Physiological and biological impacts of freshwater exposures on cetaceans, with an emphasis on bottlenose dolphins, *Tursiops* sp.

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Background & Scope

A number of studies have documented adverse health effects (e.g., skin lesions, electrolyte imbalance, microbial infection, and death) in bottlenose dolphins exposed to low salinity. In addition, some data exist on physiological responses in dolphins when water salinity is varied in a controlled manner. Our goal is to compile, synthesize, and summarize current knowledge of likely pathways and salinity/time combinations associated with adverse health effects in bottlenose dolphins following exposure to low salinity waters. Significant data gaps are anticipated with insufficient data points within historical and current research. This bibliography is broken into three sections: biological, behavioral, and environmental. Each section is an overview of the available literature specific to bottlenose dolphins, salinity, and that relationship.

Section I - Biological
Section one is intended to provide an overview of the effects of salinity on the biology of bottlenose dolphins, resulting in disease and skin lesions.

Section II – Behavioral
Section two is intended to provide an overview of bottlenose dolphins' prey and feeding patterns, habitat preferences, and population abundance in relation to salinity where applicable.

Section III – Environmental
Section three is intended to provide an overview of the environmental impacts on salinity levels and bottlenose dolphins.

Sources Reviewed

Along with a web search for other relevant materials the following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded, ProQuest's Science and Technology, Google Scholar, ScienceDirect, and JSTOR. Only English language materials were included. There was no date range specification in order to cover any relevant research.

Section I: Biological

Anderson, S. H. (1972). Treatment of water in dolphinaria. *Aquatic Mammals, 1*(3), 1-18. Retrieved from https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/1973/Aquatic_Mammals_1_3/Andersen.pdf

A review on the principles of water treatment in dolphinaria. Filter techniques, chlorination and its toxic consideration, pH control and flocculation are discussed. It is emphasized that a dolphinarium requires a higher standard and better control than an indoor swimming pool.

Birukawa, N., Ando, H., Goto, M., Kanda, N. P. L. A., Nakatsuji, H., Hata, H., & Urano, A. (2005). Plasma and Urine Levels of Electrolytes, Urea and Steroid Hormones Involved in Osmoregulation of Cetaceans. *Zoological Science, 22*(11), 1245-1257. https://doi.org/10.2108/zsj.22.1245

Cetaceans are well adapted to their hyperosmotic environment by properly developed osmoregulatory ability. A question here is how they regulate water and mineral balances in marine habitats. In the present study, we determined blood and urine levels of various chemicals involved in osmoregulation, compared them with those in artiodactyls, and characterized the values in the whales. Blood and urine samples obtained from baleen whales of common minke (Balaenoptera acutorostrata), sei (B. borealis), and Bryde's whales (B. brydei), and toothed whales of sperm whales (Physeter macrocephalus) were analyzed for osmolality, major electrolytes, urea, steroid hormones and glucose. The urine osmolality and Na+ concentrations in the cetaceans were much higher than those in the cattle. Furthermore, the cetaceans had 5 to 11-fold urea in plasma than the cattle, and 2 to 4-fold urea in urine. There were no significant difference in the plasma concentrations of corticosteroids between the cetaceans and the cattle. The present results indicate that the osmoregulatory parameters seem to be not affected by the reproductive stage and sex steroid hormones. The concentrations of urea in plasma and urine of the baleen whales were higher than those of the sperm whales, indicating a possibility that their osmoregulatory mechanisms may be correlated to their feeding habits. The present results suggest that cetaceans have unique osmoregulatory mechanisms by which they excrete strongly hypertonic urine to maintain fluid homeostasis in marine habitats.

Botta, S., Albuquerque, C., Hohn, A. A., da Silva, V. M. F., Santos, M. C. O., Meirelles, C., . . . Secchi, E. R. (2015). Ba/Ca ratios in teeth reveal habitat use patterns of dolphins. *Marine Ecology Progress Series, 521*, 249-263. http://dx.doi.org/10.3354/meps11158

Teeth and otoliths are metabolically inert structures that preserve a chronology of chemical variations that may be related to the environmental histories experienced by each organism. Because of the natural decrease of barium (Ba) and increase of strontium (Sr) bioavailability in water with increasing salinity, these elements may be especially useful to track habitat use in aquatic organisms. Therefore, we tested whether the Ba/Ca and Sr/Ca ratios in the teeth of dolphins represent a salinity gradient. The main aim was to determine whether these elements can be used as a natural tag for different aquatic environments. Teeth from 2 freshwater dolphins (Inia geoffrensis and Sotalia fluviatilis) and 2 marine species (S. guianensis and Pontoporia blainvillei) from Brazil and Uruguay were analyzed using a Laser Ablation Inductively Coupled Plasma-Mass Spectrometer. Intensity ratios of $^{138}Ba/^{43}Ca$ and $^{86}Sr/^{43}Ca$ were measured along a line that covered

all growth increments in the dentin from the second year of life onwards. Teeth from the freshwater species had mean Ba/Ca values tenfold higher than marine dolphins, confirming the inverse relationship between salinity (and thus ambient Ba/Ca) and elemental ratios in teeth. Furthermore, Ba/Ca ratios could also differentiate dolphins from lower-salinity estuarine areas from those in areas with minimal freshwater discharge. No significant differences were found for Sr/Ca values. Results presented encouraging indications for the application of this technique as a potential new tool for studying habitat use in aquatic mammals.

Counsell, C. W. W. (2013). *Effects of hypoxia on the spatial distribution of marine megafauna in the northwestern Gulf of Mexico* (Master's thesis). Retrieved from http://purl.flvc.org/fsu/fd/FSU_migr_etd-7344

Seasonal hypoxia (dissolved oxygen-DO, less than or equal to 2.0 mgl super(-1)) develops and extends over large regions (> 20,000 km super(2)) of the northwestern Gulf of Mexico shelf in the summer (May-August) as a result of nutrient inputs and salinity stratification associated with the Mississippi-Atchafalaya watershed. Hypoxia can lead to mortality, enhance metabolic costs, lead to habitat loss, and alter species interactions by modifying the behavior and spatial distributions of resident species. The direction and magnitude of these effects depends on the intensity and duration of the hypoxic event, and the species-specific DO tolerances and behavioral responses to low DO. Prior studies have shown that demersal fishes in the Gulf avoid hypoxic bottom water by aggregating near the edges of hypoxic zones. However, few studies have investigated how species interactions at upper trophic levels respond to hypoxic events. It may be that the spatial distributions of apex predators (e.g., dolphins) and other marine megafauna (e.g., sharks, sea turtles, rays) are altered by hypoxia-induced shifts in the distribution of their prey. To address this possibility, our team conducted synoptic aerial and shipboard (hydrographic) surveys of marine megafauna at both local, high resolution scales (2003-2004) and at shelf-wide lower resolution scales (2011-2012) during peak hypoxic periods of summer. Bottlenose dolphins, loggerhead and Kemp's ridley sea turtles, sharks, and cownose rays comprised most of the sightings. I found a higher probability of sighting dolphins in water with low levels of bottom DO or high standard deviation-SD of bottom DO. The presence of fish schools in the upper level of the water column also tended to improve the fit of models for dolphin sightings. These results suggest that dolphins are responding to hypoxia-induced behavioral responses of prey such that their trophic interactions are indirectly mediated by hypoxia. More broadly, I found higher probabilities of detecting marine megafauna and higher numbers of megafauna sightings in areas with bottom water hypoxia or on the edges of hypoxic events, though these trends were less consistent than the trends in dolphin distributions. The importance of DO varied as megafaunal community composition changed and across different months within the summer. Other water quality (i.e., fluorescence, salinity, temperature) and spatial (i.e., latitude, longitude, distance to shore) factors were also significant predictors of dolphin and megafauna sightings; however, the strength and direct of these relationships were not as consistent as those with hypoxia. This work helps elucidate the indirect effects of hypoxia on trophic interactions within the northwestern Gulf of Mexico.

E Rowe, L., Currey, R., Dawson, S., & Johnson, D. H. (2010). Assessment of epidermal condition and calf size of Fiordland bottlenose dolphin Tursiops truncatus populations using dorsal fin photographs and photogrammetry. *Endangered Species Research*, 11 (1) 83-89. https://doi.org/10.3354/esr00256

The bottlenose dolphin Tursiops truncatus population in Doubtful Sound, New Zealand, has declined by over 34% since 1995 and is subject to potential impacts from tourism and habitat modification via freshwater discharge from a hydroelectric power station. The bottlenose dolphin population in neighbouring Dusky Sound is exposed to much lower levels of tourism and the fiord receives only natural freshwater runoff. We used dorsal fin identification photographs from both pop- ulations to compare levels of epidermal disease and laser photogrammetry to measure the dorsal fin base length of calves (<1 yr old) to assess differences in calf size and birth seasonality between the populations. Epidermal lesions were common in both populations (affecting >95% of individuals), but lesion extent was 4 times higher in Doubtful Sound. Lesion extent was higher for female dolphins than for males in Doubtful Sound, but not in Dusky Sound. In Dusky Sound calves were larger at first observation and were born over a longer period. The short calving season in Doubtful Sound may be an adaptation to localized temperature conditions. Anthropogenic impacts may contribute to the higher levels of epidermal disease in the Doubtful Sound population. The higher extent of epidermal lesions in females and the smaller size of calves in Doubtful Sound may be a factor in the low survival of calves in the population.

Ewing, R. Y., Mase-Guthrie, B., McFee, W., Townsend, F., Manire, C. A., Walsh, M., . . . Schaefer, A. M. (2017). Evaluation of Serum for Pathophysiological Effects of Prolonged Low Salinity Water Exposure in Displaced Bottlenose Dolphins (Tursiops truncatus). *Frontiers in Veterinary Science, 4*(80). https://doi.og/10.3389/fvets.2017.00080

We conducted a retrospective study of serum biochemistry and hematologic findings from displaced, out-of-habitat bottlenose dolphins (Tursiops truncatus) exposed to various low salinity environments in waters along the southern United States including southeastern Atlantic and northern Gulf of Mexico. Serum sodium, chloride, and calculated osmolality were significantly lower and below reference ranges in displaced animals compared to free ranging case control animals. This suggests clinical hyponatremia, hypochloremia and hypo-osmolality due to an uptake of low saline water from the environment. In addition, significant differences were found in other serum chemistry variables, although none were outside of normal reference ranges for non-controlled free ranging animals. Multiple linear regressions demonstrated the degree of salinity had a greater pathophysiologic response than the duration of fresh water exposure. The Na/Cl ratio and bicarbonate were the only variables that were significantly modulated by exposure duration. These findings suggest that the degree of salinity is a critical factor when assessing and managing care for dolphins chronically exposed to low salinity water. Results from this study indicate that changes in various biochemical parameters can be used to determine fresh water exposure and aid in determining the treatment for animals recovered from low salinity waters.

Fury, C. A., & Reif, J. S. (2012). Incidence of poxvirus-like lesions in two estuarine dolphin populations in Australia: Links to flood events. *Science of the Total Environment, 416*, 536-540. https://doi.org/10.1016/j.scitotenv.2011.11.056

We report on the incidence of poxvirus-like lesions assessed by photographic identification in two estuarine populations of bottlenose dolphins (Tursiops aduncus) in Australia over a 3-year period.

Poxvirus infections of odontocetes are characterized by pinhole or ring-like skin lesions that appear as solitary or coalesced circular gray blemishes. Environmental and physiological stressors are believed to contribute to their manifestation (Van Bressem et al., 2009b). A total of 187 boat-based surveys were completed from October 2003 to September 2006 in the Clarence River (CR) and Richmond River (RR) estuaries, with 720 dolphins sighted. Forty-six individuals, including calves, were identified in the CR and 23 in the RR We investigated the temporal relationship between four flood events that occurred in the region during the study period and the occurrence of poxvirus-like skin lesions. Dolphin poxvirus-like lesions were not observed in these populations prior to 2004. Following flood events in 2004, 2005 and 2006, a total of 10 new cases were observed, 6 in the CR and 4 in the RR. Our data suggest that the occurrence of dolphin poxvirus-like lesions may be an indicator for climatic events such as flooding. Long-term follow-up of these estuarine populations is required to further clarify the factors leading to 'outbreaks' of poxvirus infections.

Geraci, J. R. (1972). Hyponatremia and the need for dietary salt supplementation in captive pinnipeds. *Journal of the American Veterinary Medical Association, 161*(6), 618-623. Retrieved from http://europepmc.org/abstract/MED/5056187

Over a 4-year period, harp seals and California sea lions maintained in fresh water experienced episodes of electrolyte imbalance characterized by low plasma sodium concentrations. Clinical manifestations ranged from mild to severe central nerves system (CNS) disturbances and death. The results of studies on the food-fish, plasma, electrolytes, and adreno-corticopic hormone tests pointed to insufficient salt intake with super-imposed physiologic and pathologic stresses as the cause of the condition.

Geraci, J. R., Hicks, B. D., & Staubin, D. J. (1979). Dolpin Pox: A Skin Disease of Cetaceans. *Canadian Journal of Comparative Medicine-Revue Canadienne De Medecine Comparee, 43*(4), 399-404. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1320012/pdf/compmed00028-0061.pdf

Poxvirus has been identified morphologically from skin lesions in captive and free-ranging bottlenosed dolphins, Tursiops truncatus and a stranded Atlantic white-sided dolphin, Lagenorhynchus acutus. The lesions, commonly referred to as ring or pinhole lesions, appear as solitary or coalesced circular grey blemishes. Advanced ring lesions may take the form of black punctiform stippled patterns known as "tattoo". Histologically, the stratum externum is thickened, and there is ballooning degeneration and eosinophilic intracytoplasmic inclusions in the stratum intermedium. These inclusions contain virus particles which exhibit typical poxvirus morphology. Stress, environmental conditions and general health appear to play a major role in the clinical manifestation of dolphin pox.

