concentrations in the liver and DDE was detected in other tissues, but it was below toxic levels [152]. The levels of PAH's in *A. americana* suggested that they were chronically exposed to petroleum products [152].

Two deformed reddish egrets chicks, *Egretta rufescens,* were found in lower LM in 1992, prompting a study into the concentrations of contaminants in nesting birds in the area [145]. Eggs from four bird species (Caspian tern, *Hydroprogne caspia,* great blue heron, *Ardea herodias,* snowy egret, *Egretta thula,* tricolored heron, *Egretta tricolor*) were collected in 1993 and 1994 from lower LM and tested for chemical contaminants and heavy metals [145]. DDE and PCB's were all found to be above detection limits in the eggs, with levels of DDE much higher than the other chemicals [145]. Mercury, selenium, boron, chromium, copper, iron, magnesium, manganese, strontium and zinc were all found in the majority of the eggs [145]. The levels of all heavy metals in the eggs, except mercury in the eggs of *H. caspia*, have decreased since the 1970's and 1980's [145]. The levels of mercury in the eggs of *H. caspia* were above the concentrations considered to be background levels and above concentrations associated with reproductive failure in some birds such as ring-necked pheasants, *Phasianus colchicus,* and mallards, *Anas platyrhynchos*; however, the concentrations of mercury were below the range at which common terns, *Sterna hirundo,* exhibit reduced reproductive success [145, 153]. The levels of DDE and PCB's during the 1993 and 1994 sampling were lower than in similar studies conducted in the 1970's and 1980's [145, 154] and lower than concentrations of DDE associated with eggshell thinning in other species of birds [145]. The concentrations of PCB's in the eggs of *H. caspia* and *A. herodias* were significantly higher than those for *E. thula*, *E. tricolor* or *E. rufescens*, but were still below levels associated with embryo deformities [145].

Marine debris

There are no data quantifying the problem of marine debris in the LM system. However, significant accumulations of plastic debris are found in LM, which has led the city of Laguna Vista, Texas to ban the use of plastic carry-out bags in retail establishments [155]. This decision was based on the information that plastic bags have led to injuries or death of marine animals in the ocean and, therefore, plastics in LM are a hazard for marine biota. In addition, marine debris is a part of an ongoing study on Padre Island National Seashore [96, 97].

Commercial & recreational fisheries & aquaculture

Commercial fisheries are economically important in both upper and lower LM. The commercial harvests of *C. nebulosus*, *S. ocellatus*, *P. cromis* and finfish in Baffin Bay and upper LM, in general, increased between 1962 and 1976 [128]. The commercial harvest of *C. sapidus* between 1968 and 1976, on the other hand, decreased overall, with a peak in catch in 1969 and decreasing harvests since 1970 [128]. The harvest of shrimp was somewhat variable from 1962 to 1976, partially due to incomplete catch data; harvest increased until the fisheries peaked in 1973 and then generally decreased [128]. The harvest of shellfish was highly variable from 1962 to 1976, with peak harvest years in 1968, 1969 and 1973 and lower harvests during intermittent years [128]. The commercial harvest of *P. cromis* in upper LM demonstrated an increase from 1981 to 1983 then decreased substantially in 1984 and was relatively constant until it increased in 1995; it then remained high until 2001 [156]. Commercial harvest of *A. probatocephalus* and *P. lethostigma* generally decreased from the early 1980's to 2001, although harvests did increase somewhat in the mid to late 1990's (from early 1990's harvest levels) [156]. The harvest of these finfish during this period was with perch trap, cast net, seine and trotline [156]. The commercial harvest of shrimp (via trawl) and *C. sapidus* (via trap, trawl, net, hook and line) were highly variable, although harvests in the late 1990's were typically lower than those in the late 1980's [156].

The commercial harvest of *C. nebulosus*, *S. ocellatus* and finfish in central and lower LM, in general, increased between 1962 and 1976 [128]. The harvest of *P. cromis* between the two extremities had similar harvests, but harvest decreased between 1963 and 1975 [128]. The harvest of *C. sapidus* and shellfish increased over this time period, although there were no data for *C. sapidus* prior to 1973 [128]. The commercial harvest of *P. cromis* in lower LM remained fairly constant from 1981 to 1989, when harvests increased until 1997, followed by a decrease in 1998, and then remained somewhat constant until 2001 [156]. The commercial harvest of *P. lethostigma* increased from the early 1980's to the late 1980's, then typically decreased until 2001 [156]. The commercial harvest of *A. probatocephalus* were highly variable [156]. The commercial harvest of mullet were also highly variable or incomplete (*e.g*. there are zeros), however harvests increased from 1992 to 2001 [156]. The commercial harvest of *C. sapidus* (via trap, trawl, net, hook and line) was variable, but overall harvests decreased between 1981 to 2001 [156]. The harvest of these finfish during this period was with perch trap, cast net, seine and trotline [156]. The harvest of bay oyster decreased substantially from 1962 to 1976, although there appeared to be some increase in harvests around 1974 to 1976 [128].

Recreational and sport fisheries are especially important to the LM area and are roughly 1.5 times larger than the bay's commercial finfish harvest [128]. Daily limits for spotted seatrout are lower in lower LM to counter declines due to overharvesting [128]. Shrimp farms once operated on the Arroyo Colorado, which in 1995 lost 80% of its 45 million shrimp due to a virus [157]. A 3 km^2 shrimp farm in LM, which has operated since 1982, was sold in 2012 to a new owner. Under new management, there are plans to expand into *S. ocellatus* fish farming [158].

Fishing gear poses a threat to *T. truncatus* as they can become entangled in or ingest fishing lines or nets. There are three records of *T. truncatus* strandings associated with fishing gear in LM between 1998-2011. In 1998, there is a record of a *T. truncatus* mortality with fishing line wrapped around the animal's tale; in 2006, a *T. truncatus* was found dead with a fishing hook in its jaw and the peduncle had a pattern that looked like it once had fishing line or net on it. In 2009, a young common bottlenose dolphin was found entangled in fishing gear and was released alive [159].

Shipping, dredging & construction

The LM area has relatively little urban development surrounding the estuary compared to some of the other Texas bays [118]. The only major urban and industrial region is the Brownsville-Harlingen metropolitan area with a population of approximately 415,000 according to 2012 census data, although the northern side also has some residential and marina development [119, 160]. Large ranches on the west and Padre Island National Seashore on the east have protected most of LM from development [118].

Shipping is economically important to the LM area, with three ports: Port Mansfield, Port Isabel and the Port of Brownsville. Port Mansfield and Port Isabel historically relied on the fishing and shrimping industries. The Port of Brownsville is a deep-draft port and serves as a primary connection for trade between the U.S. and Mexico. In 2005, this port handled over 4.5 million tons of cargo and in 2009 it handled 4.7 million tons [161, 162]. The major shipping channel in LM is the GICW, which runs through the entire LM system, forming the only permanent connection between upper and lower LM. The GICW needs to be dredged every two to five years to a depth of 4 m and 42 m wide [120]. The dredge spoil has been deposited in areas alongside the GICW, at times smothering seagrass beds and increasing turbidity of the water up to 1.2 km away [120]. This increase in turbidity from dredging to maintain channels has been linked with seagrass loss and a shift in species composition in the 1960's and 1970's [118].

Noise

There are no specific data on marine noise in LM, however given that there is boat traffic from fisheries and recreational use, shipping, port construction and dredging activities (see Shipping, dredging & construction), there is likely some level of marine noise in the LM system. However, the severity of marine noise is probably not as extreme as other bays with more shipping activity, such as Galveston Bay or Sabine Lake (see BSE: Galveston Bay area and BSE: Sabine Lake, respectively).

Tourism & boat traffic

Tourism is economically important to the LM area [163]. Impacts from recreational boaters, such as propeller scarring in seagrass beds has been significant in some areas of upper LM [164].

There is one record of a stranded *T. truncatus* in LM proper in 2002 with injuries indicative of a boat collision, although there are another three such records occurring on the gulf side of the barrier islands of LM in 2002, 2003 and 2004. Other tourist activities include bird watching and dolphin tours. There are a number of dolphin watching boat tours that operate out of South Padre Island [165-167].

Algal blooms

LM has a history of harmful algal blooms, some of which have impacted the health of the bay. LM experienced a persistent and possibly the longest continual algal bloom in history; the brown algae, *Aureoumbra lagunensis*, bloomed from 1989 to 1997 with varying degrees of severity [168-170]. Although the brown algae bloom was not toxic to adult fish or benthic invertebrates [169], the bloom decreased light at 1 m, thereby decreasing the health of seagrass beds, resulting in dieback of some beds [122, 169, 171]. The brown tide bloomed again throughout LM from February to August in 2005, in lower LM from January to February 2010, in upper LM in March 2012 and recently in Baffin Bay in May 2013 [170].

A toxic red algae, *K. brevis*, bloom occurred along the Texas coast from September 1997 to January 1998 and affected LM, closing shellfish beds in lower LM and resulted in approximately 295,000 dead fish in the Port Mansfield-Rio Grande area and ~4.2 million dead fish at the Padre Island National Seashore [57]. In October 1999, a *K. brevis* bloom along the southern tip of Texas killed roughly 400,000 fish along South Padre Island [57]. In July 2005, a *K. brevis* bloom along the Texas coast and in LM resulted in fish kills along the coast, including at South Padre Island and the closure of shellfish beds, including those in LM [168]. From October 2009 to February 2010, a *K. brevis* bloom in LM, Corpus Christi Bay and Aransas Bay resulted in fish kills, predominantly of *M. cephalus* and *A. felis* [168]. From September 2011 to January 2012, there was a large *K. brevis* bloom along the Texas coast and in many of the bays including LM that was responsible for the temporary closure of all Texas shellfish beds, including those in LM as well as fish kills in LM and two dead green sea turtles in LM [168].

The toxins from harmful algal blooms have been found in tissues from *T. truncatus* in the 2008 UME despite the absence of a bloom. The 2011-2012 UME that resulted in *T. truncatus* mortalities in this area also coincided with a large *K. brevis* bloom and could have played a role in this event (see Unusual Mortality Events).

Hypoxia

The levels of dissolved oxygen in LM were typically reported as good before 1995, although low levels of dissolved oxygen were occasionally reported seasonally in the summer and in the dead-end turning basin of the Brownsville Ship Channel [65]. Since this assessment, fish kill events have occurred due to low levels of dissolved oxygen in LM from 1995 to 1999 and 2000 to 2006 [61]. Recent water quality testing has found that levels of dissolved oxygen in LM are sometimes low, which is not surprising given the shallow, hypersaline nature of the LM bay system [172].

Adverse weather

LM is impacted by adverse weather such as hurricanes, tropical storms and occasional cold freezes. Since 1874, 14 named storms have hit within 97 km of Padre Island [173]. This area is affected by tropical systems on average every 3.78 years and it gets a direct hit once every 10 years [173]. Storm surge and rainfall from hurricanes and tropical storms dilute the salinity of LM, sometimes for years [65]. For example, after Hurricane Beulah in 1967, salinities in lower LM were reduced and did not return to their pre-hurricane levels until 1971 [65, 174].

In addition to tropical storms and hurricanes, cold fronts and 'freezes' are a threat to LM. Cold weather in 1983, 1989 and 1990 resulted in large fish kills in lower LM, as well as numerous fish kills from 1995 to 1999 and 2000 to 2006 [61, 65].

Freshwater inflows

There is little freshwater input into LM, although some drainage occurs from the North Floodway, Arroyo Colorado and Cayo Atascosa [65, 117, 119]. The total combined freshwater inflows are only ~0.83 km^3/year, creating a hypersaline bay system [65, 117, 119]. Occasionally, however, floodwaters from the Arroyo Colorado and North Floodway reduce salinities in LM [65]. For example, in 1958, these two channels carried floodwaters from the Rio Grande, severely reducing salinities to ~13 ppt for six months in lower LM [65]. Commercial fisheries are impacted by extremes in freshwater inflows in LM [128]. For example, the harvest of shellfish and bay oysters is correlated with freshwater inflows in lower LM, with higher harvests correlated with high levels of freshwater flows in summer and low levels of freshwater inflows during winter [128]. Therefore, in situations such as droughts in the summer, the harvests of commercial shellfish fisheries could be severely reduced if salinities in the bay become to high.

Habitat loss

While there are no data available quantifying the amount of habitat loss in LM due to canal construction, subsidence and wetland loss, habitat loss is likely in areas such as Brownsville where channels and ports have been built in place of natural wetlands.

Disease

Morbillivirus was the confirmed cause of the 1993-1994 UME in Texas, which included three common bottlenose dolphin strandings in LM proper, one on the bay side of Padre Island and 12 on the beaches along the Gulf side of Padre Island (Figure 5) [70, 71, 139]. Whether the stranded animals were from the estuarine stock or a coastal stock is unknown (see Unusual Mortality Events). Morbillivirus was retrospectively thought to possibly be the cause of the mortality event in 1990, which included one common bottlenose dolphin stranding in LM proper and 15 strandings on the beaches of Padre Island and South Padre Island, but a definitive cause for the 1990 event was not confirmed (Figure 4). In addition, *Brucella* was suspected to be the cause of the 2008 UME due to the high proportion of perinate strandings, but this could not be confirmed [79]. The 2008 UME involved one *T. truncatus* stranding on the bay side of the barrier island and 11 *T. truncatus* strandings on the Gulf side of the barrier islands of LM (Figure 6). Other diseases affect common bottlenose dolphin, however, here we highlight those that have been associated with high levels of mortality.

Climate change

Climate change is likely to have a significant impact on all Texas BSE's. Climate change is expected to substantially impact the LM area with rising sea levels, increased shoreline erosion and declines in water quality [175]. The national assessment of coastal vulnerability to sea level rise ranks the LM area as 'moderate' in the inshore areas to 'very high' risk for the Padre Island area. A rank of 'moderate' is a relative sea level change of 2.5 to 3.0 mm/year while a rank of 'very high' is a relative sea-level change of more than 3.4 mm/year [176].

Reductions in freshwater input via reduced rainfall and reduced freshwater inflows could increase the salinity of the already hypersaline LM, creating an unsuitable environment for the biota currently using the bay (*e.g.* fish, oysters, seagrasses, marshes). This could cascade up the food chain, impacting the suitability of the wetlands for the many species of fish and birds that use LM as nursery, feeding and wintering grounds. During the drought of the 1950's, hypersalinity led to seagrass die-off and massive fish kills in the Texas bays, especially in LM where salinity reached 80 ppt [177]. During the drought conditions of the 1990's there were significant declines in the harvests of shrimp and blue crab in LM due to heightened salinities [177]. Climate change could also potentially increase the frequency and duration of hurricanes [178] and potentially harmful algal blooms [179] along the Texas coast.

UME's of unknown etiology

The mortality event in 1990 and the official UME's in 2008, as previously described (see Unusual Mortality Events), were of unknown etiology and involved animals from LM. The investigation into the 2011–2012 UME is ongoing. The suspected cause of the 1990 event was retrospectively thought to be morbillivirus, however, this was not confirmed to be the definitive cause of the event so this event is considered here to be of unknown etiology. The 2008 UME was also of unknown etiology, although it was suspected *Brucella* could have played a role. The 1990 event involved one *T. truncatus* stranded in LM proper and 15 on the barrier islands of LM (Figure 4). The 2008 UME involved one *T. truncatus* stranding on the bay side of the barrier island and 11 *T. truncatus* strandings on the Gulf side of the barrier islands of LM (Figure 4). For the 2011 to 2012 UME, 20 *T. truncatus* were recovered from the barrier islands of LM; 18 from the Gulf side of the islands and two from the bay side of the islands (Figure 7).

Incidental research takes

Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in gillnets from fisheries research activities by Texas Parks and Wildlife [80]. Of these 31 incidents, five occurred in LM; two in 1988 and one in each of 1989, 1994 and 2012 (over 24 years) [80].

Threat assessment for *Tursiops truncatus* in Laguna Madre

Citations are included where supporting data are available. The maximum number of points per threat is 12 and the maximum total number of points possible is 228.

With a cumulative threat score of 136 and a lack of up-to date assessment data, the Laguna Madre stock ranks a high priority.

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Oil & gas pollution	1[143, 144]	2	3[13]	6
Heavy metal pollution	2[65]	3[151]	3	8
Chemical pollution	2[149]	3[65, 150, 152]	3[66, 95]	8
Marine debris	1[97, 155]	2	3	6
Recreational fisheries	2[128]	3[164]	4[4, 159]	9
Commercial fisheries	1[128, 156]	2	3[26, 102, 103]	6
Aquaculture	1[157, 158]	2	3[30]	6
Shipping	1[161, 162]	2	3[35]	6
Dredging & construction	2[120]	3[118, 120]	3[106]	8

continued

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Noise	1	2	3[38, 43]	6
Tourism & boat traffic	1[163, 165-167]	2	3[54]	6
Algal blooms	2[57, 168, 170, 180]	5[57, 122, 168, 169, 180, 181]	3[109]	10
Hypoxia	2[65, 172]	3[61]	3[60]	8
Adverse weather	2[173]	3[65, 174]	3[62]	8
Freshwater inflows	2[65]	3[128]	3[66]	8
Habitat loss	1	2	3	6
Disease	1[70, 71, 139]	0	5*[69-72]	6
Climate change	1[176]	2	3[76]	6
UME of unknown etiology	2[78, 142]	2	5*[78, 142]	9
Total				136

*mortality event was along the Texas coast and included animals from this BSE, but was not contained solely within this BSE

DAS scoring for *Tursiops truncatus* in Laguna Madre

	Score
Information on stock structure	0
Information on abundance	0
Information on mortality	0
Total	0

BSE: Corpus Christi Bay area

The Corpus Christi Bay area includes Corpus Christi Bay (CCB), Nueces Bay to the west and Oso Bay to the south (see Figure 8). Corpus Christi Bay is separated from the Gulf of Mexico by Mustang Island to the east. The Environmental Protection Agency has declared CCB to be an estuary of national significance [182]. The overall condition of the coastal bend bays (upper Laguna Madre to Aransas Bay) is poor, based on water quality (good to fair for CCB), sediment quality (good to poor for CCB), benthic index (fair to good for CCB) and fish tissue contaminants (fair to good for CCB) [147].

An ecosystem-based management plan is being developed to prioritize and direct resources to habitat preservation, creation and restoration in Nueces Bay and CCB. This plan provides information on the habitats, threats, ecosystem services of habitats and prioritization of projects in the CCB area [183]. As of 2011, workshops have been held with stakeholders to define the services of the different ecosystems within the CCB and prioritize area for protection and restoration [183]. Priority issues in CCB were hypoxia and bacteria within the broader category of water quality [183].

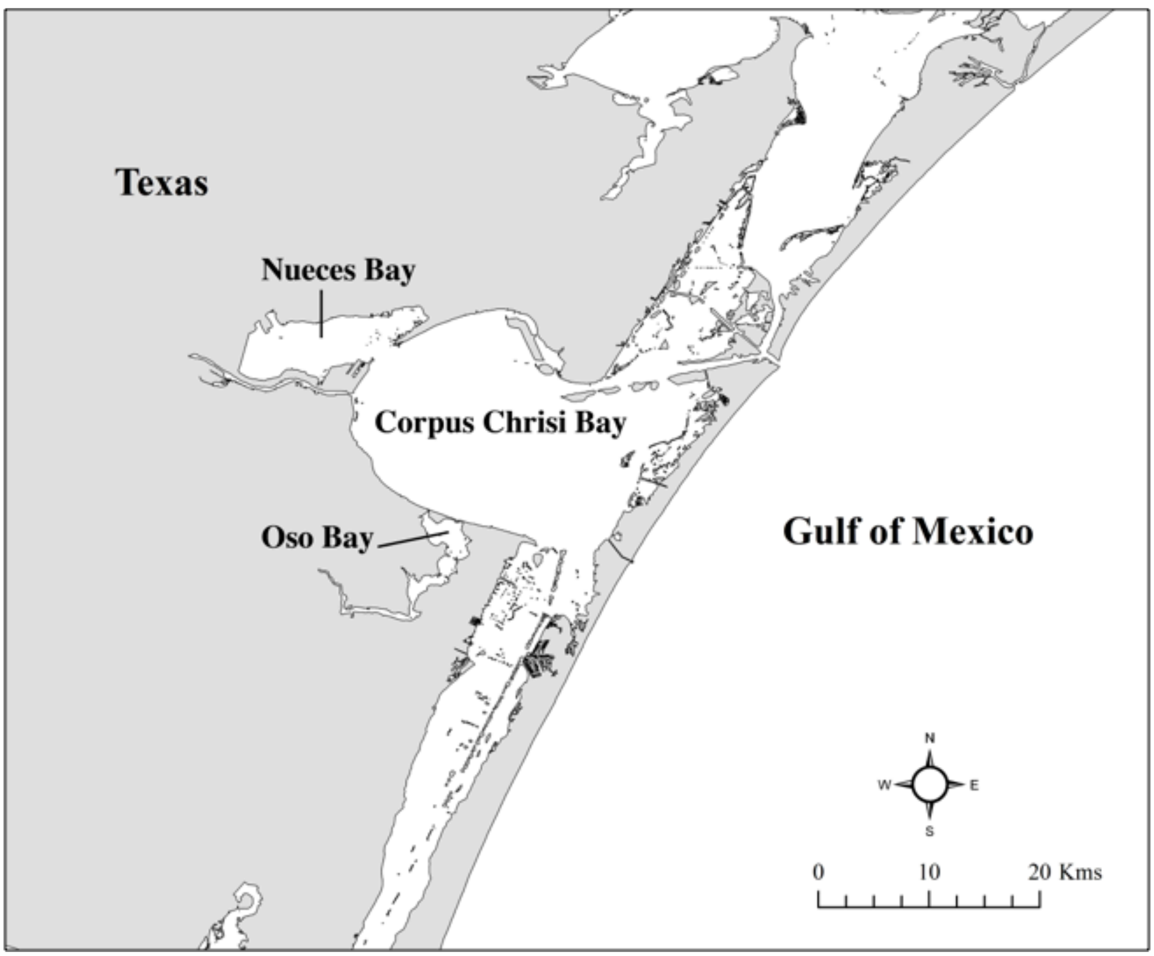

Figure 8. Corpus Christi Bay estuary, Texas

Physical attributes

CCB is a shallow bay with a surface area of ~497 km^2, an average depth of 2.5 to 3 m [105] and a maximum depth of ~12 m [94]. The connection of CCB to the Gulf of Mexico is more restricted than a 'typical' estuary due to the presence of barrier islands. CCB experiences diurnal tides between 0.2 and 0.8 m [94, 119]. CCB has an average salinity between 22 ppt [105] and 27 ppt [119]. The CCB area receives roughly 70-74 cm of precipitation each year [94, 119]. Armstrong [119] reports a loss of ~158 cm/year due to evaporation, resulting in a net loss of 84 cm/year. The long-term average air temperature is 22°C (71.7°F) with a range from 14°C (57.4°F) to 29°C (84.2°F; based on temperature data for 81 years), although a change in temperature of 11°C over a five-day period is not unusual [94]. The water temperature of CCB ranges from highs of ~30°C (86°F) in August to lows of ~15-20°C (59°F-68°F) in February [184].

Biota

Benthos

A change in the benthic community of CCB has occurred in the last 25 years, with a shift to predominantly early colonizers and opportunistic species, such as the polychaetes *Mediomastus ambiseta* and *Streblospio benedicti* and the bivalve *Mulinia lateralis* [92], most likely as a result of environmental disturbances (see Potential threats). These species are characteristic of highly disturbed environments and this change may be linked with contaminants and physical disturbances associated with altered circulation and sediment re-suspension [92].

Seagrass

Seagrass beds provide important nursery habitats for many estuarine species in the CCB area as well as providing levels of primary production estimated at ~2.52 g c/m^2/day [94]. It was recently estimated that there were almost 100 km^2 of seagrass beds in CCB in 2004 [185]. The dominant species of these seagrass beds are *H. wrightii* and *R. maritima*, the latter of which flourishes after high freshwater input. *Syringodium filiforme* is also found in CCB, although it is considered a minor species [113]. Overall, the seagrass beds in CCB have been relatively stable for the past 40 years, although there have been some localized changes in bed distribution associated with dredging. For example, between 1958 and 1995, dredging activities for shipping channels resulted in the localized loss of seagrass beds [113]. The abundance and distribution of seagrass (*H. wrightii* and *R. maritima*) in Nueces Bay, on the other hand, has changed dramatically since the 1960's. Essentially 100% of the seagrass beds were lost between 1961 and 1970, largely due to Hurricane Beulah in 1967 [113]. This event was followed by a 112% increase (compared to acreage in 1961) in seagrass beds between 1980 and 1989, and a further 47% increase from 1989 to 1994 [113]. The study by Tremblay *et al.* [185] found that seagrasses increased in total area between the 1950's and 2004 in the CCB area from ~24 km^2 to ~58 km^2, much of which occurred after 1979. The study by Tremblay *et al.* [185] includes Nueces Bay, which most likely accounts for the differences in the trends of this study and those of Pulich *et al.* [113].

Birds

A stretch of undeveloped shoreline on the bay side of Mustang Island is an important habitat for wading birds and shorebirds, including the plovers *C. melodus* and *C. alexandrinus* [91]. Birds such as *A. herodias*, *E. thula*, *E. tricolor*, green-winged teal, *Anas carolinensis*, northern shoveler, *Anas clypeata*, black-necked stilt, *Himantopus mexicanus*, *R. americana*, *T. semipalmata* and peeps, *Calidris* spp. have been observed using (feeding and resting) dredge disposal sites in Nueces Bay (see Heavy metal & chemical pollution) [93].

Fish & invertebrates

Over 234 species of fish have been documented in CCB and it is a seasonal nursery ground for many species of fish and shellfish. The most abundant species of fish and invertebrates and the seasons they are found in highest abundance in CCB are: *F. aztecus* (spring), *L. setiferus* (summer), *C. sapidus* (winter-spring), *C. similis*, *S. empusa*, roughback shrimp *Trachypenaeus similis*, *A. mitchilli* (late spring-fall), *C. arenarius* (spring-summer), *L. xanthurus* (spring), *M. undulatus* (winter-spring), *S. lanceolatus* (late spring-summer) and *S. plagiusa* (late spring-summer). Other species found in CCB are *L. brevis* (summer-fall), *D. texana*, grass shrimp *Palaemonetes* spp., *P. lethostigma*, *S. ocellatus*, *C. nebulosus*, *B. patronus* (spring), *A. felis* (summer), *A. probatocephalus*, *L. rhomboides*, *B. marinus*, *P. cromis*, *O. beta* and *M. cephalus* [119]. CCB is an important habitat to sport and commercially important species such as *C. nebulosus*, *S. ocellatus*, *P. cromis*, *C. sapidus* and shrimp [91, 94].

Common bottlenose dolphins

Data assessments

There are no published studies regarding the population genetic structure of *T. truncatus* assemblage(s) in CCB and there has not been an estimate of abundance of the dolphins in CCB in the last five years.

A 1987 report on the ecology of Texas bays provides an estimate of 300 dolphins in the CCB estuary, but the source of the information (provided as a personal communication from Oppenheimer) is unknown [119]. Leatherwood and Reeves conducted aerial surveys in 1979 and sighted 21 *T. truncatus* groups, comprised of between 1-20 individuals each, and estimated the population size in CCB to be 103.4 (95% confidence limits of 67.3, 139.5) [134]. However, the authors indicate that their results should be interpreted with a note of caution because of the potential bias of their aerial surveys for estimating population size (see BSE: Laguna Madre, Common bottlenose dolphin) and they also suggest that since the survey was conducted in September, abundances may have been well below their peak. The peak abundance of common bottlenose dolphins in CCB is believed to occur in January and abundance is lowest in October [186]. Interviews with local mariners and biologists in the CCB area conducted by Leatherwood and Reeves [134] suggest that *T. truncatus* were once present in substantial numbers and have become less common in recent decades. Leatherwood and Reeves [134] report that of the ~150 km^2 of habitat in CCB and Nueces Bay, ~101 km^2 represent ‘acceptable’ dolphin habitat. *Tursiops truncatus* in CCB have been observed beaching while feeding on mullet [187]. There are no studies regarding the population genetic structure of the *T. truncatus* in the CCB area.

Unusual Mortality Events

In 1990, a mortality event occurred from January through May along the entire northern Gulf of Mexico coast from Florida through Texas with 46% of the 344 carcasses being collected in Texas [78]. However, at this time, the Texas Marine Mammal Stranding Network (TMMSN) was more developed than some of the stranding networks in other Gulf states, which may have led to a higher proportion of stranding reports from Texas [78]. The winter of 1989-1990 was colder than normal throughout most of the Gulf [78] and the influence of the cold weather on the UME is unclear. During this event, seven *T. truncatus* stranded on Mustang Island near CCB, however, it is unknown whether these animals were from the estuarine or a coastal stock (Figure 4). Chemical contaminant levels (PCB's) were measured in 10 male *T. truncatus* that stranded in Matagorda Bay during the 1990 event [138] and in 26 *T. truncatus* collected during the event from coastal and estuarine waters from Laguna Madre to Galveston, including two male calves ('sucklings') from the CCB area [95]. While PCB levels were relatively low in the majority of the dolphins, PCB levels in a few animals were high enough to potentially negatively impact reproductive success in females [21, 138]. However, contaminant levels were not considered the cause of this mortality event [78]. Retrospectively it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this die-off was not confirmed [78].

An UME was declared for Texas from December 1993 through May 1994, with a total of 236 *T. truncatus* and four unidentified dolphin strandings in Texas [79]. During this event, two *T. truncatus* stranded in CCB proper and 10 *T. truncatus* were recovered on beaches along Mustang Island (Figure 5). It is unknown whether the stranded *T. truncatus* on the barrier island came from the coastal stock or the estuarine stock. The confirmed cause of this UME was morbillivirus [70, 71, 139].

In 2008, an UME was declared in Texas for February and March, during which 111 *T. truncatus* stranded [79]. This UME had a high proportion of perinate strandings, which suggests an infectious agent that can cause late term abortions or early neonatal loss, such as the bacterium *Brucella*, may have been involved in this event; transmission of this bacteria is often through placental tissues and maternal feeding, resulting in aborted fetuses [79, 140]. Overall along the Texas coast, a high proportion of the animals were found on the Gulf-side beaches. Of the 111 strandings, five were recovered the CCB area, on beaches along Mustang Island (Figure 6). Whether the animals recovered from this area were from the coastal or estuarine stock is unknown. An analysis of gastrointestinal contents from stranded animals, including those from Mustang Island, revealed the presence of HAB toxins domoic acid and okadaic acid (associated with a *Dinophysis* spp. and *Prorocentrum* spp. toxic algae bloom occurring at the time) [109]. Low levels of brevetoxin were also found despite an absence of an associated *K. brevis* bloom [109]. The levels of each HAB toxin were low relative to levels associated with acute mortality and the levels of okadaic acid were at levels of unknown effects; however the impact of multiple toxins (*e.g.,* okadaic acid, domoic acid and brevetoxin) on marine mammal health is unknown [109]. The toxicity of okadaic acid has, however, been shown to increase in the presence of a toxin (gymnodimine) produced by *K. brevis* [141]. However, no definitive cause for the 2008 event has been determined [116].

More recently, an UME was declared from November 2011 to March 2012 involving 126 stranded common bottlenose dolphins, at least five of which were recovered from CCB proper and seven from Mustang Island (Figure 7). A preliminary analysis indicated some animals had discolored teeth or a mud-like substance in their stomachs but the cause of the event remains unknown and the investigation is ongoing [142].

Potential threats

Anthropogenic activities have had a substantial impact on the physical environment and biota of the CCB area. The human population in the Corpus Christi metro area alone is just under 500,000. The land use around CCB is predominantly urban and industrial developments and agriculture [119]. There are 248 mineral production sites in Nueces County and 183 in San Patricio County, for a total of ~431 sites surrounding CCB [94]. Mining crude oil and natural gas, chemical refineries (petroleum, aluminum), agriculture, forestry and commercial fisheries are all economically important to the area [94]. These anthropogenic activities pose a number of threats to the CCB system and the biota that utilize this environment.

Oil & gas pollution

The oil and gas industry is economically important to the CCB area, but the industry can pose a threat to the environment and biota through leaks and spills during exploration, mining, storage and transport of oil and gas. In 1994, ~100,000 gallons of oil spilled from pipelines (Koch Industries) and created a 3 km oil slick in CCB and Nueces Bay [87]. In 2006, over 140,000 gallons of oil were spilled from a Valero oil refinery in the Corpus Christi Ship Channel [88]. Oil and gas activity resulted in fish kills in CCB between 1985 and 1989 from gasoline spills and from seismic activity during exploration between 1995 and 1999 [61].

Cheniere has plans to construct a natural gas liquefaction and import/export plant at an LNG terminal in CCB [188]. The environmental impact statement is expected to be released at the end of 2013, with a start date for construction in 2015 [189]. The facilities are expected to be able to accommodate up to 200 ships per year and LNG would be imported/exported via the La Quinta Channel, which was approved for additional dredging in 2012 [188].

Heavy metal & chemical pollution

Sources of anthropogenic pollution in CCB include domestic, industrial and agricultural wastes. There are a number of industrial effluent/wastewater discharge sites in CCB. In contaminant assessments in 1970 [94] and 1988 to 1989 [91], no pesticides, PCB's, PAH's or organic carbons were found in substantial concentrations in water samples. In the assessment by Barrera *et al.* [91], elements such as zinc, mercury, cadmium, lead, copper, arsenic and chromium were elevated in water samples. Oysters from Nueces Bay were found to have elevated levels of arsenic, cadmium, selenium, and in particularly high residues, copper and zinc [91]. In fact, oyster farms operated in Nueces bay until 1995, but were closed due to excessive levels of zinc in the water and tissues of oysters [190], presumably as a result of pollution from a zinc smelting facility in Nueces Bay at that time. In the study by Barrera *et al.* [91], zinc residues were also particularly high in blue crabs in CCB and Nueces bay, as was mercury residues in blue crabs from the Nueces River. In a study by Carr *et al.* [92], chemicals (*e.g.* PAH's, PCB's) and heavy metals were found to exceed threshold effect levels in sediments near storm-water outfalls and areas of disturbance (*e.g.*, ports/marinas). There are currently no consumption advisories or bans for shellfish or fish from the CCB area [191].

