

Freshwater Response, Scientific/Impact Assessment, and Decision-making Strategy Report

Deliverable 6 in support of Monitoring Approaches
for Bottlenose Dolphin Restoration in Louisiana

Draft 1 – June 2025

1 Introduction

1.1 Purpose & Goals

As part of the *Deepwater Horizon* (DWH) Natural Resource Damage Assessment (NRDA) settlement, the Louisiana Trustee Implementation Group (TIG) is collecting and analyzing data to inform the planning of restoration activities and to help quantify the effectiveness of future restoration projects. To understand what restoration activities may benefit common bottlenose dolphin (*Tursiops truncatus*; hereafter “dolphins”) populations in Louisiana, it is necessary to understand what threats they face.

The goal of this living document is to support NOAA’s marine mammal monitoring and adaptive management efforts in Louisiana to develop a plan for quantifying and better characterizing freshwater exposure and effects on dolphins in Louisiana. This first version of the document, and the [data repository/dictionary](#) associated with it, is the first step towards that goal, by aggregating the current state of knowledge on the topic, the remaining data gaps, and the available resources for addressing those data gaps. This report is meant to be used in conjunction with a web-based collaborative environment that houses information relevant to the effects of freshwater exposure on Louisiana dolphins (Deliverable 5), as well as [a data dictionary and user manual](#) (Deliverable 7) describing the data; protocols; forms; cases; meeting debriefs; and sampling, diagnostic, and analysis plans held in [that repository](#). Additional literature can be found in the [LA BND Citation Inventory](#).

1.2 Scope

This report represents a brief summary of the best-available information about:

1. How freshwater exposure can negatively impact dolphins, especially in the context of Louisiana waters.
2. What data gaps remain in our understanding of freshwater impacts on Louisiana dolphins and how we can address them in the future.
3. The tools we have in place to help facilitate addressing the outstanding data gaps.
4. A near-term (e.g., 3-year) strategy for activities to begin addressing those gaps.

This document is one in a series of deliverables to support decision-makers setting monitoring and adaptive management objectives for bottlenose dolphin restoration planning and monitoring restoration effectiveness in Louisiana waters. Please visit the [Louisiana MAM Monitoring Approaches for Bottlenose Dolphin Restoration project website](#), which hosts all of these documents and serves as a user manual/data dictionary for the deliverables. For convenience, all of the documents, we reference each product by the following shorthand:

- [LA BND Monitoring Plan](#), short for the: “Monitoring Plan for Common Bottlenose Dolphin Stocks across Louisiana Basins and Nearshore Coastal Waters”
- [Human-caused Threats Review](#), short for the: “Characterization of Human-Caused Threats to Bottlenose Dolphins in Louisiana”
- [Freshwater Strategy Report](#), short for the: “Freshwater Response, Scientific/Impact Assessment, and Decision-making Strategy Report”
- [DCE Report and Assessment Plan](#), short for the: “Evaluating the Threats of Disease, Contaminants, and Environmental Hazards on Louisiana Dolphin Health: A Literature Review, Conceptual Model, and Health Assessment Plan”.

The citations for all of these documents can be found in a spreadsheet: the [LA BND Citation Inventory](#).

We synthesize information from the scientific literature and publicly-available environmental assessment documents (e.g., environmental impact statements), as well as recent internal data and discussions among NOAA and their scientific collaborators during recent meetings, workshops, and presentations. For further details on any of these topics, the reader can visit the [Peer-reviewed Literature Section of the data repository](#). In particular, the NOAA Library published a literature review about freshwater and bottlenose dolphins (Poser-Rowley et al. 2018). With this information in hand, decision-makers can identify what data gaps remain in our understanding of the effects of fresh water on dolphins in Louisiana and how to collect data to address those gaps. The best-available options for how to mitigate the impacts of fresh water will depend on the analysis of those future data collection efforts. A discussion of those mitigation options is beyond the scope of this document, but NOAA conducted a series of webinars and workshops about potential monitoring and intervention options for the Mid-Barataria Sediment Diversion project. There is much overlap between the outcomes from those workshops and what could be considered regarding mitigation for dolphins threatened by freshwater exposure across the state of Louisiana. Those materials can be found in the [Meeting and Workshop Materials section of the data repository](#).

We use the term “freshwater” throughout this report to match the language in the project scope of work. However, the reader should interpret all such references to include any exposures or effects related to “low-salinity”. I.e., this report is not limited to discussions about 0 ppt salinity waters; it considers the adverse effects from a range of low-salinity exposures (typically from 0–10 ppt, but sometimes up to 20 ppt).

2 How Freshwater Exposure Affects Dolphins

2.1 Physiological Impacts

Low salinity can adversely impact dolphins via direct contact with the skin or external surfaces of the animal, and by incidental fresh water ingestion during foraging. Exposure can result in skin lesions including color changes, sores, or sloughing, which indicate progressive stages of the skin's degradation as a barrier to the marine environment (for example, Simpson and Gardner 1972, Greenwood et al. 1974, Colbert et al. 1999, Wilson et al. 1999, Gulland et al. 2008). These skin defects may become overgrown with fungi, algae, and/or bacteria and can lead to both intracellular (hydropic degeneration) and extracellular uptake of water. Ingestion of fresh water may alter intracellular and extracellular water absorption in the gut, contributing to osmotic imbalance, damage to cells, and susceptibility to localized and/or systemic infections. Although cetaceans can present a variety of skin lesions, veterinarians and biologists can specifically identify “fresh water-like lesions”: skin lesions characteristic of exposure to low-salinity water (Wilson et al. 1999, Ewing et al. 2017, Duignan et al. 2020, Fazioli et al. in prep.). For the purposes of this document, all references to skin lesions are to fresh water-like skin lesions as determined by the veterinarians and biologists that conducted each study.

Increased fresh water uptake by the skin or gut lining can lead to a variety of physiological or pathological changes, as shown in Figure 1 (for example, electrolyte or hormone imbalances, decreased osmolality, overhydration, and cellular hemolysis/anemia; Hui 1981, Andersen and Nielsen 1983, Ewing et al. 2017, Duignan et al. 2020). Under some conditions, osmotic imbalance, cellular damage, and/or secondary infection can deteriorate from mild to severe, resulting in organ or systemic impacts (for example, hemolysis, anemia, septicemia/toxemia, and cerebral or pulmonary edema), which may lead to neurological dysfunction, abnormal behavior, and death.