Gonzalvo, J., Giovos, I., & Mazzariol, S. (2015). Prevalence of epidermal conditions in common bottlenose dolphins (Tursiops truncatus) in the Gulf of Ambracia, western Greece. *Journal of Experimental Marine Biology and Ecology, 463*, 32-38. https://doi.org/10.1016/j.jembe.2014.11.004

Bottlenose dolphins (Tursiops truncatus) of the Gulf of Ambracia are exposed to numerous growing anthropogenic impacts, rendering them more prone to cutaneous changes. The prevalence of skin conditions in this resident population was evaluated based on photo-identification. Five skin

lesions previously described in other studies were considered, namely dark-fringed spots, white-fringed spots, orange patch, tattoo-like and white fin-fringe, in addition to a new particularly severe condition named as "white dots" (WD). A 37% prevalence of epidermal lesions was detected on a total of 153 dolphins. The newly identified WD was the skin condition most frequently observed (45%) in the area, showing considerable differences on its severity between individuals. From 29 dolphins affected by WD in 2012, two were severely affected throughout their 10-year photo-id records and all of them either worsened over the years, or maintained their WD condition. No cases were found in which WD resolved over time. The increasingly degraded conditions of the Gulf of Ambracia may be influencing their epidermal integrity or causing them physiological stress. The epidermal conditions here reported, in some cases very conspicuous and relatively easy to monitor over the years, might act as indicators of environmental burden.

Greenwood, A., Harrison, R., & Whitting, H. (1974). Functional and pathological aspects of the skin of marine mammals. *Functional anatomy of marine mammals, 2*, 73-110. London: Academic Press. Retrieved from http://www.worldcat.org/title/functional-anatomy-of-marine-mammals-vol-2/oclc/832360426&referer=brief_results

The comparative anatomy and physiology of marine mammals show numerous adaptations to their aquatic environment (pp. I ~42). Some may render them susceptible to certain pathological risks both in the captive and free states, and these hazards may be increased during and after capture. However, the incidence of pathology in wild cetacean and pinniped populations is not known, although there have been reports of studies on whales caught by whaling expeditions in which there were minimal reports of disease. A high mortality of captive dolphins has been reported by Nakajima et al. (1965) and Ridgway (1968). The latter observed that the initial period of adaptation to a captivity is the time of highest mortality.

Hart, L. B., Rotstein, D. S., Wells, R. S., Allen, J., Barleycorn, A., Balmer, B. C., . . . Schwacke, L. H. (2012). Skin lesions on common bottlenose dolphins (Tursiops truncatus) from three sites in the Northwest Atlantic, USA. *PLoS ONE, 7*(3), e33081. https://doi.org/10.1371/journal.pone.0033081

Skin disease occurs frequently in many cetacean species across the globe; methods to categorize lesions have relied on photo-identification (photo-id), stranding, and by-catch data. The current study used photo-id data from four sampling months during 2009 to estimate skin lesion prevalence and type occurring on bottlenose dolphins (Tursiops truncatus) from three sites along the southeast United States coast [Sarasota Bay, FL (SSB); near Brunswick and Sapelo Island, GA (BSG); and near Charleston, SC (CHS)]. The prevalence of lesions was highest among BSG dolphins ($P = 0.587$) and lowest in SSB ($P = 0.380$), and the overall prevalence was significantly different among all sites ($p<0.0167$). Logistic regression modeling revealed a significant reduction in the odds of lesion occurrence for increasing water temperatures (OR = 0.92; 95%CI:0.906-0.938) and a significantly increased odds of lesion occurrence for BSG dolphins (OR = 1.39; 95%CI:1.203-1.614). Approximately one-third of the lesioned dolphins from each site presented with multiple types, and population differences in lesion type occurrence were observed ($p<0.05$). Lesions on stranded dolphins were sampled to determine the etiology of different lesion types, which included three visually distinct samples positive for herpesvirus. Although generally considered non-fatal, skin disease may be indicative of animal health or exposure to anthropogenic or environmental threats,

and photo-id data provide an efficient and cost-effective approach to document the occurrence of skin lesions in free-ranging populations.

Hart, L. B. (2011). *The use of longitudinal and cross-sectional photographic data to study skin disease in wild bottlenose dolphins (Tursiops truncatus).* (Doctor of Philosophy), Medical University of South Carolina, Retrieved from http://cdm-library-v.musc.edu/cdm/singleitem/collection/mtd/id/524/rec/2

Many populations of bottlenose dolphins (Tursiops truncatus) inhabit coastal and estuarine waters near highly populated and developed areas, which make them susceptible to anthropogenic and terrestrial threats from pollution and runoff. Pathogens historically considered to be terrestrial and zoonotic have been identified in bottlenose dolphins (Tursiops truncatus) in recent years, possibly indicating a shift in host preference or the emergence of new diseases in naive populations. This project utilized a visual assessment approach for evaluating small cetacean health based on the prevalence, extent, and etiology of observed skin lesions and specific diseases such as lacaziosis. The prevalence of skin lesions and occurrence of different lesion types were examined among free-ranging bottlenose dolphins from three different sites in the southeastern United States (Charleston, SC; Brunswick and Sapelo, GA; Sarasota Bay, FL). The prevalence of skin lesions for the three sites ranged between 37-58% and comparisons between sites revealed significant differences in the occurrence of skin lesions, as well as differences in lesion types. A similar seasonal trend in lesion prevalence was observed for all three sites, and regression modeling revealed associations between lesion occurrence and colder water temperatures. Lacaziosis was used as a model skin disease for epidemiologic investigations of infected dolphins from Sarasota Bay and Charlotte Harbor, Florida. Approximately 2-3% of the dolphins in both populations were infected with lacaziosis or lacaziosis-like disease, and these estimates were robust to alterations in estimation methodologies. Descriptive analyses of a case series of dolphins in Sarasota Bay indicated that lacaziosis and lacaziosis-like disease were most common among adult males, and lesions were primarily located on the extremities. Case-control analyses for lacaziosis and non-lacaziosis dolphins in Sarasota Bay revealed differences in the spatial distribution and clustering of sightings, a ten-year difference in the median survival time, and social associations that suggested a non-communicable transmission pathway. Growth modeling of lacaziosis lesion progression among three lacaziosis cases from Sarasota Bay showed some individual variation in lesion progression and a gradual decrease in lesion growth over time. Furthermore, truncated modeling approaches revealed that 5-10 years of longitudinal photographic data may be sufficient for the development of similar models in other populations. Recent efforts to assess the health of wild dolphin populations have used capture and release methods; however, such methods require substantial effort, risk and cost, and are not appropriate across a broad geographic or temporal scale. Longitudinal and cross-sectional photographs of well-known bottlenose dolphin populations can be used as a non-invasive approach to develop epidemiological studies to better understand the demographic, geographic, and environmental variables that may contribute to skin disease susceptibility, transmission, and sources/reservoirs. Developing efficient means to monitor disease occurrence in these sentinel species ultimately serves as a surveillance system to track current and future emerging pathogens.

Hart, L. B., Wells, R. S., Kellar, N., Balmer, B. C., Hohn, A. A., Lamb, S. V., . . . Schwacke, L. H. (2015). Adrenal Hormones in Common Bottlenose Dolphins (Tursiops truncatus): Influential Factors and Reference Intervals. *PLoS ONE, 10*(5), e0127432. https://doi.org/10.1371/journal.pone.0127432

Inshore common bottlenose dolphins (Tursiops truncatus) are exposed to a broad spectrum of natural and anthropogenic stressors. In response to these stressors, the mammalian adrenal gland releases hormones such as cortisol and aldosterone to maintain physiological and biochemical homeostasis. Consequently, adrenal gland dysfunction results in disruption of hormone secretion and an inappropriate stress response. Our objective herein was to develop diagnostic reference intervals (RIs) for adrenal hormones commonly associated with the stress response (i.e., cortisol, aldosterone) that account for the influence of intrinsic (e.g., age, sex) and extrinsic (e.g., time) factors. Ultimately, these reference intervals will be used to gauge an individual's response to chase-capture stress and could indicate adrenal abnormalities. Linear mixed models (LMMs) were used to evaluate demographic and sampling factors contributing to differences in serum cortisol and aldosterone concentrations among bottlenose dolphins sampled in Sarasota Bay, Florida, USA (2000–2012). Serum cortisol concentrations were significantly associated with elapsed time from initial stimulation to sample collection ($p<0.05$), and RIs were constructed using nonparametric methods based on elapsed sampling time for dolphins sampled in less than 30 minutes following net deployment (95% RI: 0.91–4.21 μg/dL) and following biological sampling aboard a research vessel (95% RI: 2.32–6.68 μg/dL). To examine the applicability of the pre-sampling cortisol RI across multiple estuarine stocks, data from three additional southeast U.S. sites were compared, revealing that all of the dolphins sampled from the other sites ($N = 34$) had cortisol concentrations within the 95th percentile RI. Significant associations between serum concentrations of aldosterone and variables reported in previous studies (i.e., age, elapsed sampling time) were not observed in the current project ($p<0.05$). Also, approximately 16% of Sarasota Bay bottlenose dolphin aldosterone concentrations were below the assay's detection limit (11 pg/mL), thus hindering the ability to derive 95th percentile RIs. Serum aldosterone concentrations from animals sampled at the three additional sites were compared to the detection limit, and the proportion of animals with low aldosterone concentrations was not significantly different than an expected prevalence of 16%. Although this study relied upon long-term, free-ranging bottlenose dolphin health data from a single site, the objective RIs can be used for future evaluation of adrenal function among individuals sampled during capture-release health assessments.

Kiszka, J., Van Bressem, M. F., & Pusineri, C. (2009). Lobomycosis-like disease and other skin conditions in Indo-Pacific bottlenose dolphins Tursiops aduncus from the Indian Ocean. *Dis Aquat Organ, 84*(2), 151-157. https://doi.org/10.3354/dao02037

Lobomycosis is a chronic mycotic disease of the skin and subdermal tissues caused by the yeast-like organism Lacazia loboi, which affects humans and Delphinidae. Cases of lobomycosis and lobomycosis-like disease (LLD), a disease very similar to lobomycosis but for which a histological diagnostic is missing, have been reported in small cetaceans from the Americas and Europe. Here we report on LLD in Indo-Pacific bottlenose dolphins Tursiops aduncus from the tropical lagoon of Mayotte, between Mozambique and Madagascar. From July 2004 to June 2008, boat surveys were conducted in Mayotte waters. At least 71 adult dolphins were photo-identified. Six (5 males, 1 female) had multiple raised, greyish nodules on the dorsal fin, head, flanks, belly, back and tailstock that suggested LLD. The lesions were extensive in some cases. The calf of the positive female was also affected. LLD has been present in this community since at least 1999. As sampling was not possible, the aetiology of the disease could not be explored. The emergence of LLD in Mayotte may be related to degradation of the coastal environment associated with rapid urbanization, expanding agriculture and increased release of untreated freshwater runoffs. Other skin lesions included scars, healing wounds, whitish lesions and lumps.

Kjeld, M. (2001). Concentrations of electrolytes, hormones, and other constituents in fresh postmortem blood and urine of fin whales (Balaenoptera physalus). *Canadian Journal of Zoology, 79*(3), 438-446. https://doi.org/10.1139/z00-222

Concentrations of various blood and urine constituents were measured on postmortem samples from 286 fin whales (*Balaenoptera physalus*) caught off Iceland during the summers of 1981-1989. Measurements were carried out on both serum and urine from 21 whales so that results could be compared. The mean serum urea concentration in fin whales was similar to that in odontocetes but 5 times higher than in domesticated terrestrial mammals. Serum triglyceride concentrations were twice as high as in fasting man and showed no diurnal peaks. Serum cortisol concentrations were about 2 times lower than in domestic mammals and showed neither diurnal variation nor a significant correlation with chase time (time from sighting until killing). Serum aldosterone concentrations were similar to those in bottlenose dolphins and, as expected, showed a negative correlation with urinary Na^+ concentration. Blood thyroxine levels correlated significantly ($p < 0.003$) with chase time. Mean urinary potassium concentrations were 6 times higher than average seawater levels, while sodium and chloride levels were about 2-3 times higher than in humans but never as high as those in seawater. Urinary magnesium levels were 4-5 times higher than in domestic animals but less than half those in seawater. Average urine osmolality was higher than in seawater.

Murdoch, M. E., Mazzoil, M., McCulloch, S., Bechdel, S., O'Corry-Crowe, G., Bossart, G. D., & Reif, J. S. (2010). Lacaziosis in bottlenose dolphins Tursiops truncatus along the coastal Atlantic Ocean, Florida, USA. *Dis Aquat Organ, 92*(1), 69-73. https://doi.org/10.3354/dao02282

This study represents the first systematic study of lacaziosis (lobomycosis) in bottlenose dolphins Tursiops truncatus in the Atlantic Ocean along the east-central coast of Florida, USA. Lacaziosis is a chronic infection of the skin caused by the fungus Lacazia loboi, which affects only dolphins and humans. Previous studies have shown a high prevalence (6.8 to 12.0%) of lacaziosis in resident dolphins from the adjacent Indian River Lagoon Estuary (IRL), where the disease is endemic. We examined the prevalence of lacaziosis in this coastal area using photo-identification data collected between 2002 and 2008 to determine the prevalence of lacaziosis in coastal dolphins using photographic methodology shown to have high sensitivity and specificity in prior research. The prevalence of skin lesions compatible with lacaziosis estimated from photographic data was 2.1% (6/284), approximately 3 times lower than that described for the estuarine population using similar methods. To exclude potential bias introduced by differences in study duration and survey effort among areas, an 18 mo period when effort was most equal (January 2006 to June 2007) was chosen for statistical comparison. The prevalence of lacaziosis estimated from photographic data was significantly lower (3.8%: n = 6/160) in the Atlantic Ocean compared to the IRL (12.0%: n = 20/167) (risk ratio = 3.19, 95% CI 1.32 to 7.75, p < 0.01 by chi-square analysis). The lower prevalence of lacaziosis in dolphins found in the Atlantic Ocean and the overall lack of movement of dolphins between these habitats suggests that environmental conditions within the estuary may favor viability of L. loboi, and/or that immune compromise in resident estuarine dolphins is a precursor to the disease.