There are two superfund sites in the CCB area that are likely to impact the estuary. One superfund site is located in Ingleside, Texas, which is adjacent to CCB and Redfish Bay [192, 193]. The site once operated as an oil refinery, Falcon Refinery, and is currently inactive [192, 193]. Wetlands and residential areas surround the site and there was concern that surface water drainage and leaks and spills have contaminated these areas [192, 193]. In fact, metals, PAH's and pesticides were detected at levels that exceeded screening guidelines in sediment samples collected from areas surrounding the site [193]. In 2000, a chemical assessment found metals such as barium, manganese and mercury as well as PAH's were released into nearby wetlands and Redfish Bay [194]. The extent and nature of the potential contamination of the site is currently being assessed in order to determine the most appropriate remedial action and removal of hazardous wastes is ongoing [192]. A second superfund site, Brine Service Company, is located just west of the city of Corpus Christi; this site was once a waste disposal site for oil field wastes such as drilling fluid and refinery wastes from 1946 to the 1960's [195]. The site was discovered in 1997 and sampling revealed the metals barium, cadmium, chromium, lead, mercury and organic compounds [195]. Surface water drains from the site to nearby wetlands and CCB via Tule Lake [195]. The proposed cleanup plan for this site is expected to be completed in 2014 [195].

In a study by White and Chromartie [93], birds using dredge disposal sites in Nueces Bay were found to have elevated levels of selenium in their tissues (selenium has been known to impair reproduction in chickens). In marine mammals, selenium often binds with mercury, which may mitigate the toxic effects of mercury [196, 197].

Marine debris
Specific information regarding amounts of marine debris within CCB is lacking. However, given that: 1) the available data indicate that marine debris is a problem on the Gulf-side beaches around CCB; 2) the bay is surrounded by metropolitan and industrial areas; and 3) the bay area is used for commercial and recreational uses; marine debris could pose problems in CCB [96, 97]. Educational programs are in place in the CCB area to educate fishermen and boaters about the dangers of marine debris [96, 97].

Commercial & recreational fisheries & aquaculture
Commercial and recreational fisheries are economically important to the CCB area, with trend data available for some of the target species. Lacson and Lee [100] reported increases in catch per unit effort (CPUE) data for sub-adult *S. ocellatus* with gillnets between 1982-1993 in CCB despite previous declines in abundance due to overfishing for this species in the early 1980's, a severe freeze in 1983 and a red tide in 1986. However, there was no overall trend for this species with bag seines over the same period in CCB [100]. The CPUE data for *C. nebulosus* and *P. cromis* caught in gillnets in CCB increased from 1982-1993, although for the former species there were very low catches in 1984 [100]. There was no trend in CPUE for *C. nebulosus* using bag seines with almost no catch in 1984; the lack of catch in 1984 was attributed to a cold freeze in 1983 [100]. Overall, the harvest of *P. cromis* using perch trap, cast net, seine and trotline increased from 1981 to 2001, although it peaked in 1995-1997 [156]. The CPUE data showed no overall trend in catches for *M. undulatus* and sporadic catches of *P. lethostigma* with gillnets or bag seines, while *B. patronus* catches decreased substantially between 1982 and 1993 with gillnets and typically low catches with bag seine, with the exception of 1983 [100]. Overall harvest data for *P. lethostigma* with perch trap, cast net, seine and trotline from 1981 to 2001 also showed no overall trend, with sporadic catches [156]. CPUE data showed very high catches of *L. setiferus* using bag seines in CCB in 1979 followed by lower catches from 1980-1993, although there were some years with higher catches, such as 1984 and 1990 [100]. The CPUE

data for this species from 1982 to 1993 with trawls showed no trend and were typically poor outside of 1984-1985 and 1990-1991 [100]. Overall harvest data from 1981-2001 for *L. setiferus* from trawls demonstrated an overall decline in harvest from 1981 to 2001, although harvest was high in 1984, 1990 and 1992; the decline in harvest was substantial after 1994 [156]. The CPUE data was sporadic in catches for *C. sapidus* with gillnets from 1979 to 1993, with virtually no catches from 1979 to 1982 and a pattern of peaks and troughs between 1983 and 1993 with an overall slight decline in the overall harvest at the 'peaks' [100]. There was no trend in the CPUE data for this species using bag seines in CCB from 1978 to 1993 [100]. The overall harvest data for this species using traps, trawl and net from 1981-2001 suggests catches were sporadic, with years of both very high and low catches until 1993, when harvests declined rapidly [156]. Oyster farms operated in Nueces Bay until they were closed in 1995 [104].

Fishing gear poses a threat to *T. truncatus* as they can become entangled in or ingest fishing lines or nets. There are four records of *T. truncatus* strandings associated with fishing gear in CCB since 2000. There is a record of a *T. truncatus* mortality after becoming entangled in a crab pot in 2000 and another record in 2005 of a stranded *T. truncatus* with fishing line wrapped around its rostrum [159]. There is a record from 2004 of a *T. truncatus* stranding with rope marks and unusual circular mars on the upper and lower jaw and in 2010, a stranded *T. truncatus* was found with a strand of monofilament line tangled in the exposed muscle, however, this was thought to be picked up by the animal post-mortem [159].

Shipping, dredging & construction

Channel dredging in CCB started as early as 1857 and channels have since been made deeper and wider as boat traffic has increased [94]. The GICW is a coastal canal that runs nearly 1,700 km, from Brownsville, Texas to Fort Myers, Florida. The GICW is dredged by the Army Corps of Engineers to maintain a minimum depth of 4 m and is designed for transportation of crude petroleum and petroleum products, iron, steel, fertilizer and other bulk products. The Corpus Christi Channel connects CCB to the Gulf of Mexico through Mustang Island and is dredged as a straight channel ~13.7 m in depth. The La Quinta Channel is near Ingleside and connects to the Corpus Christi Channel and is ~13.7 m in depth. The dredging activities for shipping channels in CCB between 1958 and 1995 resulted in the localized loss of seagrass beds [113].

In 2012, additional dredging started to allow deep channel access to the port's multipurpose/container facility. Marinas have been built in the Corpus Christi area, Ingleside and along the GICW. The Port of Corpus Christi handled approximately 24.4 million tons of cargo in 2009 [162]. The Port of Corpus Christi is the 6^{th} largest port in the nation [198]. The port processes roughly ~80,000,000 tons of cargo per year and is the deepest in-shore port in the Gulf of Mexico [199, 200].

Noise

There are no specific data on the level of marine noise in CCB, however given that there is boat traffic from fisheries and recreational use, shipping, port construction and dredging activities (see Shipping, dredging & construction), there is likely some level of marine noise in the CCB area. Mass fish kill events occurred in CCB between 1995 and 1999 due to seismic activity [61].

Tourism & boat traffic

CCB is used for tourism activities such as recreational boating, bird watching, and windsurfing [98]. There are several dolphin watching tour boats operating in the CCB area and at least one advertises to occasionally allow passengers to touch dolphins from the boat with photos of people doing so on their website (departing from Ingleside) [107, 108]. There are four records of stranded *T. truncatus* in CCB with injuries indicative of a boat collision in 2002, 2004, 2006 and 2009, and there are another two such records occurring on the gulf side of the barrier islands of CCB in 1997 and 2010 [159].

Algal blooms

There are relatively recent records of toxic brown algae blooms *Dinophysis ovum* in CCB in 2008, 2010 and February-March 2012 [170]. The bloom in 2012 was responsible for the deaths of at least 4.4 million fish, including many commercially important species, such as *M. cephalus* and oysters [181].

A toxic red algae, *K. brevis*, bloom occurred along the Texas coast, including in CCB, from September 1997 to January 1998 and resulted in fish kills in CCB [57]. From December 2001 to April 2002, a *K. brevis* bloom was present in the Aransas ship Channel and resulted in the closure of shellfish beds in the area and fish kills on Padre Island near Corpus Christi [57]. In 2005, a *K. brevis* bloom along the Texas coast, including CCB, resulted in fish kills along the coast and in CCB and the delay of the opening of shellfish beds in CCB [168]. A *K. brevis* bloom occurred from September 2006 to November 2006 along the Texas coast, including CCB that also caused fish kills of primarily *B. patronus* [168]. From October 2009 to February 2010, a *K. brevis* bloom in LM, CCB and Aransas Bay resulted in fish kills, predominantly of *M. cephalus* and *A. felis* [168]. From September 2011 to January 2012, there was a large *K. brevis* bloom along the Texas coast and in many of the bays including CCB that was responsible for the temporary closure of all Texas shellfish beds [181].

The toxins from harmful algal blooms have been found in tissues from *T. truncatus* in the 2008 UME despite the absence of a bloom. The 2011-2012 UME, which resulted in *T. truncatus* mortalities in this area, also coincided with the large *K. brevis* bloom and could have played a role in this event (see Unusual Mortality Events).

Hypoxia

Hypoxia occurs in the southeast of CCB every summer and long-term data indicate that hypoxia is increasing over time as a result of increasing temperatures [111, 201, 202]. Mass fish kills (~2.1 million fish in total) have been associated with hypoxia in parts of CCB between 1980 and 1984 [61]. Montagna and Froeschke [202] found the long-term (*i.e.,* 14-19 years) effects of hypoxia were a lower abundance, biomass and diversity of benthic fauna and a higher abundance, but lower diversity of fish and mobile invertebrates in the area.

Adverse weather

CCB is affected by hurricanes, tropical storms and occasionally cold freezes. Since 1874, 11 named storms have hit within 97 km of Corpus Christi [112]. This area is affected by tropical systems on average every 4.12 years and it gets a direct hit once every 15.56 years [112]. In 1967, Hurricane Beulah wiped out nearly 100% of the seagrass beds from Nueces Bay, which did not recover until 1970 [113]. In 1983, there was a severe freeze in CCB that caused a fish kill that was so severe it caused a decline in commercial harvests of *S. ocellatus* [100].

Freshwater inflows

CCB has low levels of freshwater inflow from the Nueces River from the west and Oso Creek and Packery Channel from the south. The estimated combined inflow into CCB is generally ~0.84 km^3/year [119], however, periodic flood discharge from the Nueces River can cause substantially reduced salinities. For example, in 1963, the oyster fishery was virtually destroyed due to an excess of freshwater flow into CCB.

Habitat loss

Mustang Island has experienced a 57% loss of tidal flats (~40 km^2 reduced to ~17 km^2) between the 1950's and 2004 due to sea-level rise [114, 203]. Gibeaut *et al*. [203] used models to further predict potential changes in the shoreline of Mustang Island over the next 90 years, finding that overall there might be an increase in wetland area, but with a shift in the type of wetland habitat with a loss of low marsh (*e.g*. habitat inundated daily, important habitat for shrimp) and a gain in high marsh (*e.g*., habitats inundated at higher tides). Tremblay *et al*. [185] also found there was a loss of marsh and tidal flats through conversion to uplands in the CCB area, largely as a result of drought and relative sea-level rise.

Disease

Morbillivirus was the confirmed cause of the 1993-1994 UME in Texas, which included two *T. truncatus* mortalities from CCB proper and 10 from the beaches along Mustang Island (Figure 5) [70, 71, 139]. Morbillivirus was retrospectively thought to possibly be the cause of the mortality event in 1990, which included seven *T. truncatus* strandings from beaches on Mustang Island, but a definitive cause for the 1990 UME was not confirmed (Figure 4). In addition, *Brucella* was suspected to be the cause of the 2008 UME, which involved five *T. truncatus* strandings on Mustang Island in the CCB area, due to the high proportion of perinates, but this could not be confirmed (Figure 6) [79]. Other diseases affect common bottlenose dolphin, however, here we highlight those that have been associated with high levels of mortality.

Climate change

Climate change is likely to have a significant impact on all Texas BSE's. Climate change is expected to substantially impact this area with rising sea levels, increased shoreline erosion and declines in water quality [175]. For these bays in particular, concerns are primarily over changes in freshwater inflows from rivers, increases in the duration and frequency of droughts, increases in the frequency and intensity of hurricanes, increases in salinity in the bays and changes in ecosystem structure and function [75]. This is because the timing and amount of freshwater input, which is critical to the functioning of an estuary, will change as precipitation and land use change. In the past, severe droughts in southern Texas have resulted in hypersaline estuary environments, which in turn cause fish kills, loss of *C. sapidus* and shrimp and invasions of stenohaline species [204]. Water budget scenarios taking into account climate change, drought and population growth estimate reductions in freshwater flow into the Texas estuaries of up to 74% [75]. Such a reduction in freshwater flow into CCB would greatly alter the long-term salinity regime of CCB and result in a shift in species composition of the estuary to more marine species as the bay becomes less suitable as nursery habitat for estuarine species. CCB is particularly vulnerable to such environmental changes because of its shallow depths and broad surface area.

The national assessment of coastal vulnerability to sea level rise ranks the CCB area from 'moderate' to 'high' risk in the inshore areas to 'very high' risk for Mustang Island. A rank of 'moderate' is a relative sea level change of 2.5 to 3.0 mm/year, a rank of 'high' is a relative sea level change of 3.0 to 3.4 mm/year, while a rank of 'very high' is a relative sea-level change of more than 3.4 mm/year [176]. Climate change could also potentially increase the frequency and duration of hurricanes [178] and potentially harmful algal blooms [179] along the Texas coast.

UME's of unknown etiology

The large die-off in 1990 and the UME's in 2008 as previously described (see Unusual Mortality Events), were of unknown etiology and involved animals from CCB. The investigation into the 2011 through 2012 UME is ongoing. The suspected cause of the 1990 die-off was retrospectively thought to be the morbillivirus, however, this was not confirmed to be the definitive cause of the event, therefore, this UME is considered of unknown etiology. The 2008 UME was also of unknown etiology, although it was suspected *Brucella* could have played a role. The 1990 mortality event involved seven *T. truncatus* strandings on Mustang Island near CCB (Figure 4) and the 2008 UME involved five *T. truncatus* strandings on Mustang Island (Figure 6). For the 2011-2012 UME, five *T. truncatus* were recovered from CCB proper and seven from Mustang Island (Figure 7).

Incidental research takes

Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in gillnets from fisheries research activities by Texas Parks and Wildlife [80]. Of these 31 incidents, four occurred in CCB; two in 1996 and one in each of 1999 and 2012 (over 16 years) [80].

Threat assessment for *Tursiops truncatus* in Corpus Christi Bay

Citations are included where supporting data are available. The maximum number of points per threat is 12 and the maximum total number of points possible is 228.

With a cumulative threat score of 136 and a lack of up-to date assessment data, the Corpus Christi Bay stock ranks a high priority.

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Oil & gas pollution	2[87-89]	3[61, 90]	3[13]	8
Heavy metal pollution	2[91, 92]	3[91, 93]	3	8
Chemical pollution	2[91, 92, 94]	3[91]	3[66, 95]	8
Marine debris	2[96, 97]	2	3	7
Recreational fisheries	1[94, 98]	2	4[4, 35, 72, 99]	7
Commercial fisheries	1[94, 100, 101]	2	3[26, 102, 103]	6
Aquaculture	1[104]†	2	3[30]	6
Shipping	1[101, 105]	2	3[35]	6
Dredging & construction	2[94]	3[92, 93]	3[106]	8

continued

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Noise	2[94, 101]	3[61]	3[38, 43]	8
Tourism & boat traffic	1[107, 108]	2	4[54]	7
Algal blooms	2[109, 110]	3[110]	3[109]	8
Hypoxia	2[61, 101, 111]	3[61]	3[60]	8
Adverse weather	1[112]	2[113]	3[62]	6
Freshwater inflows	2[66, 94, 101]	2[94, 101]	3[66]	7
Habitat loss	2[101, 114]	2	3	7
Disease	1[70, 71, 139]	0	5*[69-72]	6
Climate change	1[74, 75, 114, 115]	2	3[76]	6
UME of unknown etiology	2[116]	2	5*[116]	9
Total				136

*mortality event was along the Texas coast that included animals from this BSE, but was not contained solely within this BSE
† oyster farms operated in Nueces Bay until 1995

DAS scoring for *Tursiops truncatus* in Corpus Christi Bay

	Score
Information on stock structure	0
Information on abundance	0
Information on mortality	0
Total	0

BSE: Aransas Bay to Espiritu Santo Bay

The BSE in the Aransas to Espiritu Santo Bay area includes Redfish Bay, Aransas Bay, Copano Bay, San Antonio Bay and Espiritu Santo Bay (Figure 9). Redfish, Aransas and Copano bays are discussed together below followed by the summaries for San Antonio Bay and Espiritu Santo Bay.

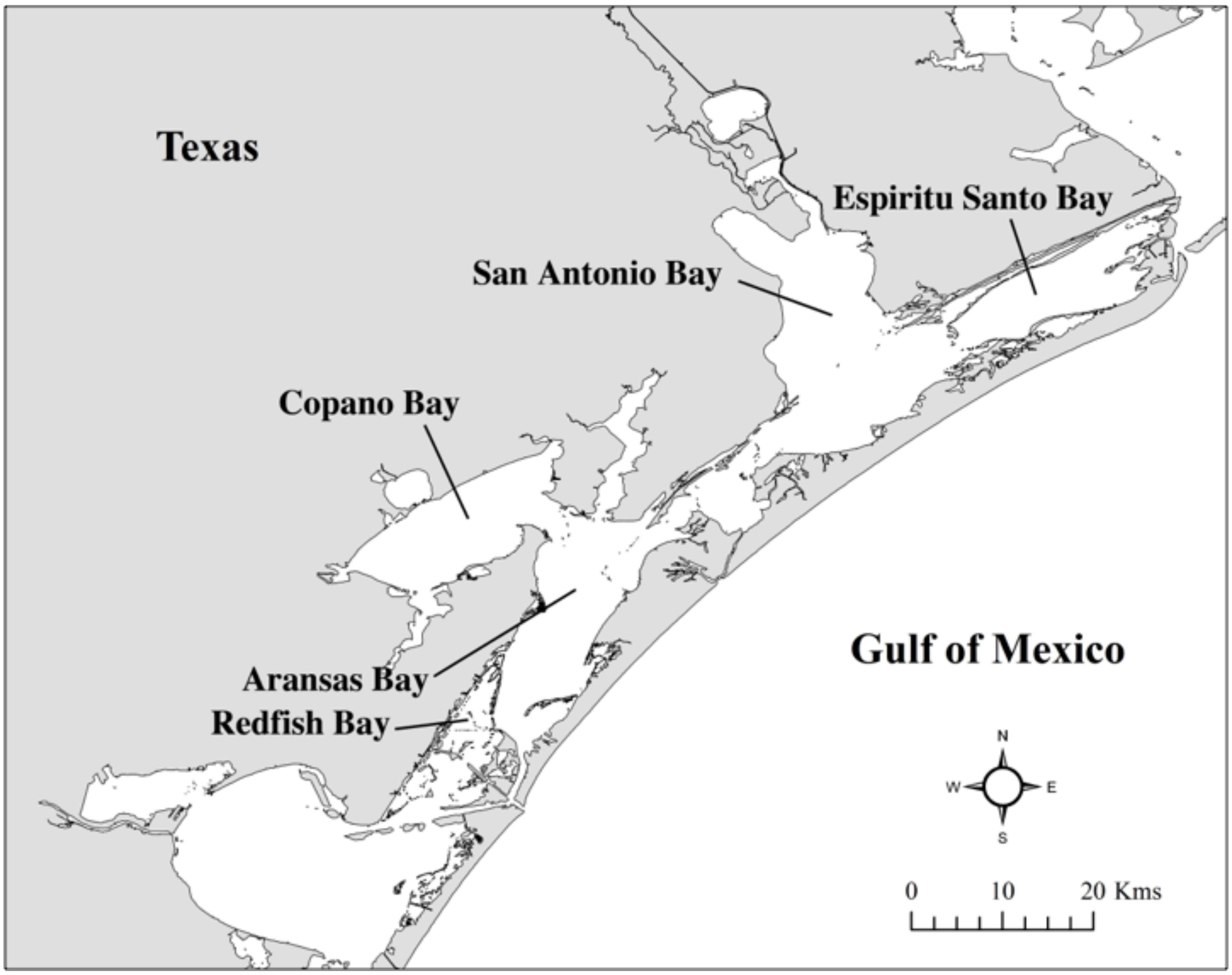

Figure 9. Aransas Bay to Espiritu Santo Bay sound and estuary (BSE) *Tursiops truncatus* stock (as assigned by the Stock Assessment Report, SAR). This BSE includes the Aransas, Redfish and Copano Bay area, San Antonio Bay and Espiritu Bay

Aransas and Copano Bay area

The Aransas and Copano Bay area includes Redfish Bay, Aransas Bay and Copano Bay (see Figure 9). The overall condition of the coastal bend bays (upper Laguna Madre to Aransas Bay) is poor, although most indices were good or good to fair for Copano and Aransas Bays, based on water quality (good to fair for Copano and Aransas Bays), sediment quality (mainly good for Copano and Aransas Bays), benthic index (good to fair for Copano and Aransas Bays) and fish tissue contaminants (mainly good for Copano and Aransas Bays) [147]. The environment and biota of Copano and Aransas is somewhat similar to that of nearby CCB.

Physical attributes

Copano Bay is a shallow bay with a surface area of ~170 km^2, an average depth of 1.1 m and a maximum depth of 2.7 m [94]. Aransas Bay is generally also shallow, with an average depth of 2.4 m and a maximum depth of 7.6 m [94]. The two bays have a combined surface area of ~460 km^2 [119]. The connection of Copano and Aransas Bays to the Gulf of Mexico is more restricted than a 'typical' estuary due to the presence of barrier islands (see Figure 9). The average tidal range of Copano Bay is 1.5 m and 0.12 m in Aransas Bay [94, 203]. The average salinity of the bays is ~13 ppt, however, the salinity of Copano and Aransas Bays fluctuates substantially [119]. It is estimated that the Copano and Aransas Bays get ~89 cm of precipitation/year, with an estimated evaporation of 151 cm/year, resulting in a net evaporation of 63 cm/year [119].

Biota

Seagrass

The seagrass beds are generally less extensive in Copano and Aransas Bays than those in nearby CCB (only 10% coverage compared to 27% in CCB). It is estimated that there are ~17 km^2 of seagrass beds in the two bays [94]. The dominant species of these seagrass beds are *H. wrightii, T. testudinum* and *R. maritima*, the latter of which flourishes after high freshwater input [94].

Birds

Copano and Aransas Bays are surrounded by marshes, which are important habitat for migratory birds such as the whooping crane, *Grus americana*, royal terns, *Thalasseus maximus*, gull-billed terns, *Gelochelidon nilotica*, *H. mexicanus*, *A. ajaja*, *E. rufescens*, white-faced ibis, *Plegadis chihi*, seaside sparrows, *Ammodramus maritimus*, *P. occidentalis*, mottled ducks, *Anas fulvigula*, black-bellied whistling-ducks, *Dendrocygna autumnalis* and herons, *Ardea* spp. [205].

Fish & invertebrates

The most abundant species of fish and invertebrates and the seasons they are found in highest abundance in Copano and Aransas Bays are *M. undulatus, A. mitchilli* (late spring-fall), *C. arenarius* (spring-summer), *L. xanthurus* (spring) and *A. felis*. Other species found in Copano Bay and Aransas Bay are *M. beryllina, F. aztecus* (spring), *L. setiferus* (summer), *C. sapidus* (winter-spring), *C. similis*, *L. brevis* (summer-fall), *S. empusa*, *T. similis*, *D. texana*, *Palaemonetes* spp, *P. lethostigma*, *S. ocellatus*, *C. nebulosus*, *B. patronus* (spring), *A. probatocephalus*, *B. marinus*, *P. cromis*, *S. lanceoatus* (late spring-summer), *S. plagiusa* (late spring-summer), *O. beta* and *M. cephalus* [119]. The estuary serves as a nursery area for many of these species, including shrimp.

Common bottlenose dolphins

Data assessments

There are no studies regarding the population genetic structure of *T. truncatus* in the Copano or Aransas Bays area.

In a survey around Port Aransas, Shane [206] found that the abundance of *T. truncatus* declined in the summer, increased from the fall to winter (roughly doubling) and declined again in the spring/summer. This was further supported by a study by McHugh [207], which found *T. truncatus* to be in greatest abundance around Aransas Pass in December (~142.5-162 individuals) and lowest in abundance in July/August (67.5-82 individuals). Shane [206] found that there appeared to be spring/summer residents, fall/winter residents and year round resident dolphins. *Tursiops truncatus* in the southern area of the study site (particularly Aransas Pass) were found to move against the tides, especially during ebb tides. This was attributed to feeding (*e.g.,* easier to catch fish, which typically move with tides) or resting [206]. Sightings of recognizable individuals were confined to specific areas rather than at random [206].

Four aerial surveys conducted in March 1978 covered estuarine waters from Port Aransas through Matagorda Bay [208]. Over these surveys, a total of 133 *T. truncatus* groups were sighted, with a mean group size of 6.95 animals for a total of ~916 animals [208]. Five sightings were made in Copano Bay with group sizes of 16 or 17 dolphins [208]. There were 36 sightings in Aransas Bay north of Aransas Pass with an average group size of four animals [208]. There was one sighting in Mesquite Bay with five animals [208].

Unusual Mortality Events

In 1990, a mortality event occurred from January through May along the entire northern Gulf of Mexico coast from Florida through Texas with 46% of the 344 carcasses being collected in Texas [78]. However, at this time, the Texas Marine Mammal Stranding Network (TMMSN) was more developed than some of the stranding networks in other Gulf states, which may have led to a higher proportion of stranding reports from Texas [78]. During this event, seven *T. truncatus* were recovered from Aransas Bay/Redfish Bay and five were recovered from San Jose and San Joseph Islands adjacent to Aransas and Copano Bays (Figure 4). It is unknown whether the stranded animals on the barrier islands came from the coastal or estuarine stock. The winter of 1989-1990 was colder than normal throughout most of the Gulf, but a definitive cause for this Gulf-wide mortality event was not identified [78]. Chemical contaminant levels (PCB's) were measured in 10 male *T. truncatus* that stranded in Matagorda Bay during the 1990 event [138] and in 26 *T. truncatus* collected during the event from coastal and estuarine waters from Laguna Madre to Galveston, including three females (two immature and one adult) from the Port Aransas area [95]. Contaminant levels were relatively low in the majority of the dolphins, although for some animals, they were high enough to have negatively impacted reproductive success in females [21, 138]. However, contaminant levels were not considered the cause of this mortality event [78]. Retrospectively it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this event was not confirmed [78].

In 1992, an UME was declared for central Texas, during which 119 *T. truncatus* strandings were recorded between January and May [79]. Of these 119 strandings, at least 36 *T. truncatus* were recovered in Aransas Bay/Redfish Bay, 15 in Copano Bay and three from the Gulf side of San Jose and San Joseph Islands (as well as one animal with no latitude and longitude data; Figure 10) [66]. Although the cause of the UME was not conclusive [116], at the time it was suggested that the mortalities might have been linked to higher concentrations of pesticides in the water combined with lower salinities (a result of high freshwater input due to record rainfall) in the bays [66]. Retrospectively, however, it was suspected that this event may have been related to the emergence of morbillivirus [79] in the Gulf of Mexico [70, 71, 139], although a definitive cause for this UME was not confirmed [79, 116].

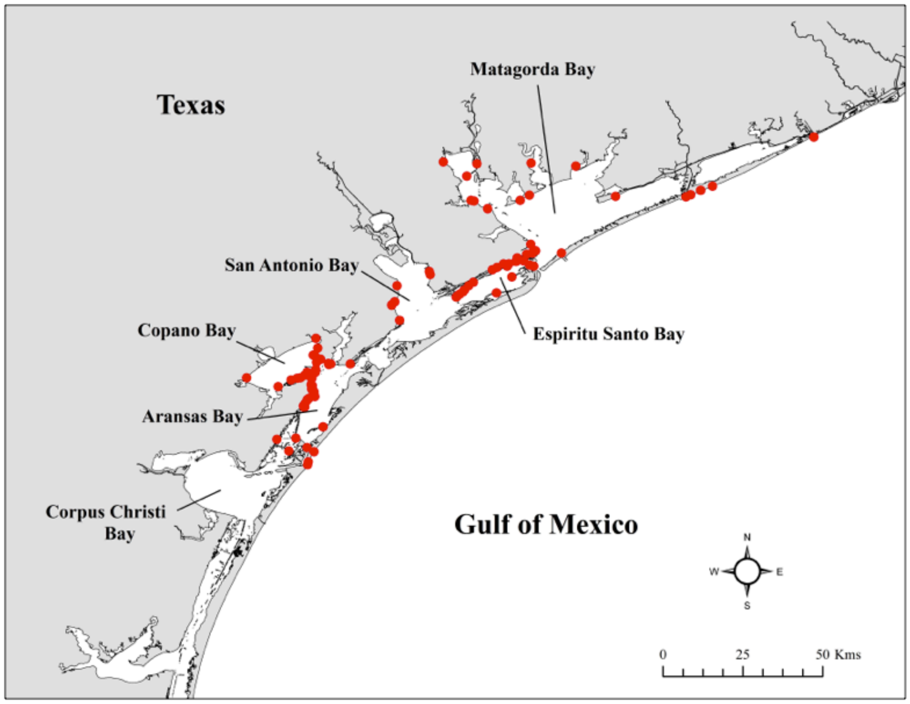

Figure 10. Locations of 110 out of 119 stranded *Tursiops truncatus* stranded in central Texas during the 1992 unusual mortality event. Some locations are approximate as latitude and longitude coordinates were not available and had to be estimated based on the location descriptions. Not all strandings are plotted as coordinates were not available for all strandings and location descriptions were not precise enough to be estimated for some cases.

An UME was declared for Texas from December 1993 through May 1994, with a total of 236 *T. truncatus* and four unidentified dolphin strandings in Texas [79]. During this event, five stranded *T. truncatus* were recovered from Copano and Aransas Bays proper, while seven were recovered on beaches along San Jose and San Joseph Islands (plus three in this area with no latitude and longitude data). Whether the stranded *T. truncatus* from the barrier islands were from a coastal or estuarine stock is unknown. The confirmed cause of this UME was morbillivirus [70, 71, 139].

In 2008, an UME was declared in Texas for February and March, during which 111 *T. truncatus* stranded [79]. This UME had a high proportion of perinate strandings, which suggests an infectious agent that can cause late term abortions or early neonatal loss, such as the bacterium *Brucella*, may have been involved in this event; transmission of this bacteria is often through placental tissues and maternal feeding, resulting in aborted fetuses [79, 140]. Overall along the Texas coast, a high proportion of the animals were found on the Gulf-side beaches. Of the 111 *T. truncatus* stranded, four were recovered in the Copano, Aransas and Redfish Bays area and two were recovered on beaches along San Jose and San Joseph Islands (Figure 6). It is unknown whether the stranded animals on the barrier islands were from a coastal stock or an estuarine stock. An analysis of gastrointestinal contents from stranded animals, including those from Padre Island, revealed the presence of HAB toxins domoic acid and okadaic acid (associated with a *Dinophysis* spp. and *Prorocentrum* spp. toxic algae bloom occurring at the time) [109]. Low levels of brevetoxin were also found despite an absence of an associated *K. brevis* bloom [109]. The levels of each HAB toxin were low relative to levels associated with acute mortality and the levels of okadaic acid were at levels of unknown effects; however the impact of multiple toxins (*e.g.,* okadaic acid, domoic acid and brevetoxin) on marine mammal health is unknown [109]. The toxicity of okadaic acid has, however, been shown to increase in the presence of a toxin (gymnodimine) produced by *K. brevis* [141]. However, no definitive cause for the 2008 event has been determined [116].

More recently, there was an UME declared from November 2011 to March 2012 involving 126 stranded common bottlenose dolphins, at least one of which was recovered from Copano Bay proper and two from the Gulf side of San Jose and San Joseph Islands (Figure 7). A preliminary analysis indicated some animals had discolored teeth or a mud-like substance in their stomachs but the cause of the event remains unknown and the investigation is ongoing [142].

Potential threats

The land use around Copano and Aransas Bays is predominantly urban and industrial developments and agriculture, similar to CCB. There are 64 mineral production sites in Aransas County and 142 in Refugio County, for a total of ~206 sites surrounding Copano and Aransas Bays. Mining natural gas, chemical (petroleum) refineries, agriculture, shipping, commercial fisheries and tourism are all economically important to the area [119]. These anthropogenic activities pose a number of threats to the biota that utilize this environment.

Oil & gas pollution

While there are no reported large oil spills in either Aransas or Copano Bay, there are a number of oil and gas pipelines and navigational channels, presenting the threat of leaks or spills [209].

Heavy metal & chemical pollution

A superfund site, the old Falcon Refinery, is located in Ingleside, Texas, which is adjacent to Redfish Bay [192, 193]. There was concern that the wetlands and residential areas surrounding the old Falcon Refinery (see Oil & gas pollution in BSE: Corpus Christi Bay area for details) had been contaminated [192, 193]. In fact, metals, PAH's and pesticides were detected at levels that exceeded screening guidelines in sediment samples collected from the areas surrounding the site [193]. In 2000, a chemical assessment found metals such as barium, manganese and mercury as well as PAH's were released into nearby wetlands and Redfish Bay [194]. The extent and nature of the potential contamination of the site is currently being assessed in order to determine the most appropriate remedial action and the removal of hazardous wastes ongoing [192].