While effects on the gut and skin would likely occur simultaneously in wild dolphins, the most visible indicators of freshwater exposure in free-swimming cetaceans are skin abnormalities; however, the presence and severity of skin abnormalities (e.g., pallor) and lesions may not be fully predictive of the severity of internal physiological/health conditions. Depending on the circumstances of the exposure—including the environment, timing, and other biological factors—skin lesions may develop, progress, and resolve in cycles if an individual is exposed to changing gradients from lower- to higher-salinity waters (Mullin et al. 2015, Ewing et al. 2017, Deming et al. 2020, Duignan et al. 2020, Fazioli and Mintzer 2020, McClain et al. 2020). When salinity increases, skin lesions may visibly resolve on the body surface; however, secondary infections and internal physiological impacts may still present a significant health risk. In addition, secondary stressors may also affect recovery (e.g., long-term infections or nutritional stress from reduced prey quality/quantity and increased energetic needs).

Low Salinity Exposure Conceptual Model Skin Exposure & Impacts

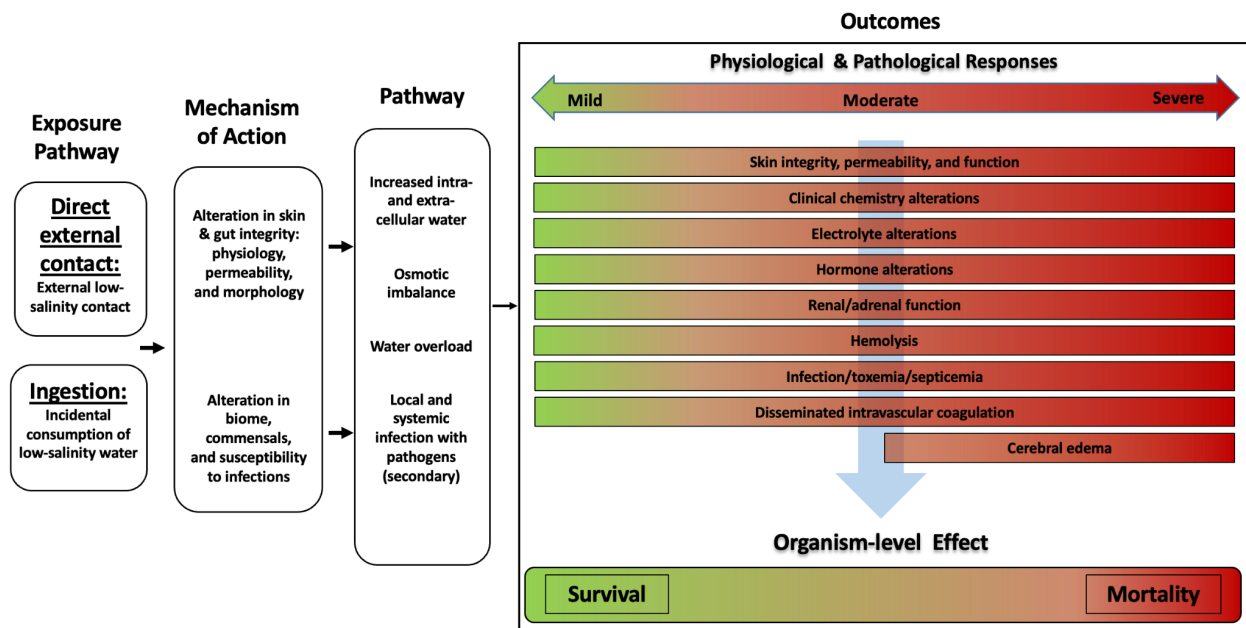


Figure 1. Conceptual model of how low salinity can cause adverse health effects to bottlenose dolphins. When dolphins are exposed to low-salinity water, either by direct external contact with their skin or by ingestion (typically incidental consumption), the osmolality differences can disrupt the integrity of the skin/gut lining and alter the skin/gut biome. These cellular- and tissue-level effects can drive osmotic and water imbalances and/or local and systemic infections. Depending on the severity of the abnormalities in these pathways, the exposed dolphin could suffer a variety of physiological/pathological responses, including abnormal skin integrity, permeability, and function; clinical chemistry alterations; electrolyte or hormone alterations; renal/adrenal dysfunction; hemolysis; infection, toxemia, and septicemia; disseminated intravascular coagulation; and/or cerebral edema. The severity and combination of these responses will determine the mortality risk for each individual dolphin.

In severe cases, freshwater exposure is fatal to individual dolphins (see [Section 2.2](#)); however, our full understanding of the parameters that contribute to the risk of serious illness and mortality is still lacking. Booth and Thomas (2021) conducted an expert elicitation to parameterize a quantitative dose-response function that estimates the time to death for dolphins in low salinity waters (which they define as less than 5 ppt). Experts integrated and synthesized the best-available scientific literature to build dose-response functions for three scenarios (Figure 2): an extended low-salinity event in a “poor” environment (Scenario 1A), an extended low-salinity event in a “good” environment (Scenario 1B), and an acute salinity change (Scenario 2). They estimated that dolphins likely can tolerate extended low-salinity events for 20–30 days with little risk of mortality, but an acute change in salinity could lead to mortality in only about six to eight days. However, the experts believed that the survival probability rapidly declined beyond this initial period; the respective median values for the time to death was 62 days for Scenario 1A, 77 days for Scenario 1B, and 22 days for Scenario 2.