Ortiz, R. M. (2001). Osmoregulation in Marine Mammals. *Journal of Experimental Biology, 204*(11), 1831. Retrieved from http://jeb.biologists.org/content/204/11/1831

Osmoregulation in marine mammals has been investigated for over a century; however, a review of recent advances in our understanding of water and electrolyte balance and of renal function in marine mammals is warranted. The following topics are discussed: (i) kidney structure and urine concentrating ability, (ii) sources of water, (iii) the effects of feeding, fasting and diving, (iv) the renal responses to infusions of varying salinity and (v) hormonal regulation. The kidneys of pinnipeds and cetaceans are reniculate in structure, unlike those of terrestrial mammals (except bears), but this difference does not confer any greater concentrating ability. Pinnipeds, cetaceans, manatees and sea otters can concentrate their urine above the concentration of sea water, but only pinnipeds and otters have been shown to produce urine concentrations of Na+ and Cl−1 that are similar to those in sea water. This could afford them the capacity to drink sea water and not lose fresh water. However, with few exceptions, drinking is not a common behavior in pinnipeds and cetaceans. Water balance is maintained in these animals via metabolic and dietary water, while incidental ingestion and dietary salt may help maintain electrolyte homeostasis. Unlike most other aquatic mammals, sea otters commonly drink sea water and manatees frequently drink fresh water. Among the various taxonomic groups of marine mammals, the sensitivity of the renin–angiotensin–aldosterone system appears to be influenced by the availability of Na+. The antidiuretic role of vasopressin remains inconclusive in marine mammals, while the natriuretic function of atrial natriuretic peptide has yet to be examined. Ideas on the direction of future studies are presented.

Powell, S. N., Wallen, M. M., Bansal, S., & Mann, J. (2018). Epidemiological investigation of tattoo-like skin lesions among bottlenose dolphins in Shark Bay, Australia. *Science of the Total Environment, 630*, 774-780. https://doi.org/10.1016/j.scitotenv.2018.02.202

Bottlenose dolphins are excellent bioindicators of ocean ecosystem health for three reasons: (a) as long-lived apex predators they accumulate biotoxins and contaminants; (b) they are visible, routinely appearing at the water's surface in coastal areas, often coming into close contact with humans; and, (c) they exhibit a range of pathogenic lesions attributable to environmental degradation. In this study, we analyzed tattoo-like skin lesions in a population of Tuisiops aduncus studied for 30+ years in Shark Bay, Australia, a UNESCO World Heritage Site. We provide important baseline data by documenting epidemiological patterns of tattoo-like skin lesions in a healthy, free-ranging population that builds on the previous data of tattoo skin disease (TSD) derived from free ranging, stranded, and dead dolphins. Individual dolphins were classified as symptomatic with tattoo-like skin disease if at least one photograph showed a lesion similar to TSD. The average age of infection was 26.6 months (+/- 34.8 months) with the symptomatic period lasting 137 +/- 29.8 days. Overall prevalence of tattoo-like skin disease in the population was 19.4%. Age, but not sex, was significant, with yearlings (1-2 years) exhibiting tattoo-like lesions more than younger and older calves. Tattoo-like lesions were rare among juvenile and adult dolphins (N = 68 calves, 4 juveniles, and 3 adults). We hypothesize that the lower prevalence in youngest calves (<1 year) is due to maternal immunity, while older individuals (>2 years) have infection-acquired immunity, as reported for other small cetaceans. The low prevalence of tattoo-like lesions in Shark Bay compared to other populations with poxvirus is consistent with reproductive and demographic viability analyses. Furthermore, by documenting the demography of the disease, we can monitor changes in the prevalence of tattoo-like lesions as a sentinel indicator of ecosystem health.

Reif, J. S., Fair, P. A., Adams, J., Joseph, B., Kilpatrick, D. S., Sanchez, R., . . . Bossart, G. D. (2008). Evaluation and comparison of the health status of Atlantic bottlenose dolphins from the Indian River Lagoon, Florida, and Charleston, South Carolina. *Journal of the American Veterinary Medical Association, 233*(2), 299-307. https://doi.org/10.2460/javma.233.2.299

OBJECTIVE: To conduct health assessments and compare outcomes in 2 populations of Atlantic bottlenose dolphins. Design-Repeated cross-sectional study.
ANIMALS: 171 Atlantic bottlenose dolphins.
PROCEDURES: During June and August of 2003 through 2005, 89 dolphins from the Indian River Lagoon (IRL), Florida, and 82 dolphins from estuarine waters near Charleston, SC, were evaluated. A panel of 5 marine mammal veterinarians classified dolphins as clinically normal, possibly diseased, or definitely diseased on the basis of results of physical and ultrasonographic examinations, hematologic and serum biochemical analyses, and cytologic and microbiologic evaluations of gastric contents and swab specimens.
RESULTS: Prevalence of dolphins classified as definitely diseased did not differ significantly between the IRL (32%) and Charleston (20%) sites. Proportions of dolphins classified as possibly diseased also did not differ. Lobomycosis was diagnosed in 9 dolphins from the IRL but in none of the dolphins from Charleston. Proportions of dolphins with orogenital papillomas did not differ significantly between the IRL (12%) and Charleston (7%) sites. From 2003 through 2005, the proportion classified as definitely diseased tripled among dolphins from the Charleston site but did not increase significantly among dolphins from the IRL. Dolphins from the Charleston site were more likely to have leukocytosis, lymphocytosis, and low serum concentrations of total protein and total J-globulins than were dolphins from the IRL.
CONCLUSIONS AND CLINICAL RELEVANCE: High prevalences of diseased dolphins were identified at both sites; however, the host or environmental factors that contributed to the various abnormalities detected are unknown.

Reif, J. S., Mazzoil, M. S., McCulloch, S. D., Varela, R. A., Goldstein, J. D., Fair, P. A., & Bossart, G. D. (2006). Lobomycosis in Atlantic bottlenose dolphins from the Indian River Lagoon, Florida. *Javma-Journal of the American Veterinary Medical Association, 228*(1), 104-108. https://doi.org/10.2460/javma.228.1.104

Objective-To determine the prevalence of lobomycosis, a mycotic infection of dolphins and humans caused by a yeastlike organism (Lacazia loboi), among dolphins in the Indian River Lagoon in Florida. Design-Cross-sectional study. Animals-146 Atlantic bottlenose dolphins. Procedure-Comprehensive health assessments of bottlenose dolphins in the Indian River Lagoon of Florida (n = 75) and in estuarine waters near Charleston, SC (71), were conducted during 2003 and 2004. Bottlenose dolphins were captured, examined, and released. Skin lesions were photographed and then biopsied. Tissue sections were stained with H&E and Gomori methenamine silver stains for identification of L loboi. Results-9 of 30 (30%) dolphins captured in the southern portion of the Indian River Lagoon had lobomycosis, whereas none of the 45 dolphins captured in the northern portion of the lagoon or of the 71 dolphins captured near Charleston, SC, did. Affected dolphins had low serum alkaline phosphatase activities and high acute-phase protein concentrations. Conclusions and Clinical Relevance-Results suggest that lobomycosis may be occurring in epidemic proportions among dolphins in the Indian River Lagoon. Localization of the disease to the southern portion of the lagoon, an area characterized by freshwater intrusion and lower salinity, suggests that exposure to environmental stressors may be contributing to the high prevalence of the disease, but specific factors are unknown. Because only dolphins and humans are naturally susceptible to infection, dolphins may represent a sentinel species for an emerging infectious disease.

Rossman, S., Ostrom, P. H., Gordon, F., & Zipkin, E. F. (2016). Beyond carbon and nitrogen: guidelines for estimating three-dimensional isotopic niche space. *Ecol Evol, 6*(8), 2405-2413. https://doi.org/10.1002/ece3.2013

Isotopic niche has typically been characterized through carbon and nitrogen ratios and most modeling approaches are limited to two dimensions. Yet, other stable isotopes can provide additional power to resolve questions associated with foraging, migration, dispersal and variations in resource use. The ellipse niche model was recently generalized to n-dimensions. We present an analogous methodology which incorporates variation across three stable dimensions to estimate the significant features of a population's isotopic niche space including: 1) niche volume (referred to as standard ellipsoid volume, SEV), 2) relative centroid location (CL), 3) shape and 4) area of overlap between multiple ellipsoids and 5) distance between two CLs. We conducted a simulation study showing the accuracy and precision of three dimensional niche models across a range of values. Importantly, the model correctly identifies differences in SEV and CL among populations, even with small sample sizes and in cases where the absolute values cannot precisely be recovered. We use these results to provide guidelines for sample size in conducting multivariate isotopic niche modeling. We demonstrate the utility of our approach with a case study of three bottlenose dolphin populations which appear to possess largely overlapping niches when analyzed with only carbon and nitrogen isotopes. Upon inclusion of sulfur, we see that the three dolphin ecotypes are in fact segregated on the basis of salinity and find the stable isotope niche of inshore bottlenose dolphins significantly larger than coastal and offshore populations.

Schwacke, L. H., Hall, A. J., Townend, F. I., Wells, R. S., Hansen, L. J., Hohn, A. A., . . . Rowles, T. K. (2009). Hematologic and serum biochemical reference intervals for free-ranging common bottlenose dolphins (Tursiops truncatus) and variation in the distributions of clinicopathologic values related to geographic sampling site. *American Journal of Veterinary Research, 70*(8), 973-985. https://doi.org/10.2460/ajvr.70.8.973

Objective: To develop robust reference intervals for hematology and clinical blood chemistry (HCBC) values based on a large sample from free-ranging bottlenose dolphins (Tursiops truncatus) and to examine potential variation related to geographic sampling site. Sample Population: 255 free-ranging bottlenose dolphins sampled between 2000-2006 from the southeast U.S. coast during health assessment studies in 4 geographic sites. Procedures: Data from multiple bottlenose dolphin capture-release projects were combined to determine reference intervals for 52 HCBC variables. A nonparametric bootstrap approach was applied to estimate 95th percentiles and associated 90% confidence intervals, and the need for partitioning by length and sex classes was determined by testing for differences in estimated thresholds using a bootstrap method. When appropriate, quantile regression was used to determine continuous functions for 95th percentiles dependent on length. The proportion of out-of-range samples for all HCBC measurements was examined for each geographic site and multivariate analysis of variance was applied to further explore variation in leukocyte subgroups. Results: A need for partitioning by length and sex class was indicated for many HCBC variables. There were few significant deviations from expected number of out-of-range samples for each geographic site. While mean leukocyte counts did not vary across sites, differences were indicated in the mean counts for leukocyte differentials. Conclusions: While differences were noted in the centrality of distributions for some parameters, the 95th percentiles estimated from the pooled data were robust and applicable across geographic sites. Reference intervals presented here provide critical information for conducting bottlenose dolphin population health studies.

Simpson JG, & MB, G. (1972). Comparative microscopic anatomy of selected marine mammals. In S. H. Ridgway (Ed.), *Mammals of the sea; biology and medicine* (pp. 298-418). Springfield, Ill.: Thomas.

Book chapter on the "major organ systems of certain marine mammals [with] comments regarding selected pathologic processes, mostly of cetaceans but with some mention of pinnipeds."

Suzuki, M., & Ortiz, R. (2016). Water Balance. In Castellini MA & M. J (Eds.), *Marine Mammal Physiology: Requisites for ocean living* (pp. 139-161). Boca Raton, FL: CRC Press Taylor & Francis Group.

Constancy of the milieu interieur is critically important for Metazoan organisms because the cells can only live within a narrow range of physicochemical conditions necessary for proper cellular functions. Water and salt are fundamental for life and the main determinants of the osmolality of the extracellular fluid. In most vertebrates, water and salt balance is rigidly controlled to maintain the osmolality at about one-third of seawater by changing the transport of water and electrolytes to meet the demands induced by the external environments. When early vertebrates ascended upon dry land they evolved robust physiological mechanisms to conserve water and electrolytes. Subsequently, when these mammals radiated into a marine environment they had to evolve mechanisms to allow them to tolerate and thrive in an external milieu of high salinity with limited availability to freshwater. A number of morphological and physiological adaptations have allowed them to cope with these osmotic challenges. Additionally, other life-history traits such as mating, molting, and migration are associated with protracted periods of fasting, which place an additional osmoregulatory burden on marine mammals. The evolved physiological mechanisms have allowed marine mammals to conserve salts and water during prolonged fasting as well with virtually no consequences. In this chapter, the osmoregulatory mechanisms in marine mammals are reviewed.

Sweeney, J. C., & Ridgway, S. H. (1975). Common diseases of small cetaceans. *Journal of the American Veterinary Medical Association, 167*(7), 533-540. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/1100576

Journal article reporting on "commonly found diseases of small cetaceans [with] information on their diagnosis, treatment, and prevalence is presented by organ or tissue primarily affected."