Analysis of heavy metals and chemicals in Copano and Aransas Bays in the 1980's found DDE, DDT, arsenic, chromium, lead, mercury, nickel, above detection limits in tissues of fish and invertebrates, although they were all below the level of concern [209]. However, copper in one oyster sample from Copano Bay was at a level of concern for human consumption [209].

Marine debris

Specific information regarding amounts of marine debris within Copano and Aransas Bays is lacking. However, given that available data suggest marine debris is a problem on the Gulf-side beaches in the Corpus Christi National Estuary Program region, which includes Copano and Aransas Bays [96, 97], marine debris may be a threat in these bays as well.

Commercial & recreational fisheries & aquaculture

Commercial and recreational fisheries are economically important to the Copano and Aransas Bays, with trend data available for some of the target species. Lacson and Lee [100] reported increases in catch per unit effort (CPUE) for sub-adult *S. ocellatus* and *P. cromis* with gillnets between 1982-1993 in Aransas/Copano Bays, although there was no trend in CPUE for bag seines for *S. ocellatus* with virtually no catch except in 1981 and 1990. The CPUE data showed no overall trend (with gillnets or bag seine) in catches for *C. nebulosus* and *P. lethostigma,* but poor catches in the latter since 1990 [100]. The CPUE data showed *B. patronus* catches in gillnets peaked in 1984 and then decreased substantially until 1993 in Aransas/Copano Bays, while in bag seines catches peaked in 1978-1979 and then sharply declined from 1980-1989 then peaked again (although not quite as high as previously) in 1990, and again declined in 1991-1993 [100]. The CPUE data also showed no overall trend in catches for *M. undulates* with gillnets or bag seines [100]. The CPUE data showed very low catches of *L. setiferus* using bag seines in Aransas/Copano Bays from 1979 to 1993 with the exception of a peak in harvest in 1990 [100]. The CPUE data for this species from 1982 to 1993 with trawls were typically poor outside of 1984, which had a high harvest [100]. The CPUE data for *C. sapidus* with gillnets from 1979 to 1993 was variable, with virtually no catches from 1979 to 1982, followed by a large harvest in 1983 and a decline in harvest from 1983 to 1993 [100]. There was no trend in the CPUE data for this species using bag seines in CCB from 1978 to 1993, with peak harvests in 1982, 1985 and 1991 and small harvests in intermittent years [100]. There is currently no aquaculture in Copano or Aransas Bay.

Fishing gear poses a threat to dolphins as they can become entangled in or ingest it. In the Copano and Aransas Bays area, there are seven stranding records with evidence of fisheries interactions, *e.g.,* fishing gear, between 2000 and 2012 [159]. In 2000, a dolphin mortality was reported with monofilament line and fishing lures wrapped around its fluke [159]. In 2009, a common bottlenose dolphin was found alive with fishing gear attached; the gear was removed and the animal released [159]. In 2010, a stranded common bottlenose dolphin was found severely entangled in various forms of fishing line, hooks and lures with obvious impaired mobility [159]. The dolphin also had a fishing hook and line in its esophagus with an attached redfish that impaired the airway [159]. In 2010, a common bottlenose dolphin was found alive with significant damage to its dorsal fin, fluke and pectoral fins from fishing gear [159]. In Copano and Aransas Bays there are also two records (in 2010 and 2011) of dolphins becoming entangled in crab pots and stranding, one of which died [159]. In 2012, a common bottlenose dolphin was caught in a gillnet but was released alive after two minutes with a minor cut on the fluke [159].

Shipping, dredging & construction

The GICW is dredged by the Army Corps of Engineers to maintain a minimum depth of 4 m and is designed for transportation of crude petroleum and petroleum products, iron, steel, fertilizer and other bulk products. In addition to the GICW which travels through Aransas and Redfish Bays, Aransas Pass is the major shipping channel connecting the Port of Corpus Christi to the Gulf of Mexico and is dredged to a depth of up to ~14 m [206].

Noise
There are no specific data on marine noise in Copano or Aransas Bays, however given that there is boat traffic from fisheries, recreational use, shipping, construction and dredging activities, there is likely some level of marine noise in this area. However, the severity of marine noise is probably not as extreme as other bays with more industrial and shipping activity, such as Galveston Bay or Sabine Lake (see BSE: Galveston Bay area and BSE: Sabine Lake, respectively).

Tourism & boat traffic
Copano and Aransas Bays are used for tourism activities such as recreational boating, bird watching, and swimming [205]. There are a number of dolphin watching tours operating in Aransas Bay [210, 211]. There are six records of stranded *T. truncatus* in Aransas and Copano Bays in 2002, 2003, 2009 and 2010, each with injuries indicative of a boat collision [159].

Algal blooms
The toxic red algae, *K. brevis*, bloomed in Aransas and Copano Bays in August and September 1991 [57]. From December 2001 to April 2002, a *K. brevis* bloom was present in the Aransas ship channel that resulted in the closure of shellfish beds in the area and fish kills [57]. In 2005, a *K. brevis* bloom along the Texas coast, including Aransas Bay, resulted in the delay of the opening of shellfish beds in this bay [168]. A *K. brevis* bloom occurred from September 2006 to November 2006 along the Texas coast, including Aransas Bay that also caused fish kills of primarily *B. patronus* [168]. From October 2009 to February 2010, a *K. brevis* bloom in LM, CCB and Aransas Bay resulted in fish kills, predominantly of *M. cephalus* and *A. felis* [168]. From September 2011 to January 2012, there was a large *K. brevis* bloom along the Texas coast and in many of the bays including Copano and Aransas Bays that was responsible for the temporary closure of all Texas shellfish beds [181].

The toxins from harmful algal blooms have been found in tissues from *T. truncatus* in the 2008 UME despite the absence of a bloom. The 2011-2012 UME, which resulted in *T. truncatus* mortalities in this area, also coincided with the large *K. brevis* bloom and could have played a role in this event (see Unusual Mortality Events).

Hypoxia
There are no specific data reported on hypoxia for Copano or Aransas Bays.

Adverse weather
Copano and Aransas Bays are affected by hurricanes and tropical storms, however city-specific data are not available for Port Aransas or Rockport. Since 1874, 11 named storms have hit within 97 km of Corpus Christi. This area is affected by tropical systems on average every 4.12 years and it gets a direct hit once every 15.56 years [112].

Freshwater inflows
The amount of freshwater inflows into Copano and Aransas Bays is ~0.48 km^3/year, primarily from the Mission and Aransas Rivers [119]. There are periods of high evaporation with low levels of freshwater inflows resulting in higher salinities in the bays as well as pulses of freshwater inflow (~periods of low salinities) [119]. These scenarios often result in salinity

stratification in Copano Bay because of its shallow depth and limited connection/mixing with other water bodies [75, 212].

Habitat loss

Mustang Island has experienced a 57% loss of tidal flats (~40 km^2 reduced to ~17 km^2) between the 1950's and 2004 due to sea-level rise [114, 203]. Gibeaut *et al*. [203] used models to further predict potential changes in the shoreline of Mustang Island over the next 90 years, finding that overall there might be an increase in wetland area, but with a shift in the type of wetland habitat with a loss of low marsh (*e.g*. habitat inundated daily, important habitat for shrimp) and a gain in high marsh (*e.g.,* habitats inundated at higher tides).

Disease

Morbillivirus was the confirmed cause of the 1993-1994 UME in Texas, which included five bottlenose *T. truncatus* mortalities from Copano Bay proper and seven from the beaches along San Jose and San Joseph Islands (plus three with no latitude/longitude data) (Figure 5) [70, 71, 139]. Morbillivirus was retrospectively thought to possibly be the cause of the large die-off in 1990 and the UME in 1992, but a definitive cause for each of these events was not confirmed. The 1990 die-off included seven *T. truncatus* strandings from Copano and Aransas Bays and five from San Jose and San Joseph Islands and the 1992 UME involved 36 *T. truncatus* strandings in Aransas and Redfish Bay, 15 in Copano Bay and three from the Gulf side of San Jose and San Joseph Islands (as well as one animal with no latitude/longitude data) (Figure 10). In addition, *Brucella* was suspected to be the cause of the 2008 UME due to the high proportion of perinates, but this could not be confirmed [79]. The 2008 UME involved four *T. truncatus* strandings from Copano and Aransas Bays and two from San Jose and San Joseph Islands (Figure 6). Other diseases affect common bottlenose dolphin, however, here we highlight those that have been associated with high levels of mortality.

Climate change

The national assessment of coastal vulnerability to sea level rise ranks the Copano and Aransas Bays as 'moderate' in the inshore areas to 'very high' risk for Mustang Island. A rank of 'moderate' is a relative sea level change of 2.5 to 3.0 mm/year while a rank of 'very high' is a relative sea-level change of more than 3.4 mm/year [176]. A rise in sea levels would impact the barrier islands of the Texas coast, including those surrounding the Copano and Aransas Bays area [114]. Mustang Island has already experienced a 57% loss of tidal flats (~40 km^2 reduced to ~17 km^2) between the 1950's and 2004 due to sea-level rise [114, 203].

UME's of unknown etiology

The large die-off in 1990 and the UME's in 1992 and 2008, as previously described (see Unusual Mortality Events), were of unknown etiology and involved animals from Copano and Aransas Bays. The investigation into the 2011 – 2012 UME is ongoing. The 1990 event involved seven *T. truncatus* strandings from Copano and Aransas Bays and five from San Jose and San Joseph Islands adjacent to Aransas and Copano Bays (Figure 4). The 1992 UME involved 36 *T. truncatus* strandings in Aransas and Redfish Bay, 15 in Copano Bay and three from the Gulf side San Jose and San Joseph Islands (as well as one animal with no latitude/longitude data) (Figure 10). The 2008 UME involved four *T. truncatus* strandings from Copano and Aransas Bays and two from San Jose and San Joseph Islands (Figure 6). For the 2011-2012 UME, one *T. truncatus* was recovered from Copano Bay and two were found along the Gulf-side of San Jose and San Joseph Islands (Figure 7).

Incidental research takes

Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in gillnets from fisheries research activities by Texas Parks and Wildlife [80]. Of these 31 incidents, 12 occurred in Copano and Aransas Bays with two in 1990, two in 1995, one in each of 1996, 1997, 2003, 2004 and 2010, two in 2011 and one in 2012 (over 22 years) [80].

San Antonio Bay

The San Antonio Bay (SAB) system includes San Antonio Bay, Guadalupe Bay and Hynes Bay. SAB is on the Texas coast north of Copano/Aransas Bays and southwest of Matagorda Bay (Figures 9 and 11). SAB marks a climatic change; north of (and including) SAB is a warm temperate zone and a subtropical climate with warm humid summers and mild winters. South of SAB is classified a subtropical with humid hot summers and mild dry winters [119].

Physical attributes

SAB is a shallow bay with a surface area of 531 km^2 [105]. The average depth of SAB is ~1.5-2 m [105] and a maximum depth of 3.66 m [94]. The tides have minor influence on SAB, with an average tidal range of 0.1 m [94]. SAB has an average salinity of ~11 ppt [119] to ~13 ppt [105], although it can vary widely depending on inflows of freshwater [213-215]. As is the case with many other BSE's on the Texas coast of the Gulf of Mexico, the connection of SAB with the Gulf is more restricted than a 'typical' estuary due to the presence of a large (~60 km barrier island, Matagorda Island (see Figure 11). SAB is connected to the Gulf of Mexico via Pass Cavallo to the northeast (near Matagorda Bay), Aransas Bay to the southwest, and when open, Cedar Bayou (via Mesquite Bay) [216]. The width of Pass Cavallo has decreased since the opening of the Matagorda Ship Channel in 1966, but has remained stable since the 1990's [217]. Cedar Bayou is a natural inlet that was predominantly open from the 1800's until 1979, except during the 1950's drought [216]. In 1979, Cedar Bay was artificially closed to protect the Texas Coastal Bend Bay system from the Ixtoc I oil spill in Mexico. Cedar Bayou has remained closed since 1979, except during various dredging efforts to restore the pass between 1987 and 1995 (which were unsuccessful) and when temporarily opened by storms in 1980 and 2003 [216]. Thus, SAB currently has virtually no direct exchange with the Gulf of Mexico [105, 218], although some flow from the Gulf can occur with storm surges or very high tides [216]. The SAB area receives roughly ~97 cm of precipitation each year [119]. Armstrong [119] reports a loss of ~142 cm/year due to evaporation, resulting in a net loss of ~45 cm/year. The water temperature of SAB ranges from highs of ~30°C (86°F) in July to lows of ~13°C (55°F) in January [219].

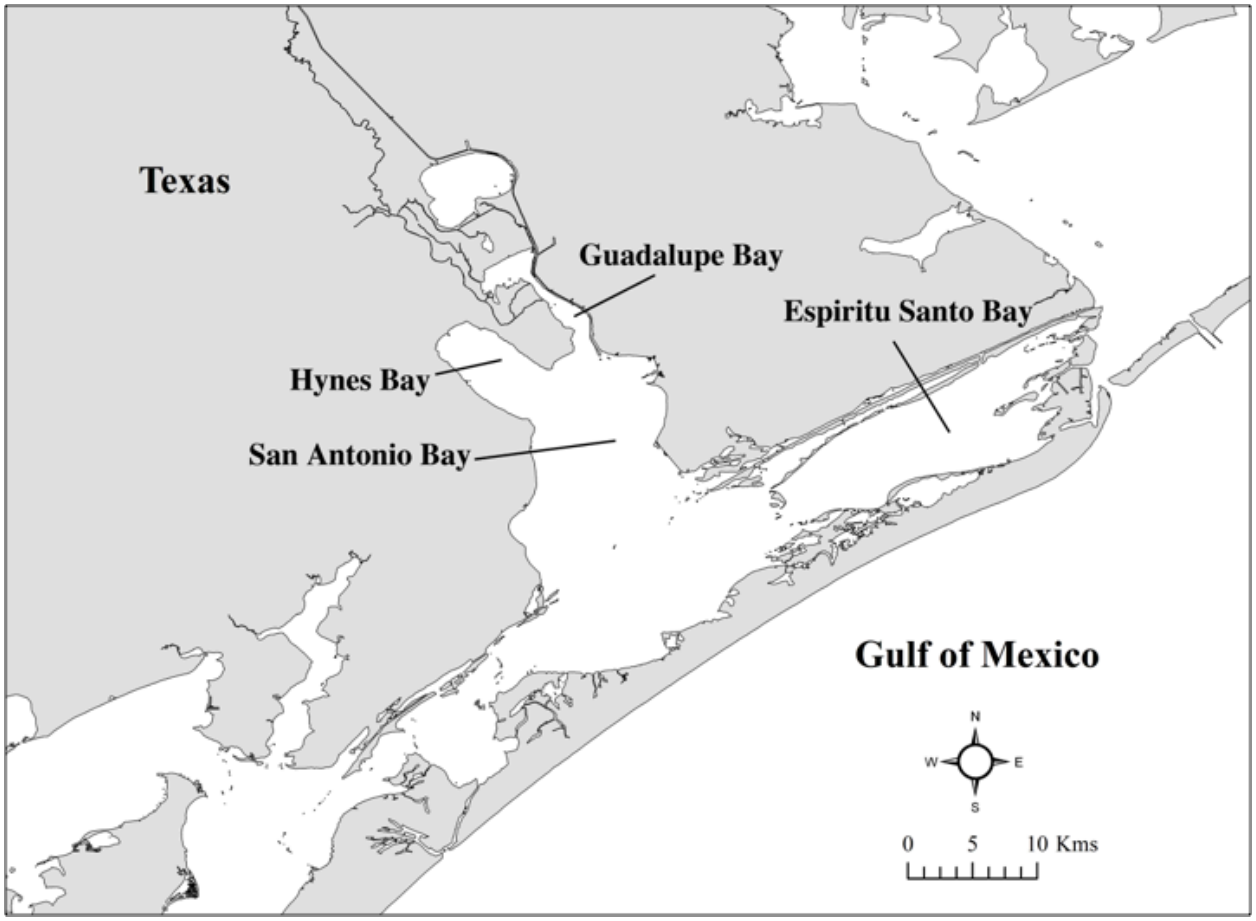

Figure 11. San Antonio Bay and Espiritu Santo Bay, Texas

Biota

Seagrass

Halodule wrightii and *R. maritima* are the predominant seagrass species found in SAB [94]. In the 1990's, there were roughly ~65 km^2 of seagrass habitat in the SAB and Espiritu Santo Bay systems (see summary below) [94, 105]. The seagrass beds are reported to be relatively stable or possibly decreasing in this area (~ 50 km^2 loss in the mid 1970's and a further loss in the early 1990's), but these observations are based on rudimentary mapping data and more detailed and recent data are required [220, 221]. SAB, Espiritu Santo Bay and Mesquite Bay are all areas for proposed seagrass monitoring to better understand patterns in seagrass bed distribution and changes over time [220, 221]. The seagrass monitoring program will attempt to establish the relationship between abiotic factors that influence seagrass condition, distribution and persistence [220, 221].

Birds

On the southwest shore of SAB lies the Aransas Wildlife Refuge (ANWR) [218], which is an undeveloped ~240 km^2 coastal refuge and wintering ground for more than 200 species of birds, as well as mammals and reptiles [222]. The ANWR is also the wintering grounds for the only naturally migrating and breeding population of the endangered *G. americana* [119, 213]. The number of *G. americana* in this population has increased substantially from 16 in 1941 to ~260

[223], which is in part due to the maintenance of the critical habitat along the Texas coast, notably the ANWR [209]. The reproductive success of this last natural population of whooping cranes is closely tied with the availability of food while they winter on the coastal wetlands of Texas, where 62-98% of their diet is comprised of blue crabs [213, 224]. Other rare or threatened bird species found in the ANWR and SAB area include the southern bald eagle, *Haliaeetus leucocephalus, P. occidentalis* and *C. melodus* [222].

Fish & invertebrates

When Cedar Bayou was open, it served as a migratory route for numerous species that utilize estuarine environments, and therefore, its status (open *vs.* closed) could affect the abundance of some euryhaline species, such as *C. sapidus*, *S. ocellatus* and *P. cromis* within the bays [216].

The most abundant species of fish found in SAB are *M. undulatus* (winter-spring)*, L. xanthurus* (spring)*, A. mitchilli*, *A. felis, L. rhomboides* and *C. arenarius* (spring-summer). Other species of fish and invertebrates that are found in SAB and the seasons which they are the most common are *M. beryllina, F. aztecus* (spring), *L. setiferus* (summer), *C. sapidus* (winter-spring), *C. similis*, *L. brevis* (spring-fall), *S. empusa*, *T. similis*, *D. texana*, *Palaemonetes* spp, *P. lethostigma*, *S. ocellatus*, *C. nebulosus*, *B. patronus* (spring), *A. felis* (summer), *A. probatocephalus*, *B. marinus*, *P. cromis*, *S. plagiusa* (spring-summer), *O. beta* and *M. cephalus* [119].

Like all other Texas bays, SAB is an important nursery habitat for a number of fish and invertebrates. For example, *S. ocellatus* use SAB as a nursery habitat for juveniles and after reaching maturity around three to five years, they migrate to Gulf waters where they spend their adult lives [131, 132]. *Mugil cephalus* depend on the estuarine environments such as SAB for development, but are euryhaline as adults, migrating to the Gulf of Mexico for spawning and returning to food-rich estuarine waters [133]. Shrimp and *C. sapidus* also use estuarine waters of SAB for development and growth while adults migrate to deeper waters in the Gulf of Mexico to spawn [216, 225].

Common bottlenose dolphins

Data assessments

There has been little research specifically on *T. truncatus* in the SAB area. There are no studies regarding the population genetic structure of the *T. truncatus* assemblage(s) in this area and there have been no abundance studies within this area in the last five years.

Four aerial surveys conducted in March 1978 covered estuarine waters from Port Aransas through Matagorda Bay [208]. Over these surveys, a total of 133 *T. truncatus* groups were sighted but no dolphins were sighted in SAB proper.

In a radio tracking study where 35 *T. truncatus* were initially captured in either Matagorda Bay or Espiritu Santo Bay in 1992 and 1993 (additional details of which can be found in the Matagorda Bay summary), two adult males and one adult female (out of 10 animals that were radio-tracked) travelled into SAB [226]. The female that travelled into SAB spent half of her time (~28 days) in SAB before travelling back to Matagorda Bay while the two males only spent one and six days, respectively, in SAB before travelling back to Matagorda Bay [226].

Unusual Mortality Events

In 1990, a mortality event occurred from January through May along the entire northern Gulf of Mexico coast from Florida through Texas with 46% of the 344 carcasses being collected in Texas [78]. However, at this time, the Texas Marine Mammal Stranding Network (TMMSN) was more developed than some of the stranding networks in other Gulf states, which may have led to a higher proportion of stranding reports from Texas [78]. During this event, one *T. truncatus* stranded in SAB and four stranded on Matagorda Island outside of SAB (Figure 4). Whether the strandings on Matagorda Island were from an estuarine stock or a coastal stock is unknown. The winter of 1989-1990 was colder than normal throughout most of the Gulf [78] and the influence of the cold weather on the UME is unclear. Chemical contaminant levels (PCB's) were measured in 10 male *T. truncatus* that stranded in Matagorda Bay during the 1990 event [138] and in 26 *T. truncatus* collected during the event from coastal and estuarine waters from Laguna Madre to Galveston [95]. While PCB levels were relatively low in the majority of the dolphins, PCB levels in a few animals were high enough to potentially negatively impact reproductive success in females [21, 138]. However, contaminant levels were not considered the cause of this mortality event [78]. Retrospectively it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this large die-off was not confirmed [78].

In 1992, an UME was declared for central Texas, during which 119 *T. truncatus* strandings were recorded between January and May [79]. Of the 119 *T. truncatus* stranded, nine were recovered in SAB proper (Figure 10) [66]. Although the cause of this UME was not conclusive [116], it was suggested at the time that the mortalities might have been linked to higher concentrations of pesticides in the water combined with lower salinities (a result of high freshwater input due to record rainfall) in the bays [66]. Retrospectively, it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this UME was not confirmed [79, 116].

An UME was declared for Texas from December 1993 through May 1994, with a total of 236 *T. truncatus* and four unidentified dolphin strandings in Texas [79]. During this event, four *T. truncatus* were recovered on beaches along Matagorda Island in the SAB area (Figure 5). Whether the recovered animals from Matagorda Island were from an estuarine or coastal stock is unknown. The confirmed cause of this UME was morbillivirus [70, 71, 139].

In 2008, an UME was declared in Texas for February and March, during which 111 *T. truncatus* stranded [79]. This UME had a high proportion of perinate strandings, which suggests an infectious agent that can cause late term abortions or early neonatal loss, such as the bacterium *Brucella*, may have been involved in this event; transmission of this bacteria is often through placental tissues and maternal feeding, resulting in aborted fetuses [79, 140]. Overall along the Texas coast, a high proportion of the animals were found on the Gulf-side beaches. Of the 111 *T. truncatus* strandings, two were recovered on beaches along Matagorda Island in the SAB area; it is unknown whether the recovered animals from Matagorda Island were from an estuarine or coastal stock (Figure 6). An analysis of gastrointestinal contents from stranded animals revealed the presence of HAB toxins domoic acid and okadaic acid (associated with a *Dinophysis* spp. and *Prorocentrum* spp. toxic algae bloom occurring at the time) [109]. Low levels of brevetoxin were also found despite an absence of an associated *K. brevis* bloom [109]. The levels of each HAB toxin were low relative to levels associated with acute mortality and the levels of okadaic acid were at levels of unknown effects; however the impact of multiple toxins (*e.g.,* okadaic acid, domoic acid and brevetoxin) on marine mammal health is unknown [109]. The toxicity of okadaic acid has, however, been shown to increase in the presence of a toxin (gymnodimine) produced by *Karenia* [141]. However, no definitive cause for the 2008 event has been determined [116].

More recently, there was an UME declared from November 2011 to March 2012 involving 126 stranded *T. truncatus*, at least one of which was recovered from Matagorda Island in the SAB/Espiritu Santo Bay area (Figure 7). A preliminary analysis indicated some animals had discolored teeth or a mud-like substance in their stomachs but the cause of the event remains unknown and the investigation is ongoing [142].

Potential threats

The land use around the bay is primarily agricultural (rice, grain, corn, cotton) and ranching [119]. In addition to agriculture, commercial fisheries, manufacturing (aluminum & chemical) and mining are economically important to the area; there are 142 mineral production sites in Refugio county and 93 in Calhoun [119].

Oil & gas pollution

In 2004, a towboat sunk in SAB, spilling at least 1,000 gallons of diesel fuel and forming an oil slick extending ~ 5 km into SAB [227]. There were no fish kills or injuries to wildlife reported with this event [227].

Heavy metal & chemical pollution

In a contaminant assessment in 1970 [94], the pesticide DDT was found in water samples and DDD, DDE, dieldrin and DDT were found in sediment samples from the Guadalupe River, which flows into SAB. In 1985, arsenic, chromium, mercury and zinc were found in the bottom sediments throughout SAB and each ranged in concentration within the bay [209]. In 1983, a barge travelling on the GICW exploded and spilled acrylonitrile into the SAB area [209].

A study was conducted to compare the average concentrations of heavy metals in the soft tissues of shellfish, crustaceans and fish from SAB to those from other locations as a part of an environmental assessment of the impact of dredging on the ANWR [228]. Biota from SAB did not have higher concentrations of heavy metals in their tissues when compared to species in other locations in the Gulf of Mexico, or elsewhere, despite more than 50 years of dredging [228]. This result was attributed to the relatively limited industrial activity around SAB, as well as low and uniform concentrations of heavy metals in sediments of SAB up to at least 2 m in depth [228]. In another study, DDT and DDE were found in *C. sapidus*, *A. felis* and oysters, but were below ‘recommended levels for protection of aquatic life’ [209]. One PAH compound was detected in an oyster sample in SAB (although the concentration was relatively low) near a barge canal where several petrochemical plants discharge industrial effluent and are a potential source of the PAH [209]. There are no superfund sites associated with SAB [229].

Marine debris

Specific information regarding the amount of marine debris in SAB bays is lacking. However, given that the available data suggest marine debris is a problem on the Gulf-side beaches in the Corpus Christi National Estuary Program region, which includes SAB [96, 97], marine debris may be a threat here as well. However, given the relatively undeveloped nature of SAB when compared to CCB, the problem of marine debris in SAB is probably not as severe.

Commercial & recreational fisheries & aquaculture

Guadalupe estuary is an important area for commercial fisheries including finfish and shellfish [94, 213]. The commercial harvests of *P. cromis* and *A. probatocephalus* in SAB from 1981 to 2001 overall have increased, although they initially decreased and were very low in the late 1980's to early 1990's [156]. The commercial harvest of mullet from 1981 to 2001 was highly variable with a peak in harvest in 1987 [156]. The commercial harvest of these finfish is with perch trap, cast net, seine and trotline [156]. The commercial harvest of shrimp (trawling) decreased slightly from 1981 to 2001 [156]. Since the early 1980's, there has been a declining trend in the commercial harvest of *C. sapidus* (via trap, trawl, net) in SAB [156]. Although the reason(s) for the decline are not clear, overfishing, water quality, habitat loss, low freshwater inflow, disease and anthropogenic activities have all been suggested as causal factors [216]. The oyster fisheries in SAB are economically very important to the area, but were temporarily closed from November 2009 until January 2010 after norovirus was detected in oysters from the bay [230]. There is currently no aquaculture in SAB.

Fishing gear poses a threat to *T. truncatus* as they can become entangled in or ingest fishing lines or nets. There are no reports of fisheries interactions involving *T. truncatus* in the stranding records for SAB [159].

Shipping, dredging & construction

Developments around SAB are minimal when compared to some other Texas bays [216]. For instance, there are no deep shipping channels running through the middle of the bay itself, as is the case for CCB or Galveston Bay. The GICW does, however, pass through the entrance to the bay and along the south end of the ANWR [231]. There are also no large ports or cities surrounding SAB and in 1987 the population around the estuary was only ~100,000 [119]. Although there are no large-scale shipping activities in SAB itself, there is a considerable amount of ship traffic via the GICW [231]. The GICW is dredged by the Army Corps of Engineers to maintain a minimum depth of 4 m and is designed for the transportation of crude petroleum and petroleum products, iron, steel, fertilizer and other bulk products. In fact, it has been estimated that the shoreline of the salt marshes along the ANWR (which lie within a few hundred meters of the GICW) has retreated at a rate of ~0.7-1.2 m/year between 1940-1986 largely from vessel-induced erosion [231]. There is a history of dredging activity in SAB for shell removal for the oyster industry since the early 1900's, reaching maximum volumes of 7-9 million m^3 of shell/year, which could potentially release pollutants such as DDD, DDE, dieldrin, DDT, arsenic, cadmium, chromium, mercury or zinc, all of which have been found in sediment samples in SAB, into the environment, and ultimately up the food chain [228].

Noise
There are no specific data on marine noise in SAB, however given that there is boat traffic from fisheries and recreational use, dredging and shipping just outside of SAB, there is likely to be some level of marine noise in SAB. However, the level of marine noise is probably not as high as other bays with more shipping activity and channels that run directly through the bay, such as Galveston Bay or Sabine Lake (see BSE: Galveston Bay area and BSE: Sabine Lake, respectively).

Tourism & boat traffic
SAB is used for tourism activities such as recreational boating, bird watching and tour boats, especially around the ANWR [213].

Algal blooms
From September 2011 to January 2012, there was an unprecedented large *K. brevis* bloom along the Texas coast. The red tide was responsible for the temporary closure of all Texas shellfish beds, including those in SAB as well as fish kills [180]. Previously, red tides along the coast of Texas that affected SAB and resulted in the closure of shellfish beds and fish kills also occurred in 2000 and 1996 [57]. In fact, the 1996 red tide that included SAB was associated with a large fish kill on Matagorda Island and oysters from nearby Espiritu Santo Bay had the highest levels of brevetoxin recorded in Texas at the time [57].

The toxins from harmful algal blooms have been found in tissues from *T. truncatus* in the 2008 UME despite the absence of a bloom. The 2011-2012 UME that resulted in *T. truncatus* mortalities in this area (on the barrier island) also coincided with the large *K. brevis* bloom and could have played a role in this event (see Unusual Mortality Events).

Hypoxia
No fish kills were reported in SAB related to hypoxia between 1970 and 1980 [61]. Since 1980, occasional fish kills have been associated with low dissolved oxygen in SAB [61], although little research has been done on hypoxia specifically on SAB. For example, between 1980 and 1984, ~3,000 fish were killed as a result of low dissolved oxygen in SAB. Similarly, the approximate numbers of fish killed due to low dissolved oxygen from 1985 to 1989 was 14,000, from 1990 to 1994 was 16,000, from 1995 to 1999 was 14 million and from 2000 to 2006 was 141,000 [61].

Adverse weather
There are no specific hurricane data available for SAB. However, data are available for Port O'Connor which is ~30 km northeast of SAB. Since 1874, 14 named storms have hit within 60 miles of Port O'Connor. This area is affected by tropical systems on average every 3.36 years and it gets a direct hit once every 12.82 years [232]. Freshwater inflow increased into SAB during Hurricane Beulah in 1967, greatly reducing salinities [233]. In 1989, there were cold freezes that resulted in large fish kills in SAB, primarily of *A. probatocephalus* [234].

Freshwater inflows
SAB receives freshwater inflows from the San Antonio River, the Guadalupe River and the Green Lake/Victoria ship channel at the head of the estuary [218]. The estimated combined inflows into SAB are generally ~2.8 km^3/year [119]. From 1942-2009, inflows increased by

~80%, with increasing high-flow surges separated by intense drought periods every 4-5 years [216].

Habitat loss

There are little data on habitat loss in SAB. There has likely been minimal habitat loss as there are no channels through SAB proper and no major metropolitan areas surrounding SAB. However, the shoreline of the salt marshes along the ANWR retreated at a rate of ~0.7-1.2 mm/year between 1940-1986, largely due to vessel-induced erosion from vessels traveling along the GICW [231].

Disease

Morbillivirus was the confirmed cause of the 1993-1994 UME in Texas, which included four *T. truncatus* mortalities on the beaches along Matagorda Island (plus three with no latitude/longitude data) (Figure 5) [70, 71, 139]. Whether the mortalities came from the coastal or the estuarine stock is unknown, although dolphins were stranded during this event in other nearby environments (*e.g*. Copano Bay), which are considered the same BSE stock. Morbillivirus was retrospectively thought to possibly be the cause of the mortality event in 1990 and the UME in 1992, but definitive causes for either of these events were not confirmed. The 1990 die-off included one *T. truncatus* stranding from SAB proper and four from Matagorda Island outside of SAB (Figure 4) and the 1992 UME involved nine *T. truncatus* strandings in SAB proper (Figure 10). In addition, *Brucella* was suspected to be the cause of the 2008 UME due to the high proportion of perinates, but this could not be confirmed [79]. The 2008 UME involved two *T. truncatus* strandings on Matagorda Island in the SAB area (Figure 6). Other diseases affect common bottlenose dolphin, however, here we highlight those that have been associated with high levels of mortality.

Climate change

Climate change is likely to have a significant impact on all Texas estuaries. Climate change is expected to substantially impact this area with rising sea levels, increased shoreline erosion and declines in water quality [175]. The national assessment of coastal vulnerability to sea level rise ranks the SAB area as 'high' in the inshore areas to 'very high' risk for the Matagorda Island area. A rank of 'high' is a relative sea level change of 3.0 to 3.4 mm/year while a rank of 'very high' is a relative sea-level change of more than 3.4 mm/year [176]. When sea level rise is combined with land loss from erosion and subsidence, the relative sea level rise will be even more substantial, with areas along barrier islands and deltas potentially experiencing higher relative sea level change due to increased subsidence [74, 75]. Climate change is likely to change the amount of freshwater inflows (*e.g*. decrease) from the Guadalupe and San Antonio Rivers into SAB, which in turn, would impact the salinity regime and composition of the habitat types in the SAB system [223]. Among other changes, the bay is likely to deepen, with more open water habitat and higher salinities with less salt marsh around the ANWR [223]. These changes are likely to affect the biota present in the bay as some species utilizing SAB as nursery areas have specific salinity preferences [235].