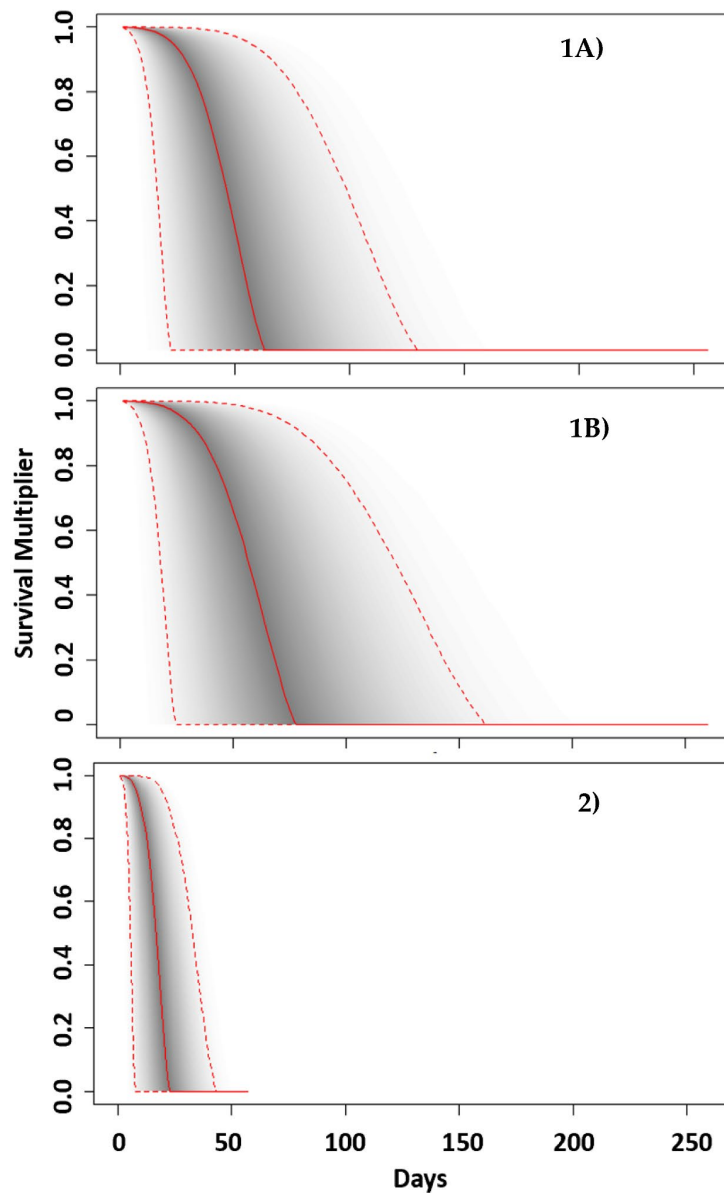


Figure 2. Dose–response functions for Scenarios 1A (extended low salinity event in “poor” environment), 1B (extended low-salinity event in “good” environment) and 2 (acute salinity change). Figure shows the quantiles of the distribution generated by 10,000 realizations; the red solid line is the median and the dashed lines are the 5th and 95th quantiles (i.e., forming a 90% interval). Figure and caption from Booth and Thomas (2021).

2.2 Examples of physiological impacts and mortality

When bay, sound, and estuary dolphins experience prolonged freshwater inundation—whether due to prolonged run-off from upstream flood waters, extreme weather events, operations of diversions (e.g., for coastal restoration) and spillways (e.g., for flood prevention/land protection), or entrapment (perceived or actual) in low salinity environments—groups of dolphins may be at risk of adverse health effects and death. Some examples from the literature and

recent case studies include:

- During 2005–2007, 30–40 dolphins were reported in eastern Lake Pontchartrain, Louisiana (where dolphins are historically rare), likely as a result of Hurricane Katrina. Many of the dolphins had minor-to-severe skin lesions likely associated with exposure to low-salinity water (Mullin et al. 2015). Lesion severity appeared to correlate with seasonal changes in salinity: worsening with lower salinity and improving with higher salinities. After additional surveys through 2010, up to 70 individuals were identified in the area, with an average of 36.5 identified dolphins per season. Salinity and water temperatures in the Lake Pontchartrain area were unusually low in winter 2010, after which only one target area dolphin was sighted (and in a different location). Twenty-

seven dolphin strandings occurred in this area in spring 2010 (March and April). The authors suggested that the likely outcome for these dolphins was that most eventually died from low-salinity exposure or the combination of annual, prolonged low-salinity exposures and low water temperatures in 2010 (Mullin et al. 2015).

- Periodic freshwater flooding in Galveston, Texas, has resulted in dolphins with skin lesions, where the severity of the lesions generally correlates with the number of days of low salinity in Galveston Bay (Fazioli and Mintzer 2020). During 2015–2019, there were four major flooding events, which resulted in long periods of lower salinity in the bay and increased skin lesion prevalence and severity in dolphins. For example, in 2019, after the wettest year on record in the United States, areas of Galveston Bay were below 5 ppt for 22 days and below 10 ppt for 63 days. Similar to the Lake Pontchartrain situation, individual dolphins in Galveston Bay that had skin lesions during periods of low salinity were also observed with improved skin condition during longer periods (several years) of higher salinity. For example, two dolphins that stranded dead in 2019 with severe skin mats and lesions were consistently observed in the bay during 2015–2019. During that five-year period, their skin lesions grew worse in severity during lower-salinity exposure periods and less in severity during higher-salinity exposure periods. Dolphin encounter rates within Galveston Bay correlate with salinity levels (Mintzer and Fazioli 2021).
- In 1992 in the bay system from Corpus Christi to Matagorda, Texas, more than 260 dolphins died after a period of record rainfall (Colbert et al. 1999, Litz et al. 2014). The resulting runoff increased pesticide concentrations in the bay and drove salinities under 10 ppt from December 1991 to April 1992. Although no definitive cause was determined for the die-off, there was low salinity in the habitat and increased contaminant loads in the water; dolphins with zero-positivity for morbillivirus antibodies co-occurred with the die-off and the dolphins exhibited evidence of circular skin lesions and a gray, pasty substance on the skin, both consistent with prolonged fresh water exposure (Duignan et al. 1996, Colbert et al. 1999, Litz 2014).
- Reports of bottlenose dolphins that were out-of-habitat (for example, up a river or creek), displaced by hurricanes or tropical storms (i.e., trapped in lakes, canals, ponds, or ditches), or stranded during known flood events were queried from the Level A stranding data from the Southeast United States (Level A stranding records [1996 to 2019] were extracted on March 3, 2016 and May 10, 2019 from <https://www.fisheries.noaa.gov/national/marine-life-distress/national-stranding-database-public-access>). Estimated (for example, from nearby USGS buoy data) or measured salinity was compared to the minimum exposure duration (in other words, from the start of a known flood event, landfall of hurricane/tropical storm, or from the time an animal was reported out of habitat until it either died, was no longer observed, or was rescued) to determine outcomes for dolphins in waters at different salinity levels. Sixteen dolphins were exposed to waters with salinity equal to or less than 5 ppt; of those exposed dolphins, six lived (37.5 percent) and 10 died (62.5 percent). Dolphins that lived were exposed to low-salinity conditions for 5–12 days; dolphins that died were exposed for 9–79 days. Seven dolphins were exposed to salinity conditions from 10–15 ppt; of those

exposed dolphins, five (71 percent) lived and 2 died (29 percent). Dolphins that lived were exposed to salinity conditions from 10–15 ppt for 20–43 days; dolphins that died were exposed for 25–62 days (Fougères, pers. comm.).

- McClain et al. (2020) reported on adverse health effects from freshwater exposure in dolphins managed under human care. Dolphins developed skin lesions within 2 to 38 days of exposure to low salinity. The prevalence of skin lesions was inversely proportional to salinity exposure. In 28.5 percent of the dolphins, veterinarians documented serum electrolyte changes within 1 to 13 days after initial exposure; however, the electrolyte changes were mild and did not result in clinical symptoms. This is likely due to the dolphins' mineralocorticoid response and conserving their electrolytes via their kidneys and adrenal glands. However, they report that “if an animal has compromised kidneys and/or adrenal glands, they may be more susceptible to rapid and life-threatening serum electrolyte changes.”
- In 2019, there was a four-fold increase in stranded bottlenose dolphins (n = 337 vs. a historical average of 83 dolphins) from Taylor County, Florida through Louisiana, the vast majority of which (88 percent) occurred from February through June. [NMFS declared a UME](#); these strandings coincided with a record-breaking year of precipitation along the northern Gulf Coast (Baker et al. 2025). This caused an unprecedented amount of fresh water discharge during 2019, which resulted in a decrease in salinity levels (to below 10 ppt) across the coastal waters in the region. This was most pronounced and prolonged in the western Mississippi Sound due to the massive freshwater discharge from the Mississippi River and associated spillways, including the Bonnet Carré Spillway, as well as flood waters into other bay, sound, and estuary (BSE) environments. The most common lesions observed during the UME were skin lesions consistent with prolonged exposure to low-salinity water, which was documented in 32 percent of fresh dead and moderately decomposed stranded dolphins. Stranded dolphins with freshwater lesions were observed after 17 days of exposure below 5 ppt, and the number of stranded animals with lesions peaked at 40 days below 5 ppt.