Van Bressem, M. F., Raga, J. A., Di Guardo, G., Jepson, P. D., Duignan, P. J., Siebert, U., . . . Van Waerebeek, K. (2009). Emerging infectious diseases in cetaceans worldwide and the possible role of environmental stressors. *Diseases of Aquatic Organisms, 86*(2), 143-157. https://doi.org/10.3354/dao02101

We reviewed prominent emerging infectious diseases of cetaceans, examined their potential to impact populations, re-assessed zoonotic risk and evaluated the role of environmental stressors. Cetacean morbilliviruses and papillomaviruses as well as Brucella spp. and Toxoplasma gondii are thought to interfere with population abundance by inducing high mortalities, lowering reproductive success or by synergistically increasing the virulence of other diseases. Severe cases of lobomycosis and lobomycosis-like disease (LLD) may contribute to the death of some dolphins. The

zoonotic hazard of marine mammal brucellosis and toxoplasmosis may have been underestimated, attributable to frequent misdiagnoses and underreporting, particularly in developing countries and remote areas where carcass handling without protective gear and human consumption of fresh cetacean products are commonplace. Environmental factors seem to play a role in the emergence and pathogenicity of morbillivirus epidemics, lobomycosis/LLD, toxoplasmosis, poxvirus-associated tattoo skin disease and, in harbour porpoises, infectious diseases of multifactorial aetiology. Inshore and estuarine cetaceans incur higher risks than pelagic cetaceans due to habitats often severely altered by anthropogenic factors such as chemical and biological contamination, direct and indirect fisheries interactions, traumatic injuries from vessel collisions and climate change.

Van Bressem, M. F., Van Waerebeek, K., Aznar, F. J., Raga, J. A., Jepson, P. D., Duignan, P., . . . Siebert, U. (2009). Epidemiological pattern of tattoo skin disease: a potential general health indicator for cetaceans. *Diseases of Aquatic Organisms, 85*(3), 225-237. https://doi.org/10.3354/dao02080

The presence of tattoo skin disease (TSD) was examined in 1392 free-ranging and dead odontocetes comprising 17 species from the Americas, Europe, South Africa, New Zealand and Greenland. We investigated whether TSD prevalence varied with sex, age and health status. TSD was encountered in cetaceans from the Pacific and Atlantic Oceans as well as in those from the North, Mediterranean and Tasman Seas. No clear patterns related to geography and host phylogeny were detected, except that prevalence of TSD in juveniles and, in 2 species (dusky dolphin Lagenorhynchus obscurus and Burmeister's porpoise Phocoena spinipinnis), in adults was remarkably high in samples from Peru. Environmental factors and virus properties may be responsible for this finding. Sex did not significantly influence TSD prevalence except in the case of Peruvian P. spinipinnis. Generally, there was a pattern of TSD increase in juveniles compared to calves, attributed to the loss of maternal immunity. Also, in most samples, juveniles seemed to have a higher probability of suffering TSD than adults, presumably because more adults had acquired active immunity following infection. This holo-endemic pattern was inverted in poor health short-beaked common dolphins Delphinus delphis and harbour porpoises Phocoena phocoena from the British Isles, and in Chilean dolphins Cephalorhynchus eutropia from Patagonia, where adults showed a higher TSD prevalence than juveniles. Very large tattoos were seen in some adult odontocetes from the SE Pacific, NE Atlantic and Portugal's Sado Estuary, which suggest impaired immune response. The epidemiological pattern of TSD may be an indicator of cetacean population health.

Van Bressem, M.-F., Van Waerebeek, K., Flach, L., Reyes, J., César, M., Santos, O., . . . Castro, C. (2008). *Skin diseases in cetaceans*. Scientific Committee document SC/60/DW8, International Whaling Committee. Santiago, Chile. Retrieved from https://iwc.int/document_1665

Micro-organisms that are known or suspected to cause skin diseases in cetaceans are briefly reviewed. Viruses belonging to four families i.e. Caliciviridae, Herpesviridae, Papillomaviridae and Poxviridae were detected by electron microscopy, histology and molecular techniques in vesicular skin lesions, black dots perceptible by the touch, warts and tattoos in several species of odontocetes and mysticetes. Herpesviruses, poxviruses and likely a cutaneous papillomavirus are cetacean specific. Among bacteria, Dermatophilus spp., Erysipelothrix rhusiopathiae, Mycobacterium marinum, Pseudomonas spp., Streptococcus iniae and Vibrio spp. were isolated from ulcerative dermatitis, pyogranulomatous dermatitis and panniculitis, diamond skin disease and slow-healing

ulcers and abscesses. Aeremonas spp., Mycobacterium marinum, Pseudomonas spp. and Vibrio spp. are normally present in the marine environment while Erysipelothrix rhusiopathiae and Streptococcus iniae are fish pathogens that may also infect captive dolphins. Most seem to be opportunistic pathogens, exploiting some break-down in the host's defenses to initiate an infection. Selection of antibiotic-resistant bacteria through the prophylactic use of antibiotics in aquaculture is suggested to be a growing problem in South America and may account for the emergence of unusual cutaneous conditions. At least four groups of fungi i.e. Candida albicans, Fusarium spp., Trichophyton spp. and Lacazia loboi cause skin diseases. Candidiasis occurs predominantly in captive odontocetes. The lesions are often localized around the body orifices and may become extensive, granulating and ulcerated. Fusariosis is characterized by firm, erythematous, cutaneous nodules. Trichophyton spp. was isolated from widespread superficial nodules in an Atlantic T. truncatus kept in captivity in Japan. Lobomycosis or lacaziosis is distinguished by grayish, whitish to slightly pink, verrucuous lesions, often in pronounced relief that may ulcerate. While initially described only in Tursiops truncatus and Sotalia guianensis from the Americas, lobomycosis seems to be expanding to other continents. The role of ballast water in transporting fungi worldwide should be investigated. Finally, ciliated protozoans, likely Kyaroikeus cetarius, caused invasive dermatitis in small cetaceans from the USA and Korea. The aquatic environment of cetaceans is naturally home to bacteria and fungi but cetacean skin has several mechanisms to impede invasion. Chemical contaminants may affect natural skin barriers and depress the immune system. Wounds and specific viral infection (poxvirus, herpesvirus) may provide routes of entry.

van der Toorn, J. D. (1987). A biological approach to dolphinarium water purification. I. Theoretical aspects. *Aquatic Mammals, 13*(3), 83-92. Retrieved from https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/1987/Aquatic_Mammals_13_3/13-03_VanDerToorn.pdf

In this paper an overview is given of several alternative techniques for dolphinarium water purification, that may make water conditions more natural. Discussed are water composition, biological filtration, based on the trickling filter principle, and foam fractionation. Indications are given to their possible applicauons in dolphinarium water treatment systems.

Wells, R. S., Rhinehart, H. L., Hansen, L. J., Sweeney, J. C., Townsend, F. I., Stone, R., . . . Rowles, T. K. (2004). Bottlenose Dolphins as Marine Ecosystem Sentinels: Developing a Health Monitoring System. *EcoHealth, 1*(3), 246-254. https://doi.org/10.1007/s10393-004-0094-6

Bottlenose dolphins (Tursiops truncatus), as long-lived, long-term residents of bays, sounds, and estuaries, can serve as important sentinels of the health of coastal marine ecosystems. As top-level predators on a wide variety of fishes and squids, they concentrate contaminants through bioaccumulation and integrate broadly across the ecosystem in terms of exposure to environmental impacts. A series of recent large-scale bottlenose dolphin mortality events prompted an effort to develop a proactive approach to evaluating risks by monitoring living dolphin populations rather than waiting for large numbers of carcasses to wash up on the beach. A team of marine mammal veterinarians and biologists worked together to develop an objective, quantitative, replicable means of scoring the health of dolphins, based on comparison of 19 clinically diagnostic blood parameters to normal baseline values. Though the scoring system appears to roughly reflect dolphin health, its general applicability is hampered by interlaboratory variability, a lack of independence between some of the variables, and the possible effects of weighting variables. High score variance seems to indicate that the approach may lack the sensitivity to identify trends over

time at the population level. Potential solutions to this problem include adding or replacing health parameters, incorporating only the most sensitive measures, and supplementing these with additional measures of health, body condition, contaminant loads, or biomarkers of contaminants or their effects that can also be replicated from site to site. Other quantitative approaches are also being explored.

Wilson, B., Arnold, H., Bearzi, G., Fortuna, C. M., Gaspar, R., Ingram, S., . . . Hammond, P. S. (1999). Epidermal diseases in bottlenose dolphins: impacts of natural and anthropogenic factors. *Proceedings of the Royal Society B-Biological Sciences, 266*(1423), 1077-1083. https://doi.org/10.1098/rspb.1999.0746

Experimental studies have highlighted the potential influence of contaminants on marine mammal immune function and anthropogenic contaminants are commonly believed to influence the development of diseases observed in the wild. However, estimates of the impact of contaminants on wild populations are constrained by uncertainty over natural variation in disease patterns under different environmental conditions. We used photographic techniques to compare levels of epidermal disease in ten coastal populations of bottlenose dolphins (Tursiops truncatus) exposed to a wide range of natural and anthropogenic conditions. Epidermal lesions were common in all populations (affecting >60% of individuals), but both the prevalence and severity of 15 lesion categories varied between populations. No relationships were found between epidermal disease and contaminant levels across the four populations for which toxicological data were available. In contrast, there were highly significant linear relationships with oceanographic variables. In particular, populations from areas of low water temperature and low salinity exhibited higher lesion prevalence and severity. Such conditions may impact on epidermal integrity or produce more general physiological stress, potentially making animals more vulnerable to natural infections or anthropogenic factors. These results show that variations in natural environmental factors must be accounted for when investigating the importance of anthropogenic impacts on disease in wild marine mammals.

Section II: Behavioral

Barros, N., & Wells, R. S. (1998). Prey and feeding patterns of resident bottlenose dolphins (Tursiops truncatus) in Sarasota Bay, Florida. *Journal of Mammalogy, 79*(3), 1045- 1059. https://doi.org/10.2307/1383114

Stomach contents of a resident community of bottlenose dolphins (Tursiops trnncatus) from the Sarasota Bay area of the westcentral coast of Florida were studied to examine potential factors leading to patterns of habitat use. Composition and size of prey were analyzed and correlated with feeding behavior of individual dolphins of known histories. Examination of stomach contents of 16 stranded dolphins revealed a diet composed exclusively of fish (->15 species), most of which were associated with seagrasses in varying degrees. Observational records for <-21 years showed that feeding typically occurred in shallow (2-3 m) waters and in the vicinity of seagrasses in 23% of cases. Dolphins usually fed alone or in small groups and on non-obligate schooling prey. The main species of prey were soniferous, an indication that passive listening may be important in detection of prey. The close agreement between species of fishes represented in stomach contents and habitat of prey, as indicated by observations of feeding, suggests that analysis of stomach contents is a

reasonable approach for studying prey and feeding patterns of dolphins. Meadows of seagrass are one of the habitats of importance to dolphins in the Sarasota Bay area, and their protection is important for conservation of these animals.

Barry, K., Gorgone, A. M., & Mase, B. (2008). *Lake Pontchartrain, Louisiana Bottlenose Dolphin Survey Summary 28 April 2008 – 10 May 2008*. Miami, FL: Protected Resources and Biodiversity Division. Retrieved from https://deltas.usgs.gov/bonnetReports/DolphinReport.pdf

Monitoring report on a bottlenose dolphin group in Lake Pontchartrain, a lagoon with salinity that varies seasonally, influenced by Mississippi River inputs.

Fury, C. A., & Harrison, P. L. (2011). Impact of flood events on dolphin occupancy patterns. *Marine Mammal Science, 27*(3), E185-E205. https://doi.org/10.1111/j.1748-7692.2010.00447.x

The aim of this study was to assess potential impacts of water quality changes associated with floods on the occupancy of Indo-Pacific bottlenose dolphins (Tursiops aduncus) in two subtropical estuaries in Australia. Boat-based surveys were conducted in the Clarence River estuary (CR) and Richmond River estuaries (RR) over 3 yr. Principal components analysis (PCA) showed that when the dolphins were absent from the estuaries, three water quality components were extracted in the CR and two components in the RR. The PCA(1) component included high loadings for salinity, turbidity, and pH for the CR (46%); and salinity, turbidity, pH, and dissolved oxygen (DO) for the RR(51%). Randomization tests showed that dolphins abandoned both estuaries at times of lower salinity, and during periods of higher turbidity and of lower levels of pH and dissolved oxygen in the RR that were associated with floods. The time until dolphins returned to the estuary postflood depended on the length and severity of the flood, but generally dolphins were observed in waters with salinity levels above 29 parts per thousand. Their delayed return postflood could be for their physiological health, or because their prey returned to the estuaries under these higher salinity conditions, or more likely a combination of both factors.