UME's of unknown etiology

The large die-off in 1990 and UME's in 1992 and 2008, as previously described (see Unusual Mortality Events), were of unknown etiology and involved animals from SAB. The investigation into the 2011 – 2012 UME is ongoing. The suspected cause of the die-off in 1990 and the UME in 1992 were retrospectively thought to be morbillivirus, however, this was not confirmed to be the definitive cause of these events, so these UME's are considered of unknown etiology. The 2008 UME was also of unknown etiology, although it was suspected *Brucella* could have played a role. In particular, the 1990 UME involved one *T. truncatus* stranding from SAB proper and four from Matagorda Island outside of SAB (Figure 4). The 1992 UME involved nine *T. truncatus* strandings in SAB proper (Figure 10) while all (n = 2) of the animals from the 2008 UME were recovered from Matagorda Island (Figure 6). For the 2011-2012 UME, one *T. truncatus* was recovered from Matagorda Island in the SAB/Espiritu Santo Bay area (Figure 7).

Incidental research takes

Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in gillnets from fisheries research activities by Texas Parks and Wildlife [80]. Of these 31 incidents, three occurred in SAB with one in each of 1993, 1997 and 2012 (over 19 years) [80].

<u>Espiritu Santo Bay</u>

Espiritu Santo Bay (ESB; Figure 11) is biologically similar to SAB and is often grouped together with SAB in the literature.

Physical attributes

ESB lies to the northeast of San Antonio Bay and to the southwest of Matagorda Bay on the Texas coast (Figure 11). The bay is ~25 km long and ~8 km wide. The average depth of ESB is ~1.5-2 m, with a maximum depth of ~4 m [94]. The tides have minor influence on ESB, with an average tidal range of 0.1 m [94]. The connection of ESB with the Gulf of Mexico is restricted due to the presence of a large barrier island, Matagorda Island. The connections from ESB to the Gulf of Mexico are the same as those for SAB: Pass Cavallo to the east (near Matagorda Bay), Aransas Bay to the west and when open, Cedar Bayou [216]. ESB has an average salinity of ~22 ppt [235]. In the study by Longley [235], ESB was found to be a more 'stable' estuary environment than SAB in terms of salinity and nutrients.

Biota

Seagrass

Halodule beaudetti and *R. maritima* are the dominant types of seagrass in ESB [235]. The seagrass beds in the SAB and ESB area are reported to be relatively stable or possibly decreasing in this area (~50 km^2 in the mid 1970's and a further loss in the early 1990's), but these observations are based on rudimentary mapping data and more detailed and recent data are required [220, 221]. SAB, ESB and Mesquite Bay are all areas for proposed seagrass monitoring to better understand patterns in seagrass bed distribution and change over time [220, 221]. The seagrass monitoring program will attempt to establish the relationship between abiotic factors that influence seagrass condition, distribution and persistence [220, 221].

Birds

The birds found in ESB are the same as those found in SAB; threatened birds utilizing this area include *G. americana,* which winters on Matagorda Island, *H. leucocephalus, P. occidentalis* and *C. melodus* [119, 213].

Fish & invertebrates

The composition of fish and invertebrates in ESB is largely similar to that of SAB. The most abundant species of fish and invertebrates found in ESB are *A. mitchilli, C. sapidus*, *L. brevis*, *A. probatocephalus, L. rhomboids, L. setiferus, P. aztecus, Palaemonetes* spp, *C. nebulosus, B. marinus*, *A. felis*, *B. patronus*, ladyfish, *Elops* spp., longnose killifish, *Fundulus similis, L. xanthurus, M. beryllina, P. lethostigma, M. cephalus, M. undulatus, P. cromis* and *S. ocellatus*. ESB is likely to be an important nursery for many of these species as juveniles have been caught in high abundances for many of these species including shrimp, *A. probatocephalus, C. sapidus*, *B. patronus* and *S. ocellatus* [235].

Other species

Adult and sub-adult bull sharks, *Carcharhinus leucas,* have been caught in ESB [235]. Although rare in Texas, on August 13, 2005, a West Indian manatee, *Trichechus manatus* was sighted in the southwest end of ESB [236].

Common bottlenose dolphins

Data assessments

There are no specific studies involving sampled *T. truncatus* from ESB. However, there are studies involving dolphins from Matagorda Bay (MB) and the study by Lynn [237] (see below) demonstrates that there is movement of *T. truncatus* between ESB and MB. Details for studies involving *T. truncatus* from MB are found in the MB BSE.

Range size and site fidelity of *T. truncatus* was assessed in MB via radio tracking and photographic surveys from 1992-1993 [226, 237]. Radio tracking data were collected for 10 individuals from the 9th of July to the 13th of September 1992 and photographic surveys of 35 freeze-branded animals were conducted from May 1992 to June 1993 in the MB, ESB and SAB areas [237]. Of the 10 individuals that were radio-tracked, seven remained within the vicinity of the original capture site near Port O'Connor. The other three individuals spent at least half the time around Port O'Connor, but also travelled to western ESB and SAB, and one spent half the time in SAB [238]. *Tursiops truncatus* were also observed moving between MB and ESB via the GICW, Big Bayou and Saluria Bayou [238].

Population size estimates from mark/recapture information obtained from photographic surveys suggest 218 (± 71.4 95% CI) *T. truncatus* use an area of 312 km^2 in MB and ESB [237].

Four aerial surveys conducted in March 1978 covered estuarine waters from Port Aransas through MB [208]. Over these surveys, a total of 133 *T. truncatus* groups were sighted, with a mean group size of 6.95 animals for a total of ~916 animals [208]. Twenty-eight of the sightings were made in SAB/ESB waters [208]. The abundance estimate generated for the entire survey area was 1,319 animals (S.E. = 130), but the authors believed this to be a relatively conservative estimate and they note several potential biases in the data [208].

Unusual Mortality Events

In 1990, a mortality event occurred from January through May along the entire northern Gulf of Mexico coast from Florida through Texas with 46% of the 344 carcasses being collected in Texas [78]. However, at this time, the Texas Marine Mammal Stranding Network (TMMSN) was more developed than some of the stranding networks in other Gulf states, which may have led to a higher proportion of stranding reports from Texas [78]. During this event, four *T. truncatus* stranded in ESB and one stranded on Matagorda Island; it is unknown whether the stranded animals on Matagorda Island in particular were from a coastal or estuarine stock (Figure 4). The winter of 1989-1990 was colder than normal throughout most of the Gulf [78] and the influence of the cold weather on the UME is unclear. Chemical contaminant levels (PCB's) were measured in 10 male *T. truncatus* that stranded in Matagorda Bay during the 1990 event [138] and in 26 *T. truncatus* collected during the event from coastal and estuarine waters from Laguna Madre to Galveston [95]. While PCB levels were relatively low in the majority of the dolphins, PCB levels in a few animals were high enough to potentially negatively impact reproductive success in females [21, 138]. However, contaminant levels were not considered the cause of this mortality event [78]. Retrospectively, it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this UME was not confirmed [78].

In 1992, an UME was declared for central Texas, during which 119 *T. truncatus* strandings were recorded between January and May [79]. Of these 119 strandings, 26 where recovered in ESB proper (Figure 10) [66]. Although the cause of this UME was not conclusive [116], at the time it was suggested that the mortalities may have been linked to higher concentrations of pesticides in the water combined with lower salinities (a result of high freshwater input due to record rainfall) in the bays [66]. Retrospectively, however, it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this UME was not confirmed [79, 116].

An UME was declared for Texas from December 1993 through May 1994, with a total of 236 *T. truncatus* and four unidentified dolphin strandings in Texas [79]. During this event, four *T. truncatus* were recovered on beaches along Matagorda Island in the ESB area (Figure 5). It is unknown whether the stranded *T. truncatus* recovered on Matagorda Island were from an estuarine or a coastal stock. The confirmed cause of this UME was morbillivirus [70, 71, 139].

In 2008, an UME was declared in Texas for February and March, during which 111 *T. truncatus* stranded [79]. This UME had a high proportion of perinate strandings, which suggests an infectious agent that can cause late term abortions or early neonatal loss, such as the bacterium *Brucella*, may have been involved in this event; transmission of this bacteria is often through placental tissues and maternal feeding, resulting in aborted fetuses [79, 140]. Overall along the Texas coast, a high proportion of the strandings were found on the Gulf-side beaches. Of the 111 *T. truncatus* strandings, one animal was recovered on the beach along Matagorda Island in the ESB area; it is unknown whether this animal came from a coastal stock or an estuarine stock (Figure 6). An analysis of gastrointestinal contents from stranded animals, including those from Padre Island, revealed the presence of HAB toxins domoic acid and okadaic acid (associated with a *Dinophysis* spp. and *Prorocentrum* spp. toxic algae bloom occurring at the time) [109]. Low levels of brevetoxin were also found despite an absence of an associated *K. brevis* bloom [109]. The levels of each HAB toxin were low relative to levels associated with acute mortality and the levels of okadaic acid were at levels of unknown effects; however the impact of multiple toxins (*e.g.,* okadaic acid, domoic acid and brevetoxin) on marine mammal health is unknown [109]. The toxicity of okadaic acid has, however, been shown to increase in the presence of a toxin (gymnodimine) produced by *Karenia* [141]. However, no definitive cause for the 2008 event has been determined [116].

More recently, there was an UME declared from November 2011 to March 2012 involving 126 stranded *T. truncatus*, two of which was recovered from Matagorda Island in the ESB area (Figure 7). A preliminary analysis indicated some animals had discolored teeth or a mud-like substance in their stomachs but the cause of the event remains unknown and the investigation is ongoing [142].

Potential threats

As is the case with SAB, there are no large cities surrounding ESB. In Calhoun County (the County surrounding ESB), agriculture, commercial fisheries, manufacturing (aluminum & chemical) and mining are economically important to the area; there are 93 mineral production sites in Calhoun County [119]. These anthropogenic activities pose a number of threats to the biota that utilize this environment.

Oil & gas pollution

Within Calhoun County there are ~321 oil and gas operators and ~3,048 wells [239] as well as pipelines and platforms within ESB [209]. Gamble *et al.* [209] found that sediment samples from ESB generally had higher levels of contamination from oil and grease than those from SAB, Aransas Bay or MB. In the same study, detectable amounts of PAH's were found in an *A. felis* from ESB in an area where sediments also demonstrated high levels of oil and grease [209]. ESB has oil and gas wells and pipelines and petroleum products are transported along the GICW that runs through this bay, which is most likely the source of the oil and grease in the sediment and the PAH's in the sea catfish [209]. In 1983, between 43,500 and 62,500 liters of oil were spilled from a barge into Pass Cavallo and Matagorda Island [240]. Most of the oil was blown into the Gulf of Mexico and onto the Gulf side of Matagorda Island. Shellfish harvesting in MB and ESB was temporarily closed as a result of the spill [241].

Heavy metal & chemical pollution

In a contaminant study comparing levels of metals and chemicals in sediments and biota in the Aransas Bay, ESB and MB area, *C. sapidus* in ESB were found to contain some of the highest levels of arsenic, chromium, copper, lead and nickel, although the levels were still considered low [209].

Marine debris

Specific information regarding the amount of marine debris within ESB bays is lacking, however, marine debris is a threat virtually anywhere anthropogenic activities are occurring through littering (intentional or accidental) or via household or industrial wastes [242, 243].

Commercial & recreational fisheries & aquaculture

Commercial and recreational fisheries operate in the ESB area; however, no trend data are available for these harvests. There is currently no aquaculture in ESB. Fishing gear poses a threat to dolphins as they can become entangled in or ingest it. There is one record in ESB of a dolphin becoming entangled in fishing gear and dying [159].

Shipping, dredging & construction
The Galveston-to-Corpus Christi segment of the GICW supports more than 50,000 vessel trips per year [231]. Shrimp trawlers, tour boats, and tug boats also operate in this stretch of the GICW [231]. The GICW is dredged by the Army Corps of Engineers in ESB to maintain a minimum depth of 4 m [231].

Noise
There are no specific data on marine noise in ESB, however given that there is boat traffic, ship traffic and dredging activity on the GICW, there is likely some level of marine noise in ESB. However, the level of marine noise is probably not as high as other bays with more shipping activity, such as Galveston Bay or Sabine Lake (see BSE: Galveston Bay area and BSE: Sabine Lake, respectively).

Tourism & boat traffic
ESB is a popular spot for recreational boating, bird watching and shelling [244]. However, no specific information on tourism impacts is available.

Algal blooms
From September 2011 to January 2012, there was an unprecedented large *K. brevis* bloom along the Texas coast that also impacted ESB. The red tide was responsible for fish kills and for the temporary closure of all Texas shellfish beds, including those in ESB [180]. Previously, red tides along the coast of Texas that affected ESB and resulted in the closure of shellfish beds and fish kills also occurred in 2000 and 1996 [57]. In fact, the 1996 red tide that included ESB was associated with a large fish kill on Matagorda Island and oysters from ESB had the highest levels of brevetoxin recorded in Texas at the time [57].

The toxins from harmful algal blooms have been found in tissues from *T. truncatus* in the 2008 UME despite the absence of a bloom. The 2011-2012 UME, which resulted in *T. truncatus* mortalities in this area (on the barrier island), also coincided with the large *K. brevis* bloom and could have played a role in this event (see Unusual Mortality Events).

Hypoxia
There are no specific data reported on hypoxia for ESB.

Adverse weather
Since 1874, 14 named storms have hit the within 97 km of Port O'Connor (western end of Matagorda Bay). This area is affected by tropical systems on average every 3.36 years and it gets a direct hit ~ once every 12.82 years [232].

Freshwater inflows
ESB has no major freshwater rivers with direct inflows into the bay, however salinities in the bay are lowered by ~ 5 ppt during very high levels of freshwater inflows from the Guadalupe River and San Antonio Rivers via SAB [235].

Habitat loss
While there are no data available quantifying the amount of habitat lost in ESB due to canal construction, subsidence and wetland loss, there has possibly been a loss of habitat in areas near the GICW associated with erosion from ship traffic and channel construction and maintenance, as is the case in nearby SAB [231].

Disease
Morbillivirus was the confirmed cause of the 1993-1994 UME in Texas, which included four common bottlenose dolphins from the beaches along Matagorda Island (Figure 5) [70, 71, 139]. Whether the mortalities came from the coastal or the estuarine stock is unknown, although dolphins stranded during this event in other nearby environments (*e.g*. Copano Bay, Matagorda Bay). Morbillivirus was retrospectively thought to possibly be the cause of the large die-off in 1990 and the UME in 1992, but a definitive cause for either of these events was not confirmed. The 1990 event included four *T. truncatus* strandings from ESB proper and one from Matagorda Island adjacent to ESB (Figure 4) and the 1992 UME involved 26 *T. truncatus* strandings in ESB proper (Figure 10). In addition, *Brucella* was suspected to be the cause of the 2008 UME due to the high proportion of perinates, but this could not be confirmed [79]. The 2008 UME involved one *T. truncatus* stranding on Matagorda Island in the ESB area (Figure 6). Other diseases affect common bottlenose dolphin, however, here we highlight those that have been associated with high levels of mortality.

Climate Change
The national assessment of coastal vulnerability to sea level rise ranks the ESB area as 'moderate' in the inshore areas to 'very high' risk for the Matagorda Island area. A rank of 'moderate' is a relative sea level change of 2.5 to 3.0 mm/year while a rank of 'very high' is a relative sea-level change of more than 3.4 mm/year [176].

UME's of unknown etiology
The large die-off in 1990 and the UME's in 1992 and 2008, as previously described (see Unusual Mortality Events), were of unknown etiology and involved animals from ESB. The investigation into the 2011 – 2012 UME is ongoing. The suspected cause of the die-off in 1990 and the UME in 1992 were retrospectively thought to be the morbillivirus, however, this was not confirmed to be the definitive cause of these events so these UME's are considered of unknown etiology. The 2008 UME was also of unknown etiology, although it was suspected *Brucella* could have played a role. The 1990 event involved four *T. truncatus* strandings from ESB proper and one from Matagorda Island adjacent to ESB (Figure 4). The 1992 UME involved 26 *T. truncatus* strandings in ESB proper (Figure 10) while only one *T. truncatus* from the 2008 UME was recovered from Matagorda Island (Figure 6). For the 2011-2012 UME, two *T. truncatus* were recovered from Matagorda Island in the ESB/SAB area (Figure 7).

Incidental research takes
Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in gillnets from fisheries research activities by Texas Parks and Wildlife [80]. Of these 31 incidents, three occurred in ESB with one in each of 1984, 1989 and 2010 (over 26 years) [80].

Threat assessment for *Tursiops truncatus* in Copano Bay, Aransas Bay, San Antonio Bay and Espiritu Santo Bay (These are considered a single BSE stock.)

Citations are included where supporting data are available. The maximum number of points per threat is 12 and the maximum total number of points possible is 228.

With a cumulative threat score of 127 and a lack of up-to date assessment data, the Copano Bay, Aransas Bay, San Antonio Bay and Espiritu Santo Bay stock ranks a high priority.

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Oil & gas pollution	2[192, 193, 209, 227, 240]	3[209, 241]	3[13]	8
Heavy metal pollution	2[194, 209]	3[91, 93, 209]	3	8
Chemical pollution	2[94, 194, 209]	3[192, 193, 209]	3[66, 95]	8
Marine debris	1	2	3	6
Recreational fisheries	2[213, 244]	2[159]	4[4, 159]	8
Commercial fisheries	1[94, 156, 213]	2[216]	4[26, 102, 103]	7
Aquaculture	0	NA	NA	0
Shipping	2[231]	3[231]	3[35]	8
Dredging & construction	2[228, 231]	2[228, 231]	3[106]	7

continued

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Noise	1	2	3[38, 43]	6
Tourism & boat traffic	1[213, 244]	2	4[54]	7
Algal blooms	2[57, 168, 180]	3[57, 168, 180, 181]	3[109]	8
Hypoxia	1[61]	2[61]	3[60]	6
Adverse weather	1[232]	2[233]	3[62]	6
Freshwater inflows	1[216]	2[216]	3[66]	6
Habitat loss	2[114, 231]	2	3	7
Disease	1[70, 71, 139]	0	5*[69-72]	6
Climate change	1[114, 176, 203, 223]	2[114, 223]	3[76]	6
UME of unknown etiology	2[78, 116, 142]	2	5*[66, 78, 116]	9
Total				127

*mortality event along the Texas coast that included animals from this BSE, but was not contained solely within this BSE

DAS scoring for *Tursiops truncatus* in Copano Bay, Aransas Bay, San Antonio Bay and Espiritu Santo Bay

	Score
Information on stock structure	0
Information on abundance	0
Information on mortality	0
Total	0

BSE: Matagorda Bay

The Matagorda Bay (MB) system includes Matagorda Bay, Lavaca Bay, Tres Palacios Bay, East Matagorda Bay, Keller Bay and Carancahua (alternative spelling Karankawa) Bay (Figure 12). MB is on the Texas coast to the northeast of SAB and to the southwest of Galveston Bay. The MB estuarine system is the third largest in Texas [119]. This system also includes the Colorado River delta, which almost completely separates East Matagorda Bay from the other bays in the system [119]. An estuary condition report in 2006 considered MB to be in 'good' health [236].

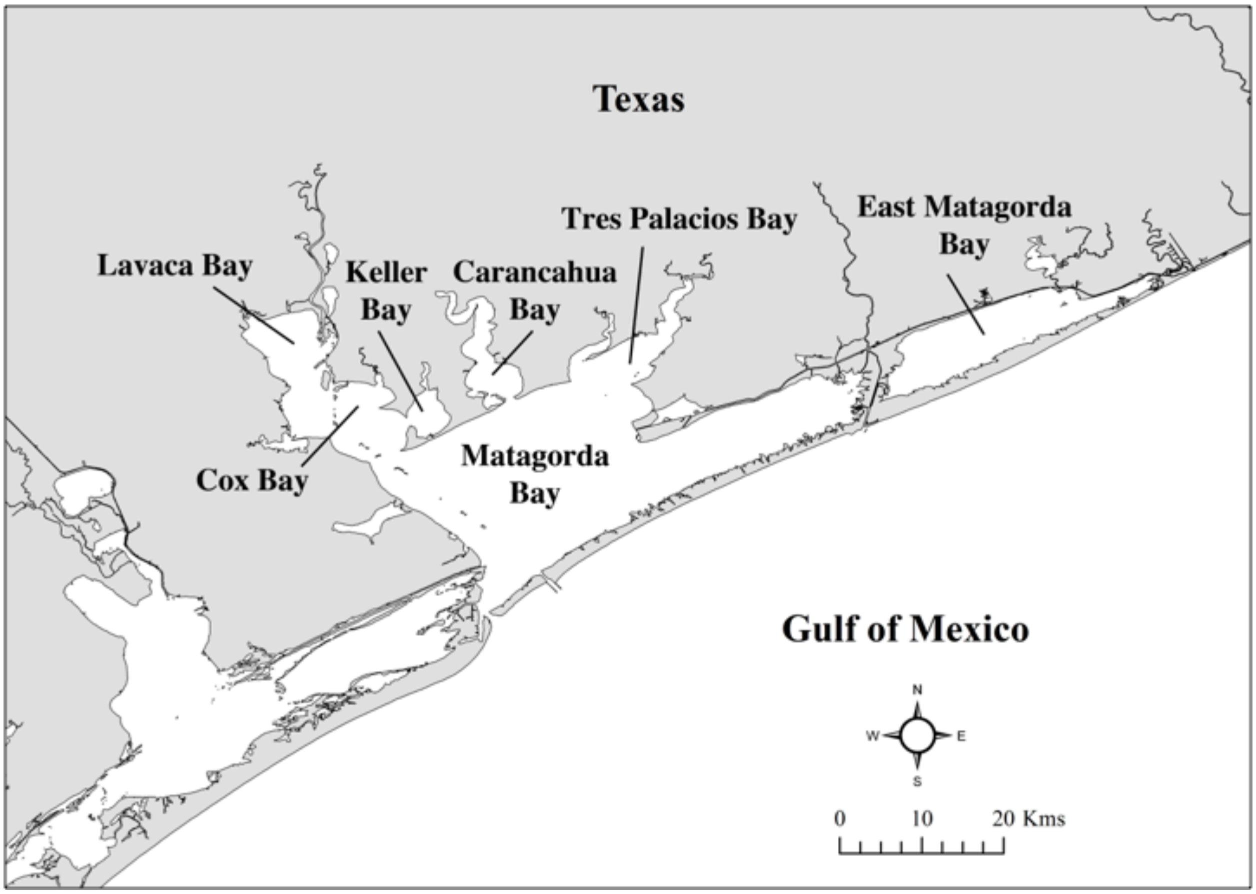

Figure 12. Matagorda Bay estuary, Texas

Physical attributes

The MB system is a large, shallow estuarine system covering a total of ~1,093 km^2 [105]. The average depth of MB is ~ 2m [105, 119] with maximum depths of 10.97 m in MB and Lavaca Bay, 3.66 m in Tres Palacios Bay and 1.5 in East Matagorda Bay [94]. The average salinity of the MB estuary is ~19 ppt [105] to 23 ppt [119], although salinities tend to be highly variable depending on environmental factors such as freshwater inflows. As is the case with many other bays and estuaries in Texas, the connection of MB with the Gulf of Mexico is more restricted than a 'typical' estuary due to the presence of a large barrier, Matagorda Peninsula. Exchange between the MB system and the Gulf of Mexico occurs via Pass Cavallo and the Matagorda Ship Channel to the southwest, Greens Bayou on the Matagorda Peninsula, the Colorado River delta area and Brown Cedar Cut (east end of East Matagorda Bay) [245]. MB experiences diurnal tides with a mean tidal range of 0.21 m [94]. The MB area receives roughly ~106 cm of precipitation each year [119]. Armstrong [119] reports a loss of ~143 cm/year due to evaporation, resulting in a net loss of ~37 cm/year. The mean water temperature of MB ranges from highs of ~29°C (84°F) in the summer (June-August) to lows of ~13°C (55°F) in the winter (December-February) [246].

Biota

Seagrass

Halodule wrightii and *R. maritima* are the predominant seagrass species found in the MB system [94]. There are roughly ~28 km^2 of seagrass habitat in the MB system [105]. There was a decrease in seagrass habitat in MB of ~ 11 km^2 in the late 1980's to early 1990's [220, 221]. MB, East Matagorda Bay, Cox Bay and Carancahua Bay are all proposed areas for seagrass monitoring [220, 221].

Birds

Over 250 species of birds are found in the surrounding wetlands of MB including *P. occidentalis*, *H. leucocephalus, P. chihi, E. rufescens* and *C. melodus*. In addition, the endangered whopping crane, *G. americana,* has been known to winter on Matagorda Island [236].

Fish & invertebrates

The most abundant species of fish and invertebrates and the seasons they are found in highest abundance in MB are: *F. aztecus* (spring), *L. setiferus* (summer), *C. sapidus* (winter-spring), *C. similis*, *L. brevis* (summer-fall), *S. empusa*, *T. similis*, *P. lethostigma, A. mitchilli* (late spring-fall), *S. ocellatus*, *C. nebulosus*, *C. arenarius* (spring-summer), *L. xanthurus* (spring), *B. patronus* (spring), *A. felis* (summer), *M. undulatus* (winter-spring), *B. marinus*, *S. plagiusa* (late spring-summer), *S. lanceolatus* (late spring-summer), *O. beta* and *M. cephalus* [119].

The occurrences of shrimp in MB are highly seasonal; larvae use estuarine waters for development and growth and adults migrate to deeper waters in the Gulf of Mexico to spawn [236]. The abundance of *F. aztecus* in MB peaks in May-June and the abundance of *L. setiferus* peaks from July to November [236]. In contrast to shrimp, *C. sapidus* and oysters occupy MB year round [236]. *Mugil cephalus* and *B. patronus* depend on the estuarine environments such as MB for development, but are euryhaline as adults [133, 236], migrating to the Gulf of Mexico for spawning and returning to food-rich estuarine waters [247]. *Sciaenops ocellatus* also uses MB as nursery habitat for juveniles, however after reaching maturity around 3.5 to 5 years, they migrate to Gulf waters where they spend their adult lives [131, 132].

In a study of nekton abundance in Cox Bay (in Lavaca Bay), the highest biomass of nekton occurred in late winter and spring, which was attributed to increases in young *M. undulatus* and *L. xanthurus* [119]. An increase in biomass was also found midsummer, when catches were dominated by *M. undulatus*, *A. mitchilli*, shrimp and *A. felis* [119].

Other species

Although rare in Texas, on July 25 and 26, 2005, a single *T. manatus* was sighted near Port O'Connor and again on August 13 2005 in ESB [236]. Small numbers of green sea turtles, *Chelonia mydas,* Kemp's ridley's turtles, *Lepidochelys kempii,* can also been found in MB [236].

Common bottlenose dolphins

Data Assessments

A population genetic study of *T. truncatus* in the Gulf of Mexico included 34 samples from MB collected in 1992 [248]. The study used a 359-bp portion of the mitochondrial control region (mtDNA) and nine microsatellite loci and found significant population structuring between MB, Sarasota Bay, FL, Charlotte Harbor, FL, Tampa Bay, FL, and a coastal stock (1-12 km offshore) in the Gulf of Mexico along the Florida coast [248]. MB was the most differentiated of the five sampling sites. Further stock structure studies are ongoing and include additional samples collected from MB in 2012 and 2013.

Gruber [246] found that the dolphins in MB exhibited seasonal movements in and out of the bay and seasonal utilization of particular regions with daily movements that were influenced by tidal flow and time of day. The highest densities of *T. truncatus* in MB were found on the northern side of the Matagorda Ship Channel around Pass Cavallo [246]. The estimated population density within MB in waters stretching from Pass Cavallo to Port O'Connor ranged from a high of 1.29 dolphins/km^2 (98.16 animals) in February 1979 to a low of 0.396 dolphins/km^2 (30.08 dolphins) in April 1980 [246]. Over a five-day survey period in 1978, there were 26 sightings of *T. truncatus* along the edges of MB, particularly in the western reaches of the bay, but only one sighting of a single individual in the middle of the bay. This finding suggests that *T. truncatus* may not utilize the middle of the bay as much as other areas, at least in winter months [208].

Range size and site fidelity of *T. truncatus* was assessed in MB via radio tracking and photographic surveys from 1992-1993 [226, 237]. Radio tracking data were collected for 10 individuals from the 9th of July to the 13th of September 1992 and photographic surveys of 35 freeze-branded animals were conducted from May 1992 to June 1993 in the MB, ESB and SAB areas [237]. Using the photographic survey data, Lynn [237] estimated an abundance of 218 (± 71.4 95% CI) *T. truncatus* in a 312 km^2 area within MB and ESB. Males and females exhibited similarly sized mean ranges (~140 km^2). However, males were found to utilize the extremities of their ranges more often or for longer periods of time than females [226, 237]. Of the 10 individuals that were radio-tracked, seven remained within the vicinity of the original capture site (near Port O'Connor). The other three individuals spent at least half the time around Port O'Connor, but also travelled to western ESB and SAB, and one spent half of the time in SAB [238]. *Tursiops truncatus* were observed moving between MB and ESB via the GICW, Big Bayou and Saluria Bayou [238]. The radio-tagging data suggest that tracked dolphins left the bay system and swam into the Gulf of Mexico on three occasions (one individual on one occasion and a second individual on two occasions) [238]. For all three occasions the position of the animals was believed to be within 1 km offshore of Pass Cavallo, however given the potential errors in triangulation [249], offshore movements may have occurred more or less often [238]. Ten of the freeze-branded animals captured in northeast MB were never re-sighted during the study, but a few were sighted after the survey ended [237]. One of the freeze branded animals (FB523) was sighted in May and June 1994 offshore near Galveston, Texas jetties [237]. There was also a citizen sighting of a freeze branded animal at the Corpus Christi Ship Channel jetties in November 1992, although the freeze brand number is unknown [237]. Gruber [246] also observed a dolphin in MB that was originally described from the CCB area [237, 250]. This suggests that there may be some long-distance movements of common bottlenose dolphins occurring along the Texas coast, but whether these animals were estuarine residents or coastal animals remains unknown.

Unusual Mortality Events

In 1990, a mortality event of *T. truncatus* occurred from January through May along the entire northern Gulf of Mexico coast from Florida through Texas with 46% of the 344 carcasses being collected in Texas [78]. However, at this time, the Texas Marine Mammal Stranding Network (TMMSN) was more developed than some of the stranding networks in other Gulf states, which may have led to a higher proportion of stranding reports from Texas [78]. The winter of 1989-1990 was colder than normal throughout most of the Gulf [78] and the influence of the cold weather on the UME is unclear. During this event, four *T. truncatus* stranded in MB proper, 23 in East MB, which had frozen over for 2.5 days [251], and 15 *T. truncatus* stranded on the Gulf side of Matagorda Island (in addition to one animal with no associated latitude and longitude data) (Figure 4). Whether the stranded animals on Matagorda Island in particular were from an estuarine or coastal stock is unknown. Most *T. truncatus* in the MB area were emaciated and the mortality event was preceded by extremely cold water temperatures that caused East MB to freeze over, windy conditions causing a mean low tide 30-60 mm below normal and substantial fish kills [251]. However, stomach content analysis of *T. truncatus* from this event showed no difference in prey compared to before the event [78]. Chemical contaminant levels (PCB's) were measured in 10 male *T. truncatus* that stranded in MB during the 1990 event [138] and in 26 *T. truncatus* collected during the event from coastal and estuarine waters from Laguna Madre to Galveston, including two males and two females from Port O'Connor [95]. While PCB levels were relatively low in the majority of the dolphins, PCB levels in a few animals were high enough to potentially negatively impact reproductive success in females [21, 138]. However, contaminant levels were not considered the cause of this mortality event [78]. Retrospectively, it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this large die-off was not confirmed [78].

In 1992, an UME was declared for central Texas, during which 119 *T. truncatus* strandings were recorded between January and May [79]. Of the 119 *T. truncatus* stranded during this event, 15 were recovered in MB, five were recovered just east of East Matagorda Bay and eight strandings had no latitude/longitude data (so their exact location within the Matagorda region is unknown; Figure 10) [66]. Although the cause of this UME was not conclusive [116], at the time it was suggested that the mortalities might have been linked to higher concentrations of pesticides in the water combined with lower salinities (a result of high freshwater input due to record rainfall) in the bays [66]. Retrospectively, however, it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this UME was not confirmed [79, 116].

An UME was declared for Texas from December 1993 through May 1994, with a total of 236 *T. truncatus* and four unidentified dolphin strandings in Texas, most of which were recovered along the beaches from the Matagorda Peninsula to Sabine Pass [79]. Of these reported strandings, eight *T. truncatus* stranded within MB proper while 14 stranded on beaches along the Gulf side of Matagorda Island (Figure 5). Whether the animals stranded on Matagorda Island in particular were from an estuarine or coastal stock is unknown. The confirmed cause of this UME was morbillivirus [70, 71, 139].