Despite this collection of freshwater-related events, we still do not have a detailed understanding of how fluctuating freshwater exposures lead to adverse health effects in dolphins.

3 Data Gaps and How to Address Them

3.1 Refining Exposure and Effect Relationships

Establishing a reliable dose-response relationship (or in this case, exposure-effect relationship; in this document, we will continue to use the “dose-response” terminology) between survival probability and the number of days a dolphin is exposed to salinity less than 5 ppt (Booth and Thomas 2021) was an important first step in quantifying and characterizing the effects of freshwater on dolphins. However, to better understand the problem, we need to refine the dose-

response parameters, definitions, and relationships to a more detailed level. The question is now more broadly: **How does the duration and severity of low-salinity exposure lead to freshwater disease in dolphins?** This question will require a series of dose-response relationships, along with a collection of factors that may influence those relationships. The related data gaps can be grouped into three categories:

1. How to define, describe, and quantify exposure and effects/outcomes?
2. How does the accumulation of repeat exposures potentially change effects/outcomes?
3. What intrinsic and extrinsic factors can influence effects/outcomes?

3.2 A Better Understanding of Exposure and Effect

The dose-response curves in Figure 2 show a negative relationship where the more days a dolphin spends in less than 5 ppt salinity, the lower its survival probability. However, we can strive for more granularity for each of these parameters to better characterize both the variability in salinity conditions over time and the progression of freshwater disease over time—i.e., what other quantitative metrics could be used on the dose-response axes to better understand freshwater disease prior to death? (It is worth noting that more data to continue to refine the Booth and Thomas [2021] dose-response curves is also an important ongoing need.) For example:

Exposure

- Is 5 ppt an appropriate threshold for “low salinity”? Salinity is a continuum that coastal dolphins experience over time. Thus, should the threshold be relative to each individual’s “baseline” salinity exposure?
- Is there a difference in effects if the number of days is consecutive or if there are temporary interruptions of higher-salinity conditions? (Additional discussion in [Section 3.3](#))
- Do effects manifest immediately or can they be delayed? For how long?
- Could differences in water ingestion rates among individual dolphins influence effects?
- Could differences in prey quality/quantity influence effects?
- Are there other ways to integrate the severity (e.g., low salinity in ppt) and duration (e.g., number of days) into one metric of exposure?

Effects

- For population models, survival probability and reproductive success rates are both important parameters. How does freshwater exposure affect the rates of pregnancy, successful birthing, and calf survival?
- Which specific biomarkers/analytes/symptoms/adverse health effects (referred to below as “adverse health effects”) are most predictive of mortality or serious injury?
- Which specific adverse health effects (e.g., skin lesions, behavior changes, electrolyte imbalance, anemia, high liver enzymes, hydropic degeneration, edema) are most correlated with freshwater exposure?
- Which specific adverse health effects are most easily monitored and could represent the most robust data collection targets?

Overall, the most important way to address data gaps about freshwater exposure's effects on dolphins is to gather, synthesize and evaluate paired health, behavioral, and exposure data from as many individual dolphins as possible, in order to create and update dose-response curves and the factors that can influence them. In theory, one could produce dozens of individual dose-response curves for each combination of exposure metrics and effects metrics suggested by the questions above. Further studies could address any number of those relationships, but logistically/realistically, data collection is limited to aggregating across efforts that 1) are already ongoing or planned using other funding sources, 2) could be planned and implemented to address the questions at hand, but would likely be limited in scope/size, or 3) are reactive to opportunistic scenarios such as spillway openings or responses/interventions with at-risk dolphins, if resources can be mobilized quickly (requires prescient planning).

Prioritizing data gaps will be different for various stakeholders. For example, for coastal resource managers, the most important data gaps will be about 1) estimating/evaluating the risk of activities that will lower salinity in dolphin habitat and 2) identifying means for mitigation, prevention, and monitoring. However, for those responding to dolphins/populations in distress, the most important data gaps will be about the aspects of exposure and effects that will best inform intervention opportunities/strategies/outcomes. Considering the best-available information and logistical feasibility, we identify a set of priority data gaps that could be addressed in the immediate future, *if* a concerted effort to standardize methods, techniques, data collection, and analysis can be implemented across Louisiana and the Southeast U.S.

3.2.1 Spatiotemporal Models to Predict Salinity

To infer what freshwater exposures lead to specific adverse health effects in wild dolphins (whether free-swimming or stranded), it is unlikely that one can expect robust movement/sightings data (by individual) to quantify severity and duration. Thus, similar to the approaches in Takeshita et al. (2017) and Garrison et al. (2020), dose-response efforts will require modeled estimates of salinity over space and time throughout Louisiana dolphin stock areas. In Barataria Bay, existing hydrographic models could provide estimates, depending on collaboration with the teams developing those products (e.g., Delft3D). Those modelers (or ones with similar expertise) could develop new models for other Louisiana basins, or simpler models using more limited salinity data and cofactors could be developed (discussed further in the [Workshop Discussion Summary](#) from the 2023 Mid-Barataria Bay Monitoring Workshop).

3.2.2 Satellite-linked Telemetry Tags that Measure Salinity

Satellite-linked telemetry tags can provide location information for individual animals for months at a time, and efforts are underway to add the capability for also measuring salinity. Although the technology is still in development, tags that measure salinity could be available in the next few years, and, when paired with 1) health data collected while the dolphin is in-hand (e.g., bloodwork; skin samples, assessments, and photos; behavioral examinations; ultrasound) and 2) any additional follow-up monitoring of the dolphin (e.g., photographs of lesions; behavioral assessments), would provide rich information about dose-response relationships in each tagged

individual. Satellite-linked telemetry tags (either the currently available versions without salinity capabilities or the versions under development with salinity capabilities) are limited to either temporarily captured dolphins (so that a dorsal fin tag can be attached prior to release) or to dolphins that bow ride for application using the TADpole device (Moore et al. 2024), which may not be applicable for BSE Louisiana dolphins.