Gregory, P. R., & Rowden, A. A. (2001). Behaviour patterns of bottlenose dolphins (Tursiops truncatus) relative to tidal state, time of day, and boat traffic in Cardigan Bay, West Wales. *Aquatic Mammals, 27*(2), 105-113. Retrieved from https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/2001/AquaticMammals_27-02/27-02_Gregory.PDF

Diurnal behaviour patterns of the bottlenose dolphin (Tursiops truncatus) were investigated at two sites in relation to tidal state, time-of-day, and boat traffic in Cardigan Bay, west Wales. The two sites chosen were New Quay and Ynys Lochtyn. Between-site variability existed in the occurrence of dolphins. However, no relationship was found between the numbers of dolphins observed in relation to the tidal cycle or time-of-day at either of the two sites. Dolphin movement patterns were correlated with tidal state at both sites, with the dolphins moving with the tidal flow or during slack water. No relationship was found between movement patterns and time-of-day. Foraging behaviour was correlated with tidal state at both sites, with dolphins foraging mainly between the flood and ebb tides of high water. Foraging in relation to group size was not significant at either site. No relationship was found between foraging behaviour and time-of-day. Statistically significant behavioural responses were noted towards boat traffic. Dolphins generally displayed a neutral response toward boats, i.e., the dolphins showed no apparent change in directional movement,

prior to and after the arrival of the vessel. However, dolphins displayed a negative response toward kayaks, and a positive response toward tourist boats. Dolphin's reactions toward boats in relation to group size were not statistically significant. The study supported the findings of previous studies on bottlenose dolphins in other localities; however, the effect of kayaks requires further investigation. Recommendations are made for future avenues of research regarding this species

Gulland, F. M. D., Nutter, F. B., Dixon, K., Calambokidis, J., Schorr, G., Barlow, J., . . . Baker, C. S. (2008). Health Assessment, Antibiotic Treatment, and Behavioral Responses to Herding Efforts of a Cow-Calf Pair of Humpback Whales (*Megaptera novaeangliae*) in the Sacramento River Delta, California. *Aquatic Mammals, 34*(2), 182-192. https://doi.org/10.1578/am.34.2.2008.182

A mother and female calf humpback whale (Megaptera novaeangliae) pair were observed at an atypical location, 72 nmi inland in the Port of Sacramento, California, on 16 May 2007. Sequencing of mtDNA from a skin biopsy showed the cow to be an E1 haplotype, which is common in the California feeding population. Both animals had lacerations, suggesting sharp trauma from a boat strike. Photographs taken over 11 d showed generalized deterioration of skin condition and necrotic wound edges. Behavioral responses were recorded during attempts to move the animals downriver to the Pacific Ocean. The attempts included playback of alarm tones, humpback and killer whale sounds, banging hollow steel pipes ("Oikami pipes"), spraying water from fire hoses on the water surface, and utilizing tug and power boat engine noise and movement. None of these deterrents resulted in significant, consistent downstream movement by the whales. Antibiotic therapy (ceftiofur) was administered by a dart, representing the first reported antibiotic treatment of free-ranging live whales. After 11 d, the animals swam downstream from fresh water at Rio Vista to brackish water, and their skin condition noticeably improved 24 h later. The animals followed the deep-water channel through the Sacramento Delta and San Francisco Bay, reaching the ocean at least 20 d after first entering the Sacramento River.

Hastie, G. D., Wilson, B., Wilson, L. J., Parsons, K. M., & Thompson, P. M. (2004). Functional mechanisms underlying cetacean distribution patterns: hotspots for bottlenose dolphins are linked to foraging. *Marine Biology, 144*(2), 397-403. https://doi.org/10.1007/s00227-003-1195-4

Many studies have shown that the distribution of cetaceans can be closely linked to habitat, but the underlying function of the preferred habitats often remains unclear. Only when behavioural observations are made in relation to habitat types can functional mechanisms behind the habitat use be revealed. Within the range of a bottlenose dolphin (Tursiops truncatus) population off NE Scotland, dolphins show clear preferences for several discrete areas. If the observed patterns of distribution are related to foraging, we predict that behaviour patterns shown by dolphins would reflect this relationship. In this study we identify behaviours of dolphins at the water surface that were related to feeding events, evaluate whether the patterns of distribution were related to foraging and whether they were related the local submarine habitat characteristics. To investigate whether visible surface evidence of foraging behaviour varied spatially, we analysed data collected from 104 regular boat-based surveys made within the Moray Firth, NE Scotland, between 1990 and 2000. To determine whether underlying bathymetry had any influence on the surface behaviour of dolphins, a land-based observation study was carried out in the populations core region of use. The results of this study show that feeding behaviour by dolphins was significantly higher in areas used intensively by dolphins. Furthermore, there were clear relationships between feeding events and

the submarine habitat characteristics; certain forms of feeding occur primarily over steep seabed gradients, and in deeper waters during June and July. These results quantitatively support the hypothesis that the distinctive patterns of distribution shown by these dolphins are related to foraging behaviour or opportunities, and that submarine habitat characteristics may be a significant factor in the foraging efficiency of dolphins. Future work should focus on collecting detailed information on the distribution patterns of prey within the study area to allow direct comparisons between predator and prey distributions.

Irvine, A. B., Scott, M. D., Wells, R. S., & Kaufmann, J. H. (1981). Movements and activities of the Atlantic bottlenose dolphin, Tursiops-truncatus, near Sarasota, Flordia. *Fishery Bulletin, 79*(4), 671-688. Retrieved from https://spo.nmfs.noaa.gov/content/movements-and-activities-atlantic-bottlenose-dolphin-tursiops-truncatus-near-sarasota

A tagging-observation program was conducted to study the behavioral ecology of Atlantic bottlenose dolphins near Sarasota, Florida. Forty-seven bottlenose dolphins (24 males, 23 females) were captured, tagged, and released a total of90 times from 29 January 1975 through 25 July 1976. Tagged animals were identified during regular boat surveys, and information was collected on all individuals and groups encountered. A total of997 tagged or marked bottlenose dolphins were sighted. A population of bottlenose dolphins was identified in an estuarine-nearshore area extending about 40 km to the south from Tampa Bay and up to 3 km into the Gulf of Mexico. Social organization was characterized by small dynamic groups that appeared to be subunits of a larger socially interacting herd. Average group size of 688 groups was 4.8 bottlenose dolphins (standard error = 0.16), Bottlenose dolphins concentrated in different areas seasonally, possibly in response to distribution changes of important prey species. Feeding strategies of the bottlenose dolphins apparently varied according to available water depth and differed from strategies of pelagic small cetaceans. Calving apparently occurred from spring to early fall.

Miller, L. J., Mackey, A. D., Solangi, M., & Kuczaj, S. A. (2013). Population abundance and habitat utilization of bottlenose dolphins in the Mississippi Sound. *Aquatic Conservation: Marine and Freshwater Ecosystems, 23*(1), 145-151. https://doi.org/10.1002/aqc.22781

Distance sampling principles were utilized to examine population density and abundance for bottlenose dolphins (Tursiops truncatus) in the Mississippi Sound. Information was collected during summer and winter to allow for examination of habitat utilization and abundance during two different seasons. 2. Within the study area of the Mississippi Sound there are approximately 2225 bottlenose dolphins. The population was larger during the summer than during the winter months. 3. Dolphins utilized coastal areas more during the summer, potentially as nursery grounds, as evidenced by larger numbers of calves and percentage of groups containing calves during this time. Bottlenose dolphin densities were lower in this area during the winter suggesting migration to deeper waters potentially in search of prey. 4. As the Mississippi Sound is regularly utilized for a variety of human activities, the monitoring of dolphin populations in this area is critical to determine increasing or decreasing trends in population abundance due to potential anthropogenic factors that may affect animal populations. 5. Similar studies around the world could provide evidence for areas that could be protected to ensure survival of species such as dolphins and other marine mammals.

Mullin, K. D., Barry, K., Sinclair, C., Litz, J., Maze-Foley, K., Fougeres, E., . . . Tumlin, M. (2015). *Common Bottlenose Dolphins (Tursiops Truncatus) in Lake Pontchartrain, Louisiana, 2007 to Mid-2014*: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center. http://doi.org/10.7289/V51C1TT8

Lake Pontchartrain (LP) is a brackish lagoon (1,630 km2) in southeastern Louisiana connected by two passes on the eastern end to open estuarine waters. Salinity in LP varies seasonally and is generally lowest in late spring and highest in summer and fall (range ≈ 0–15 ppt). Common bottlenose dolphins (Tursiops truncatus; dolphins) are distributed throughout estuarine waters in the northern Gulf of Mexico but records of dolphins in LP were historically rare. In 2007, 30–40 dolphins were reported in eastern LP just to the west of the Norfolk Southern railroad and U.S. Route 11 bridges ("target area") and reports suggested that dolphins had been there since Hurricane Katrina in August 2005. An initial survey in May 2007 confirmed the location and number of dolphins and revealed that most of them had minor to severe skin lesions that were thought to result from exposure to low salinity water. Periodic photo-identification surveys (n = 35) were conducted from spring 2007 through spring 2010 in the target area, eastern LP (east of the bridges) and the two passes. Dolphins were sighted in the target area during 90% of the surveys through winter 2010 after which none were sighted. Seventy-four dolphins were identified in the target area and averaged 34.2 dolphins/survey (n = 25, S.D. = 6.73, range 22–45). Dolphins with unmarked dorsal fins, including calves and neonates, averaged 2.0 dolphins/survey (S.D. = 1.76, range = 0–6). Twenty-three identified dolphins in the target area had more than 700 days from their first to their last sighting and these individuals were sighted during 8 to 11 of the 11 seasons surveyed where dolphins were sighted. Sixty-one dolphin groups were sighted in eastern LP and the passes with 141 individuals identified, but none were sighted more than four times. There were few identified individuals that were sighted in multiple locations (i.e., target area, eastern LP, the two passes). Skin lesions occurred on over 90% of the target area dolphins and on 30–100% of those from other locations. Lesion severity appeared to be seasonal, and worsened and improved with lower and higher salinities, respectively. Twentyseven dolphin strandings occurred in the LP area in spring 2010. Salinity and water temperatures in the LP area were unusually low in winter 2010. Only one target area dolphin was sighted in another location post winter 2010. While it was presumed that most of the target area dolphins likely died, only one target area dolphin was among the 12 stranded dolphins from the LP area with a dorsal fin photo of sufficient quality to attempt to match to previously identified dolphins. Twenty-four dolphin strandings also occurred in the LP area in 2013 after only three strandings in 2011and 2012. The origin of the 2013 strandings is unknown, due in part to the lack of LP monitoring after 2010.

Muzquiz-Villalobos, M., & Pompa-Mansilla, S. (2018). Marine mammals of Mexico: Richness patterns, protected areas, and conservation trends. *Estuarine Coastal and Shelf Science, 208*, 153-160. https://doi.org/10.1016/j.ecss.2018.05.002

Mexico registers about 60% of the total of marine mammals worldwide. However, species listed under a risk category show that, globally, Mexico faces big marine mammal conservation challenges. Thus, it becomes essential to successfully apply the existing knowledge into interdisciplinary conservation programs. We generated a presence/absence species richness map containing all 47 marine mammal species recorded in Mexico's Exclusive Economic Zone. After selecting nine oceanographic variables influencing marine mammal species richness, the top three factors influencing such richness were sea surface temperature and dissolved oxygen grouped in component #1, and salinity composed component #2. We also identified the species that are

protected within a Marine Protected Area (MPA) category and its representation in management programs of these areas. Currently, 98% of marine mammal species distributed in Mexican waters are protected within an MPA; nevertheless, around 12% of them are not listed in management programs. Three priority sites in the Pacific Ocean and one for the Gulf of Mexico were identified to promote their conservation. Considering the sentinel and umbrella attributes of marine mammals, the information presented here will not only benefit their populations, but will also contribute to address marine species and ecosystems threats and improve the effectiveness of conservation plans.

Natoli, A., Birkun, A., Aguilar, A., Lopez, A., & Hoelzel, A. R. (2005). Habitat structure and the dispersal of male and female bottlenose dolphins (Tursiops truncatus). *Proc Biol Sci, 272*(1569), 1217-1226. https://doi.org/10.1098/rspb.2005.3076

Bottlenose dolphins (Tursiops truncatus) are widely distributed and a high degree of morphometric and genetic differentiation has been found among both allopatric and parapatric populations. We analysed 145 samples along a contiguous distributional range from the Black Sea to the eastern North Atlantic for mitochondrial and nuclear genetic diversity, and found population structure with boundaries that coincided with transitions between habitat regions. These regions can be characterized by ocean floor topography, and oceanographic features such as surface salinity, productivity and temperature. At the extremes of this range there was evidence for the directional emigration of females. Bi-parentally inherited markers did not show this directional bias in migration, suggesting a different dispersal strategy for males and females at range margins. However, comparative assessment based on mitochondrial DNA and nuclear markers indicated that neither sex showed a strong bias for greater dispersal on average. These data imply a mechanism for the evolutionary structuring of populations based on local habitat dependence for both males and females.

Reif, J. S., Schaefer, A. M., Daniel, M., Harrington, T., Hanisak, D., Titcomb, E., & Mazzoil, M. (2018). Dolphin Sightings in the Vicinity of Land/Ocean Biogeochemical Observatories: Relationships with Weather and Water Quality. *Aquatic Mammals, 44*(4), 367-373. https://doi.org/10.1578/am.44.4.2018.367

The objective of this study was to test the potential influence of short-term changes in water quality on the frequency of sightings of common dolphins (Tursiops truncatus) in the Indian River Lagoon, Florida The study was based on two data sources: (1) Land/Ocean Biogeochemical Observatories (LOBOs) that provided real-time monitoring of multiple water quality and weather parameters, and (2) standardized methods for identifying and counting individual dolphins using photo-identification techniques. Water quality parameters included salinity, water color (chromophoric dissolved organic matter), conductivity, dissolved oxygen concentration, oxygen saturation, chlorophyll, nitrate and phosphate concentrations, temperature, and turbidity. Weather was assessed using data for air temperature, barometric pressure, humidity, light, and wind speed and direction. Variables were measured continuously over a one-year period and analyzed as the mean for each parameter the hour before, during, and after each dolphin sighting period. Short-term variations in sightings within 0.5 km of the LOBO were measured using previously established photo-identification techniques on a weekly basis. In multivariable regression analyses, statistically significant inverse associations were found between air temperature and the frequency of dolphin sightings for all three time periods. The results demonstrate the feasibility of integrating variation

in weather and water chemistry data with dolphin movements as potential indicators of ecosystem quality and climate change.