In 2008, an UME was declared in Texas for February and March, during which 111 *T. truncatus* stranded primarily on the Gulf-side beaches [79]. This UME had a high proportion of perinate strandings, which suggests an infectious agent that can cause late term abortions or early neonatal loss, such as the bacterium *Brucella*, may have been involved in this event; transmission of this bacteria is often through placental tissues and maternal feeding, resulting in aborted fetuses [79, 140]. During this event, no dolphins were recovered in MB; however, five animals were recovered just east of East Matagorda Bay (Figure 6). These stranded animals may have been from a coastal stock, however their proximity to East Matagorda Bay is worth mentioning (Figure 6). An analysis of gastrointestinal contents from animals stranded in 2008 revealed the presence of HAB toxins domoic acid and okadaic acid (associated with a *Dinophysis* spp. and *Prorocentrum* spp. toxic algae bloom occurring at the time) [109]. Low levels of brevetoxin were also found despite an absence of an associated *K. brevis* bloom [109]. The levels of each HAB toxin were low relative to levels associated with acute mortality and the levels of okadaic acid were at levels of unknown effects; however the impact of multiple toxins (*e.g.,* okadaic acid, domoic acid and brevetoxin) on marine mammal health is unknown [109]. The toxicity of okadaic acid has, however, been shown to increase in the presence of a toxin (gymnodimine) produced by *Karenia* [141]. However, no definitive cause for the 2008 event has been determined [116].

More recently, there was an UME declared from November 2011 to March 2012 involving 126 stranded *T. truncatus*, five of which were recovered from MB and one just east of East Matagorda Bay (Figure 7). A preliminary analysis indicated some animals had discolored teeth or a mud-like substance in their stomachs but the cause of the event remains unknown and the investigation is ongoing [142].

Potential threats

The MB area has relatively little urban development surrounding the estuary; there are, however, small cities along its western and northern sides as well as major industry around Lavaca Bay. There are 93 mineral production sites in Calhoun County and 144 in Matagorda County, for a total of ~237 sites surrounding MB. [94]. Mining oil and natural gas, petroleum refineries, agriculture (cattle, rice, cotton) and commercial fisheries are all economically important to the area [94]. These anthropogenic activities pose a number of threats to the biota that utilize this environment.

Oil & gas pollution

Within Matagorda County there are ~496 oil and gas operators and ~5,419 wells and within Calhoun County there are ~321 operators and ~3,048 wells [239, 252]. Calhoun LNG originally planned to develop a liquid natural gas import terminal at Port Lavaca in MB, but in February 2013 its request to cancel the operation was approved [253, 254]. However, Excelerate Energy now plans to build a LNG export terminal at Port Lavaca-Port Comfort. Two floating units capable of processing and storing 3-4 million tons of LNG each year are proposed. Large LNG transport vessels using the Matagorda Ship Channel would access this terminal and transport LNG to other markets [255].

In 1978, a tugboat ran aground near Port O'Connor and spilled ~2,500 gallons of fuel oil into MB. Dolphins were documented swimming within the oil slick [246]. In 1983, between 10,000 and 14,000 gallons of oil were spilled from a barge into Pass Cavallo and Matagorda Island and Peninsula [240]. Most of the oil was blown into the Gulf of Mexico and onto the Gulf side of Matagorda Island [240]. Shellfish harvesting in MB and ESB was temporarily closed as a result of the spill [241]. Between September 2003 and January 2009 there have been 24 documented pipeline incidents in Matagorda County involving both gas and oil, although many of these have occurred on land [256].

Heavy metal & chemical pollution

In the late 1980's and early 1990's, MB was one of the top three drainage areas in the Gulf of Mexico for the highest amount of agricultural pesticide and the drainage ranked the highest for herbicide use (over 1.2 million pounds and over 1 million pounds, respectively, in 1987) [257]. The major herbicides applied include atrazine, propanil and molinate [257]. In contaminant assessments in 1970 [94], the pesticides DDD, DDE and DDT were found in water samples from Lavaca Bay (cumulatively 1.02 parts per billion, ppb), but not in water samples from East Matagorda Bay or Tres Palacios Bay. However, these pesticides were found in sediment samples from East Matagorda Bay (2.83 ppb) and Tres Palacios Bay (amount not reported) (sediment samples not taken for Lavaca Bay) [94].

In 1948, an aluminum smelting plant was established at Point Comfort in MB and caused severe mercury pollution in Lavaca Bay until 1980, when the operation was closed [258, 259]. The oyster fishery adjacent to Point Comfort closed in the 1970's due to high levels of mercury in tissues of oysters and crabs [209, 258]. Oyster fishing was later re-opened in this area, but the fin fishery and crab fisheries in the area were closed in 1988 [258, 259]. The site was listed on the Environmental Protection Agency National Priorities List (NPL) in 1994 and a remedial action plan was decided on in 2001 [258, 259]. Clean-up of the site is underway and among other things, the remedial action plan included the preservation of 3 km^2 refuge habitat including 0.3 km^2 of intertidal salt marsh and 0.05 km^2 (11 acres) of oyster reef habitat in Lavaca Bay [260]. A study by Brown *et al*. [258] found mercury in sediment samples from the oyster reefs, salt marshes, open water environments, ship channels and dredge spoil sites from Lavaca Bay and MB [258]. In 2011, the Environmental Protection Agency conducted a review of the site and found that overall, there was a downward trend in mercury concentrations in open water and salt marsh sediments [261]. However, small localized areas of open water sediments had not recovered as quickly as had been predicted [261]. In 2000, the Texas Department of Health reduced the size of the closed area for fishing and most of the bay is now open to fisheries [259].

In a study of chemicals and heavy metals in birds, the concentrations of mercury, DDE and PCB's in Forster's tern, *Sterna forsteri*, eggs from Lavaca Bay were found to be higher than in those from SAB, however, no differences in hatching success were found between the sites [262]. Similarly, the concentrations of mercury, selenium and PCB's in black skimmer, *Rynchops niger*, eggs from Lavaca Bay were found to be higher than those from Laguna Vista, but chemical residues did not affect hatching success in Lavaca Bay [262]. PCB's and DDE were also found in *H. caspia*, eggs from Lavaca Bay, although levels of mercury and selenium were low [262].

Marine debris
Specific information regarding the amount of marine debris within MB bays is lacking, however, marine debris is a threat virtually anywhere anthropogenic activities are occurring through littering (intentional or accidental) or via household or industrial wastes [242, 243].

Commercial & recreational fisheries & aquaculture
Farfantepenaeus aztecus, *L. setiferus*, *C. sapidus*, *B. patronus*, *M. cephalus*, *S. ocellatus* and oysters are all commercially important species in MB [236]. Shrimp in particular are one of the most valuable resources along the Texas coast and this industry has an economic impact of $330 million annually and supports ~ 1,800 full time jobs in MB [236]. Commercial shrimpers in MB alone landed one quarter of the total shrimp catch from all Texas bays from 1995-1999. Mean annual landings by the MB commercial fleet from 1980-1984 totaled $4.8 million for brown shrimp and $5.9 million for white shrimp. In 2001, in Calhoun and Matagorda counties (the two encompassing MB) there were a total of 569 licensed shrimpers, accounting for 24% of all licenses in the 18 coastal counties of Texas [225].

From 1981 to 2001, the catch of finfish such as *P. cromis* and *A. probatocephalus* with perch trap, cast net, seine and trotline in MB appeared to be somewhat variable [156]. The catch of *P. cromis* peaked in the late 1980's and again in the late 1990's and had both high and low catches in other years [156]. The catches of *A. probatocephalus* were variable and overall catches were low, with peak harvests in the mid 1980's [156]. Harvest of *P. lethostigma* increased from 1981 to roughly 1991 and then generally decreased until 2001 [156]. Mullet catches have been somewhat variable; catches were somewhat high in the 1980's but were substantially lower throughout the 1990's [156]. Shrimp harvest (trawling) trends from 1981 to 2001 have fluctuated somewhat, but with no apparent increasing or decreasing trend [156]. The harvest of *C. sapidus* (trap, trawl, net) increased from 1981 to 1989, then generally decreased until 1995 when catches began to fluctuate [156]. There is currently no aquaculture in MB.

Tursiops truncatus in MB have been observed eating ribbonfish (Trachipteridae), *C. arenarius*, whiting, *Menticirrhus littoralis*, and *M. undulatus,* all in association with shrimp boats and often dolphins in MB would not eat *M. cephalus* [246]. When shrimpers are present in MB, *T. truncatus* are very often found associated with them [237]. Informal discussions with shrimpers included candid descriptions of accidental captures of dolphins in the trawl, 'fishing' for *T. truncatus* using hook, bait and line, hand-feeding *T. truncatus* and shooting to scare away or kill dolphins, particularly before the fishery switched to cotton-poly nets at which point the fisherman interviewed indicated that damage to nets was greatly diminished [246].

Fishing gear poses a threat to *T. truncatus* as they can become entangled in or ingest fishing lines or nets. There are no reports of fisheries interactions involving *T. truncatus* in the stranding records for MB [159].

Shipping, dredging & construction
Dredging activities have been taking place in MB since at least the early 1900's. In 1929, a flood in the Colorado River created a large delta that cut MB off from East MB, and changed the flow of freshwater into the system. In 1935, the Army Corps of Engineers dredged a channel through the delta so that the Colorado River drained directly into the Gulf of Mexico [236]; then in 1991, they dredged a diversion channel so water from the Colorado River would once again flow into MB (see Freshwater inflows below for more details) [236].

The Matagorda Ship Channel cuts through Matagorda Peninsula and the southern portion of the bay, connecting local ports (Port O'Connor, Port Lavaca, Point Comfort, Port of Palacios) of MB to the GICW [119, 263]. The Port of Lavaca and the Port of Calhoun each handled approximately 3.2 million tons in 2009 [162]. The GICW channel is dredged to an average depth of ~11 m throughout its ~35 km length in MB [263]. The GICW is designed for transportation of crude petroleum and petroleum products, iron, steel, fertilizer and other bulk products.

Noise
There are no specific data on marine noise in MB, however given that there is boat traffic, shipping vessel traffic, port activity at Port O'Connor and dredging activities, there is likely some level of marine noise in the MB area, which may increase once the LNG export terminal is operational [264]. However, the level of marine noise is probably not as severe as other bays with more shipping activity, such as Galveston Bay or Sabine Lake (see BSE: Galveston Bay area and BSE: Sabine Lake, respectively).

Tourism & boat traffic
MB is used for bird watching, recreational boating, recreational and sport fishing in Saluria Bayou, the GICW and MB proper [245].

Algal blooms
There was a relatively recent record of a toxic brown algae bloom *D. ovum* in MB in 2008. From September 2011 to January 2012, there was a large *K. brevis* bloom along the Texas coast and in the bays, including MB, that was responsible for the temporary closure of all Texas shellfish beds [168]. This was followed by another red tide event in August 2012 on the Texas coast which was known to affect Galveston Bay [168]. While it is unclear whether *K. brevis* was present in MB during this August 2012 event, there were fish kills reported at the mouth of the Colorado River during this time [168]. Previously, red tides that affected MB and resulted in the closure of shellfish beds and fish kills also occurred in 1996 (see Espiritu Santo Bay summary for details) [57].

The toxins from harmful algal blooms have been found in tissues from *T. truncatus* during the 2008 UME despite the absence of a bloom. The 2011-2012 UME, which resulted in *T. truncatus* mortalities in this area, also coincided with the large *K. brevis* bloom and could have played a role in this event (see Unusual Mortality Events).

Hypoxia
At least one large fish kill has been associated with hypoxia in MB [61]. Prior to 1994, there were few fish kills in MB due to hypoxia, however between 1995 and 1999, low dissolved oxygen levels resulted in a fish kill that included ~74 million Gulf menhaden [61].

Adverse weather
MB is affected by hurricanes and tropical storms. Since 1871, 16 named storms have hit within 97 km of MB. MB is affected by a hurricane or tropical storm on average every 2.92 years and has a direct hit (within 40 miles) on average once every 7.78 years [265]. In 1983 and 1989, there were cold freezes that resulted in large fish kills in MB and East MB, primarily of *B. patronus* in 1983 and *P. cromis, S. ocellatus* and *C. nebulosus* in 1989 [234].

Freshwater inflows
A balance of freshwater inflow is very important to estuarine health. The MB system receives freshwater inflows from the Lavaca River, the Colorado River delta [119] and numerous creeks and bayous [245]. The estimated combined inflow of freshwater into the MB system is approximately 3.6 km^3/year [119]. Historically, the Colorado River drained directly into MB, which was open to East Matagorda Bay [236]. Flooding over a long period of time combined with a great flood in 1929 created a delta that cut MB off from East Matagorda Bay [236]. In 1935 the Army Corps of Engineers dredged a channel through the delta so that the Colorado River drained directly into the Gulf of Mexico [236]. This changed the freshwater inflow regime, which corresponded with a dramatic, negative change in the bay's fisheries in the 1970's [236]. Therefore, in 1991, additional dredging was undertaken so water from the Colorado River would once again flow into MB to reduce salinities, increase nutrient inflows and develop marshlands in an attempt to increase biological productivity [236].

In 1992, there was a large flood of freshwater into MB, which resulted in a substantial decline of the oyster industry as a result of decreased salinities (oysters prefer salinities greater than 10 ppt) [236, 266]. In contrast, in 2000, there was a drought that resulted in extremely high salinities in MB which resulted in high oyster mortality and disease; it took the oyster beds more than 2 years to recover to their pre-drought 'health' [236].

Habitat loss
While there are no data available quantifying the amount of habitat lost in MB due to canal construction, subsidence and wetland loss, there has possibly been a loss of habitat in areas near the GICW associated with erosion from ship traffic and channel construction and maintenance, as is the case in other BSE's such as SAB [231].

Disease
Lobo's disease, an infection of the skin caused by a fungus, was diagnosed in a male *T. truncatus* in MB for the first time in 1992 and was the first case in the western Gulf of Mexico [267]. In addition to Lobo's disease, morbillivirus was the confirmed cause of the 1993-1994 UME in Texas, which included eight common bottlenose dolphin mortalities from MB proper and 14 mortalities along the beaches along the Gulf side of Matagorda Island (Figure 5) (see Unusual Mortality Events) [70, 71, 139]. Morbillivirus was retrospectively thought to possibly be the cause of the die-off in 1990 and the UME in 1992, but a definitive cause for either of these

events was not confirmed. The 1990 event included four *T. truncatus* strandings from MB proper, 23 in East MB and 15 on the Gulf side of Matagorda Island (Figure 4) (as well as one *T. truncatus* with no latitude/longitude data). The 1992 UME involved 15 *T. truncatus* strandings in MB proper, five strandings just east of East MB and eight strandings with no latitude/longitude data (Figure 10). In addition, *Brucella* was suspected to be the cause of the 2008 UME due to the high proportion of perinates, but this could not be confirmed [79]. The 2008 UME involved five *T. truncatus* strandings recovered just east of East MB (Figure 6). Other diseases affect common bottlenose dolphin, however, here we highlight those that have been associated with high levels of mortality.

Climate change

Climate change is likely to have a significant impact on all BSE's in Texas. Climate change is expected to substantially impact this area with rising sea levels, increased shoreline erosion and declines in water quality [175]. The national assessment of coastal vulnerability to sea-level rise ranks the MB area as 'high' for the inshore areas to a 'very high' risk for the Matagorda Peninsula area [176]. A rank of 'high' is a relative sea level change of 3.0 to 3.4 mm/year, while a rank of 'very high' is a relative sea-level change of more than 3.4 mm/year [176].

Climate change may change the amount of freshwater inflow (*e.g.* decrease) entering the BSE's from rivers, which in turn, will impact the salinity regime and composition of the habitat types in the estuary [175]. These changes are likely to affect the biota present in the bay as some species utilizing the Gulf as nursery areas have specific salinity preferences (*e.g.* see freshwater inflows above) [235]. In addition, a predicted increase in air temperature of a few degrees could strongly influence the temperature of shallow bay waters, which are typically slow moving or stagnant [175]. As temperatures rise, estuaries with little mixing will become even more stratified further decreasing bottom water oxygen concentrations [175]. Specifically for MB, increased water column stratification, changes in salinity and temperature could hinder development of juvenile shrimp in the bay, potentially reducing the harvestable adult population [175] as well as impacting the food chain. Climate change could potentially increase the frequency and duration of hurricanes [178] and potentially harmful algal blooms [179] along the Texas coast.

UME's of unknown etiology

The large die-off in 1990 and UME's in 1992 and 2008, as previously described (see Unusual Mortality Events), were of unknown etiology and involved *T. truncatus* mortalities from MB. The investigation into the 2011 – 2012 UME is ongoing. The suspected cause of the die-off in 1990 and UME in 1992 were retrospectively thought to be the morbillivirus, however, this was not confirmed to be the definitive cause of these events so they are considered here to be of unknown etiology. The 2008 UME was also of unknown etiology, although it was suspected *Brucella* could have played a role. In particular, the 1990 event involved four *T. truncatus* strandings from MB proper, 23 in East MB and 15 on the Gulf side of Matagorda Island (Figure 4) (as well as one *T. truncatus* with no latitude/longitude data). The 1992 UME involved 15 *T. truncatus* strandings in MB proper, five strandings just east of East MB and eight strandings with no latitude/longitude data (Figure 10). The 2008 UME involved five *T. truncatus* strandings recovered just east of East MB (Figure 6). For the 2011-2012 UME, five *T. truncatus* were recovered from MB and one just east of East Matagorda Bay (Figure 7).

Incidental research takes

Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in gillnets from fisheries research activities by Texas Parks and Wildlife [80]. Of these 31 incidents, four occurred in MB with one in each of 1985, 1990, 2007 and 2008 (over 23 years) [80].

Threat assessment for *Tursiops truncatus* in Matagorda Bay

Citations are included where supporting data are available. The maximum number of points per threat is 12 and the maximum total number of points possible is 228.

With a cumulative threat score of 123 and a lack of up-to date assessment data, the Matagorda Bay stock ranks a high priority.

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Oil & gas pollution	1 [240, 255]	2 [241]	3 [13]	6
Heavy metal pollution	2 [258]	3 [209, 258, 262]	3	8
Chemical pollution	2 [94, 257]	3 [262]	3 [66, 95]	8
Marine debris	1	2	3	6
Recreational fisheries	1 [245]	2	3 [4, 159]	6
Commercial fisheries	1 [156, 236]	2	3 [26, 102, 103]	6
Aquaculture	0	NA	NA	0
Shipping	1 [162]	2	3 [35]	6
Dredging & construction	2 [236, 263]	2	3 [106]	7

continued

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Noise	1	2	3[38, 43]	6
Tourism & boat traffic	1[245]	2	3[54]	6
Algal blooms	2[168, 170]	3[57]	3[109]	8
Hypoxia	1[61]	5[61]	3[60]	9
Adverse weather	1[232]	2	3[62]	6
Freshwater inflows	2[236]	3[236, 266]	3[66]	8
Habitat loss	1	2	3	6
Disease	1[70, 71, 139, 267]	0	5*[69-72]	6
Climate change	1[176]	2	3[76]	6
UME of unknown etiology	2[66, 78, 142]	2	5*[78, 142]	9
Total				123

*mortality event was along the Texas coast that included animals from this BSE, but was not contained solely within this BSE

DAS scoring for *Tursiops truncatus* in Matagorda Bay

	Score
Information on stock structure	1[248]
Information on abundance	0
Information on mortality	0
Total	1

BSE: West Bay

West Bay (WB) lies to the southwest of Galveston Bay (GB), is typically included as part of the GB estuary complex and is fairly similar to GB (see BSE: Galveston Bay area). However, some aspects of West Bay differ from GB proper and, therefore, this bay deserves specific attention. For our purposes, the West Bay area also includes Bastrop Bay, Christmas Bay and Drum Bay to the south of San Luis Pass (Figure 13).

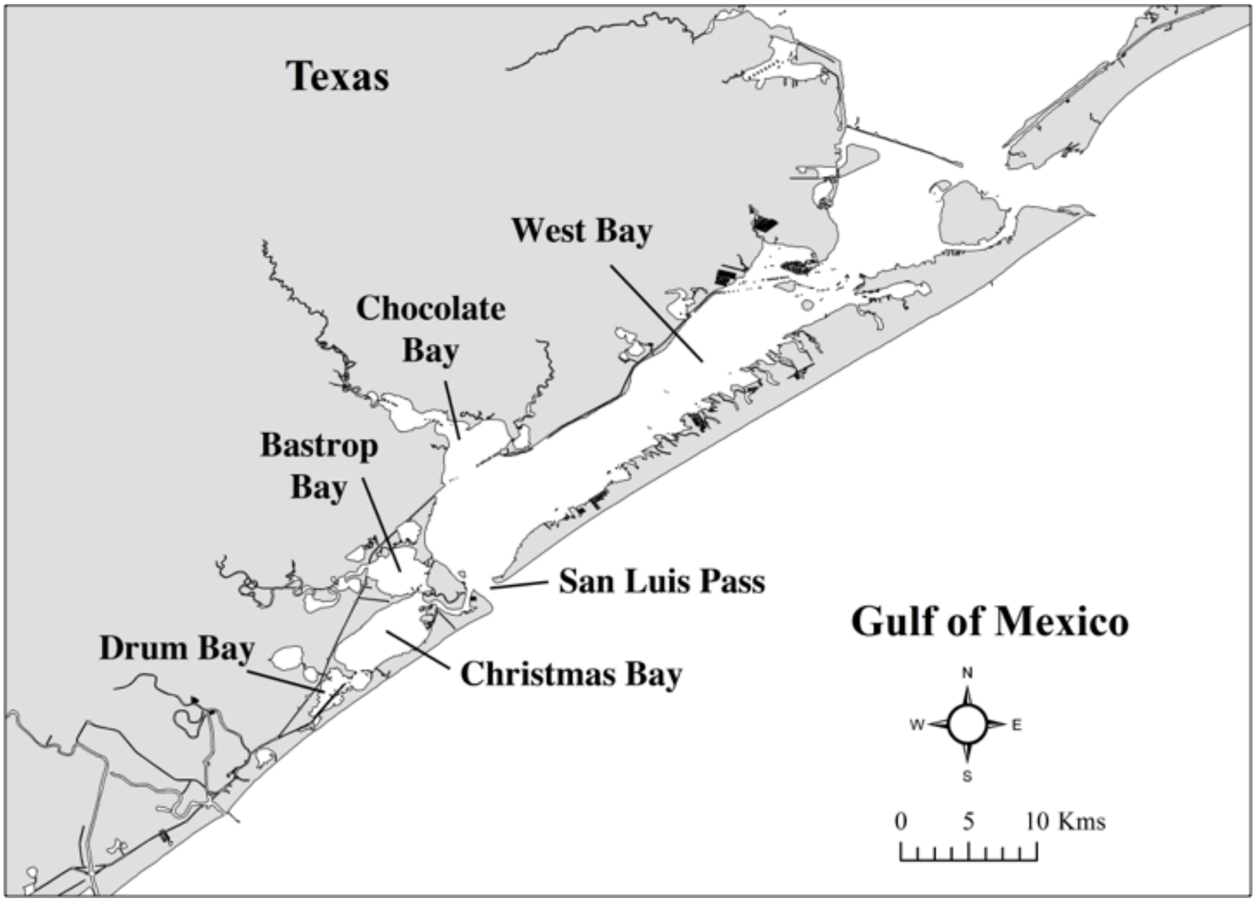

Figure 13. West Bay and sub-bays, Texas

Physical attributes

WB is a long, narrow bay with a surface area of approximately 180 km^2, an average depth of 1.2 m and a maximum depth of 7 m [94]. The average salinity of WB is between 15 and 32 ppt and tends to be more saline than nearby GB [268]. The GB area as a whole receives roughly 135 cm of precipitation each year with a loss of ~119 cm/year due to evaporation, resulting in a net gain of 16 cm/year [268]. The long-term average air temperature of WB is 20.7°C (69.3°F) with a range of 12.6°C (54.7°F) to 27.9°C (82.3°F), based on temperature data for 54 years from Angleton, Texas [94]. WB experiences diurnal tides of ~0.2 m [94]. WB is separated from the Gulf of Mexico by Galveston Island. Exchange with Gulf waters occurs via San Luis Pass to the south and through Bolivar Pass (also known as Bolivar Roads) to the north (the 'main' entrance to GB).

Biota

Seagrass

Historically, *H. wrightii, R. maritima* and *T. testudinum* were the dominant species of seagrass in WB [268]. There has been a substantial loss in seagrass in WB since the 1960's [268, 269]. The decline in seagrass beds in WB was relatively rapid. Between 1956 and 1965, total seagrass bed coverage declined from an area of 5.7 km^2 to 2 km^2 [221, 268]. The decline continued, with 0.5 km^2 of seagrass beds remaining in 1975, until seagrass beds completely disappeared in the 1980's [221, 268]. Subsidence, hurricane Carla and erosion are all believed to have contributed to the destruction of seagrass beds in WB; however, it may be that waterfront developments and the associated decrease in water quality and increased pollution led to the complete loss of seagrass beds [268]. Naturally occurring (as opposed to reintroduced) seagrasses still remain in Christmas Bay, a small, semi-isolated sub-bay at the southern end of WB, where *H. wrightii* and *R. maritima* are the dominant species [268].

In the mid to late 1990's, seagrass restoration projects began in WB near Galveston Island State Park [221] after environmental reports suggested that the water and sediment condition had improved since the 1980's and new waterfront developments had decreased to a point that seagrass restoration could be attempted in the area [270]. These restoration projects have had limited success; some seagrass beds have sparsely been maintained while others completely failed after only a single year [270].

Birds

Like other coastal areas of Texas, WB is an important habitat for water birds and shorebirds. North Deer Island, on the eastern end of WB, has been identified as one of the most important bird rookeries on the upper Texas coast, with between 20,000 and 40,000 nesting pairs of birds of 17 species [269]. More than 500 bird species reside, winter or migrate through southeast Texas. Threatened bird species in the WB and GB area include *P. occidentalis, E. rufescens, P. chihi,* wood stork, *Mycteria americana* and *H. leucocephalus* [269]. Other bird species found in WB include the olivaceous cormorant, *Phalacrocorax brasilianus, A. herodias, A. ajaja*, black-crowned night heron, *Nycticorax nycticorax, E. tricolor,* ibises (Family Threskiornithidae), laughing gull, *Leucophaeus atricilla,* great egret, *Ardea alba, E. thula,* little blue heron, *Egretta caerulea*, terns, *Sterna sp*., *R. niger, R. americana*, *C. semipalmatus*, sanderling, *Calidris alba*, western sandpiper, *Calidris mauri*, dunlin, *Calidris alpina*, dowitcher, *Limnodromus olivaceus* and *P. squatarola* [269].

Fish & invertebrates

The most abundant fish and invertebrate species and the seasons they are found in the highest abundance in WB are *M. undulatus* (winter-spring), *A. mitchilli* (late spring-fall), *L. setiferus* (summer), *B. patronus* (spring), *L. xanthurus* (spring), *F. aztecus* (spring), *C. arenarius* (spring-summer), *C. sapidus* (winter-spring) and *A. felis* (all seasons) [119]. Other species found in WB are *C. similis*, *S. empusa*, *T. similis*, *S. lanceolatus* (late spring-summer), *S. plagiusa* (late spring-summer), *L. brevis* (summer-fall), *D. texana*, *P. lethostigma*, *S. ocellatus*, *C. nebulosus*, *A. probatocephalus*, *L. rhomboides*, *B. marinus*, *P. cromis*, *O. beta*, *M. beryllina* and *M. cephalus* [119].

Common bottlenose dolphins

Data assessments

Tursiops truncatus are the only marine mammals found in WB [269]. Surveys of *T. truncatus* have found they predominantly utilize Chocolate Bay, a sub-bay of WB, and the San Luis Pass area, rather than WB proper (although they may travel through it) [271].

There are no studies regarding the population structure of the *T. truncatus* assemblage(s) in WB. There are no robust estimates of the abundance of *T. truncatus* in GB from the last five years. However, there were several studies of the abundance and habitat use of *T. truncatus* in this area in the 1990's and early 2000's.

In 1990, surveys around Galveston Island sighted 16 groups of *T. truncatus* at the southwest end of WB, near San Luis Pass (including Gulf of Mexico waters); however, no sightings were made in the central or northeast portions of WB [271]. Based on these observations, it was hypothesized that *T. truncatus* in the southwest areas of WB do not travel to the northeast parts of the bay. Surveys in 1995 and 1996 identified 37 resident and 34 transient (in Gulf waters) *T. truncatus* in the San Luis Pass area [271]. Of the 71 individuals identified in the 1995 and 1996 surveys, 14 were also present in 1990, suggesting some animals had long-term site fidelity [271]. Three of the 71 animals were also sited in GB, indicating some movement of animals between these sites [271]. Resident animals displayed seasonal patterns in movements; during the summer, *T. truncatus* were most often sighted in Chocolate Bay while in the winter months they were more commonly found in the Gulf of Mexico [271]. This seasonal shift in the distribution of *T. truncatus* was linked with environmental changes in the bay and the distribution of prey species [271]. For instance, the temperature and salinity of WB decreases in the winter months, resulting in many fish and invertebrate species migrating out of the bay and into the Gulf of Mexico, where they spawn, then returning to the bays in the spring and summer when salinity and temperatures in the bay increase [271]. During the 1995 and 1996 surveys, the average group size was 10.6 animals (n = 83 groups sightings), with the largest groups occurring in the spring and the smallest groups occurring in the fall [272]. The results also indicated that *T. truncatus* preferentially associated with particular individuals while avoiding others [272].

From 1997 to 2001, abundance surveys of *T. truncatus* were conducted in WB and Chocolate Bay in continuation of the studies conducted in 1990 and 1995 [273]. Since the 1990 study, 13 animals demonstrated site fidelity through to 2001 and since the 1995 studies, 41 animals fulfilled residency requirements to 2001, although the status of seven animals from the latter category was undetermined at the end of the survey period in 2001 [273]. The density of *T. truncatus* in the study area from 1997 to 2001 varied from 0.94 to 1.01 dolphins/km^2. As was the case in earlier surveys, there appeared to be a seasonal shift in resident dolphin movements, with higher dolphin densities in the Chocolate Bay during the summer and higher *T. truncatus* densities in the Gulf waters in the winter [273]. Estimates of abundance in WB in the summer ranged from 28 (95% CI = 26 – 71) in 1998 to 38 (95% CI = 33-51) in 2000 [273].

In 2002 and 2003, surveys identified 110 individual dolphins around the San Luis Pass and Chocolate Bay areas. Of the 110 dolphins, 75 were 'Gulf ' dolphins that were typically sighted only once and 35 were residents, which used both WB and Gulf waters [274]. Of the 35 resident dolphins, 25 were previously identified in the San Luis Pass and WB area in other studies [271, 274]. When compared to the dolphins in GB, the patterns of association between resident animals (n = 35) in the surveys in the San Luis Pass area were stronger [274].

A study of the behavior and foraging patterns of the *T. truncatus* in the San Luis Pass area found that the behavior of resident bay and Gulf dolphins differed [275]. Resident bay dolphins primarily foraged in WB and Chocolate Bay and the pass area in groups while coastal *T. truncatus* primarily foraged alone in the coastal areas [275].

Unusual Mortality Events

In 1990, a mortality event occurred from January through May along the entire northern Gulf of Mexico coast from Florida through Texas with 46% of the 344 carcasses being collected in Texas [78]. However, at this time, the Texas Marine Mammal Stranding Network (TMMSN) was more developed than some of the stranding networks in other Gulf states, which may have led to a higher proportion of stranding reports from Texas [78]. The winter of 1989-1990 was colder than normal throughout most of the Gulf [78] and the influence of the cold weather on the UME is unclear. During this event, one *T. truncatus* stranded in WB proper and 25 *T. truncatus* stranded on Galveston Island (Figure 4). It is unknown whether the stranded animals on Galveston Island were from an estuarine or coastal stock. Chemical contaminant levels (PCB's) were measured in 10 male *T. truncatus* that stranded in Matagorda Bay during the 1990 event [138] and in 26 *T. truncatus* collected during the event from coastal and estuarine waters from Laguna Madre to Galveston, including 10 males (three of which were calves) and three females (one calf) from the Galveston, Texas area (city) [95]. While PCB levels were relatively low in the majority of the dolphins, PCB levels in a few animals were high enough to potentially negatively impact reproductive success in females [21, 138]. However, contaminant levels were not considered the cause of this mortality event [78]. Retrospectively it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this UME was not confirmed [78].

An UME was declared for Texas from December 1993 through May 1994, with a total of 236 *T. truncatus* and four unidentified dolphin strandings in Texas, most of which were recovered along the beaches from the Matagorda Peninsula to Sabine Pass [79]. During this event, one *T. truncatus* was recovered in WB proper and 51 were recovered from the Gulf side beaches along Galveston Island in the WB area, however, latitude/longitude data are not available for two additional animals in the WB area (Figure 5). Whether the stranded animals on Galveston Island were from a coastal or estuarine stock is unknown. The confirmed cause of this UME was morbillivirus [70, 71, 139].

In 2007, an UME was declared in Texas in February and March when 64 *T. truncatus* and two unidentified dolphins stranded, primarily in Galveston and Jefferson counties in Texas (with a few were found in nearby Cameron Parish, Louisiana) (Figure 14) [79]. The following year, in 2008, an UME was declared again in Texas for February and March, during which 111 *T. truncatus* stranded [79]. A high proportion of neonates were recovered in both of these events and most carcasses were found primarily on the Gulf-side beaches. Of the 64 *T. truncatus* and two unidentified dolphins stranded during the 2007 event, 18 animals were stranded along the Gulf side of Galveston Island in the WB area (Figure 14). Of the 111 *T. truncatus* strandings during the 2008 event, two animals were recovered from WB proper while 35 animals were stranded along the Gulf side of Galveston Island in the WB area (Figure 6). Whether the animals recovered from Galveston Island during these two events were from estuarine or coastal stocks is unknown. The 2007 and 2008 UME's had a high proportion of perinate strandings, which suggests an infectious agent that can cause late term abortions or early neonatal loss, such as the bacterium *Brucella*, may have been involved in these events; transmission of this bacteria is often through placental tissues and maternal feeding, resulting in aborted fetuses [79, 140]. An analysis of gastrointestinal contents from animals stranded in 2008 revealed the presence of HAB toxins domoic acid and okadaic acid (associated with a *Dinophysis* spp. and *Prorocentrum* spp. toxic algae bloom occurring at the time) in some of the stranded dolphins [109]. Low levels of brevetoxin were also found despite an absence of an associated *K. brevis* bloom [109]. The levels of each HAB toxin were low relative to levels associated with acute mortality and the levels of okadaic acid were at levels of unknown effects; however the impact of multiple toxins (*e.g.,* okadaic acid, domoic acid and brevetoxin) on marine mammal health is unknown [109]. The toxicity of okadaic acid has, however, been shown to increase in the presence of a toxin (gymnodimine) produced by *Karenia* [141]. However, no definitive cause for the 2008 event has been determined [116].