3.2.3 Controlled Exposures

With the appropriate veterinary guidance, health (e.g., bloodwork, skin samples) and behavioral parameters could be collected from managed dolphins under human care exposed to specific salinity conditions. This would represent the most reliable way to directly correlate known salinity exposures to specific adverse effects metrics, but would be limited to effects/effect levels that would ensure the well-being of the dolphins.

3.2.4 Skin Lesion Severity, Coverage, and Prevalence

Skin lesions are an enticing effects metric because of recent developments (Fazioli et al. in prep.) to bring together field biologists and veterinary pathologists and develop a semi-quantitative scoring system for lesion severity, coverage, and progression using only photographs from free-swimming dolphins. This would facilitate both retrospective and prospective analyses of a key adverse health effect from freshwater exposure, and could then be related to salinity data collected by the photo-identification (photo-ID) field teams coincident with the photographs and/or with modeled salinity data.

3.2.5 Reproductive Outcomes

Adverse health effects to pregnant and nursing dolphins and young calves can have negative repercussions on reproductive success and calf survival. However, few data are available to look at direct relationships between low salinity exposure and pregnancy rate, birth rate, calf survival, or overall reproductive outcome. The combined data from salinity estimates (see [Sections 3.2.1](#) and [3.2.2](#)), photo-ID surveys, remote biopsy surveys, and hands-on health assessments could provide information on a dose-response relationship between freshwater exposure and reproductive outcome. However, it would likely require several years of data across multiple field efforts (and perhaps could include information from live-stranded dolphins) to produce the necessary statistical power for reliable analyses. While daunting, starting to collect such data as soon as possible will be important for ensuring that the data gap can be addressed as early as possible.

3.2.6 Identifying Key Bioindicators of Freshwater Disease

While skin lesions offer one method for evaluating the progression of freshwater disease in dolphins, blood chemistry, haematology, and hormone analyses offer alternative, non-lethal analytes for potentially predicting a dolphin's status after/during exposure to low salinity. Bloodwork could also provide evidence during the early stages of freshwater disease progression, prior to visualization of skin lesions (as well as in parallel with/underlying skin lesion progression). Urine could also provide information about both freshwater exposure and

effects, but can be more difficult to collect without specialized training. Efforts to correlate individual or groups/panels of bioindicators with a dolphin's overall health status, skin lesions, or survival probability would provide more options for how to collect data for and apply informative dose-response curves. Similar to potential future activities to address reproductive outcomes, collecting enough data for robust analyses would likely require combining information across years and multiple field efforts, but would not be restricted to pregnant animals and could include stranded dolphins (live or fresh dead carcasses). Beyond updating dose-response curves, these data and analyses would also be critical for building a better understanding of the mechanisms and pathways underpinning freshwater disease progression. [Section 4](#) discusses the samples that should be prioritized to inform these bioindicator analyses. It is important to ensure that teams of biologists, veterinarians, pathologists, and statisticians collaborate to analyze the data from various perspectives.

3.3 Cumulative Effects of Repeat Exposures

In some scenarios, a dolphin may be exposed to continuous low salinity conditions for months without any disruption. The dose response curves in Booth and Thomas (2021) are especially applicable in such circumstances. However, there are many situations where individual dolphins experience intermittent low salinity conditions, either within a given week/month/year or over the course of their lifetimes living in brackish wetlands. In some cases, repeated exposures may result in cumulative effects where the individual dolphin cannot recover between exposures and becomes more susceptible to accelerated progression of freshwater disease. In other cases, it is possible that annual exposures to less severe low salinity conditions may result in dolphins that acclimate to their environment and, thus, build resilience to future low salinity conditions.

What combination of salinity levels (ppt) and time are required to pause or facilitate recovery from the progression of freshwater disease? It is clear that dolphins with (sometimes severe) skin lesions can fully recover after prolonged exposure to higher salinity conditions (Fazioli and Mintzer 2020). Could dolphins gain benefits from shorter-term movements if, for example, they find local refugia with higher salinity water? Tagging dolphins with satellite-linked telemetry tags that can measure salinity could prove especially useful to identify whether dolphins can find pockets with higher salinity within bays, sounds, and estuaries, potentially including dredged waterways for vessels. When considering what metrics to use for these intermittent exposure scenarios in future dose-response curves, it will be important to identify appropriate means to integrate over fluctuating periods of high and low salinity conditions (e.g., rolling averages of salinity per day).

While some preliminary analyses of intermittent exposures have been presented anecdotally in the literature (e.g., Takeshita et al. 2017, McClain et al. 2020, Fazioli and Mintzer 2020), dedicated efforts to better characterize the relationships between exposure, effects, and potential recovery are a significant data gap. Options could include:

- **A more formal and integrated analysis of the existing datasets.** This effort would be limited by the metrics available for each dataset. For example, Takeshita et al. (2017) only has a single time point for health endpoints but more robust modeled salinity

estimates. Fazioli and Mintzer (2020) has paired skin lesion photographs and hand-collected salinity measurements, but the salinity measurements are limited to the time of each sighting.

- **Developing and deploying satellite-linked telemetry tags capable of measuring salinity.** As discussed in [Section 3.2.2](#), and with a special focus on characterizing the variety of prevalence of 1) dolphin movements in and out of low/high salinity conditions and 2) adverse health effects (likely primarily limited to photographs of skin lesions) before and after various potential recovery periods.
- **Controlled exposures.** As discussed in [Section 3.2.3](#), but with planned times to allow for recovery. This presents the most reliable and feasible method for accurate descriptions and quantification of intermittent low salinity exposure. Although retrospective in nature, some of the cases reported in McClain et al. (2020) were based on dolphins in controlled conditions and could serve as a template for future studies.

The goal to achieve a better understanding and characterization of freshwater exposure and effects on dolphins in Louisiana will require efforts that can be done both sequentially and in parallel. Although many of the specific activities to investigate how intermittent exposure changes the dose-response relationships in Booth and Thomas (2021) are very similar to those assuming a continuous, unbroken exposure (as presented in [Section 3.2](#)), tackling the latter would likely help the interpretation of the former. Thus, while the data collection and analysis could proceed in parallel, development of metrics that integrate recovery periods and the resulting interpretation of analyses using those metrics, could be conducted sequentially.

3.4 Intrinsic and Extrinsic Factors that Influence Outcomes

The dose-response relationships developed in Booth and Thomas (2021) are based on what experts believed for “the average bottlenose dolphin in the population” where the low salinity scenario occurred. An explanation from their methods further explains their reasoning: “...experts agreed to elicit for the ‘average’ animal, to help them provide realistic judgements of what could occur in a typical population (minimizing the risk of implausible values being elicited). It was discussed with experts that this could include averaging over any factors that could cause variation in response, such as health just prior to exposure, sex, age, etc. However, such averaging needs to take account of the expert’s belief about the effect of such factors and the proportion of animals in each category (or distribution in each category for continuous variables).” For investigations focused on population modeling, one must generate reasonable approximations for input parameters—hopefully pairing such estimates with some range of plausibility, variability, and/or uncertainty. However, when analyses or predictions require an evaluation of subgroups of animals or even individuals, one must consider the specific demographics and circumstances of those individuals in their local environments. I.e., what are the intrinsic and extrinsic factors that could influence a dose-response relationship for specific dolphins?