Wursig, B., & Lynn, S. K. (1996). *Movements, site fidelity, and respiration patterns of bottlenose dolphins on the central Texas coast*. Retrieved from Miami, FL: Retrieved from https://repository.library.noaa.gov/view/noaa/8531

Radio-tracking of 10 bottlenose dolphins (Tursiops truncatus), from 9 July 1992 to 13 September 1992, and photographic surveys of 35 freeze-branded dolphins, from May 1992 to June 1993, were conducted in the Matagorda Bay area of Texas, in response to a mass mortality event which occurred between Matagorda and Aransas Bays, Texas, during spring 1992. The primary goals of the study were to assess range size and site fidelity, as well as to initiate a long-term ecological study by collecting data on social and behavioral patterns. The Matagorda Bay dolphin population was found to be numerically robust, occupying all regions of the bay surveyed. Mean range size, based on radio telemetry, was 140km^ (SD=90.7, n=10 dolphins). Males and females had similar range sizes though males visited the extremities of their ranges more frequently or for longer periods. Several generalities were observed: (1) Dolphins were capable of, and often did, traverse their range in several hours. (2) Dolphins traveled widely on some days, perhaps crossing their own ranges, while on other days movement was very confined, within 1-2km^. This did not appear to have a temporal or geographic pattern. (3) Dolphins tended to spend about 1-4 days in a particular portion of their range. (4) Movement tended to be more confined at night than during daytime. (5) Dolphins tended to visit the extremes of their ranges only in the daytime. The assertions of (4) and (5) may be biased as a result of less sampling effort at night, with fewer triangulations than during daytime and no visual sightings. Most, if not all, of the 35 freeze-branded dolphins appeared to be resident to the Matagorda-Espiritu Santo Bay area with much fluidity of group membership. Overall mark/recapture population size estimates from photo-identification suggested that 218±71.4 (95%CI) dolphins utilized an area of 312km^in Matagorda and Espiritu Santo Bays, similar to an estimate made in 1981. Dolphins spent longer times at the surface and dove less often at night, indicating lower activity levels at night. Observations of long-distance movement between Texas bays, and an autumn increase in dolphin numbers in the study area, suggested that the study animals were not an isolated population.

Section III: Environmental

A. Colbert, A., Scott, G., Fulton, M., Wirth, E., Daugomah, J., D. Strozier, E., & B. Galloway, S. (1999). *Investigation of Unusual Mortalities of Bottlenose Dolphins along the Mid-Texas Coastal Bay Ecosystem during 1992*. Retrieved from https://repository.library.noaa.gov/view/noaa/3094

An investigation was conducted into the deaths of more than 220 bottlenose dolphins (Tursiops truncatus) that occurred within the coastal bay ecosystem of mid-Texas between January and May 1992. The high mortality rate was unusual in that it was limited to a relatively small geographical area, occurred primarily within an inshore bay system separated from the Gulf of Mexico by barrier islands, and coincided with deaths of other taxa including birds and fish. Factors examined to determine the potential causes of the dolphin mortalities included microbial pathogens, natural biotoxins, industrial pollutants, other environmental contaminants, and direct human interactions.

Emphasis was placed on nonpoint source pesticide runoff from agricultural areas, which had resulted from record rainfall that occurred during the period of increased mortality. Analytical results from sediment, water, and biota indicated that biotoxins, trace metals, and industrial chemical contamination were not likely causative factors in this mortality event. Elevated concentrations of pesticides (atrazine and aldicarb) were detected in surface water samples from bays within the region, and bay salinities were reduced to <10 ppt from December 1991 through April 1992 due to record rainfall and freshwater runoff exceeding any levels since 1939. Prolonged exposure to low salinity could have played a significant role in the unusual mortalities because low salinity exposure may cause disruption of the permeability barrier in dolphin skin. The lack of established toxicity data for marine mammals, particularly dermal absorption and bioaccumulation, precludes accurate toxicological interpretation of results beyond a simple comparison to terrestrial mammalian models. Results clearly indicated that significant periods of agricultural runoff and accompanying low salinities co-occurred with the unusual mortality event in Texas, but no definitive cause of the moralities was determined.

Andersen, S. H., & Nielsen, E. (1983). Exchange of water between the harbor porpoise, Phocoena phocoena, and the environment. *Experientia, 39*(1), 52-53. https://doi.org/10.1007/BF01960622

During determination of total body water and net water turnover in the harbor porpoise, Phocoena phocoena, it was demonstrated that the porpoise exchanged water with an isosmotic environment by way of free diffusion and with hypo- or hyperosmotic environment by way of osmosis.

Barco, S. G., Swingle, W. M., Mlellan, W. A., Harris, R. N., & Pabst, D. A. (2006). Local abundance and distribution of bottlenose dolphins (Tursiops truncates) in the nearshore waters of Virginia Beach, Virginia. *Marine Mammal Science, 15*(2), 394-408. https://doi.org/10.1111/j.1748-7692.1999.tb00809.x

We investigated patterns of abundance and distribution for coastal migratory Atlantic bottlenose dolphins (Tursiops truncatus) that appear seasonally in the nearshore waters of Virginia Beach, Virginia. The study was conducted along 24 km of shoreline at the southern point of the Chesapeake Bay mouth from April 1994 to March 1995. This is the first study to investigate the relationship between the abundance of coastal migratory dolphins and factors that might affect their movement. A profile analysis of variance revealed significant differences in local abundance and distribution throughout the year. Dolphin number was positively correlated with water temperature and not correlated with photoperiod. Although prey distribution and abundance are two factors thought to affect dolphin presence, in this study the relationship between these two factors and dolphin abundance was unclear. Greater numbers of dolphins were found in the ocean section of the study area. However, significantly higher ratios of neonatal dolphins were observed in the bay section, suggesting the bay serves as a nursery area. The observed relationship between local dolphin abundance and environmental factors in Virginia may provide insight into dolphin distribution and migration along the Atlantic coast of the United States.

Carmichael, R. H., Graham, W. M., Aven, A., Worthy, G., & Howden, S. (2012). Were multiple stressors a 'perfect storm' for northern Gulf of Mexico bottlenose dolphins (Tursiops truncatus) in 2011? *PLoS ONE, 7*(7), e41155. https://doi.org/10.1371/journal.pone.0041155

An unusual number of near term and neonatal bottlenose dolphin (Tursiops truncatus) mortalities occurred in the northern Gulf of Mexico (nGOM) in 2011, during the first calving season after two well documented environmental perturbations; sustained cold weather in 2010 and the Deepwater Horizon oil spill (DWHOS). Preceding the stranding event, large volumes of cold freshwater entered the nGOM due to unusually large snowmelt on the adjacent watershed, providing a third potential stressor. We consider the possibility that this extreme cold and freshwater event contributed to the pattern of perinatal dolphin strandings along the nGOM coast. During the 4-month period starting January 2011, 186 bottlenose dolphins, including 46% perinatal calves (nearly double the percentage for the same time period from 2003-2010) washed ashore from Louisiana to western Florida. Comparison of the frequency distribution of strandings to flow rates and water temperature at a monitoring buoy outside Mobile Bay, Alabama (the 4(th) largest freshwater drainage in the U.S.) and along the nGOM coast showed that dolphin strandings peaked in Julian weeks 5, 8, and 12 (February and March), following water temperature minima by 2-3 weeks. If dolphin condition was already poor due to depleted food resources, bacterial infection, or other factors, it is plausible that the spring freshet contributed to the timing and location of the unique stranding event in early 2011. These data provide strong observational evidence to assess links between the timing of the DWHOS, other local environmental stressors, and mortality of a top local predator. Targeted analyses of tissues from stranded dolphins will be essential to define a cause of death, and our findings highlight the importance of considering environmental data along with biological samples to interpret stranding patterns during and after an unusual mortality event.

Chabanne, D., Harrison, L.-M., Holyoake, C., Finn, H., Stephens, N., & Bejder, L. (2012). *Swan Canning Riverpark dolphin population ecology and health investigations, Final report to the Swan River Trust for Project RSP10MUR03*. Murdoch University. Retrieved from http://researchrepository.murdoch.edu.au/id/eprint/38588/

An investigation into the deaths of six Indo-Pacific bottlenose dolphins (Tursiops aduncus) within the Swan Canning Riverpark between May-October 2009 found that a suite of factors likely contributed to the mortalities (Beazley 2010; Holyoake et al. 2010). This investigation, along with research undertaken for Swan Canning Research Innovation Program (SCRIP) Project: —Toxicant exposure, population genetics, and trophic associations of bottlenose dolphins (Tursiops sp.) in the Swan River‖ (Holyoake et al. 2011), emphasised the vulnerability of the resident community to natural and anthropogenic stressors and the need to improve the scientific basis for the long-term conservation of dolphins within the estuary. To support this aim, the Swan River Trust and Murdoch University entered into a collaborative agreement Project to undertake further health and ecology investigations into dolphins in the Swan Canning Riverpark and to conclude analyses of existing data and samples. This report presents the major findings for this project.

Cubero-Pardo, P. (2007). Environmental factors governing the distribution of the bottlenose (Tursiops truncatus) and the spotted dolphin (Stenella attenuata) in Golfo Dulce, South Pacific, off Costa Rica*/Factores ambientales que gobiernan la distribución del delfín bufeo (Tursiops truncatus) y del delfín manchado (Stenella attenuata) en el Golfo Dulce, Pacífico sur de Costa Rica*. *Investigaciones Marinas. Valparaiso, 35*(2), 15-23. Retrieved from https://scielo.conicyt.cl/scielo.php?script=sci_abstract&pid=S0717-71782007000200002&lng=es&nrm=iso&tlng=en

This study, conducted from June 1996 to July 1997, was directed at determining the abiotic environmental factors governing the distribution of the bottlenose dolphin (Tursiops truncatus)

and the pan-tropical spotted dolphin (Stenella attenuata) in Golfo Dulce. The spotted dolphin was associated with significantly deeper zones (t-test = -9.761; $p < 0.001$, n = 202) and with higher salinity (t-test = -3.538; p = 0.001; n = 202) than the bottlenose dolphin. The combination of environmental variables in the distribution areas of each species in Golfo Dulce was different, both spatially (F = 9.724, df = 12; $p < 0.001$) and seasonally (F = 9.735; df = 12; $p < 0.001$). Of all the environmental variables considered, Multiple Discriminant Analysis showed depth to be the main factor differentiating the distribution areas of the two species. The relationship between group size in each species, depth, and the location of their distribution areas in relation to the shore were analyzed and evidence regarding these aspects and variations in foraging strategies and prey composition was proposed to explain the differences found in their spatial distributions. Seasonal variations in salinity in the distribution areas and their inverse relationship with the time of the year were analyzed in relation to their possible combined effects on prey composition during different seasons in order to explain the seasonal variations in distribution patterns.

Das, A., Justic, D., Inoue, M., Hoda, A., Huang, H. S., & Park, D. H. (2012). Impacts of Mississippi River diversions on salinity gradients in a deltaic Louisiana estuary: Ecological and management implications. *Estuarine Coastal and Shelf Science, 111*, 17-26. https://doi.org/10.1016/j.ecss.2012.06.005

Large-scale river diversions on the lower Mississippi River are considered to be an important component of wetland restoration efforts in coastal Louisiana. Diversions are used primarily for salinity control but increasingly proposed also as a major way to deliver sediments and nutrients to coastal wetlands impacted by the construction of flood control levees. We used a coupled hydrology-hydrodynamics model of the Barataria estuary, a site of the Davis Pond Diversion - the world's largest river diversion project, to examine salinity variations under different diversion discharge scenarios. Discharge scenarios were selected based on actual freshwater discharges in different years and management alternatives that included a scenario with several new diversions. The model results indicate that river diversions strongly affect salinities only in the middle section of the Barataria estuary. The upper parts of the estuary are fresh most of the time and so the excess fresh water from river diversions has only a minor impact on salinity in this region. Also, the Davis Pond diversion has little impact on salinities in the coastal section of the estuary because of strong marine influence in this area adjacent to the Gulf of Mexico. Interestingly, the predicted salinity differences between different model scenarios can be as high as 10 in some months and places. These differences can be biologically significant depending on the salinity tolerance of different species and could cause a shift in community composition within the affected region.

Davis, R. W., Ortega-Ortiz, J. G., Ribic, C. A., Evans, W. E., Biggs, D. C., Ressler, P. H., . . . Würsig, B. (2002). Cetacean habitat in the northern oceanic Gulf of Mexico. *Deep Sea Research Part I: Oceanographic Research Papers, 49*(1), 121-142. https://doi.org/10.1016/S0967-0637(01)00035-8

Cetaceans (whales and dolphins) are diverse and abundant upper trophic level predators in the Gulf of Mexico, a semi-enclosed, intercontinental sea with a total area of about 1.5 million km2. The objectives of this study were to better define the habitat of cetaceans in the northern oceanic Gulf of Mexico. An integrated methodology was used that included visual surveys and hydrographic collections from ships. Near real-time sea surface altimetry from the TOPEX/POSEIDON and ERS satellites was used during ship surveys to determine the location of hydrographic features (e.g.,

cyclones, anticyclones and confluence zones). Archival satellite sea surface altimetry data were also used to retrospectively determine the location of hydrographic features for analysis with earlier cetacean sightings. We estimated zooplankton and micronekton biomass using both net and acoustic sampling to indicate the amount of potential food available for higher trophic level foraging by cetaceans. Nineteen cetacean species were identified during ship surveys. Cetaceans were concentrated along the continental slope in or near cyclones and the confluence of cyclone–anticyclone eddy pairs, mesoscale features with locally concentrated zooplankton and micronekton stocks that appear to develop in response to increased nutrient-rich water and primary production in the mixed layer. A significant relationship existed between integrated zooplankton biomass and integrated cephalopod paralarvae numbers, indicating that higher zooplankton and micronekton biomass may correlate with higher concentrations of cetacean prey. In the north-central Gulf, an additional factor affecting cetacean distribution may be the narrow continental shelf south of the Mississippi River delta. Low salinity, nutrient-rich water may occur over the continental slope near the mouth of the Mississippi (MOM) River or be entrained within the confluence of a cyclone–anticyclone eddy pair and transported beyond the continental slope. This creates a deep-water environment with locally enhanced primary and secondary productivity and may explain the presence of a resident, breeding population of sperm whales within 100km of the Mississippi River delta. Overall, the results suggest that the amount of potential prey for cetaceans may be consistently greater in the cyclone, confluence areas, and south of the MOM, making them preferential areas for foraging. However, this may not be true for bottlenose dolphins, Atlantic spotted dolphins and possibly Bryde's whales, which typically occur on the continental shelf or along the shelf break outside of major influences of eddies.