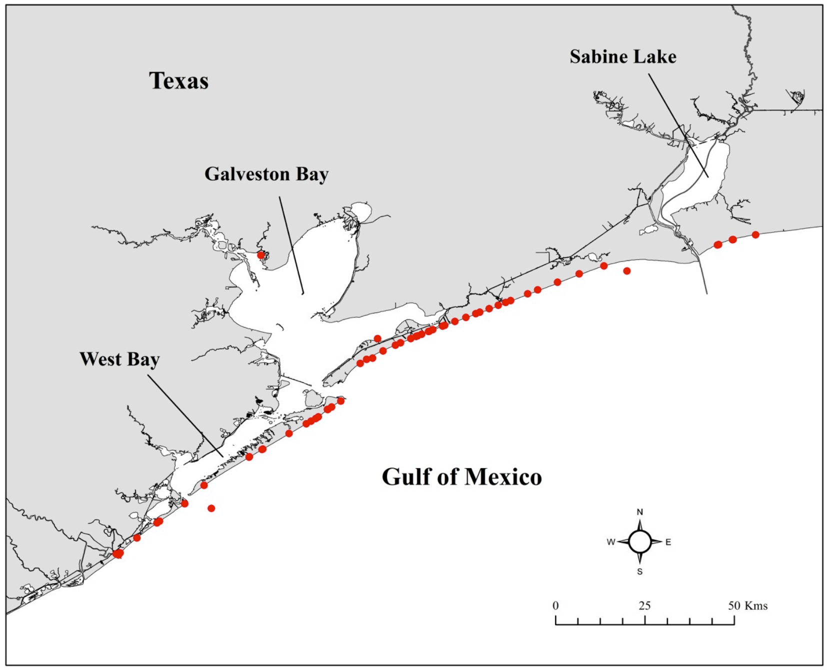

Figure 14. Location of 64 stranded *Tursiops truncatus* during the 2007 unusual mortality event. Some locations are approximate as latitude and longitude coordinates were not available and had to be estimated based on the location descriptions.

More recently, there was an UME declared from November 2011 to March 2012 involving 126 stranded *T. truncatus*. Two mortalities were recorded in WB proper while 37 were recorded on the Gulf side of Galveston Island in the WB area (Figure 7). A preliminary analysis indicated some animals had discolored teeth or a mud-like substance in their stomachs but the cause of the event remains unknown and the investigation is ongoing [142].

Potential threats

WB is influenced by the industrialized urban areas surrounding the bay and the greater GB area; most notably Houston to the north and Galveston, which lies at the eastern end of the bay where WB meets GB. Mining, oil and natural gas, petroleum and petrochemical refineries, shipping, agriculture (beef and dairy cattle, poultry, rice, figs, citrus fruit), commercial fisheries and tourism are all economically important to the area [94]. There are ~142 mineral production sites in Brazoria County and ~88 in Galveston County, for a total of ~230 sites surrounding WB [94]. These anthropogenic activities pose a number of threats to the biota that utilize this environment.

Oil & gas pollution

Oil production in 1979 in Brazoria, Chambers, Harris and Galveston counties was 52 million barrels. By 2001, production had decreased to 5.4 million barrels [276]. There have been repeated oil spills in GB, some of the more notable oil spills that impacted areas close to WB are briefly described below.

In 1979, 250,000 barrels of oil were spilled from the oil tanker, *Burmah Agate*, after it collided with another vessel in the Gulf of Mexico off of Galveston, Texas [277]. A large portion of the oil was consumed by fire, with 2,100 barrels reaching the shore. The most severe impacts occurred on the western end of Galveston Island (ocean side), with some oil also reaching the entrance to GB [277]. In 1990, 692,000 gallons of catalytic feedstock oil spilled into GB when the tank ship *Shinoussa* collided and sank a tank barge, *Apex 3417*, and damaged a second tank barge in the Houston Ship Channel [278]. The spill prompted a temporary ban on shellfish harvesting, shrimping and other fisheries across most of GB and threatened important nesting grounds for birds [279]. A second major spill in 1990 occurred in the Gulf of Mexico, off the coast of Texas when the tank ship *Mega Borg* exploded during a cargo transfer of oil with another vessel [280]. An estimated 4 million gallons of oil were spilled into the Gulf of Mexico, forming a 50 km long slick, with some tar balls eventually washing up in GB [279, 280]. In 1991, 40,000 gallons of oil were spilled from an Amoco Pipeline CO barge facility into the GICW and into GB where it posed a threat to wildlife habitat [279]. From 1998 to 2009, 3,746 spills with a total volume of ~416,000 gallons were reported in the Lower GB watershed [269]. While the majority of spills were small in nature, there were a few larger spills [269].

Heavy metal & chemical pollution

WB receives pollution from storm water runoff, domestic sewage, industrial discharge from the petroleum and chemical plants and refineries, agricultural run-off and pollution from shipping traffic [269, 281, 282]. It has been estimated that cumulatively, the GB estuary area, which includes WB, receives more industrial and household wastes than all other Texas estuaries and their local watershed combined [283]. A number of studies examining the concentrations of contaminants in the sediments and fish tissues in the GB area have included testing of samples from WB. Recent analysis of sediment samples collected in the bays of GB in 2009 and 2010 found that samples rate as 'very good' in terms of concentrations of heavy metals and some show improvement since the 1970's [269]. Two sediment samples collected from WB in 2000 had levels of PCB's that exceeded the safety thresholds [269].

Heavy metal and chemical concentrations in sediments and fish tissues have historically been and are of current concern; there are, at times, advisories for the consumption of seafood in some areas of WB [191, 269]. Mercury concentrations in the tissues of fish and crab in the GB/WB area appear to have increased since the 1970's, but the values are typically still below those thought to be of concern to human health, as are the concentrations of other heavy metals [269]. However, one *A. probatocephalus* from WB in 1999 had mercury levels that exceeded the screening levels [269].

Trace metals and organic contaminants have been measured and monitored in oysters in the GB estuary area since 1986, with the development of the National Status and Trends (NS&T) Mussel Watch Program, an initiative by the National Oceanic and Atmospheric Administration (NOAA) to assess the contaminant levels in coastal and estuarine environments [281, 284]. From 1986 to 1994, the concentrations of PCB's, DDT and dieldrin in oysters from WB generally decreased; however, the concentration of PCB's in oysters generally exceeded the limit for sub-lethal effects [281]. From 1986 to 1990, the average concentrations of cadmium, chromium, copper, manganese and lead in oysters from WB were within 10% of those elsewhere in the Gulf of Mexico [284]. However, over this same time period, concentrations of silver, nickel, selenium, tin and zinc were 20% (or more) higher in oysters from GB and WB [284]. In particular, the levels of lead in oysters from WB were much higher than those in oysters from elsewhere, including those from GB [284]. In a second study, oysters collected from GB and WB from 1986 to 1998 were found to contain PAH's with no evidence of declines in concentration over time [285]. The types of PAH's found were indicative of petroleum or petroleum product contamination, urban run-off and industrial activities and were at levels considered high when compared to national levels [285].

Levels of contaminants were assessed in the diet and tissues of waterbirds at the eastern end of WB in the 1980's [286, 287]. Low levels of DDE, DDD and high levels of PCB's were found in all prey fish [286]. Both DDE and PCB's were found at detectable levels in the tissue of *P. brasilianus*, *L. atricilla* and *R. niger* and their eggs, with evidence of bioaccumulation [286, 287]. The concentrations of DDE found in eggs were at a level known to cause reproductive problems in some birds [287]. However, no eggshell thinning was associated with the high levels of DDE and the levels of DDE were still reduced when compared to the levels measured in the 1970's, although the levels of PCB's had not decreased [287].

In a study measuring the levels of heavy metals in *P. brasilianus*, *L. atricilla* and *R. niger* from the eastern end of WB in 1980-1981, lead, mercury, cadmium and selenium were detected in all three species [288]. The levels of lead and cadmium were below the levels known to be lethal to birds or cause behavioral changes [288]. The levels of mercury were generally above background levels, although none approached the lethal range for terrestrial birds, although they may be at levels thought to have sub-lethal impacts [288]. The levels of selenium in some of the birds exceeded the levels that are associated with reduced fecundity and reproductive problems in chickens [288].

Marine debris

Specific information regarding the amount of marine debris within WB bays is lacking, however, marine debris is a threat virtually anywhere anthropogenic activities are occurring through littering (intentional or accidental) or via household or industrial wastes [242, 243].

Recreational & commercial fisheries & aquaculture

Commercial fisheries are economically important in the WB area. In the 1990's, GB, including WB, was ranked as the second most productive estuary in the U.S. in terms of seafood production [276]. The most commercially important species for the entire GB estuary complex are shrimp, oysters and *C. sapidus*, although shrimp are the most important for WB [276].

Long-term CPUE data from 1977 to 2009 exhibit no trend in the harvest of *L. setiferus* using bag seines [269]. Long-term CPUE data for *M. undulatus* from 1977 to 2009 in WB, on the hand, exhibit an increasing trend in both trawls and gillnets (the later trend observed only in WB of the GB complex) [269]. However, since 1982, the average size of *M. undulatus* in the trawl catches has decreased significantly (by ~1 cm), while larger *M. undulatus* are caught in gillnets [269, 289]. CPUE data from 1977 to 2009 for *C. nebulosus* using bag seines show no trends while data using gillnets demonstrated an increase in CPUE as well as an increase in catches in the older age classes [269]. *Lutjanus griseus* is a tropical/subtropical marine species and is generally only found in WB within the GB estuary complex because WB typically has higher salinities. *Lutjanus griseus* appear in the catch records sporadically in WB in the 1990's and then more consistently in the mid-2000's, increasing in frequency into the late 2000's, suggesting that the species gradually expanded its range to include WB [269]. Recreational fisheries are also economically important in the GB estuary complex, including WB, generating over $2.8 billion in economic activity annually [269]. There is currently no aquaculture in WB.

Fishing gear poses a threat to *T. truncatus* as they can become entangled in or ingest fishing lines or nets. There are no reports of fisheries interactions involving *T. truncatus* in the stranding records for WB [159].

Shipping, dredging & construction

Shipping is very important in the greater GB estuary complex with ports in Houston, Texas City and, at the eastern end of WB, Galveston. There are no large ports within WB proper. The major shipping channel that runs through WB is the GICW, the coastal canal that runs nearly 1,700 km, from Brownsville Texas to Fort Myers Florida. The GICW is dredged by the Army Corps of Engineers to maintain a minimum depth of 4 m and is designed for transportation of crude petroleum and petroleum products, iron, steel, fertilizer and other bulk products [269]. The GB Ship Channel is a major navigational channel that is 6.8 km long and 12 m deep (which must be dredged regularly) and provides entry to GB at the eastern end of WB, where WB meets GB [290]. Waterfront developments and the associated decrease in water quality from dredging and increased pollution is believed to have led to the complete loss of seagrass beds in WB [268].

Noise

There are no specific data on marine noise in WB, however given that there is a substantial amount of boat traffic, shipping, activity around the port in Galveston at the west end of WB and dredging activities, there is likely some consistent level of marine noise in the WB area.

Tourism & boat traffic

Tourism is economically important to the WB area. Important tourism activities include recreational fishing, boating, duck hunting, bird watching, camping and sightseeing [269, 276]. With more than 88,000 recreational boats registered in the GB estuary complex (including WB), impacts of boating activities include disposal of sewage, propeller scarring, re-suspension of sediment, increased shoreline erosion, damage to seagrass beds and boating accidents with wildlife [276]. There are two records of stranded *T. truncatus* on the Gulf side of the barrier islands of WB in 2002 and 2009, each with injuries indicative of a boat collision.

Algal blooms

Within the bays and bayous of GB and WB, fish kills due to phytoplankton blooms and low dissolved oxygen are an almost annual occurrence in late summer [291]. For example, in 2005, a fish kill of more than 10,000 *B. patronus* near Galveston Island on the border of WB and GB was due to a combination of a cyanobacteria bloom and low dissolved oxygen [291].

In addition, there are occasional *K. brevis* blooms that impact the Texas coast, including the entire GB system, which result in fish kills and the closure of shellfish beds. In August 2012, there was a *K. brevis* bloom in GB and WB, that resulted in a large fish kill of ~1 million fish [168]. From September 2011 to January 2012, there was another large *K. brevis* bloom along the Texas coast and in most of the bays, including GB and WB that was responsible for the temporary closure of all Texas shellfish beds, including those in GB and WB and fish kills in GB. Previously, large red tides that affected WB and resulted in the closure of shellfish beds and fish kills also occurred in 2000, 1996, 1986, 1976 and 1972 [57].

The toxins from harmful algal blooms have been found in tissues from *T. truncatus* in the 2008 UME despite the absence of a bloom. The 2011-2012 UME, which resulted in *T. truncatus* mortalities in WB and the Gulf side of Galveston Island, also coincided with the large *K. brevis* bloom and could have played a role in this event (see Unusual Mortality Events).

Hypoxia

The dissolved oxygen levels in the GB estuary area, including WB, have recently been determined overall to be 'good' [292]. However, in 1998, a major fish kill event occurred in WB (and East Bay) as low dissolved oxygen waters from GB were pushed into the former bays after Tropical Storm Frances [61]. Data from water samples collected in sub-bays of WB from 1969 to 2009 revealed a declining trend in dissolved oxygen concentrations, although the reported values remain within the range considered healthy [269].

Adverse weather

WB is affected by hurricanes and tropical storms. Since 1871, 18 named storms have hit GB. This area is affected by tropical systems on average every 2.66 years and it gets a direct hit roughly once every 8.29 years [293]. In 1998, Tropical Storm Frances, hit the GB/WB area, pushing low dissolved oxygen waters from GB into WB (and East Bay), generating a major fish kill event [61]. In 2008, Hurricane Ike hit the GB and WB area and substantially impacted the ecosystem [269]. For example, the storm surge inundated wetlands, increased the salinity of the soil and resulted in vegetation die-offs [269]. Oyster reefs were buried by re-suspended sediment, large fish kill events were recorded, 200 chemical spills were reported during flooding plus an unknown number of unreported spills and marine debris littered WB and GB [269].

Hurricanes and tropical storms are not the only adverse weather to affect WB; there are occasional cold freezes that cause fish kills. In 1983 and 1989, 15.7 and 22 million fish were killed, respectively, as a result of unusually cold weather in the GB estuary complex [61].

Freshwater inflows

WB receives freshwater inflow directly from Chocolate Bayou, Mustang Bayou and other small bayous [269]. Compared to nearby GB, WB receives lower volumes of freshwater inflows and is a more saline environment [269], however, freshwater inflows are generally reported for the GB estuary as a whole, inclusive of WB.

Habitat loss
While habitat loss has been substantial throughout most of GB due to subsidence and the extraction of groundwater and petroleum, most of the habitat loss due to subsidence in WB is limited to the northeastern parts of the bay [294]. However, habitat loss in WB has occurred through conversion of wetlands to croplands in the Chocolate Bay area from the 1950's to the 1990's [269]. Most seagrass beds in WB had disappeared by the 1980's [221, 268].

In 1989, the GB Estuary Program (GBEP) was established to increase public awareness and monitor habitat degradation, wetland loss and pollution in the GB area, including WB [292]. The GBEP has a regional monitoring plan for GB, organizing the efforts of different agencies to ensure data availability without duplication of effort. The GBEP and its partnering agencies have restored 32 km^2 of habitat so far and are currently working to increase wetland conservation, control exotic species, promote water conservation and assess the safety of consuming seafood from GB, among other goals [292].

Disease
Morbillivirus was the confirmed cause of the 1993-1994 UME in Texas, which included one common bottlenose dolphin mortality from WB proper and 51 mortalities on Gulf side beaches along Galveston Island adjacent to WB, as well as two mortalities in the WB area that had no associated latitude/longitude data (Figure 5) [70, 71, 139]. Morbillivirus was retrospectively thought to possibly be the cause of the large die-off in 1990, but a definitive cause for this UME was not confirmed. The 1990 die-off included one *T. truncatus* stranding from WB proper and 25 on Galveston Island (Figure 4). In addition, *Brucella* was suspected to be the cause of the 2007 and 2008 UME's due to the high proportion of perinates in each of these events, but this could not be confirmed [79]. The 2007 UME involved 18 *T. truncatus* strandings on the Gulf side of Galveston Island adjacent to WB (Figure 14) and the 2008 UME involved two *T. truncatus* strandings in WB proper and 35 strandings along the Gulf side of Galveston Island adjacent to WB (Figure 6). Other diseases affect common bottlenose dolphin, however, here we highlight those that have been associated with high levels of mortality.

Climate change
Climate change is likely to have a significant impact on all Texas estuaries. Climate change is expected to substantially impact this area with rising sea levels, increased shoreline erosion and declines in water quality [175]. The national assessment of coastal vulnerability to sea level rise ranks the WB area as 'moderate' for the inshore areas to 'very high' risk for the Galveston Island area [176]. A rank of 'moderate' is a relative sea level change of 2.5 to 3.0 mm/year while a rank of 'very high' is a relative sea-level change of more than 3.4 mm/year [176]. In addition, climate change could potentially increase the frequency and duration of hurricanes and potentially harmful algal blooms along the Texas coast [178, 179, 269].

UME's of unknown etiology
The large die-off in 1990 and the UME's in 2007 and 2008, as previously described (see Unusual Mortality Events), were of unknown etiology and involved animals from WB. The investigation

into the 2011 – 2012 UME is ongoing. The suspected cause of the 1990 event was retrospectively thought to be the morbillivirus, however, this was not confirmed to be the definitive cause of this die-off so this event is considered of unknown etiology. The 2007 and 2008 UME's were also of unknown etiology, although it was suspected *Brucella* could have played a role. The 1990 die-off involved one *T. truncatus* stranding from WB proper and 25 on Galveston Island (Figure 4). The 2007 UME involved 18 *T. truncatus* strandings on the Gulf side of Galveston Island adjacent to WB (Figure 14). The 2008 UME involved two *T. truncatus* strandings in WB proper and 35 strandings along the Gulf side of Galveston Island adjacent to WB (Figure 6). For the 2011-2012 UME, two *T. truncatus* were recovered from WB and 37 strandings were recovered along the Gulf side of Galveston Island adjacent to WB (Figure 7).

Incidental research takes

Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in gillnets from fisheries research activities by Texas Parks and Wildlife [80]. Of these 31 incidents, none occurred in WB [80].

Threat assessment for *Tursiops truncatus* in West Bay

Citations are included where supporting data are available. The maximum number of points per threat is 12 and the maximum total number of points possible is 228.

With a cumulative threat score of 123 and a lack of up-to date assessment data, the West Bay stock ranks a high priority.

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Oil & gas pollution	2[276-278]	2[277, 279]	3[13]	7
Heavy metal pollution	2[269]	3[269, 284, 288]	3	8
Chemical pollution	2[269, 283]	3[191, 268, 269, 281, 285-288]	3[66, 95]	8
Marine debris	1	2	3	6
Recreational fisheries	1[269, 276]	3[276]	3[4, 159]	7
Commercial fisheries	1[269, 276]	2	3[26, 102, 103]	6
Aquaculture	0	NA	NA	0
Shipping	1[269]	2	3[35]	6
Dredging & construction	1[269, 290]	2[268]	3[106]	6

continued

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Noise	1	2	3[38, 43]	6
Tourism & boat traffic	1[269, 276]	2	3[54]	6
Algal blooms	2[57, 168, 170]	3[57, 168, 291]	3[109]	8
Hypoxia	1[269]	2[61]	3[60]	6
Adverse weather	2[293]	5[61, 268, 269]	3[62]	10
Freshwater inflows	1[269]	2	3[66]	6
Habitat loss	1[269, 294]	2	3	6
Disease	1[70, 71]	0	5*[69-72]	6
Climate change	1[176]	2	3[76]	6
UME of unknown etiology	2[78, 116, 142]	2	5*[78, 142]	9
Total				123

*mortality event was along the Texas coast that included animals from this BSE, but was not contained solely within this BSE

DAS scoring for *Tursiops truncatus* in West Bay

	Score
Information on stock structure	0
Information on abundance	0
Information on mortality	0
Total	0

BSE: Galveston Bay area

The Galveston Bay (GB) area includes upper Galveston Bay, lower Galveston Bay, East Bay and Trinity Bay (see Figure 15). West Bay (WB), to the southwest has already been described in a separate BSE summary. The Galveston Bay estuary lies to the west of Sabine Lake and to the northeast of Matagorda Bay. This estuary system is the second largest on the Texas coast [1], the seventh largest in the United States [268, 295] and was declared an estuary of national significance by the U.S. Environmental Protection Agency National Estuary Program in 1989 [268, 296]. The overall condition of GB is on the low side of 'fair', based on water quality (poor), sediment quality (fair to poor), benthic index (fair) and fish tissue contaminants (good to fair) [292].

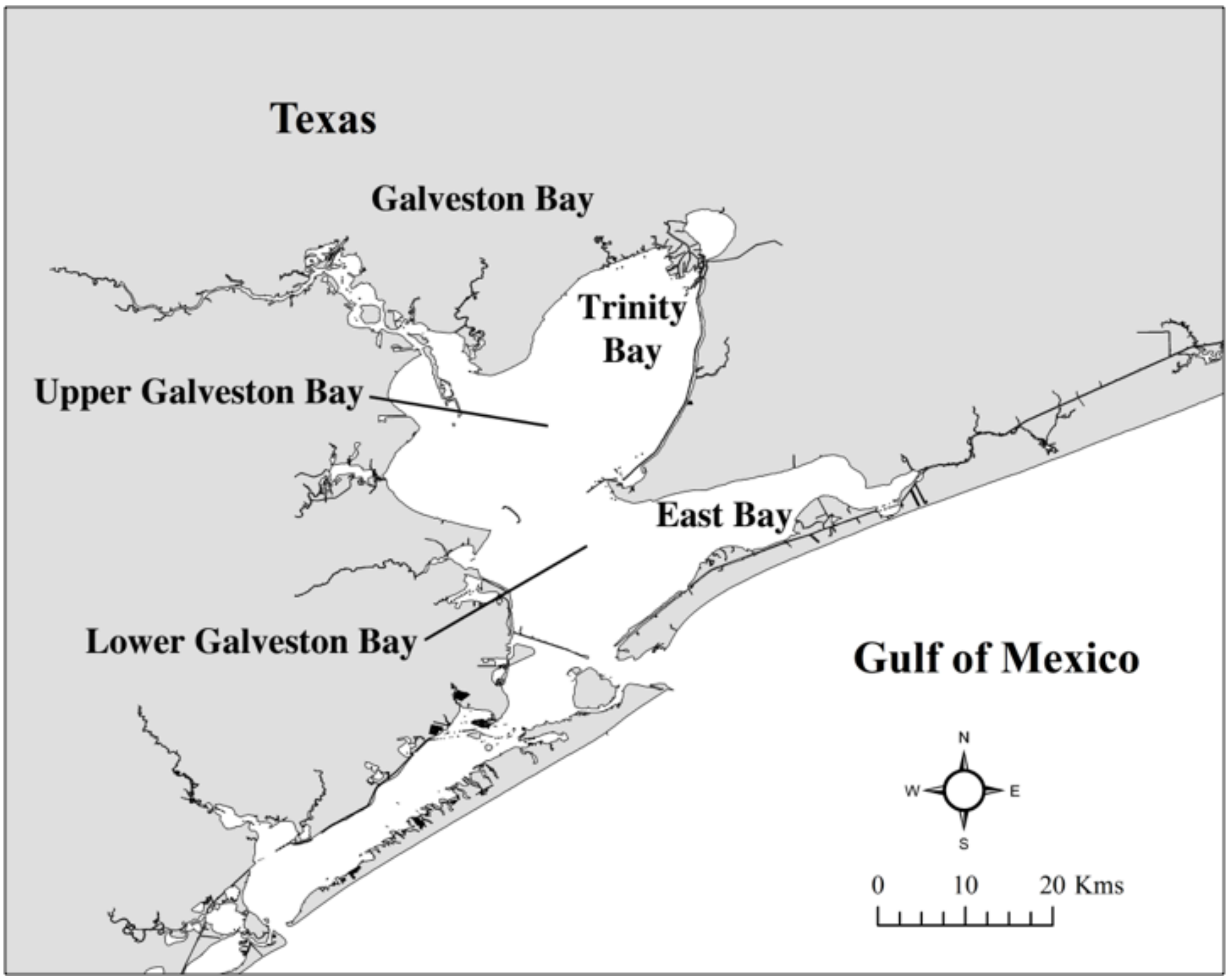

Figure 15. Galveston Bay estuary, Texas

Physical attributes

GB is a large, shallow bay with a surface area of ~1,399 km^2, an average depth of 2 m [105, 119] and a maximum depth of 13 m [94]. The average salinity of GB is 11 to 17.6 ppt [119, 296]. The GB area receives roughly 135 cm of precipitation each year with a loss of ~119 cm/year due to evaporation, resulting in a net gain of 16 cm/year [119]. The long-term annual average air temperature is 21.1°C (69.9°F) with a range of 12.7°C (54.9°F) to 28.5°C (83.3°F), based on temperature data for 97 years, although this data is only through 1969 [94]. The water surface temperature of GB ranges from highs of almost 29°C (84°F) in summer to lows of 14°C (57°F) in winter [269]. GB experiences diurnal tides ranging from 0.3 to 0.5 m in the three main bays (GB, Trinity Bay and East Bay) [94]. GB is separated from the Gulf of Mexico primarily by Bolivar Peninsula and partially by Galveston Island to the south [296]. Exchange with Gulf waters occurs through Bolivar Pass (also known as Bolivar Roads), Rollover Pass (since 1955) and San Luis Pass via WB [296]. Rollover Pass is a man-made pass through the Bolivar peninsula that was constructed in 1955 to improve water quality, promote fish migration into East Bay and improve local recreational fisheries [297]. However, the pass greatly altered the dynamics of sediment transport in the area, increasing shoreline erosion of adjacent beaches and depositing sediment in the GICW that must continually be dredged [297]. In addition, the construction of Rollover pass has substantially increased the salinity in East Bay and Rollover Bay as well as increased the risk of oil and/or pollutant spills entering East Bay [297]. For these reasons, the U.S. Army Corps of Engineers and Texas General Land Office has applied to close Rollover Pass [297].

Biota

Seagrass

Ruppia maritima and *H. wrightii* are the predominant seagrasses found in GB, both historically and currently [268]. There has been a substantial loss in seagrass in GB since the 1960's [269]. In 1956, there were ~20.7 km^2 of seagrass beds in GB, most of which disappeared by the mid to late 1970's [268, 295, 298]. There are a number of factors attributed to the loss of seagrass beds in GB and in some cases, the flourish of seagrass in the 1950's. For instance, the severe drought of the 1950's reduced the levels of freshwater flow into GB, subsequently decreasing turbidity, which may have allowed seagrass beds to flourish in the mid 1950's [268]. Since the early 1960's, however, the abundance of seagrass in GB has declined considerably, notably coinciding with Hurricane Carla, which has been attributed with damaging seagrass beds in parts of GB [269, 295, 299]. The inability of seagrasses to recover in most of GB after Hurricane Carla has been linked with poor water quality and high turbidity, largely from urban developments, dredging and pollution [268, 270, 295]. Seagrass restoration projects, including several seagrass transplanting projects, have been underway in GB since the mid 1990's with the objective of creating 1,400 acres of seagrass beds [295, 300]. Such projects have had limited success in both GB and nearby WB [269, 270, 295, 300].

Birds

Like other coastal areas of Texas, GB is an important habitat for water birds and shorebirds. More than 500 bird species reside, winter or migrate through southeast Texas [301]. Threatened bird species in the GB area include *P. occidentalis, E. rufescens, P. chihi, M. americana* and *H. leucocephalus* [269]. Other bird species found in GB include *P. brasilianus, A. herodias, A. ajaja*, *N. nycticorax, E. tricolor,* ibises (Family Threskiornithidae), *L. atricilla, A. alba, E. thula, E. caerulea*, *Sterna sp*., *R. niger, R. americana*, *C. semipalmatus*, *C. alba*, *C. mauri*, *C. alpina*, *Limnodromus sp*. and *P. squatarola* [269].

From 1987 to 2006, the numbers of *N. nycticorax*, *A. herodias*, *E. tricolor*, *P. chihi*, *E. rufescens*, *L. atricilla* and *P. brasilianus* decreased substantially in GB [269]. The reasons for these declines in abundance are not clear, but may be related to a decrease in the quality or availability of nesting and feeding habitat (*e.g.,* wetlands), human disturbance or predation [269, 276]. On the other hand, *P. occidentalis* has shown a dramatic increase in abundance in GB. In the 1980's there were no *P. occidentalis* nesting in the GB area, however in 2006, more than 1,800 breeding pairs were observed [269].

Fish & invertebrates

The most abundant fish and invertebrate species and the seasons they are found in the highest abundance in GB are *M. undulatus* (winter-spring), *A. mitchilli* (late spring-fall), *L. setiferus* (summer), *B. patronus* (spring), *L. xanthurus* (spring), *F. aztecus* (spring), *C. arenarius* (spring-summer), *C. sapidus* (winter-spring) and *A. felis* (all seasons) [119]. Other species found in GB are *C. similis*, *S. empusa*, *T. similis*, *S. lanceolatus* (late spring-summer), *S. plagiusa* (late spring-summer), *L. brevis* (summer-fall), *D. texana*, *P. lethostigma*, *S. ocellatus*, *C. nebulosus*, *A. probatocephalus*, *L. rhomboides*, *B. marinus*, *P. cromis*, *O. beta*, *M. beryllina* and *M. cephalus* [119]. GB remains an important nursery area for many estuarine fish despite the loss of seagrass beds from most of the bay [302, 303].

In a study assessing 55 years of fish kills in coastal Texas waters, GB had the highest number of fish kill events and the highest numbers of fish killed [61]. From 1951 to 2006, there were approximately 400 fish kill events in GB, with over 141 million fish killed [61]. The fish kills were generally caused by low dissolved oxygen (see Hypoxia), pollution (see Heavy metal and chemical pollution), cold freezes (see Adverse weather) and algal blooms (see Algal blooms) [61]. The majority of the fish killed in these events were *B. patronus*, followed by *M. cephalus*, *L. rhomboides* and *M. undulatus* [61].

Other species

Three threatened species of turtle can be found in GB as they migrate along the coast, *L. kempii, C. mydas,* and loggerhead sea turtle, *Caretta caretta* [269]. There was once a diamondback-terrapin, *Malaclemys terrapin,* fishery in GB that was overexploited in the 1800's [269].

Common bottlenose dolphins

Data assessments

Common bottlenose dolphins are the only marine mammals regularly found in GB [269]. There are no studies regarding the population structure of *T. truncatus* in the GB area. There are no robust estimates of the abundance of common bottlenose dolphins in GB within the last five years. However, there were studies of dolphin abundance and habitat use in this area during the 1980's and 1990's.

A study from 1982 to 1984 observing a 170 km^2 area near the city of Galveston found that *T. truncatus* densities varied from zero to 3.294 individuals/km^2 (±4.325) off the beaches, 1.848 individuals/km^2 (±2.613) in the channels and 0.104 individuals/km^2 (±0.212) in the bays [304]. It was also observed that the abundance of *T. truncatus* in GB was highest in the spring and the dolphins appeared to have a strong preference for the areas around the bay inlet [304]. Observed group sizes were between 1-27, with an average of 3.1 animals per group [304].

In the summer and fall of 1991, the behavior of *T. truncatus* in the GB system and the adjacent Gulf of Mexico waters was observed [305]. Over 1,000 individuals were identified during this study, approximately 200 of which were believed to be residents [305]. Feeding behaviors were found to increase in the fall, possibly due to higher energy requirements as a result of the decrease in water temperatures and the decrease in prey abundance as many fish species migrate out of the bay system [305].

Surveys of the GB Ship Channel from 1990-1992 found that *T. truncatus* utilized the channel year round, but abundances peaked in the spring and fall [290]. A total of 240 *T. truncatus* were identified, 56 of which were observed in all three survey years [290]. During the survey, a number of animals had distinctive markings; some from natural sources while others were likely the result of human interactions. Five of the individuals had scars that were consistent with wounds from shark bites, *e.g.,* crescent shaped [290]. Ten *T. truncatus* had scars, cuts or markings suggestive of boat propeller injuries and others (number not reported) had bent or cut dorsal fins [290]. In addition, one *T. truncatus* had marks consistent with a rope around its girth and another had a fluke that appeared to have been cut with a knife [290].

During photo identification surveys from 1990-1991, 1,000 individual *T. truncatus* were identified in GB and the coastal Gulf waters around the northeast end of Galveston Island [56]. However, the majority of animals were only sighted once, suggesting that many were travelling through the area, with only 200 individuals utilizing the area long-term [56]. Patterns of association between individuals (n = 34) in the survey area were weak, with exchange of members between groups [56].

In Matagorda Bay (south of GB), range size and site fidelity of *T. truncatus* was assessed via radio tracking and photographic surveys from 1992-1993 [226, 237]. One of the freeze branded animals tagged in Matagorda Bay (FB523) was sighted offshore near Galveston, Texas jetties in May and June 1994 [237]. Furthermore, in a study of site fidelity and habitat use of *T. truncatus* in the southwestern end of the GB estuary complex in 1995-1996 (see BSE: West Bay for details), three animals identified in San Luis Pass were also seen in GB, indicating some movement between these sites sometimes occurs [271].