Thus, in addition to updating the existing dose-response curves and developing new dose-response curves for other pairs of exposure and effects metrics, it would be helpful to develop

criteria for how to adjust those curves depending on the unique dolphin- and environment-related conditions. This would help veterinarians and biologists make decisions during intervention/response activities, as well as tailor more general assumptions about freshwater to more specific basins, stocks, or subpopulations for broader management/conservation/restoration decision making.

Intrinsic factors are generally related to a dolphin's specific demography, health, and life history, including (but not limited to): sex, age, social relationships, learned behaviors, reproductive status, body condition, immunological status, non-freshwater-related diseases or conditions. More information about specific infectious and non-infectious diseases that could act as additional stressors with freshwater disease can be found in the [DCE Report and Assessment Plan](#). Extrinsic factors are typically related to a dolphin's local environment and the non-freshwater-related stressors present therein, including (but not limited to) the stress and bioenergetic costs associated with: living in a low-salinity environment (e.g., changes in buoyancy, increased foraging times, shifts in prey quality/quantity, changes in wound healing), vessel traffic/strikes, fisheries, dredging and construction, gas and oil production, wind energy, marine debris, pollution, harmful algal blooms, hypoxia, extreme weather events, habitat loss, and climate change. For a more detailed discussion of such stressors, see the [Human-caused Threats Review](#).

Some influential factors may represent a blend of intrinsic and extrinsic. For example, low salinity conditions may result in an alteration in a dolphin's available prey, shifting fish assemblages from more marine species to freshwater species and potentially affecting the quantity of high-quality prey. If these shifts are prolonged, they may eventually lead to malnutrition in dolphins with high site-fidelity. In severe cases with young dolphins, such a scenario could lead to developmental issues and lasting adverse health effects. Thus, nutritional state due to prey quality and quantity could be considered both an intrinsic and extrinsic factor.

In terms of data collection, the requirements to address data gaps about intrinsic and extrinsic factors are very similar to those in [Sections 3.2](#) and [3.3](#). When observations about exposure and effects are recorded, responders and scientists typically also document the most relevant demographic and environmental cofactors of those listed above, if the information is available. The major concern would be to ensure that data recorders across efforts are collecting data on each factor in a standardized and consistent manner. Thus, most data collection can and should be conducted in parallel with the activities described in [Sections 3.2](#) and [3.3](#). However, when sample sizes are large enough to reliably evaluate potential correlational/causal relationships between extrinsic factors and dose-response curves, specific efforts may be required to identify other environmental datasets that could be used in analyses (see the [Human-caused Threats Review](#) and the [DCE Report and Assessment Plan](#) for preliminary suggestions). Analyses and interpretation of data about intrinsic and extrinsic factors would certainly benefit from the efforts suggested in [Sections 3.2](#) and [3.3](#), although more formal processes for evaluating how the dose-response relationships in Booth and Thomas (2021) might change depending on specific factors could be conducted immediately.

4 Available Tools to Address Data Gaps

There are a number of data gaps in our understanding and characterization of freshwater exposure and effects on Louisiana dolphins, but there are already many tools available to facilitate standardized and consistent data collection, analysis, and interpretation to fill those gaps. Some were developed with freshwater disease in mind and can be used without any changes, while others might require a small number of changes to be useful for this effort. Where applicable, we make note of any tools that may need significant development or updating, but do not review them in detail. Future versions of this plan should prioritize those efforts. Here, we focus on methods, protocols, and sampling/analysis plans that are especially useful to address the data gaps discussed above. We do not list every tool available, but the reader can reference the [data repository](#) to see a wider collection of relevant materials.

4.1 Remote Data Collection of Free-swimming Dolphins

Observations of free-swimming dolphins—whether by biologists and veterinarians on small vessels, on shore, or via unoccupied aerial vehicles (UAVs; hereafter “drones”)—offer a non-invasive and relatively low-cost (compared to the resources required for hands-on assessments) information on health, behavior, and population structure. Field techniques like photo-ID surveys and remote biopsy collections are the foundation of marine mammal science (see the [LA BND Monitoring Plan](#), Section 1.2.2 for more information). More recently, scientists have begun to integrate drone photogrammetry and sample collection (blow/exhalate) into cetacean investigations (blow samples can also be collected using poles or via drones). Future versions of this plan should also evaluate whether the development of remote blood collection devices, such as the Hemotag (F. Gomez, NMMF, pers. comm.) are developed, tested, and ready to implement. While hands-on efforts provide opportunities to collect more tissue samples and health data, remote surveys are generally safer for both people and animals and require fewer personnel, vessels, and planning time/needs. Taken together, these remote data collection methods should play a key role in addressing data gaps about freshwater exposure and effects on dolphins in Louisiana, especially in situations where a rapid response is necessary (e.g., interventions or opportunistic studies).

Collecting observational longitudinal data of dolphins that may be exposed to low-salinity water is critical for supporting the development of dose-response curves. Whether as part of planning for response/interventions or prior to/during field research activities, stranding network partners and field biologists should use standardized datasheets to record and share data about the dolphin’s location, water quality (e.g., salinity and temperature at various depths), behavior (e.g., attitude), and health (e.g., skin lesions)—pairing the observations with photographs as much as possible. Whenever possible, the datasheets from individual sightings should then be combined and summarized for a longitudinal case description to facilitate analysis of freshwater disease progression and integrating exposure information.

4.1.1 Photo-identification Surveys

Although typically used to estimate dolphin population metrics (e.g., abundance, survival, density), recent efforts by the Galveston Bay Dolphin Research Program have led to a new tool to characterize and quantify the prevalence and severity/progression of freshwater disease (especially based on skin lesions, but also considering eye pathologies) using photographs from photo-ID surveys (Fazioli et al. in prep.). The dolphin [Freshwater-Related Evaluation of Skin Health \(FRESH\) protocol](#) is a collaboration between veterinary pathologists (who typically evaluate dolphin skin lesions from photographs and histopathological samples) and field biologists (who observe free-ranging dolphins first-hand, record observational data, take photographs, and process/evaluate the photographs) to standardize the process and train field biologists to use the tool's flowcharts and scoring rubric.