Devkota, J., & Fang, X. (2015). Quantification of Water and Salt Exchanges in a Tidal Estuary. *Water, 7*(12), 1769-1791. https://doi.org/10.3390/w7051769

A calibrated three-dimensional hydrodynamic model was applied to study subtidal water and salt exchanges at various cross sections of the Perdido Bay and Wolf Bay system using the Eulerian decomposition method from 6 September 2008 to 13 July 2009. Salinity, velocity, and water levels at each cross section were extracted from the model output to compute flow rates and salt fluxes. Eulerian analysis concluded that salt fluxes (exchanges) at the Perdido Pass and Dolphin Pass cross sections were dominated by tidal oscillatory transport FT, whereas shear dispersive transport FE (shear dispersion due to vertical and lateral shear transport) was dominant at the Perdido Pass complex, Wolf-Perdido canal, and the lower Perdido Bay cross sections. The flow rate QF and total salt transport rate FS showed distinct variation in response to complex interactions between discharges from upstream rivers and tidal boundaries. QF and FS ranged from −619 m3·s−1 (seaward) to 179 m3·s−1 (landward) and −13,480–6289 kg·s−1 at Perdido Pass when river discharges ranged 11.0–762.5 m3·s−1 in the 2008–2009 simulation period.

Fazioli, K. L., Hofmann, S., & Wells, R. S. (2006). Use of Gulf of Mexico Coastal Waters by Distinct Assemblages of Bottlenose Dolphins (*Tursiops truncatus*). *Aquatic Mammals, 32*(2), 212-222. https://doi.org/10.1578/am.32.2.2006.212

Management and conservation decisions affecting coastal bottlenose dolphins (*Tursiops truncatus*) benefit from consideration of population parameters such as population size, stability, distribution, habitat use, and gene flow, as well as social organization patterns. Long-term study of bottlenose dolphins in inshore areas suggested population units are based on the social structure and habitat use of resident dolphins, but little is known about dolphins in open coastal waters just offshore.

This study examined the stock structure of bottlenose dolphins in an open coastal habitat, made comparisons to adjacent inshore population units, and evaluated interactions between dolphins in these two regions. We conducted a 14-mo boatbased photographic identification study along 93 km of the west coast of Florida, extending 9.3 km offshore. We identified 580 individual dolphins in the study area and designated these individuals as "Inshore" (long-term bay residents) or "Gulf" (observed predominantly in Gulf waters) regional population units. Dolphins used the Gulf habitat differently, depending on season and regional designation. Sighting frequencies of "Gulf" dolphins suggested patterns of seasonal residency, extended geographic range out of the study area, or transience, with fewer individuals displaying yearround residence. In general, dolphins in this coastal region appear to divide into overlapping communities defined by preferred geographic ranges, habitat use patterns, and social associations.

Fury, C. (2009). *Abundance, behaviour and habitat use patterns of Indo-Pacific bottlenose dolphins (Tursiops aduncus) in the Clarence and Richmond River estuaries in northern New South Wales, Australia* (Thesis). Southern Cross University. Lismore, NSW. Retrieved from https://epubs.scu.edu.au/theses/89/

Bottlenose dolphins (Tursiops spp.) are a widely studied species in marine habitats, however, information on estuarine populations in Australia is very limited. To fully understand the importance of estuaries as habitats for dolphins there needs to be clear quantitative data on dolphin populations and their habitat use in estuaries. This study provides the first published data on Indo-Pacific bottlenose dolphins (Tursiops aduncus) abundance estimates, site fidelity, individual ranging patterns, habitat use, flood impacts and sexual segregation patterns over a 3-year period in the Clarence River (CR) and Richmond River (RR) estuaries in northern New South Wales, Australia. The results indicate that, at present, the CR estuary is sustaining a larger dolphin community with a predominantly resident population compared to the RR estuary, which supports a smaller community with lower site fidelity. The CR estuary dolphin abundance estimate of 71 (62-81 95% CI, CV = 0.07) is more than twice the size of the RR estuary abundance estimate of 34 (19-49 95% CI, CV = 0.23). Differences in site fidelity were observed between the estuaries with 60% and 37% of identified dolphins determined as residents, 26% and 21% as occasional visitors, and 14% and 42% as transients for the CR and RR, respectively. Resource partitioning was apparent in both estuaries with the mean distance resident dolphins were found upstream from the River mouth being greater than for the occasional visitors and transients. Tursiops aduncus was seen all year round in the CR and RR estuaries, with peak sightings occurring in spring at both sites. In the CR the dolphin population showed consistent seasonal fluctuations, whereas this did not occur in the RR population. In the CR the largest spatial distribution of dolphins in the estuary was observed in spring and winter, while in summer they were primarily restricted to the main estuary channel. Different behaviours that were observed; feeding, socialising, travelling, and milling and resting, were found to be influenced by season, tidal phase and tidal range. In both estuaries the core habitat areas used by the population for feeding consisted of areas with considerable slope near the edge of tidal sand banks, adjacent to deeper channels at the entrances of canals, creeks or artificial breakwalls. In addition, the core habitat areas used by the population for milling and resting behaviour in both estuaries occurred in shallow, sheltered areas, often associated with seagrass beds. Socialising occurred more frequently in the CR throughout most of the deeper waters of the estuary, whereas in the RR it was primarily restricted to a small area of medium depth in the estuary. The major determinant of T. aduncus occupancy in the two estuaries was the flood events that occurred, which resulted in the dolphins abandoning the estuary. The mean predicted probabilities for sighting dolphins during non-flood periods were 0.87 and 0.71, during a flood 0.21 and 0.04, and during a post-flood recovery period 0.83 and 0.80 in the CR and RR, respectively.

Principal Components Analysis (PCA) showed that when the dolphins were absent from the estuaries, three components were extracted from the water quality parameters in the CR, and two components in the RR. High loadings from the PCA were associated with the changing salinity, turbidity, pH, dissolved oxygen and temperature associated with the flood events. The return of the dolphins to the estuary following a flood depended on the length and severity of the flood event, but generally the dolphins seemed to prefer waters with salinity levels above 29 ‰. This could be associated with higher salinities being important for their physiological health, or because their prey returned to the estuaries during these higher salinity conditions, more likely a combination of both of these factors. Sexual segregation patterns were observed in T. aduncus populations with mixed gender and female groups mainly recorded in the CR, whereas in the RR female groups dominated the estuary. In the CR, ignificant differences occurred in sightings between the mixed and female groups in relation to water depth and behaviour. Mixed gender groups were sighted predominantly in deeper water and were involved in social behaviour including sexual behaviour and male herding of females. In contrast, the female groups were observed across all water depths, predominately feeding and also participating in more milling and resting behaviours. The high occurrence of aggressive herding behaviour by males in the CR was significantly different at varying depths, tides and seasons, occurring more often in deeper water, at higher tides and in non-breeding seasons. Female groups were found to utilise the small, shallow tributaries and travel for longer distances up these smaller tributaries than the mixed groups, which were concentrated in the deeper main channel of the estuary. The deeper water of the channels may facilitate the males in herding the females, while the female groups' habitat selection of shallow estuary areas may provide a sanctuary from aggressive males, access to suitable prey items or prey density for mothers and their calves, or a combination of these factors. This study has provided the first detailed research on T. aduncus dolphin population dynamics, habitat use, occupancy and sexual segregation patterns in two Australian subtropical estuaries. To ensure the long-term survival of both of these dolphin populations, management of future increased anthropogenic disturbances from boat traffic, pollution, dolphin watching, industrial or urban development, over-fishing and habitat degradation of the catchment is needed. Good quality water conditions, the protection of the core feeding areas and small shallow tributaries for females and their calves, and sheltered areas for resting behaviour all need to be maintained for the continued conservation of these important dolphin populations.

Holyoake, C., Finn, H., Stephens, N., Duignan, P., Salgado Kent, C., Raudino, H., . . . McElligott, D. (2010). *Technical report on the Bottlenose dolphin (Tursiops aduncus) unusual mortality event within the Swan Canning Riverpark, June-October 2009*. Retrieved from http://mucru.org/our-research/south-west-marine-research-program/marine-mammal-health-project/

This technical report reviews findings from an investigation into the mortalities of six bottlenose dolphins (Tursiops aduncus) in the Swan Canning Riverpark in 2009. The report: (a) describes the epidemiology and pathology of these mortalities; (b) presents background information on the ecology of dolphins in the Swan Canning Riverpark and factors known to affect dolphin health; and (c) discusses the potential role of chemical contaminants in the mortalities. These mortalities were investigated in context of dolphin deaths in the Swan Canning Riverpark prior to 2009 and a series of mortalities of dolphins in the Bunbury area between 2008-10, as well as marine mammal mortality events in other locations.

Hornsby, F. E., McDonald, T. L., Balmer, B. C., Speakman, T. R., Mullin, K. D., Rosel, P. E., . . . Schwacke, L. H. (2017). Using salinity to identify common bottlenose dolphin habitat in Barataria Bay, Louisiana, USA. *Endangered Species Research, 33*, 181-192. https://doi.org/10.3354/esr00807

Following the Deepwater Horizon (DWH) oil spill, numerous studies were conducted to determine impacts on common bottlenose dolphins Tursiops truncatus. Common bottlenose dolphins are found in estuarine environments of the northern Gulf of Mexico which vary in salinity, depending on location (e.g. distance to freshwater source), season, and ocean tides. Although common bottlenose dolphins can be found in low-salinity waters (<15 ppt), they cannot tolerate very low salinity for long periods of time. We matched dolphin telemetry data in Barataria Bay, Louisiana (USA), with contemporaneous estimates of salinity to establish a salinity threshold and identify preferred dolphin habitat. Dolphins frequently used areas where salinity was higher than similar to 11 ppt, sometimes used areas for short periods of time with predicted salinity of similar to 8 ppt, and avoided waters with salinities below similar to 5 ppt. While not a hard boundary, the similar to 8 ppt threshold can be used to delineate reasonable polygons of preferred dolphin habitat. We temporally averaged the location of the similar to 8 ppt isohaline from 2005 through 2012 to establish areas of preferred dolphin habitat. In Barataria Bay, the polygon of dolphin habitat encompasses 1167 km(2), and extends from the bay's barrier islands to approximately half-way through marshes in northern parts of the bay. This polygon of suitable common bottlenose dolphin habitat was then ultimately used to quantify cetacean injury due to DWH oil.

Lin, T.-H., Akamatsu, T., & Chou, L.-S. (2014). Seasonal Distribution of Indo-Pacific Humpback Dolphins at an Estuarine Habitat: Influences of Upstream Rainfall. *Estuaries and Coasts, 38*(4), 1376-1384. https://doi.org/10.1007/s12237-014-9886-2

River estuaries are dynamic regions that are influenced by the interactions between freshwater and seawater as well as seasonal variations in river runoffs. Studies focusing on the distribution of Indo-Pacific humpback dolphins (Sousa chinensis) have indicated their general tendency toward estuarine habitats. The seasonal activities of humpback dolphins are likely to synchronize with environmental fluctuations. This study investigated the effects of seasonal changes in river runoffs on the distribution gradient of humpback dolphins by deploying acoustic data loggers along the Xin Huwei River estuary, Western Taiwan, between July 2009 and September 2012. Seasonal shifts were observed in the areas with high detected duration of humpback dolphins, which mainly stayed near the river mouth during the dry seasons but moved seaward during rainy seasons and following heavy rainfall. In addition, the gradient of ambient ultrasonic pulses, dominated by snapping shrimp sounds, exhibited regional differences following heavy rainfall. The outward movements of the humpback dolphins and the snapping shrimp sounds in the estuary indicated a temporary trophic-system shift in response to local environmental changes resulting from high volumes of river runoffs. In the future, the seasonal variation in the distribution of humpback dolphins must be considered during the conservation management of this critically endangered population.

Manton, V. (1986). Part 1. Anatomy and physiology. 12. Water management. In Bryden MM & H. R (Eds.), *Research on dolphins.* (pp. 189-208). Oxford: Clarendon Press.

Book chapter on dolphin biology and pollution of water sources they live in.

Marley, S. A., Salgado Kent, C. P., & Erbe, C. (2017). Occupancy of bottlenose dolphins (Tursiops aduncus) in relation to vessel traffic, dredging, and environmental variables within a highly urbanised estuary. *Hydrobiologia, 792*(1), 243-263. https://doi.org/10.1007/s10750-016-3061-7

Coastal areas, and thus coastal species, are at increasing risk from human activities. Sections of the coastline of Western Australia are undergoing intense coastal development to fulfil commercial, industrial, and recreational requirements. Multiple populations of bottlenose dolphins (Tursiops aduncus) occur around this coastline; however, small community sizes and limited genetic exchange rates make them susceptible to anthropogenic pressure. This study investigated the occupancy of dolphins within the Swan–Canning Rivers, an urbanised estuary, with regard to (1) presence/absence, (2) abundance, and (3) duration in terms of time spent in the area. These response variables were related back to environmental conditions (tidal state, tidal height, salinity, temperature), vessel traffic, and dredging activities using generalised additive modelling. Theodolite tracking data revealed high levels of boat traffic at the two sites considered; however, dolphin occurrence was only negatively affected by vessel density at one of these sites. Dolphin occupancy was also significantly influenced by temperature, with possible seasonal effects. No dolphins were sighted on days when backhoe dredging was present; however, low sample sizes limited statistical interpretation. These results highlight the need to consider context in behavioural response studies, in terms of habitat type studied, explanatory variables considered, and response variables selected.