A study in 2001 surveyed almost 4,000 km^2 of habitat to determine the environmental conditions in which *T. truncatus* most often occur and fed in GB [306]. The majority of *T. truncatus* feeding behaviors occurred in the GB ship channel and Bolivar Roads Pass [306]. Important variables in predicting whether dolphins would be present and feeding included distance to the Gulf of Mexico, surface water temperature, depth and presence of shrimp boats [306].

Unusual Mortality Events

In 1990, a mortality event occurred from January through May along the entire northern Gulf of Mexico coast from Florida through Texas with 46% of the 344 carcasses being collected in Texas [78]. However, at this time, the Texas Marine Mammal Stranding Network (TMMSN) was more developed than some of the stranding networks in other Gulf states, which may have led to a higher proportion of stranding reports from Texas [78]. The winter of 1989-1990 was colder than normal throughout most of the Gulf [78] and the influence of the cold weather on the UME is unclear. During this event, three *T. truncatus* stranded in GB proper (plus one in the ship channel just outside GB) and 14 stranded on Galveston Island (Figure 4). It is unknown whether the stranded animals on Galveston Island in particular were from an estuarine or coastal stock. Chemical contaminant levels (PCB's) were measured in 10 male *T. truncatus* that stranded in Matagorda Bay during the 1990 event [138] and in 26 *T. truncatus* collected during the event from coastal and estuarine waters from Laguna Madre to Galveston, including 10 males (three of which were calves) and three females (one calf) from Galveston city [95]. While PCB levels were relatively low in the majority of the dolphins, PCB levels in a few animals were high enough to potentially negatively impact reproductive success in females [21, 138]. However, contaminant levels were not considered the cause of this mortality event [78]. Retrospectively, it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this UME was not confirmed [78].

An UME was declared for Texas from December 1993 through May 1994, with a total of 236 *T. truncatus* and four unidentified dolphin strandings in Texas, most of which were recovered along the beaches from the Matagorda Peninsula to Sabine Pass [79]. During this event, four *T. truncatus* stranded within GB proper and 26 stranded on Gulf side beaches along Galveston Island, although latitude/longitude data are not available for an additional two animals in the GB area (Figure 5). Whether the animals recovered from Galveston Island were from an estuarine or coastal stock is unknown. The confirmed cause of this UME was morbillivirus [70, 71, 139].

In 2007, an UME was declared in Texas in February and March when 64 *T. truncatus* and two unidentified dolphins stranded, primarily in Galveston and Jefferson counties in Texas (with a few were found in nearby Cameron Parish, Louisiana) (Figure 14) [79]. The following year, in 2008, an UME was declared again in Texas for February and March, during which 111 *T. truncatus* stranded [79]. A high proportion of neonates were recovered in both of these events and most carcasses were found primarily on the Gulf-side beaches. Of the 64 *T. truncatus* and two unidentified dolphins stranded during the 2007 event, two animals were recovered from GB proper while 19 animals were recovered along the Gulf side of Galveston Island in the GB area (Figure 14). Of the 111 *T. truncatus* strandings during the 2008 event, 24 animals were recovered along the Gulf side of Galveston Island in the GB area (Figure 6). Whether the animals recovered from Galveston Island during these two events were from estuarine or coastal stocks is unknown. The 2007 and 2008 UME's had a high proportion of perinate strandings, which suggests an infectious agent that can cause late term abortions or early neonatal loss, such as the bacterium *Brucella*, may have been involved in these events; transmission of this bacteria is often through placental tissues and maternal feeding, resulting in aborted fetuses [79, 140]. An analysis of gastrointestinal contents from animals stranded in 2008 revealed the presence of HAB toxins domoic acid and okadaic acid (associated with a *Dinophysis* spp. and *Prorocentrum* spp. toxic algae bloom occurring at the time) [109]. Low levels of brevetoxin were also found despite an absence of an associated *K. brevis* bloom [109]. The levels of each HAB toxin were low relative to levels associated with acute mortality and the levels of okadaic acid were at levels of unknown effects; however the impact of multiple toxins (*e.g.,* okadaic acid, domoic acid and brevetoxin) on marine mammal health is unknown [109]. The toxicity of okadaic acid has, however, been shown to increase in the presence of a toxin (gymnodimine) produced by *Karenia* [141]. However, no definitive cause for the 2008 event has been determined [116].

More recently, there was an UME declared from November 2011 to March 2012 involving 126 stranded *T. truncatus*. Three mortalities were recorded in GB proper while 14 were recorded on the Gulf side of Galveston Island in the GB area (Figure 7). A preliminary analysis indicated some animals had discolored teeth or a mud-like substance in their stomachs but the cause of the event remains unknown and the investigation is ongoing [142].

Potential threats

GB is heavily influenced by the highly industrialized urban areas surrounding the bay, most notably Houston, Texas City and Galveston [119, 282]. The population of the counties directly surrounding GB (Harris, Chambers, Galveston) increased from 1.6 million in 1960 to approximately 4.5 million in 2012 [292, 307]. Roughly 20% of this population lives within 2 miles of GB [300]. GB is thought to be changing more rapidly due to anthropogenic activities than any other area on the Texas coast [119].

Mining, crude oil and natural gas, chemical refineries, commercial fisheries and agriculture are all economically important to the area [94]. The majority of the urban and industrial areas surrounding GB are on the western side of the bay while the eastern side is dominated by agricultural and mining activities [269, 276, 300]. There are 116 mineral production sites in Chambers County, 88 in Galveston County and 378 in Harris County, for a total of 582 sites surrounding GB [94]. As much as half of the nation's chemical production and one third of the nation's petroleum production occurs in the counties surrounding GB [276, 282, 285, 292]. There are an estimated 22 km^2 of cropland in the counties surrounding GB [269]. Major agricultural crops include rice, soybean, corn, cotton and sorghum [119, 276]. Agriculture can have a substantial impact on GB as irrigation, pest control (herbicides, pesticides) and fertilization practices can impact water quality as well as the amount and timing of freshwater inflows into the bay [269]. These anthropogenic activities pose a number of threats to the biota that utilize this environment.

Oil & gas pollution

Oil production in 1979 in Brazoria, Chambers, Harris and Galveston counties was 52 million barrels. By 2001, production had decreased to 5.4 million barrels [15]. There have been repeated oil spills in GB, some of the more notable oil spills are briefly described below.

In 1979, 250,000 barrels of oil were spilled from the oil tanker, *Burmah Agate*, after it collided with another vessel in the Gulf of Mexico off of Galveston, Texas [277]. A large portion of the oil was consumed by fire, with 2,100 barrels reaching the shore. The most severe impacts occurred on the western end of Galveston Island (ocean side), with some oil also reaching the entrance to GB [277]. In 1990, 692,000 gallons of catalytic feedstock oil spilled into GB when the tank ship *Shinoussa* collided and sank a tank barge, *Apex 3417*, and damaged a second tank barge in the Houston Ship Channel [278]. The spill prompted a temporary ban on shellfish harvesting, shrimping and other fisheries across most of GB and threatened important nesting grounds for birds [279]. A second major spill in 1990 occurred in the Gulf of Mexico, off the coast of Texas when the tank ship *Mega Borg* exploded during a cargo transfer of oil with another vessel [280]. An estimated 4 million gallons of oil were spilled into the Gulf of Mexico, forming a 50 km long slick, with some tar balls eventually washing up in GB [279, 280]. In 1991, 40,000 gallons of oil were spilled from an Amoco Pipeline CO barge facility into the GICW and into GB where it posed a threat to wildlife habitat [279]. In 1994, 200,000 gallons of oil and fuel were spilled in the Houston Ship Channel when a tugboat sunk near the mouth of the San Jacinto River [279].

From 1998 to 2009, 3,746 spills with a total volume of ~416,000 gallons were reported in the Lower GB watershed [269]. The highest number of spills was reported in Harris County, most likely because of the industrial and shipping facilities along the Houston Ship Channel [269]. While the majority of spills were small in nature, there were a few larger spills. In 2000, 70,000 gallons were spilled in a facility spill in the Houston Ship Channel [269]. In 2001, two vessel spills, one in the Houston Ship Channel and the other in GB proper, released a total of 80,000 gallons of oil [269]. Since 2009 there have been a number of small oil spills in GB [308]. In March 2014, a collision between two ships resulted in ~168,000 gallons of fuel oil spilling into GB [10]. Hundreds of birds including the threatened *C. melodus* were oiled after the spill, many of which died or had little hope of surviving [10]. In addition, a higher than normal number of common bottlenose dolphins stranded in the area in the aftermath of the spill, at least two of which had oil on their bodies. However, at this time it is not possible to conclude whether or not the increase in strandings is related to the oil spill [309]. Clean up of the oil spill was on going at the time of this report.

Heavy metal & chemical pollution
GB receives pollution from storm water runoff, domestic sewage, industrial discharge from the many petroleum and chemical plants and refineries, agricultural run-off and pollution from shipping traffic [269, 281, 282]. It has been estimated that cumulatively, GB receives more industrial and household wastes than all other Texas estuaries and their local watershed combined [283]. In 1990, it was estimated that 224 billion gallons of wastewater was discharged in GB, 174 million gallons of which was from municipal sources [269].

There are four superfund sites in the GB area, at least two of which have impacted the estuary. The superfund site, Malone Services Company, borders GB and adjacent wetlands [310]. The site served as a storage and disposal facility for oil and chemical waste from 1964 until it was shut down in 1997 [310]. Analysis of sediment samples next to the site in GB found detectable, but low levels of chromium and lead and natural siltation was determined to be the best method of remediation for these contaminants [310]. The Tex Tin Corporation superfund site is located in Texas City; the site was used for a number of different industrial chemical activities (*e.g.* tin smelting, heavy metal recovery, waste oil recovery) until the early 1990's [311, 312]. Chemical analysis of nearby sediments indicated the PAH's, aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver, tin, vanadium and zinc were collectively high enough to cause a heath concern in the late 1990's, although the levels of PAH's were not as high in relation to levels of concern to those of trace metals [311, 312]. The other two superfund sites are Hall Street, which was a waste disposal site and MOTOCO, Inc, which was at one time a waste recycling facility, with no marine impacts at either of these sites [313].

There have been a number of studies involving the concentrations of contaminants in the sediments and fish tissues in GB. Heavy metal and chemical concentrations in sediments and fish tissues in particular have historically been and are of current concern; there are often advisories for the consumption of seafood in some areas of GB [269, 314]. In general, the contaminants of greatest concern in seafood are PCB's [269, 314, 315], with fish from the Houston Ship Channel often exceeding the levels of concern for human consumption [269, 315-317]. However, no established program to monitor contaminants in seafood has been established [269]. Some of these studies are briefly highlighted below.

Contaminants in sediments

Between 2000 and 2004, dioxins were found in sediment samples from the Houston Ship Channel (where concentrations were highest), the San Jacinto River and Upper and Lower GB [269]. At least one source of dioxins is a waste site that was used for paper mills for 30 years and has succumbed to subsidence and now lies below the river [269]. Recent analysis of sediment samples collected in the bays of GB in 2009 and 2010 found that samples rate as 'very good' in terms of (low) concentrations of heavy metals and some show improvement since the 1970's [269]. The Houston Ship Channel has the worst quality of sediment in terms of heavy metals (currently rated as 'good') but this area has also shown improvement since the 1970's [269].

Contaminants in biota

Fish

Fish kills were associated with pollutants in GB in the 1960's and 1970's, triggering cleanup efforts that improved the water quality in the mid-1970's [282]. In a study assessing 55 years of fish kills in coastal Texas waters from 1951 to 2006, GB had the highest number of fish kill events and the highest numbers of fish killed [61]. A number of these events were mass mortality events related to pollutants combined with low dissolved oxygen in GB. For example, in 1971-1972, 25.7 million fish were killed from low dissolved oxygen and a hydrogen sulfide spill combined with permitted discharge and in 1980, 12.9 million fish were killed due to low dissolved oxygen conditions combined with a sewer line spill and non-point source run-off [61].

In 1990, the Texas Department of State and Health Services (TDSHS) collected fish and crabs from the Houston Ship Channel and Upper GB to test for contaminants [316]. The results from these tests found that PCB's in the tissues of *A. felis* and *C. sapidus* were at levels that could pose a risk to human health [316]. Since 1990, the TDSHS has advised that *A. felis* and *C. sapidus* from a 50 mi^2 area of GB (including the upper Houston Ship Channel from the San Jacinto River to Houston) not be consumed by children, women who are pregnant, nursing mothers and only be eaten in one 8-ounce portion per month by others due to elevated levels of dioxins [316]. In 1996, the TDSHS collected fish, oyster and crabs from the Houston ship channel and Upper GB to reassess the seafood advisory in the area, finding no change in contaminant levels to warrant the removal of the advisory [316]. In 2001, this advisory was extended to the consumption of all fish in the area of the upper Houston Ship Channel, Upper GB and lower San Jacinto River because of elevated levels of pesticides, PCB's and dioxins [276]. In 2003 and 2004, this advisory was again revisited and decided that it should continue, as the concentrations of contaminants such as PCB's in fish (*e.g., C. nebulosus*) exceeded the levels of concern for public health [316]. Assessments of contaminants in fish collected in 2006 and 2007 from lower GB found that the concentration of PCB's in *B. marinus* were at a level that posed a hazard to human health. The concentration of PCB's alone in *C. nebulosus* were not present at a level to pose a hazard to human health, however, when the PCB's were considered in combination with the levels of the other contaminants, the consumption of *C. nebulosus* was thought likely to pose a hazard to human health [316]. *Pogonias cromis*, *S. ocellatus*, *P.*

lethostigma and *C. sapidus* from lower GB collected in 2006 and 2007 did not have PCB's or other contaminants at concentrations that posed a hazard to human health [316]. More recent testing in 2008 found that almost all of the fish collected in the Houston Ship Channel had PCB concentrations that exceeded health standards [269, 315]. Mercury concentrations in the tissues of fish and crab appear to have increased since the 1970's, but the values are still below those to be of concern to human health, as are the concentrations of other heavy metals [269].

As filter feeders that are harvested for human consumption, it is important to monitor the concentrations of contaminants in oysters in GB. Trace metals and organic contaminants have been measured and monitored in oysters in GB since 1986, with the development of the National Status and Trends (NS&T) Mussel Watch Program, an initiative by the National Oceanic and Atmospheric Administration (NOAA) to assess the contaminant levels in coastal and estuarine environments [281, 284]. From 1986 to 1990, the average concentrations of cadmium, chromium, copper, manganese and lead in oysters from GB were within 10% of those elsewhere in the Gulf of Mexico [284]. However, over this same time period, concentrations of silver, nickel, selenium, tin and zinc were higher in oysters from GB by 20% or more [284]. Jiann and Presley [284] found that the trace metal concentrations of the oysters sampled in 1992 and 1993 varied between sites in GB, and only one site in lower GB had significantly higher concentrations of silver, copper, lead and zinc than those in the Gulf of Mexico [284]. The concentrations of all metals, except arsenic, were highest in the summer and lowest in the winter spring [284]. This temporal change in concentration is likely linked with changes in environmental conditions such as salinity and metal input [284].

The concentrations of DDT/DDE in oysters decreased between 1986 and 1994 and were below the limit proposed to protect wildlife [281]. The median concentrations of PAH's in oysters from GB were generally below the limit of biological effects, with the exception of samples from one site (a ship channel) in 1991 which had a history of high PAH concentrations [281]. However, the concentrations of PCB's in oysters from GB generally exceeded the limit for sub-lethal effects, although there has been a decrease in concentrations of PCB's since 1986 [281]. In a second study with four additional years of data, oysters collected from GB from 1986 to 1998 were found to contain PAH's with no evidence of declines in concentration over time [285]. The types of PAH's found were indicative of petroleum or petroleum product contamination and were at levels considered high when compared to national levels [285]. For example, the PAH concentrations in oysters from some sites in GB were in the top 25% of the most polluted sites monitored by the NS&T [285].

Birds

Levels of contaminants were assessed in the diet and tissues of *P. brasilianus* observed feeding in the Houston Ship Channel in 1980 [286]. Low levels of DDE, DDD and high levels PCB's were found in all prey fish [286]. Both DDE and PCB's were found at detectable levels in the tissue of the birds and their eggs, with evidence of bioaccumulation [286, 287]. However, no eggshell thinning was associated with the high levels of DDE and the concentrations of DDE and PCB's were reduced when compared to the levels measured in the 1970's [287]. In a similar study measuring the levels of contaminants in the diet of the *R. niger* in 1980, low levels of DDE were found in the prey species tidewater silverside, *Menidia peninsulae*, sheepshead minnow, *Cyprinodon variegatus,* and Gulf killifish, *Fundulus grandis* [318]. In addition, PCB's were also found in two prey species; in low concentrations in *M. cephalus* and in high concentrations in the *C. variegatus* [318]. Both DDE and PCB's were detected in the tissue of the birds and their eggs, with evidence of bioaccumulation [287, 318]. The concentrations of DDE found in eggs in the 1980's were at a level known to cause reproductive problems in some birds [287]. However, no eggshell thinning was associated with the high levels of DDE and the levels of DDE were still reduced when compared to the levels measured in the 1970's (PCB's did not decrease) [287].

In a study measuring the levels of heavy metals in *P. brasilianus*, *L. atricilla* and *R. niger* from 1980-1981, lead, mercury, cadmium and selenium were detected in all three species [288]. The levels of lead and cadmium were below the levels known to be lethal or to cause behavioral changes in birds [288]. The levels of mercury were generally above background levels, although none approached the lethal range for terrestrial birds, although they may be at levels to have sub-lethal impacts [288]. The levels of selenium in some of the birds exceeded the levels that are associated with reduced fecundity and reproductive problems in chickens [288].

Marine debris

Specific information regarding the amount of marine debris within GB bays is lacking. However, it is known that marine debris is a substantial problem in the GB area and the removal of large marine debris such as sunken and derelict vessels was conducted in 2005 [319]. Additional funding is being sought to continue the project [319].

Commercial & recreational fisheries & aquaculture

Commercial and recreational fisheries are important in the GB area. In fact, in the 1990's, GB was ranked as the second most productive estuary in U.S. in terms of seafood production [276]. It has been estimated that roughly one third of the state's commercial fishing income comes from the GB area [292]. *Farfantepenaeus aztecus*, *L. setiferus*, *C. sapidus* and oysters are all commercially important species [269, 292, 320]. Shrimp, which became popular in the 1920's, are considered the most important commercial fishery in GB [276]. There are some discrepancies in the catch data for shrimp over time. Long-term catch per unit effort (CPUE) data from 1977 to 2009 exhibit an increase in the harvest of *L. setiferus* using bag seines in Trinity Bay, but not in any other areas of GB [269]. In contrast, the CPUE for *L. setiferus* in trawl samples decreased from 1982 to 1990 [269, 321].

Oysters are the second most important commercial fishery in the GB area, and have operated since the 1850's [276]. The majority of oysters commercially harvested from Texas come from GB [285, 322]. The oyster reefs were estimated to cover more than 100 km^2 of the bay in 1991, although there have been no recent estimates of reef size [269, 322]. While most of the oyster reefs are natural, approximately 18% are man-made on the dredge spoil shoulders of channels [323]. The distribution of reefs in GB shifted between the 1950's and 1990's, most likely as a result of changes in circulation and dredging, although the changes in reef distribution/area have not been quantified [269, 324]. At the time, annual oyster harvests were believed to be increasing from the 1990's to 2001, with an average harvest of almost 4 million pounds per year between 1994 and 1998 and an average harvest of 4.6 million pounds per year between 1997 and 2001 [269, 276]. The perceived increase in harvest was linked to the fact that more areas of GB were being opened to commercial fisheries and/or more fishermen were targeting oysters as a result of decreasing prices for shrimp [276]. However, when looking at longer-term harvest data from

1986 to 2009, the CPUE data demonstrate declining trends in East Bay, Trinity Bay, upper and lower GB [269].

The *C. sapidus* fishery in GB became important after 1960, with more *C. sapidus* harvested from GB than from any other Texas estuary prior to 1998 [269, 276, 300]. However, *C. sapidus* trawl data show a decrease in harvests in some areas of GB between 1982 and 2009 [269, 300, 321]. The decrease in catch is believed to be due to a decline in abundance of larger crabs (from high levels of fishing pressure) since recruitment appears to be fairly constant [276, 321]. In 1997, Texas Parks and Wildlife Department set trap and size limits for *C. sapidus*, prohibiting the take of egg-bearing females and initiated a voluntary program to buy licenses back [276].

There are also commercial fisheries for finfish such as *P. cromis*, *P. lethostigma*, *A. probatocephalus* and *M. cephalus*, but they make up less than 5% of the total harvest from GB [269, 276]. There was a decrease in the finfish harvest as a whole from 1980 to 2001, although the decrease may be the result of a change in gear type in the early 1980's, *e.g.* gillnetting was banned in saltwater habitats in the 1ate 1980's [276]. Over a longer time period, from 1977 to 2009, the harvest of *B. patronus* and *P. lethostigma* varied widely with no trends in catch anywhere in GB for both bag seine and trawl [269]. In contrast, the CPUE for *M. undulatus* from 1982 to 2009 appears to be increasing in trawl catches throughout most of GB, as does the CPUE for *C. nebulosus* in gillnets (data for 1977-2009) [269]. *Cynoscion nebulosus* are stocked in GB by the Texas Parks and Wildlife Department, with more than 30 million fingerlings added since 1992 [325]. *Sciaenops ocellatus*, which have been stocked in GB since 1980, also show an increasing trend in CPUE in Trinity Bay [269, 325].

Recreational fisheries are also economically important in GB, generating over $2.8 billion in economic activity annually [269]. Between 1993 and 2003, GB had the highest number of recreational marine fish landed among all Texas bays [269]. The species with the highest levels of harvest from 1990 to 2001 were *C. arenarius, C. nebulosus*, *S. ocellatus*, *P. lethostigma* and *M. undulatus* [276]. There is currently no aquaculture in GB.

Fishing gear poses a threat to dolphins as they can become entangled in or ingest it. For example, there are at least five records of dolphins becoming entangled in fishing gear in the GB area between 1998 and 2012 [159]. In 1998, a dead dolphin was found with monofilament line and rope wrapped around both pectoral fins. In 2009, a dead dolphin was found with a monofilament line with a hook in its stomach along with a whole catfish. In 2011, a dolphin was found entangled in a crap pot with a rope wrapped around its peduncle and flukes; the animal was weak but swam away after the gear was cut away. Also in 2011, a dead dolphin was found with a fishing lure in its stomach. In 2012, a dead dolphin was found with a fishing hook in its stomach.

Shipping, dredging & construction

Shipping is very important in the GB area with ports in Houston, Galveston and Texas City, all of which are deep-draft ports. The Port of Houston is the second largest port in the nation in terms of total tonnage, with over 200 million tons of cargo moving through the port each year [326]. The Port of Galveston handled approximately 5.8 million tons of cargo in 2009 [162]. The two primary channels used for shipping within GB are the Houston Ship Channel and the GB Ship Channel. The GB Ship Channel is a major navigational channel that is 6.8 km long and 12 m deep and provides entry to GB [290]. The Houston Ship Channel is 84 km long, 160 m wide and 14 m deep and transects GB, extending from Houston to the Gulf of Mexico [119, 326]. In order for larger ships to use the GB ports, the GB Ship Channel and the Houston Ship Channel must be dredged regularly. A recently completed dredging project that widened and deepened the Houston Ship Channel used the dredged material to restore and create intertidal marshes, bird nesting habitat and recreational islands [269, 276, 300]. When the channel was previously dredged, the dredge material was disposed in the middle of the bay [269]. The third major channel in the GB area is the GICW, the coastal canal that runs nearly 1,700 km, from Brownsville Texas to Fort Myers Florida. The GICW is dredged by the Army Corps of Engineers to maintain a minimum depth of 4 m and is designed for transportation of crude petroleum and petroleum products, iron, steel, fertilizer and other bulk products [269]. The GB portion of the GICW was completed in 1934 between GB and the Sabine River, extending across lower GB [269]. Recreational boaters also use the GICW for fishing, water skiing and sightseeing [269].

Noise

There are no specific data on marine noise in GB, however given that there is a substantial amount of boat traffic from fisheries and recreational use, shipping, activity around the ports in Galveston, Houston and Texas City and dredging activities, there is likely a consistent level of marine noise in the GB area.

Tourism & boat traffic

Tourism is also economically important to the GB area. Important tourism activities include recreational boating, duck hunting, bird watching, camping, sightseeing and dolphin watching [269, 276]. With more than 88,000 recreational boats registered in GB (including West Bay), impacts of boating activities in GB include disposal of sewage, propeller scarring, re-suspension of sediment, increased shoreline erosion, damage to seagrass beds and boating accidents with wildlife [269]. Within the GB area there are at least three tour operators offering dolphin watching options [327].

There are five records of stranded *T. truncatus* in GB in 1996, 2000, 2001, 2006 and 2013 each with injuries indicative of a boat collision, although there is an additional record occurring on the Gulf side of the barrier islands of GB in 2010. In addition, during dolphin surveys of the GB Ship Channel from 1990-1992, 10 of the 240 identified *T. truncatus* had scars, cuts or markings suggestive of boat propeller injuries and others (number not reported) had bent or cut dorsal fins [290].

Algal blooms

Within the bays and bayous of GB, fish kills due to phytoplankton blooms and low dissolved oxygen are an almost annual occurrence in late summer [291]. For example, in 2005, a fish kill of more than 10,000 *B. patronus* near Galveston Island was due to a combination of a cyanobacteria bloom and low dissolved oxygen [291].

In addition, there are occasional *K. brevis* blooms that impact the Texas coast, including the entire GB system, or the entire Texas coast that result in massive fish kills and the closure of shellfish beds. In August 2012, a *K. brevis* bloom in GB resulted in a large fish kill of ~1 million fish, primarily *B. patronus* [168]. From September 2011 to January 2012, there was another large *K. brevis* bloom along the Texas coast that was responsible for the temporary closure of all Texas shellfish beds, including those in GB, and fish kills in GB [168]. Previously, large red tides that affected GB and resulted in the closure of shellfish beds and fish kills also occurred in 2000, 1996 and 1972 [57]. The red tide in 2000 caused a fish kill of roughly 6.8 million fish in GB [61].

The toxins from harmful algal blooms have been found in tissues from *T. truncatus* in the 2008 UME despite the absence of a bloom. The 2011-2012 UME, which resulted in *T. truncatus* mortalities in this area, also coincided with the large *K. brevis* bloom and could have played a role in this event (see Unusual Mortality Events).

Hypoxia

The dissolved oxygen levels in GB have recently been determined overall to be 'good' [292]. Data from water samples collected in bays of GB from 1969 to 2009 revealed a declining trend in dissolved oxygen concentrations, although the reported values remain within the range considered healthy [269]. However, in a study assessing 55 years of fish kills in coastal Texas waters GB had both the highest number of fish kill events and the highest numbers of fish killed [61]. From 1951 to 2006, there were approximately 400 fish kill events in GB, with approximately 141 million fish killed, a majority of which were associated with low dissolved oxygen conditions [61]. A number of these events were mass mortality events related to hypoxic conditions in GB. For example, from 1971-1972, 25.7 million fish were killed, in 1977, nine million fish were killed and in 1980, 12.9 million fish were killed due to low dissolved oxygen conditions, although there were often multiple factors implicated, *e.g.,* low dissolved oxygen and pollution (see pollution) [61]. Within the bays and bayous of GB, fish kills due to low dissolved oxygen and phytoplankton blooms are an almost annual occurrence in late summer [291]. In 2005, a fish kill of more than 10,000 *B. patronus* near Galveston Island was due to a combination of a cyanobacteria bloom and low dissolved oxygen [291].

Adverse weather

GB is affected by hurricanes and tropical storms. Since 1871, 18 named storms have hit GB. This area is affected by tropical systems on average every 2.66 years and it gets a direct hit ~ once every 8.29 years [293]. In 2008, Hurricane Ike hit GB and substantially impacted the ecosystem [269]. For example, the storm surge inundated wetlands, increasing the salinity of the soil, resulting in vegetation die-offs [269]. Oyster reefs were buried by re-suspended sediment, large fish kill events were recorded, 200 chemical spills were reported during flooding plus an unknown number of unreported spills, and marine debris littered GB [269]. Since the early 1960's, the abundance of seagrass in GB has declined considerably, notably coinciding with Hurricane Carla, which has been attributed with damaging seagrass beds in parts of GB [269, 295, 299]. The inability of seagrasses to recover in most of GB after Hurricane Carla has been linked with poor water quality and high turbidity, largely from urban developments, dredging and pollution [268, 270, 295].

Hurricanes and tropical storms are not the only adverse weather to affect GB; there are occasional cold snaps that cause fish kills in GB. In 1983 and 1989, 15.7 and 22 million fish were killed, respectively, as a result of unusually cold weather in GB [61].

Freshwater inflows

GB receives the majority of its freshwater inflow from the Trinity River from the northern side of Trinity Bay and from the San Jacinto River, in the northern part of GB [119, 296]. GB receives the second-highest volume of freshwater inflow of any Texas estuary [322], at ~12.06 km^3/year [119]. As the population of Houston increases in the future, the demand for freshwater is likely to increase, especially as the environment becomes more arid [328, 329]. This increase in demand for water coupled with the depletion and mandatory reductions in groundwater extraction have resulted in an increased use of rivers as a water source [328]. Plans to divert water from the Trinity River and/or San Jacinto River would substantially alter the freshwater flow regime into GB, affecting salinity, circulation and supply of sediments and nutrients [269, 323, 328]. This could, in turn, severely impact the biota in the estuary by creating an unsuitable habitat, particularly for vulnerable life stages, *e.g.,* juveniles [269]. In 2007, a senate bill was passed for a scientific and stakeholder committee to make recommendations on the environmental flows needed to maintain the ecological integrity of the aforementioned rivers and GB [328]. The flow levels set by the state agency were ultimately lower than those recommended by the scientific committee [328].

There are a number of factors attributed to the loss of seagrass beds in GB and in some cases, the flourish of seagrass in the 1950's (see Biota: Seagrass). For instance, the severe drought of the 1950's reduced the levels of freshwater flow into GB, subsequently decreasing turbidity, which may have allowed seagrass beds to flourish in the mid 1950's [268].

Habitat loss

In GB, more than 134 km^2 of wetlands (roughly half of those present) were lost between 1953 and 1989, largely as a result of urban developments, land conversion to agricultural lands, subsidence and relative sea-level rise [269, 292, 294, 330]. Subsidence, due to the extraction of groundwater in Houston is strongly affecting the GB area [268, 269, 331]. The rate of subsidence reached almost 3 m between 1943 and 1978 [269]. However, the rate of subsidence has slowed around GB in the past 20 years, largely as a result of decreases in groundwater extraction rates [269, 330]. In fact, an analysis of the same land area that showed substantial loss of wetlands between 1953 and 1989 actually demonstrated the reverse pattern from 1996 to 2005; there was a net gain of roughly 8 km^2 in wetlands [269]. Although there were methodological differences between the two studies, it would appear as though the loss of wetlands has slowed since the 1980's [269].

In 1989, the GB Estuary Program (GBEP) was established to increase public awareness and monitor habitat degradation, wetland loss and pollution in the GB area [292]. The GBEP has a regional monitoring plan for GB, organizing the efforts of different agencies to ensure data availability without duplication of effort. The GBEP and its partnering agencies have restored 32 km^2 of habitat so far and are currently working to increase wetland conservation, control exotic species, promote water conservation and assess the safety of consuming seafood from GB, among other goals [292].

Disease
Morbillivirus was the confirmed cause of the 1993-1994 UME in Texas, which included 4 common bottlenose dolphin mortalities in GB proper and 26 mortalities on Gulf side beaches along Galveston Island adjacent to GB, as well as two mortalities in the GB area that had no associated latitude/longitude data (Figure 5) [70, 71, 139]. Morbillivirus was retrospectively thought to possibly be the cause of the large die-off in 1990, but a definitive cause for this event was not confirmed. The 1990 die-off included three *T. truncatus* strandings from GB proper (plus one in the ship channel just outside GB) and 14 on Galveston Island adjacent to GB (Figure 4). In addition, *Brucella* was suspected to be the cause of the 2007 and 2008 UME's due to the high proportion of perinates in each of these events, but this could not be confirmed [79]. The 2007 UME involved two *T. truncatus* strandings in GB proper and 19 *T. truncatus* strandings on the Gulf side of Galveston Island adjacent to GB (Figure 14). The 2008 UME involved 24 strandings along the Gulf side of Galveston Island adjacent to GB (Figure 6). Other diseases affect common bottlenose dolphin, however, here we highlight those that have been associated with high levels of mortality.

Climate change
Climate change is likely to have a significant impact on all Texas estuaries. Climate change is expected to substantially impact this area with rising sea levels, increased shoreline erosion and declines in water quality [175]. The national assessment of coastal vulnerability to sea level rise ranks the GB area as 'moderate' in the inshore areas to 'very high' risk for the Galveston Island area [176]. A rank of 'moderate' is a relative sea level change of 2.5 to 3.0 mm/year while a rank of 'very high' is a relative sea-level change of more than 3.4 mm/year [176]. The relative sea-level rise in some areas of GB could be substantial given the high rates of subsidence and associated habitat loss that have already been observed [269, 331].