We recommend that any teams conducting photo-ID surveys in Louisiana be trained in the FRESH protocol and implement the methods into their study design (e.g., the recommendations in the [LA BND Monitoring Plan](#)). If there are any planned releases of freshwater (e.g., an opening of the Bonnet Carré Spillway), deploying photo-ID crews for documenting water quality along with dolphin locations, density, abundance, and skin health (using the FRESH protocol) before, during, and after the event would provide an extremely important dataset for addressing data gaps about freshwater exposure and effects to Louisiana dolphins. We also recommend that all efforts be made to combine and synthesize the results of any/all photo-ID surveys (including data from the FRESH protocol) across Louisiana and the neighboring states.

Fazioli et al. are currently preparing a manuscript describing the FRESH protocol, the testing implemented to develop it, and a written training document for users. They expect to submit the manuscript to a peer-reviewed journal in the Summer of 2025. Because this tool is critical for improving our understanding of freshwater exposure and effects on Louisiana dolphins, we recommend that, in addition to the written training document, additional resources/efforts should be put in place to develop, disseminate, and implement interactive training materials and workshops for users.

While conducting photo-ID surveys, biologists also have an opportunity to collect environmental (e.g., water salinity measurements, weather, nearby vessels), social (e.g., mom-calf pairs, group size and associations), and activity (e.g., slow/fast travel, feeding, socializing) data. However, to the best of our knowledge, there is no standardized datasheet (or section of a datasheet) to record freshwater disease-specific data. Recorders have blank space to record any additional observations, but to address freshwater data gaps, we recommend that veterinarians, field biologists, and MMHSRP coordinators discuss the utility of a specific set of freshwater-related criteria for photo-ID survey members to record systematically at each sighting. Then, if appropriate, example datasheets should be updated, included in future versions of this report, and disseminated. If possible, this could be included in any training for the FRESH protocol moving forward.

4.1.2 Remote Biopsy Surveys

Field biologists can use modified rifles or crossbows to collect a small skin and blubber biopsy from free-swimming dolphins. These tissues can then be analyzed by a variety of diagnostic methods to evaluate the animal's health and pregnancy status (e.g., histopathology, blubber hormones, environmental contaminant concentrations), sex (using genetics), and age (using epigenetics), as well as the animal's genetic assignment to a specific stock/population. In the case of sampling dolphins with freshwater disease, care must be taken to ensure the well-being of the dolphin, to not exacerbate effects from conditions that are already compromising the animal's integument. Thus, samples from remote biopsy surveys will likely be biased towards mild to moderate cases of freshwater disease, including dolphins with light discoloration and non-ulcerated target-like skin lesions (as defined in the FRESH protocol), and excluding dolphins with ulcerated and/or bloody target-like skin lesions and overgrowth of mats/films (e.g., fungal or bacterial layers over the skin). However, histopathological assessment of these samples would still be valuable to addressing data gaps about the early stages of freshwater-related skin lesions. Blubber hormone levels, especially aldosterone and cortisol, would also be informative. Sampling for remote biopsies typically does not allow for data collection on a dolphin's freshwater exposure in the days/weeks prior to sampling. Thus, targeting dolphins with robust sightings histories or previous satellite-linked telemetry data could facilitate assumptions about exposures using modeled salinity estimates (if available).

4.1.3 Drone Surveys

Unoccupied aerial vehicles (UAVs), or drones, can be used to collect photographs of free-swimming marine mammals, survey for beached carcasses, and even collect breath/exhalate/blow samples (Goskowicz et al. in prep.). By extending the range at which field biologists can survey and offering unique vantage points for photographs, the technology offers a cost-effective way to collect unique types of data. To date, photogrammetry analyses are the most wide-spread, detailing measurement techniques for length, volume/mass, and body condition scoring (Perkins-Taylor et al. 2024, Bierlich et al. 2024, Goskowicz et al. in prep.)—all metrics that could be used, when paired with salinity measurements, to help evaluate freshwater exposure and effects on Louisiana dolphins.

Although the FRESH protocol (Section 4.1.1) was designed for side-on photographs taken during photo-ID surveys from small vessels, we recommend that a panel of subject matter experts discuss how the protocol could be adapted to incorporate images collected from a drone—whether using the same side-on photograph angle or a top-down photograph perspective. This could especially improve the estimates of skin lesion coverage (a key component for determining skin lesion progression/severity in the FRESH protocol) and could allow field crews to work more productively in conditions with poor lighting/environmental conditions, or if a dolphin is in an area inaccessible by boat.

Drones can also be used to hold agar plates over a dolphin's blowhole as it surfaces and exhales (O'Mahony et al. 2024). The resulting sample of mucus/exhalate can be used for

diagnostic tests (e.g., microbiomics, cultures for bacteria/fungus), however little has been done to evaluate what diagnostics would be most informative to relate back to freshwater exposure.

4.2 Hands-on Data Collection with Living Dolphins

Biologists and veterinarians have a unique opportunity for data and sample collection when a living dolphin is in-hand, whether during a response/intervention situation or during hands-on health assessments using temporary catch-and-release methods. While the safety of the personnel and the well-being of the dolphin are of utmost precedence (and therefore may limit the amount of time for examination), hands-on scenarios offer a chance to collect a variety of important samples and physical/behavioral data. We will first describe a general prioritization for both response activities and catch-and-release health assessments ([Section 4.2.1](#)), then discuss any unique considerations that should be made for each ([Sections 4.2.2](#) and [4.2.3](#)).

While response/intervention activities can offer rare access to data about freshwater exposures and effects in wild dolphins (e.g., dolphins washed into freshwater lakes after storms), there are typically few cases each year (see the [Case Studies section](#) of the data repository). Conversely, temporary catch-and-release health assessments can result in larger sample sizes, but generally do not target dolphins if the assessment could be especially stressful to a specific animal (e.g., dolphins with progressive freshwater disease). Thus, we recommend that efforts to address freshwater-related data gaps with Louisiana dolphins integrate both types of data sources as much as possible, with considerations for the limitations and caveats associated with each.

4.2.1 General live dolphin freshwater disease sampling priority list

The Marine Mammal Health and Stranding Response Program (MMHSRP) developed a Live Animal Freshwater Disease Sampling protocol [document](#) for Stranding Network Partners. Here, we present a slightly modified version with additional potential samples/examination data and a minor reorganization in the order of priority. In some cases, the suggested additions to the protocol may require more widespread training for Stranding Network Partner biologists and veterinarians; these are marked with an asterisk and future versions of this plan could further develop those training activities. The following data needs/samples/procedures are listed in order from highest priority to lowest priority, but most can be collected concurrently depending on the number of trained personnel present. Of course, the reality of each situation will determine what items from the list are feasible, depending on the personnel, their training, the resources available to them at the moment, the weather/environment, and—first and foremost—the well-being of the personnel and the dolphin(s).