Mase-Guthrie B, Townsend F, McFee W, Manire C, Ewing RY, & T., P. (2005). *Cases of prolonged freshwater exposure in dolphins along the Southeast United States*. Paper presented at the Society for Marine Mammalogy 16th Biennial Conference, San Deigo, CA. Retrieved from https://www.marinemammalscience.org/wp-content/uploads/2014/09/Abstracts-SMM-Biennial-San-Diego-2005.pdf

Since 1992, there have been 13 reported cases of dolphins found swimming "out of habitat" in fresh water rivers and/or estuaries experiencing low salinity in the Southeast U.S. These cases involved Tursiops truncatus ((Tt), n=11) Stenella frontalis (n=1) and Stenella attenuata ((Sa), n=1). Coastal bottlenose dolphins have been observed to frequent fresh water systems associated with their home ranges. However, in the cases reported here, the animals were trapped in the freshwater system and were unable to leave due to various causes. Factors resulting in an "out of habitat" situation for these cases included climatic (e.g., hurricane), anthropogenic (e.g., construction) and other unknown host factors. Ten of the 13 cases resulted in the animals' death. In the three remaining instances, the animals were captured and released or rehabilitated. Here we report on the clinical signs of prolonged fresh water exposure in four separate instances which occurred in Louisiana (Tt, n=1), Florida Panhandle (Sa, n=1), Florida West Coast (Tt, n=1) and South Carolina (Tt, n=2). The salinity in all four sites ranged from 0 ppt to 5 ppt. Time of individual exposure was approximated to be from five days to three weeks. The clinical findings observed for freshwater exposure included corneal edema, generalized skin pallor, various skin lesions and electrolyte imbalance. The information presented here can be used to provide baseline information for prolonged exposure to freshwater and better determine a point to which intervention is warranted.

Mazzoil, M., Reif, J. S., Youngbluth, M., Murdoch, M. E., Bechdel, S. E., Howells, E., . . . Bossart, G. D. (2008). Home Ranges of Bottlenose Dolphins (Tursiops truncatus) in the Indian River Lagoon, Florida: Environmental Correlates and Implications for Management Strategies. *EcoHealth, 5*(3), 278-288. https://doi.org/10.1007/s10393-008-0194-9

Photo-identification surveys conducted between 2002 and 2005 were used to determine dolphin home ranges and site fidelity within the Indian River Lagoon (IRL), Florida. The IRL was divided into six segments based on hydrodynamics and geographic features for purposes of characterization. Among the 615 dolphins with identifiable dorsal fins, 339 had ≥6 sightings and were used in segment and linear range analyses. The majority (98%) of dolphins were seen in ≤3 consecutive segments (331/339); of these, 44% (144/331) occurred in two segments, and 33% (109/331) in one segment. No dolphins were observed in all six segments. The largest number of dolphins was sighted in segment 1C (North Indian River). However, the highest density of dolphins was found in segment 2 (North-Central Indian River). Re-sighting rates for dolphins with ≥6 sightings ranged from 2.8 to 8.7 times observed. The mean linear home range varied from 22 to 54 km. Distributional analyses indicated that at least three different dolphin communities exist within the IRL: Mosquito Lagoon, and the North and South Indian River. No statistically significant correlations were found between the total number or density per km2 of dolphins and surface water area, salinity, or contaminant loads within segments of the lagoon. These results suggest that dolphins do not selectively avoid areas with relatively unfavorable water quality. IRL dolphins should be studied on smaller spatial scales than currently practiced, and potential anthropogenic impacts should be evaluated based on geographic partitioning.

Meager, J. J., & Limpus, C. (2014). Mortality of inshore marine mammals in eastern Australia is predicted by freshwater discharge and air temperature. *PLoS ONE, 9*(4), e94849. https://doi.org/10.1371/journal.pone.0094849

Understanding environmental and climatic drivers of natural mortality of marine mammals is critical for managing populations effectively and for predicting responses to climate change. Here we use a 17-year dataset to demonstrate a clear relationship between environmental forcing and natural mortality of inshore marine mammals across a subtropical-tropical coastline spanning a latitudinal gradient of 13 degrees (>2000 km of coastline). Peak mortality of inshore dolphins and dugongs followed sustained periods of elevated freshwater discharge (9 months) and low air temperature (3 months). At a regional scale, these results translated into a strong relationship between annual mortality and an index of El Nino-Southern Oscillation. The number of cyclones crossing the coastline had a comparatively weak effect on inshore marine mammal mortality, and only in the tropics. Natural mortality of offshore/migratory cetaceans was not predicted by freshwater discharge, but was related to lagged air temperature. These results represent the first quantitative link between environmental forcing and marine mammal mortality in the tropics, and form the basis of a predictive tool for managers to prepare responses to periods of elevated marine mammal mortality.

Miller, C. E., & Baltz, D. M. (2010). Environmental characterization of seasonal trends and foraging habitat of bottlenose dolphins (Tursiops truncatus) in northern Gulf of Mexico bays. *Fishery Bulletin, 108*(1), 79-86. Retrieved from https://spo.nmfs.noaa.gov/content/environmental-characterization-seasonal-trends-and-foraging-habitat-bottlenose-dolphins

A description of the foraging habitat of a cetacean species is critical for conservation and effective management. We used a fine-scale microhabitat approach to examine patterns in bottlenose dolphin (Tursiops truncatus) foraging distribution in relation to dissolved oxygen, turbidity, salinity, water depth, water temperature, and distance from shore measurements in a highly turbid estuary on the northern Gulf of Mexico. In general, environmental variation in the Barataria Basin marine environment comprises three primary axes of variability (i.e., factors: temperature and dissolved oxygen, salinity and turbidity, and distance and depth) that represent seasonal, spatial-seasonal, and spatial scales, respectively. Foraging sites were differentiated from nonforaging sites by significant differences among group size, temperature, turbidity, and season. Habitat selection analysis on individual variables indicated that foraging was more frequently observed in waters 4-6 on deep, 200-500 m from shore, and at salinity values of around 20 psu. This fine-scale and multivariate approach represents a useful method of exploring the complexity, gradation, and detail of the relationships between environmental variables and the foraging distribution patterns of bottlenose dolphin.

Mouton, M., & Botha, A. (2012). Cutaneous lesions in cetaceans: an indicator of ecosystem status? In *New approaches to the study of marine mammals*: InTech. https://doi.org/10.5772/54432

Book chapter discussing the impact of marine pollution on cetaceans.

Pitchford, J. L., Pulis, E. E., Evans, K., Shelley, J. K., Serafin, B. J. S., Solangi, M. (2016). Seasonal Density Estimates of Tursiops truncatus (Bottlenose Dolphin) in the Mississippi Sound from 2011 to 2013. *Southeastern Naturalist 15*(2), 188-206. https://doi.org/10.1656/058.015.0201

We conducted vessel-based line-transect sampling from December 2011 to November 2013 to quantify Tursiops truncatus (Bottlenose Dolphin) density over 8 consecutive seasons in the Mississippi Sound. Density estimates showed temporal variation ranging from 0.27 Dolphins/km2 (CV% = 31.3) in spring 2013 to 1.12 Dolphins/km2 (CV% = 21.6) in spring 2012. Density in winter and summer was stable compared to fall and spring, which fluctuated across years. We also noted spatial variation-density was commonly highest in the central and eastern portions of the Mississippi Sound. Spatial and temporal variation in temperature and salinity were potentially driving shifts in Bottlenose Dolphin density. Additional regularly collected density estimates using standardized protocols are needed in order to draw more definitive conclusions regarding the status and trend of this population.

Pitchford, J. L., Howard, V. A., Shelley, J. K., Serafin, B. J. S., Coleman, A. T., & Solangi, M. (2016). Predictive spatial modelling of seasonal bottlenose dolphin (Tursiops truncatus) distributions in the Mississippi Sound. *Aquatic Conservation: Marine and Freshwater Ecosystems, 26*(2), 289-306. https://doi.org/10.1002/aqc.25471

1. Spatial distribution models (SDMs) have been useful for improving management of species of concern in many areas. This study was designed to model the spatial distribution of bottlenose dolphins among seasons of the year in the Mississippi Sound within the northern Gulf of Mexico. 2.

Models were constructed by integrating presence locations ofdolphins acquired from line-transect sampling from 2011–2013 with maps of environmental conditions for the region to generate a likelihood of dolphin occurrence for winter (January–March), spring (April–June), summer (July–September), and autumn (October–December) using maximum entropy. 3. Models were successfully generated using the program MaxEnt and had high predictive capacity for all seasons (AUC (area under curve) > 0.8). Distinct seasonal shifts in spatial distribution were evident including increased predicted occurrence in deepwater habitats during the winter, limited predicted occurrence in the western Mississippi Sound in winter and spring, widespread predicted occurrence over the entire region during summer, and a distinct westward shift of predicted occurrence in autumn. 4. The most important environmental predictors used in SDMs were distance to shore, salinity, and nitrates, but variable importance differed considerably among seasons. 5. Geographic shifts in predicted occurrence probably reflect both direct effects of changing environmental conditions and subsequent changes in prey availability and foraging efficiency. 6. Overall, seasonal models helped to identify preferred habitats for dolphins among seasons of the year and can be used to inform management of this protected species in the northern Gulf of Mexico.

Reif, J. S., Schaefer, A. M., Bossart, G. D., & Fair, P. A. (2017). Health and Environmental Risk Assessment Project for bottlenose dolphins Tursiops truncatus from the southeastern USA. II. Environmental aspects. *Diseases of Aquatic Organisms, 125*(2), 155-166. https://doi.org/10.3354/dao03143

Bottlenose dolphins Tursiops truncatus are the most common apex predators found in coastal and estuarine ecosystems along the southeastern coast of the USA, where these animals are exposed to multiple chemical pollutants and microbial agents. In this review, we summarize the results of investigations of environmental exposures evaluated in 360 free-ranging dolphins between 2003 and 2015. Bottlenose dolphins inhabiting the Indian River Lagoon, Florida (IRL, n = 246), and coastal waters of Charleston, South Carolina (CHS, n = 114), were captured, given comprehensive health examinations, and released as part of a multidisciplinary and multi-institutional study of individual and population health. High concentrations of persistent organic pollutants including legacy contaminants (DDT and other pesticides, polychlorinated biphenyl compounds) as well as 'emerging' contaminants (polybrominated diphenyl ethers, perfluorinated compounds) were detected in dolphins from CHS, with lower concentrations in the IRL. Conversely, the concentrations of mercury in the blood and skin of IRL dolphins were among the highest reported worldwide and approximately 5 times as high as those found in CHS dolphins. A high prevalence of resistance to antibiotics commonly used in humans and animals was detected in bacteria isolated from fecal, blowhole, and/or gastric samples at both sites, including methicillin-resistant Staphylococcus aureus (MRSA) at CHS. Collectively, these studies illustrate the importance of long-term surveillance of estuarine populations of bottlenose dolphins and reaffirm their important role as sentinels for marine ecosystems and public health.

Rosel, P. E., & Watts, H. (2007). Hurricane impacts on bottlenose dolphins in the northern Gulf of Mexico. *Gulf of Mexico Science*, *25*(1), 88. https://doi.org/10.18785/goms.2501.07

The impacts of hurricanes on marine mammals are not well described (but see Langtimm and Beck, 2003; Marsh, 1989). However, a variety of long- and short-term effects are possible.

Sprogis, K. R., Christiansen, F., Wandres, M., & Bejder, L. (2018). El Nino Southern Oscillation influences the abundance and movements of a marine top predator in coastal waters. *Glob Chang Biol, 24*(3), 1085-1096. https://doi.org/10.1111/gcb.13892

Large-scale climate modes such as El Nino Southern Oscillation (ENSO) influence population dynamics in many species, including marine top predators. However, few quantitative studies have investigated the influence of large-scale variability on resident marine top predator populations. We examined the effect of climate variability on the abundance and temporary emigration of a resident bottlenose dolphin (Tursiops aduncus) population off Bunbury, Western Australia (WA). This population has been studied intensively over six consecutive years (2007-2013), yielding a robust dataset that captures seasonal variations in both abundance and movement patterns. In WA, ENSO affects the strength of the Leeuwin Current (LC), the dominant oceanographic feature in the region. The strength and variability of the LC affects marine ecosystems and distribution of top predator prey. We investigated the relationship between dolphin abundance and ENSO, Southern Annular Mode, austral season, rainfall, sea surface salinity and sea surface temperature (SST). Linear models indicated that dolphin abundance was significantly affected by ENSO, and that the magnitude of the effect was dependent upon season. Dolphin abundance was lowest during winter 2009, when dolphins had high temporary emigration rates out of the study area. This coincided with the single El Nino event that occurred throughout the study period. Coupled with this event, there was a negative anomaly in SST and an above average rainfall. These conditions may have affected the distribution of dolphin prey, resulting in the temporary emigration of dolphins out of the study area in search of adequate prey. This study demonstrated the local effects of large-scale climatic variations on the short-term response of a resident, coastal delphinid species. With a projected global increase in frequency and intensity of extreme climatic events, resident marine top predators may not only have to contend with increasing coastal anthropogenic activities, but also have to adapt to large-scale climatic changes.