For GB, which has relatively high levels of freshwater inflow, concerns are primarily over reductions in freshwater input, increases in the duration and frequency of droughts, increases in salinity in the bays and, therefore, changes in ecosystem structure and function [269]. The timing and amount of freshwater input, which is critical to the functioning of an estuary, will change as precipitation and land use changes. In the past, severe droughts in southern Texas have resulted in hypersaline estuary environments, which in turn caused fish kills, loss of *C. sapidus* and shrimp and invasions of stenohaline species [204]. Water budget scenarios taking into account climate change, drought and population growth estimate reductions in freshwater flow into the Texas estuaries of up to 74% [75]. Such a reduction in freshwater flow into GB would greatly alter the long-term salinity regime and result in a shift in species composition of the estuary to more marine species as the bay becomes less suitable as nursery habitat for estuarine species. For example, during the drought of the 1950's, freshwater inflows to GB severely decreased, which increased the salinity of GB. This impacted the abundance of oysters in the bay and harvest almost ceased and white shrimp catch decreased dramatically [332]. In addition, climate change could potentially increase the frequency and duration of hurricanes [178, 269] and potentially harmful algal blooms [179] along the Texas coast.

UME's of unknown etiology
The large die-off in 1990 and UME's in 2007 and 2008, as previously described (see Unusual Mortality Events), were of unknown etiology and involved animals from GB. The investigation

into the 2011 – 2012 UME is ongoing. The suspected cause of the large die-off 1990 was retrospectively thought to be the morbillivirus, however, this was not confirmed to be the definitive cause of this die-off so this event is considered of unknown etiology. The 2007 and 2008 UME's were also of unknown etiology, although it was suspected *Brucella* could have played a role. In particular, the 1990 event involved three *T. truncatus* strandings from GB proper (plus one in the ship channel just outside GB) and 14 on Galveston Island adjacent to GB (Figure 4). The 2007 UME involved two *T. truncatus* strandings in GB proper and 19 *T. truncatus* strandings on the Gulf side of Galveston Island adjacent to GB (Figure 14). The 2008 UME involved 24 strandings along the Gulf side of Galveston Island adjacent to GB (Figure 6). For the 2011-2012 UME, three stranded *T. truncatus* were recovered from GB and 14 along the Gulf side of Galveston Island adjacent to GB (Figure 7).

Incidental research takes

Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in gillnets from fisheries research activities by Texas Parks and Wildlife [80]. Of these 31 incidents, none occurred in GB [80].

Threat assessment for *Tursiops truncatus* in Galveston Bay

Citations are included where supporting data are available. The maximum number of points per threat is 12 and the maximum total number of points possible is 228.

With a cumulative threat score of 145 and a lack of up-to date assessment data, the Galveston Bay stock ranks a high priority.

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Oil & gas pollution	2[269, 276-278, 310]	3[277, 279]	3[13]	8
Heavy metal pollution	2[269]	3[269, 284, 288, 310, 312]	3	8
Chemical pollution	2[269, 283, 292]	5[61, 191, 268, 269, 281, 285-288, 314, 315]	3[66, 95]	10
Marine debris	2[319]	2	3	7
Recreational fisheries	2[269]	3[269, 276]	4[4, 159]	9
Commercial fisheries	2[269, 276, 292]	3[276, 321]	3[26, 102, 103]	8
Aquaculture	0	NA	NA	0
Shipping	2[162, 269, 326]	2	3[35]	7
Dredging & construction	2[269, 290, 297]	3[268, 269, 297, 324]	3[106]	8

continued

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Noise	1	2	3[38, 43]	6
Tourism & boat traffic	1[269, 276]	2	4[54]	7
Algal blooms	2[57, 168]	5[57, 61, 168, 291]	3[109]	10
Hypoxia	2[269]	5[61]	3[60]	10
Adverse weather	2[293]	5[61, 269, 295, 299]	3[62]	10
Freshwater inflows	2[269, 328]	3[268, 332]	3[66]	8
Habitat loss	2[268, 269, 292, 294]	3[269]	3	8
Disease	1[70, 71]	0	5*[69-72]	6
Climate change	1[176, 269]	2	3[76]	6
UME of unknown etiology	2[78, 116, 142]	2	5*[78, 142]	9
Total				145

*mortality event was along the Texas coast that included animals from this BSE, but was not contained solely within this BSE

DAS scoring for *Tursiops truncatus* in Galveston Bay

	Score
Information on stock structure	0
Information on abundance	0
Information on mortality	0
Total	0

BSE: Sabine Lake

Sabine Lake estuary (SL) includes Sabine Lake, the Sabine-Neches Canal, the Port Arthur Canal and Sabine Pass (Figure 16) [117, 119]. SL is situated on the Texas-Louisiana border and lies to the northeast of Galveston Bay in Texas and to the west of Calcasieu Lake in Louisiana.

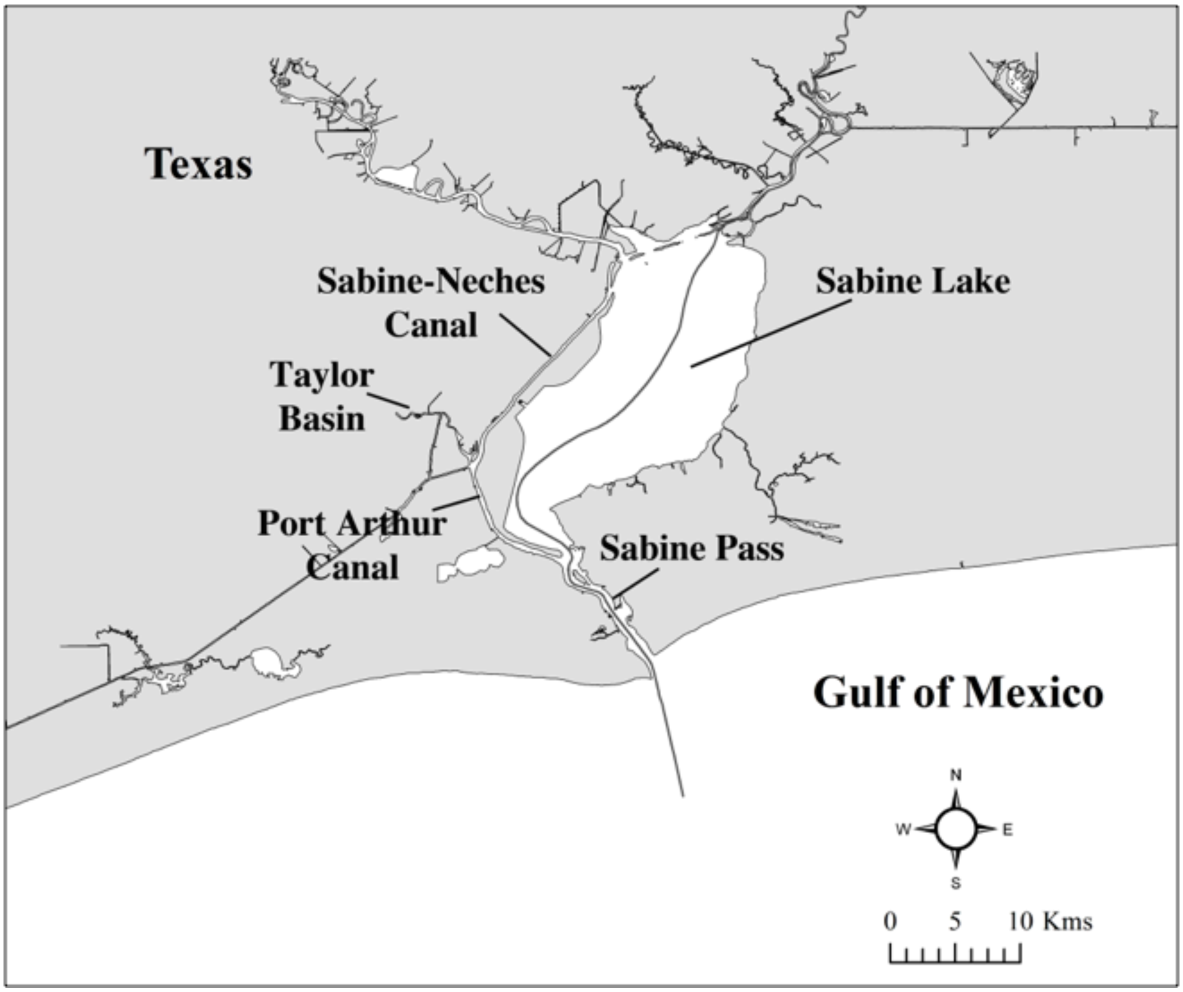

Figure 16. Sabine Lake, Texas

Physical attributes
SL is a lake-like estuary with a surface area of 243 km^2 [105]. The average water depth of SL is 2.0 m, although depths reach a maximum of about 12 m in areas where it has been dredged [105, 119]. The average salinity of SL is ~11 ppt, although salinities as low as 2.3 ppt have been reported [105]. The connection of SL with the Gulf of Mexico is highly restricted and exchange with Gulf waters occurs only through the narrow Sabine Pass, with a tidal range of less than 0.1 m in SL [94, 117]. The SL area receives the most precipitation each year when compared to other Texas estuaries, receiving roughly 142 to 152 cm/year [119, 333, 334]. When combined with an annual evaporation rate of approximately 112 cm/year (which is lower than the other estuaries in Texas), this results in a net gain of 30 to 40 cm/year [119, 333]. The air temperature

of the SL area ranges from average highs of ~29°C (84°F) in the summer (June to August) to average lows of ~12°C (54°F) in the winter (December to February), based on data over 50 years from Port Arthur [94].

Biota

Seagrass

The dominant seagrass species in SL is *R. maritima,* although there is no estimate available on the acreage of seagrass beds in SL [94]. This seagrass is especially well suited for SL because it is tolerant of low salinity environments [335].

Birds

Like other coastal areas of Texas, SL is an important habitat for water birds and shorebirds. The Sabine National Wildlife Refuge, on the eastern end of SL has been identified as an 'international important bird area' due to the 300 species of wading, marsh and water birds that use the ~500 km^2 refuge [336]**.** Bird species found in the SL area include *A. ajaja*, *N. nycticorax, E. tricolor,* ibises (Family Threskiornithidae) and the threatened *C. melodus* [337].

Fish & invertebrates

Common fish and invertebrates species in SL include *P. aztecus*, *L. setiferus*, *C. sapidus*, American oyster, *Crassostrea virginica, S. ocellatus, P. cromis,* flounder, *Paralichthys* spp., *C. nebulosus, A. probatocephalus, L. xanthurus, B. patronus* and *M. undulatus* [94, 338].

Common bottlenose dolphins

Data assessments

Common bottlenose dolphins are found in SL, with reports from fishermen observing them in the shipping channels [338]. There are also at least five reports of stranded common bottlenose dolphins from SL and the Sabine channel [159]. There are no studies regarding the population structure of the dolphin assemblage(s) in the SL area and there has not been an estimate of the abundance of common bottlenose dolphins in SL in the last five years.

Unusual Mortality Events

In 1990, a mortality event occurred from January through May along the entire northern Gulf of Mexico coast from Florida through Texas with 46% of the 344 carcasses being collected in Texas [78]. However, at this time, the Texas Marine Mammal Stranding Network (TMMSN) was more developed than some of the stranding networks in other Gulf states, which may have led to a higher proportion of stranding reports from Texas [78]. During this event, one *T. truncatus* stranded in SL proper and six stranded on nearby coastal regions; the later may have come from a coastal stock, although their population origins remain unknown (Figure 4). The winter of 1989-1990 was colder than normal throughout most of the Gulf [78] and the influence of the cold weather on the UME is unclear. Chemical contaminant levels (PCB's) were measured in 10 male *T. truncatus* that stranded in Matagorda Bay during the 1990 event [138] and in 26 *T. truncatus* collected during the event from coastal and estuarine waters from Laguna Madre to Galveston [95]. While PCB levels were relatively low in the majority of the dolphins, PCB levels in a few animals were high enough to potentially negatively impact reproductive success in females [21, 138]. However, contaminant levels were not considered the cause of this mortality event [78]. Retrospectively it was suspected that this event may have been related to the emergence of morbillivirus in the Gulf of Mexico [70, 71, 139], although a definitive cause for this UME was not confirmed [78].

An UME was declared for Texas from December 1993 through May 1994, with a total of 236 *T. truncatus* and four unidentified dolphin strandings in Texas [79]. During this event, one *T. truncatus* was recovered in SL proper and two were recovered on nearby coastal regions; whether the later mortalities were from coastal stocks or estuarine stocks remains unknown (Figure 5). The confirmed cause of this UME was morbillivirus [70, 71, 139].

In 2007, an UME was declared in Texas in February and March when 64 *T. truncatus* and two unidentified dolphins stranded, primarily in Galveston and Jefferson counties in Texas (with a few were found in nearby Cameron Parish, Louisiana) (Figure 14) [79]. The following year, in 2008, an UME was declared again in Texas for February and March, during which 111 *T. truncatus* stranded [79]. A high proportion of neonates were recovered in both of these events and most carcasses were found primarily on the Gulf-side beaches. During the 2007 and 2008 events, no animals were stranded in SL proper, however five and four animals were stranded in nearby coastal regions, respectively (Figures 6 and 14). Whether these strandings were from coastal stocks or estuarine stocks remains unknown. The 2007 and 2008 UME's had a high proportion of perinate strandings, which suggests an infectious agent that can cause late term abortions or early neonatal loss, such as the bacterium *Brucella*, may have been involved in these events; transmission of this bacteria is often through placental tissues and maternal feeding, resulting in aborted fetuses [79, 140]. An analysis of gastrointestinal contents from animals stranded in 2008 revealed the presence of HAB toxins domoic acid and okadaic acid (associated with a *Dinophysis* spp. and *Prorocentrum* spp. toxic algae bloom occurring at the time) [109]. Low levels of brevetoxin were also found despite an absence of an associated *K. brevis* bloom [109]. The levels of each HAB toxin were low relative to levels associated with acute mortality and the levels of okadaic acid were at levels of unknown effects; however the impact of multiple toxins (*e.g.,* okadaic acid, domoic acid and brevetoxin) on marine mammal health is unknown [109]. The toxicity of okadaic acid has, however, been shown to increase in the presence of a toxin (gymnodimine) produced by *Karenia* [141]. However, no definitive cause for the 2008 event has been determined [116].

More recently, there was an UME declared from November 2011 to March 2012 involving 126 stranded common bottlenose dolphins. A single mortality was recorded in SL proper and one was recorded on the Gulf coast to the southwest of SL, the later may have come from a coastal stock, although their population origins remain unknown (Figure 7). A preliminary analysis indicated some animals had discolored teeth or a mud-like substance in their stomachs but the cause of the event remains unknown and the investigation is ongoing [142].

Potential threats

SL is influenced by the industrial and urban areas of Beaumont, Orange and Port Arthur, which lie on the west and north sides of the estuary [119]. Mining, oil and natural gas extraction, petrochemical and other chemical refineries, shipping, ranching, forestry, agriculture (rice and soybeans) and tourism are all economically important to the area [94, 339]. There are ~144 mineral production sites in Jefferson county and 70 in Orange County (no data for Cameron

Parish, Louisiana), for a total of at least 214 sites surrounding SL [94]. These anthropogenic activities pose a number of threats to the biota that utilize this environment.

Oil & gas pollution

As the nation's center for oil refining and the number one crude oil import channel, SL is under constant threat of oil and gas spills. In January 2010, the towing vessel *Dixie Vengeance* and the two barges it was towing collided with the cargo tank *Eagle Otome* carrying crude oil, spilling 10,000 barrels (~420,000 gallons) of crude oil into the Sabine-Neches Waterway [340]. The waterway was temporarily closed due to concerns over the possibility of harmful gases being released from the spilled oil [340]. Oiled birds were treated and at least two birds were found dead after the spill [341]. In October 2010, ~300 gallons of fuel spilled from a shrimp boat in the Sabine-Neches Waterway south of the GICW after two ships collided, resulting in the temporary closure of the waterway [342]. In April 1993, a pipeline in Texas discharged ~88,000 gallons of crude oil into the Sabine-Neches River [343].

Phase I of a liquefied natural gas (LNG) plant was constructed on the Louisiana coast of Sabine Pass and service commenced in 2008, with construction of Phase II underway in 2009 [338].

Heavy metal & chemical pollution

Chemical analysis of sediment samples from the SL area indicate that sediments are not highly toxic [344]. The concentrations of heavy metals such as arsenic, chromium, copper, cobalt, nickel, lead, zinc, aluminum, iron and manganese in sediment samples collected from throughout SL proper and the channels were low when compared to other Texas bays and the Gulf of Mexico and concentrations throughout SL were generally uniform [344, 345]. The concentrations of PAH's in sediment samples were highest in samples from the upper Neches River and Taylor Basin (see Figure 1) [344]. The concentrations of PAH's in sediment samples were not uniform throughout SL; concentrations were higher in the canals than in SL proper and also decreased seaward [344]. The concentrations of silver, zinc and copper in oysters collected from SL in the 1980's were high, and were attributed to the oyster's proximity to highly industrial areas [346]. Levels of dioxins and furans in clams from the Neches River downstream from a pulp mill were above detectable levels which was accompanied with an advisory to limit or avoid eating fish from the Neches River in the 1990's [347].

There are nine superfund sites in the Texas counties surrounding SL. Of these superfund sites, at least four likely discharged contaminants into SL and were considered a sufficient threat to human or environmental health to require remedial action. The Star Lake Canal superfund site is two industrial canals in Port Nueces used as an industrial wastewater and storm water discharge site for chemical and manufacturing facilities [348]. The surface waters of these canals flow into SL, potentially carrying harmful chemicals such as chromium, copper, PAH's and PCB's into nearby wetlands and SL. Chemical testing found pentachlorophenol and toxaphene in the sediments of one of the canals [348]. The remedial action plan for this site is in preparation to reduce the risk to the biota that utilize these habitats [348]. The Baily Waste Disposal superfund site was an industrial and municipal waste disposal site at the confluence of SL and the Neches River in the 1950's until 1971 [349]. Contaminants found at the site included metals, arsenic compounds, benzene, phenols and chlorinated hydrocarbons in the soil [349]. Site wastes contaminated by organic compounds and heavy metals drained into nearby marsh habitats [349].

Clean-up for this site has been completed and the site was deleted from the NPL in 2007 [349]. The Triangle Chemical Company is a superfund site in Bridge City [350]. The site operated as a chemical mixing facility from the 1970's until 1981 where raw materials and finished products were stored at the site [350]. Contamination of groundwater and soil by volatile organic compounds at the site occurred from discharge, leaks and spills from old storage drums and tanks [350]. Seven fish kill events in Coon Bayou were linked to chemical discharges from this superfund site into the bayou over a six year period from 1976 to 1982 [350]. The risk to health of humans and the environment were mitigated by actions which secured the site and removed hazardous chemicals from contaminated areas, with remedial action completed in 1990 and removal of the site from the NPL in 1997 [350]. In Port Arthur, oil refinery activities at the Old Gulf Refinery have been releasing hazardous chemicals such as aromatic hydrocarbons and metals into the Neches River since 1902 [351]. In 1993, work began to control sources of contamination and in 2004 a restoration plan for the site was finalized [351]. Another superfund site that may have posed a risk to SL and worth brief mention is the Palmer Barge site near Port Arthur [352]. This site operated as a former barge cleaning and maintenance site from 1982 to 1997 [352]. In 2005, the site was cleaned up (*e.g.* removal of contaminated soils and other substances that may have been contaminated from metals or pesticides) and the site's use remains industrial/commercial [352]. The remaining four superfund sites in the SL area are: (1) the Maintech International Superfund Site, which was a barge cleaning facility that could have potentially discharged or leaked polynuclear aromatic hydrocarbons; (2) International Creosoting, a wood treatment facility; (3) State Marine, another barge cleaning facility that could have potentially discharged metals or organics; (4) a salvage yard which did not pose a threat to SL [229].

In September 2008, Hurricane Ike caused extensive flooding along the Texas coast, which resulted in a high level of run-off flowing into SL; this run-off was contaminated with industrial pollutants, household chemicals and waste [353]. In 2010, the Department of State Health Services (DSHS) collected fish from SL to test the levels of contaminants present in the tissues of fish [353]. All of the fish had the heavy metals copper, mercury, selenium, mercury and zinc present, most contained arsenic and all fish had some level of DDE and PCB's [353]. The levels of PCB's in *B. marinus* from SL exceeded the DSHS guidelines for consumption and therefore, there is a consumption limit and advisory in place for this species in SL [353]. In addition, the concentration of arsenic in two alligator gar, *Atractosteus spatula,* from SL exceeded the DSHS guidelines [353].

Marine debris

Specific information regarding the amount of marine debris within SL bays is lacking, however, marine debris is a threat virtually anywhere anthropogenic activities are occurring through littering (intentional or accidental) or via household or industrial wastes [242, 243]. There are however, some data available for post-hurricane season amounts of debris in the adjacent wetland, Sabine National Wildlife Refuge (SNWR), where almost 7 million m^3 of debris were spread over 7 km^2 acres of marsh in 2005 [354]. Given the proximity to the SNWR and the large amount of debris found there, SL was most likely also impacted in a similar way after this hurricane.

Commercial & recreational fisheries & aquaculture

SL is among the Texas estuaries with the lowest yields of shrimp and finfish harvest [119, 339, 355]. The harvest of shrimp decreased from 1962 to 1976 [339]. The harvest of *C. nebulosus* was highly variable from 1962 to 1968, followed by a sharp decline in harvests from 1969 to 1976 [339]. The harvest of *S. ocellatus* from 1962 to 1976 was highly variable while the harvest of *P. cromis* decreased over this period, but all catches were low [339]. The harvests of *C. virginica* and *C. sapidus* in SL generally increased from 1962 to 1973, but then decreased from 1973 to 1976 [339].

The catches of finfish in gillnets in SL from 1986 to 2004 varied between species. From 1986 to 2004, the harvest of *C. nebulosus* and *P. cromis* in gillnets in SL generally increased [356]. The harvest of *S. ocellatus* in gillnets was highly variable between 1986 and 2004, although overall catches in the spring increased [356]. The harvest of *C. arenarius* in gillnets was highly variable in the fall (and virtually zero in the spring) between 1986 and 2004 [356]. The harvest of *M. undulatus* in gillnets increased in the fall, but decreased in the spring between 1986 and 2004 [356]. The finfish harvest from sport and recreational fisheries exceeds the commercial finfish harvest in SL [339]. There is currently no aquaculture in SL.

Fishing gear poses a threat to *T. truncatus* as they can become entangled in or ingest fishing lines or nets. There are no reports of fisheries interactions involving *T. truncatus* in the stranding records for SL [159].

Shipping, dredging & construction

The Sabine-Neches Waterway provides a passageway for shipping from the Gulf of Mexico to the deep-draft ports of Beaumont, Port Arthur and Orange in Sabine Lake. Port Arthur handled approximately 31.7 million tons of cargo in 2008 (but only 470,000 in 2009) and Port Beaumont handled 69.5 million tons of cargo in 2008 (but only 2.9 million tons in 2009) [162]. The Sabine-Neches Waterway is the fourth largest waterway in the U.S. and the nations number one crude oil import channel [357]. It is a ~84 km long series of interlocking channels extending from the Sabine and Neches rivers, travelling southwest past Port Arthur (known as the Sabine-Neches Canal in this region), through the southern part of SL and out to the Gulf of Mexico via Sabine Pass [338]. The channels of the Sabine-Neches Waterway are regularly maintained to depths of 12 m through dredging and there is currently a proposal to deepen it to 14 m to allow larger vessels to use the channels [338, 357]. In 2003, almost 75,000 vessel and barge trips were recorded utilizing the Sabine-Neches Waterway [338]. The GICW connects to the Sabine-Neches waterway just south of Port Arthur [338]. Shipping is economically important to SL and in particular, Port Arthur. The city of Port Arthur is the center for oil refining in the U.S. [358]. The Port of Orange handles 800,000 tons of cargo annually. It also serves as a location for ship berthing and repair. The docks to the aforementioned (see Oil & gas pollution) LNG plant requires maintenance dredging which impacts roughly 6 acres of open water habitat [337].

Noise

There are no specific data on marine noise in SL, however given that there is a substantial amount of boat traffic from fisheries and recreational use, shipping, activity around the ports in Port Arthur, Port of Orange and Beaumont and dredging activities, there is likely a consistent level of marine noise in the SL area.

Tourism & boat traffic
Tourism is economically important to the SL area. Tourism activities include boating, water skiing, hunting, bird watching and sight seeing [336, 339].

Algal blooms
In 2000, a large *K. brevis* bloom along the Texas coast that included SL resulted in the closure of shellfish beds and a fish kill event of roughly two million fish [57]. The *K. brevis* blooms of 2013, 2011 - 2012, 2009 – 2010, 2006 and 2005 did not impact SL [168].

Hypoxia
SL had large fish kill events between 1990 and 1994 (~1.1 million fish) and between 1995 and 1999 (~6.1 million fish), all due to low dissolved oxygen [61]. However, the number of fish kill events in SL due to low dissolved oxygen overall is much lower than those for the other Texas bays [61].

Adverse weather
SL is affected by hurricanes and tropical storms. Since 1871, 19 named storms have hit within 97 km of Port Arthur. This area is affected by tropical systems on average every 2.88 years and it gets a direct hit once every 8.81 years [359].

Freshwater inflows
SL receives freshwater inflows from the Sabine and Neches rivers [119]. The combined inflow of freshwater into SL is roughly 16 km^3 per year; making it the estuary with the highest level of annual freshwater inflows in Texas [119]. There is a tendency for the waters in SL to become stratified as a result of the high level of freshwater flows, with more dense, saline waters sitting at the bottom of the water column [337]. SL has undergone an increase in salinity over time despite the high level of freshwater flow as a result of dredging and deepening of channels and oil and gas exploration [360].

Habitat loss
SL has been impacted by habitat loss. The best documented loss of habitat occurred between 1956 and 1978, with a net loss of 38 km^2 of marsh habitat in the Neches River valley at the head of SL, due to oil extraction and fault movement [361]. Additional losses of roughly 3.4 km^2 of freshwater marshes, woodlands and swamps have been documented further upstream between 1938 and 1956 [330].

Disease
Morbillivirus was the confirmed cause of the 1993-1994 UME in Texas, which included one common bottlenose dolphin stranding in SL proper and two strandings on nearby coastal regions (Figure 5) [70, 71, 139]. Morbillivirus was retrospectively thought to possibly be the cause of the large die-off in 1990, but a definitive cause for this event was not confirmed. The 1990 die-off included one *T. truncatus* stranding from SL proper and six strandings in nearby coastal regions (Figure 4). The 2007 and 2008 UME’s included no *T. truncatus* standings in SL proper, however, five and four *T. truncatus* stranded in nearby coastal areas, respectively (Figures 14 and 6, respectively). Other diseases affect common bottlenose dolphin, however, here we highlight those that have been associated with high levels of mortality.

Climate change

Climate change is likely to have a significant impact on all Texas bays and estuaries. Climate change is expected to substantially impact the area with rising sea levels, increased shoreline erosion and declines in water quality [175]. The national assessment of coastal vulnerability to sea level rise ranks the Texas coastal area of SL (it does not rank SL proper) as 'very high' risk [176]. A rank of 'very high' is a relative sea-level change of more than 3.4 mm per year [176]. In addition, reductions in rainfall and reduced freshwater inflow would increase the salinity of SL. While SL tends to be lower salinity environment when compared to the other estuaries in Texas (therefore hypersalinity is unlikely to be a threat), the populations found in SL have evolved within this environment and there could be substantial repercussions from a sudden increase in salinity in this habitat, particularly in the type of plant and marsh plants inhabiting the area. During the drought of the 1950's, increases in salinity in the estuaries led to seagrass die-off and massive fish kills in the Texas bays [177]. Climate change could also potentially increase the frequency and duration of hurricanes [178] and potentially harmful algal blooms [179] along the Texas coast.

UME's of unknown etiology

The large die-off in 1990 and the UME's in 2007 and 2008, as previously described (see Unusual Mortality Events), were of unknown etiology and involved animals from SL. The investigation into the 2011 – 2012 UME is ongoing. The suspected cause of the large die-off in 1990 was retrospectively thought to be the morbillivirus, however, this was not confirmed to be the definitive cause of this die-off so this event is considered of unknown etiology. The 2007 and 2008 UME's were also of unknown etiology, although it was suspected *Brucella* could have played a role. The 1990 event involved one *T. truncatus* stranding from SL proper and six stranded in nearby coastal regions (Figure 4). In the 2007 and 2008 UME's, there were no *T. truncatus* standings in SL proper, however, five and four *T. truncatus* stranded in nearby coastal areas, respectively (Figures 14 and 6, respectively). For the 2011-2012 UME, one *T. truncatus* was recovered from SL proper and one was recovered on the Gulf coast to the southwest of SL (Figure 7).

Incidental research takes

Since 1984, there have been 31 incidents of common bottlenose dolphins entangled in gillnets from fisheries research activities by Texas Parks and Wildlife [80]. Of these 31 incidents, none occurred in SL [80].

Threat assessment for *Tursiops truncatus* in Sabine Lake

Citations are included where supporting data are available. The maximum number of points per threat is 12 and the maximum total number of points possible is 228.

With a cumulative threat score of 120 and a lack of up-to date assessment data, the Sabine Lake stock ranks a high priority.

Threat	**Threat Prevalence**	**Environmental Impacts**	**Impacts-Dolphin**	**Total**
Oil & gas pollution	2 [338, 340, 342, 343, 351, 357, 358]	2 [341, 360]	3 [13]	7
Heavy metal pollution	1 [346, 349]	2 [344, 345, 353]	3	6
Chemical pollution	2 [344, 348]	3 [347, 350, 353]	3 [66, 95]	8
Marine debris	2 [354]	2	3	7
Recreational fisheries	1 [339]	2	3 [4, 159]	6
Commercial fisheries	1 [119, 339, 355]	2	3 [26, 102, 103]	6
Aquaculture	0	NA	NA	0
Shipping	2 [162, 338, 342]	2	3 [35]	7
Dredging & construction	1 [337, 338, 357]	2 [360]	3 [106]	6

continued

Threat	Threat Prevalence	Environmental Impacts	Impacts-Dolphin	Total
Noise	1	2	3 [38, 43]	6
Tourism & boat traffic	1 [339]	2	3 [54]	6
Algal blooms	1 [57]	3 [57]	3 [109]	7
Hypoxia	1 [61]	3 [61]	3 [60]	7
Adverse weather	1 [359]	3 [353]	3 [62, 159]	7
Freshwater inflows	1	2	3 [66]	6
Habitat loss	2 [330, 361]	2	3	7
Disease	1 [70, 71, 139, 267]	0	5* [69-72]	6
Climate change	1 [176]	2	3 [76]	6
UME of unknown etiology	2 [78, 142]	2	5* [78, 142]	9
Total				120

*mortality event was along the Texas coast that included animals from this BSE, but was not contained solely within this BSE

DAS scoring for *Tursiops truncatus* in Sabine Lake

	Score
Information on stock structure	0
Information on abundance	0
Information on mortality	0
Total	0

Summary: Threat Assessment Scores for Texas Bay, Sound and Estuary Common Bottlenose Dolphins Stocks

Cumulative Threat Scores (CTS), Data Assessment Scores (DAS) and final Priority Level for the bay, sound and estuary (BSE) *Tursiops truncatus* stocks in Texas. Also included are the high level threats identified within each area. The maximum number of points possible for the CTS and DAS are 228 and 20, respectively.

Table 4. Summary of threat assessment scores, overall priority levels and the identified high level threats for Texas Bay, Sound and Estuary common bottlenose dolphin stocks

BSE	CTS	DAS	Priority level	High level threats
Laguna Madre	136	0	High	Algal blooms, recreational fisheries, pollution (heavy metal & chemical), dredging & construction, hypoxia, adverse weather, freshwater inflows
Corpus Christi	136	0	High	Pollution (oil & gas, heavy metal, chemical), dredging & construction, noise, algal blooms, hypoxia
Aransas to Espiritu Santo Bay	127	0	High	Pollution (oil & gas, heavy metal, chemical), recreational fisheries, shipping, algal blooms
Matagorda Bay	123	1	High	Hypoxia, pollution (heavy metal & chemical), algal blooms, freshwater inflows
West Bay	123	0	High	Adverse weather, pollution (heavy metal & chemical), algal blooms
Galveston Bay	145	0	High	Chemical pollution, algal blooms, hypoxia, adverse weather, recreational fisheries, pollution (oil & gas, heavy metal), commercial fisheries, dredging & construction, freshwater inflows, habitat loss
Sabine Lake	120	0	High	Chemical pollution

All of the Texas BSE *T. truncatus* stocks score as a 'high priority' with medium levels of threats and virtually no data assessment available (on population structure, abundance or mortality) for each stock. That all have similar CTS values is not entirely surprising as, with perhaps the exception of Laguna Madre, these BSEs are in the same geographic area with similar anthropogenic activities (*e.g.,* shipping, dredging, oil and gas industries) and have often been impacted by similar environmental stressors (*e.g.* algal blooms, storms, changes in freshwater inflows). However, some of the high level threats identified differ between locations. For example, recreational fisheries were identified as 'high-level' threats in Laguna Madre, Aransas Bay to Espiritu Santo Bay and Galveston Bay, but not elsewhere. Regardless, it should be noted that the failure to identify an individual threat as 'high-level' might be due to data deficiencies in the impact categories of the CTS scheme rather than the stressors not being important or 'high-level'. Using the CTS scoring scheme, Galveston Bay, Corpus Christi and Laguna Madre are the areas with the highest levels of threats while Sabine Lake has the lowest level of threats (although this may in part be due to data deficiencies). Given that none have adequate abundance, stock structure or mortality information, we recommend prioritizing within this group first based on the CTS score, namely the Galveston Bay stock would receive the highest priority, followed by Laguna Madre and Corpus Christi Bay stocks. The remaining four stocks have nearly identical scores. However, there is also the additional caveat that the Aransas Bay to Espiritu Santo Bay stock had the additional stressor of incidental research takes. Although not formally scored, 18 common bottlenose dolphins were caught as by-catch in fisheries research gear from this area over 28 years, which needs to be taken into consideration when ultimately prioritizing these stocks for research. The Sabine Lake stock stands out as one with absolutely no information available on the common bottlenose dolphins present there, with reports only from fishermen and a few strandings.

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