1. For female dolphins of reproductive age, a reproductive ultrasound scan* must be completed first. If possible, the other systems listed in point 8 below could also be scanned at this time.
2. Water salinity and temperature measurements at capture and release sites (surface and depth profile)

3. Satellite-linked telemetry tag (preferably with the capability to record salinity if/when available)
4. Photographs of skin (focusing especially on any lesions), eyes, dorsal fin, and full body
5. Sex, total straight-line length, and girth at the anterior insertion of the dorsal fin
6. High priority blood samples for:
 - a. Serum chemistry
 - b. Complete blood counts
 - c. i-Stat measurements using EC8+ and CG4+ cartridges
 - d. Morbillivirus titer
 - e. Osmolality (serum and plasma, until a preference can be determined empirically)
7. Lower priority blood samples for:
 - a. Fibrinogen
 - b. Archived serum/plasma, if any blood remains after collecting all other samples
8. Physical examination, including:
 - a. Body condition
 - b. Notes on skin and any lesions (paired with photographs)
 - c. Other point of care diagnostics
 - d. Behavioral/neurological examination**
9. Ultrasound scans* (if not done above), prioritizing:
 - a. Renal
 - b. Pulmonary
 - c. Reproductive organs
 - d. Gastrointestinal tract
10. Urine* for:
 - a. Urinalysis
 - b. Osmolality
 - c. Chemistry
11. Weight, if possible
12. Lower priority needs, if the dolphin is stable and there is time:
 - a. Water samples for eDNA at capture and release sites
 - b. Skin biopsy (can use the dorsal fin plug from satellite-linked tag deployment, if available, or a wedge/punch biopsy if not)
 - i. Histopathology
 - ii. PCR for *Brucella*
 - iii. Omics/molecular biology (especially genetics/epigenetics and microbiomics)
 - iv. Stable isotopes
 - c. Biopsy or scrapings of skin lesions:
 - i. Omics/molecular biology (especially genetics/epigenetics)
 - ii. Morphology
 - iii. PCR for fungus/pathogens
 - iv. Histopathology
 - d. Blow/exhalate, using an agar plate and/or a soft catheter tube*
 - i. Cultures for bacteria, fungus, and mycoplasma

- ii. PCR for morbillivirus
 - iii. Cytology
- e. Blood cultures, if auscultation or other examinations indicate significant bacterial illness
- f. Feces, for biotoxins

Additional information for the sample collection, containers/media, and storage requirements can be found in the [data repository](#).

**The datasheets for live-dolphin examinations currently have some elements associated with behavior and neurological function. However, given the possibility that more progressive freshwater disease may feature cerebral edema, we recommend that future versions of this plan include the development of a specific behavioral/neurological section in the datasheets, including (but not limited to): attitude (bright, alert, and responsive [BAR]/quiet, alert, and responsive [QAR]), eye movement, buoyancy/floating position in water (before, during, and after an assessment), presence and nature of tremors.

4.2.2 Sick/Injured Dolphin Response/Intervention

The collection of data and samples during response and/or intervention activities with sick or injured dolphins will especially be subject to the capture, handling, and veterinary activities necessary in each case. Responders will need to prioritize what can be done depending on if the dolphin is stranded live on a beach or is free-swimming, and the health status of the dolphin. If the dolphin is captured in one location and moved to another for release, samples and examinations can potentially be conducted during transport—at the discretion of the veterinarian(s) in attendance. This could especially facilitate conducting ultrasound scans, collecting urine, and weighing the animal (before or after transport). If the dolphin is taken into rehabilitation, staff should especially take care to pair all observations about health and recovery with water salinity and time/duration.

4.2.3 Temporary Catch-and-Release Health Assessments

All of the examination criteria and samples included above are usually part of temporary catch-and-release health assessment protocols conducted in the Southeast U.S. over the past decade. Thus, little needs to be changed from the [datasheets and procedures](#) normally used in those efforts. However, if freshwater disease is a priority concern, the order of priority could change, and thus should be discussed with the organizers and veterinarians for each effort. This could be an important consideration in cases where a dolphin needs to be released earlier than normal.

4.3 Hands-on Data Collection with Dolphin Carcasses

The broader array of data and samples that can be collected from fresh dolphin carcasses is an important complement to the examinations and sample collections from live dolphins. Gross pathology and histopathology offer critical information about the physiological mechanisms that

led to mortality. As above, MMHSRP has developed a Dead Animal Freshwater Disease Sampling protocol [document](#) for Stranding Network Partners. Again, we present a slightly modified version with very few additional potential samples/examination data and a minor reorganization in the order of priority. The data needs/samples/procedures are listed in order from highest priority to lowest priority, but many can be collected concurrently depending on the number of trained personnel present. Of course, the reality of each situation will determine what items from the list are feasible, depending on the personnel, their training, the resources available to them at the moment, the weather/environment, and the well-being of the personnel. Priority would be for full sample collection from fresh dead animals, fewer samples would be collected from more decomposed carcasses.

1. Water salinity and temperature measurements (surface and depth profile)
2. Photographs of skin (focusing especially on any lesions), eyes, and full body
3. Skin/skin lesions (paired with photographs):
 - a. Histopathology
 - b. Cultures
 - c. Frozen samples
 - d. Algal mat scrapings
 - e. Skin scrapings onto microscope slides
4. Eyes:
 - a. One eye into formalin
 - b. From the other eye:
 - i. Corneal scraping onto microscope slides
 - ii. Vitreous for electrolytes/chemistry
5. Urine* for:
 - a. Urinalysis
 - b. Osmolality
 - c. Chemistry
6. Sex
7. Body condition score and morphometrics
 - a. Total straight-line length
 - b. Girth at the anterior insertion of the dorsal fin
 - c. Weight, if possible
8. Full histopathology tissue set collection
 - a. Include brain and adrenal gland, if possible*
9. Standard frozen tissue set collection
 - a. To include lung, brain, spinal cord, liver, pulmonary lymph node, spleen, kidney, adrenal gland, and notable lesions
10. Blubber for contaminants and other analyses (only from fresh dead carcasses)
11. Serum extraction from clotted blood for:
 - a. Serum chemistry
 - b. Serum osmolality
 - c. Renin
 - d. Hormones

12. Stomach contents
13. Samples for age estimation:
 - a. Tooth
 - b. Pectoral flipper (radiograph on-site or freeze entire flipper)
 - c. Skin sample for epigenetics
14. Milk

Additional information for the sample collection and storage requirements can be found in the [data repository](#).

5 A Near-term Strategy for Response and Scientific/Impact Assessment Decision Making

The goal of this living document is to support NOAA’s marine mammal monitoring and adaptive management efforts in Louisiana to develop a plan for quantifying and better characterizing freshwater exposure and effects on Louisiana dolphins. This first version of the document, and the [data repository/dictionary](#) associated with it, is a first step towards that goal, by aggregating the current state of knowledge on the topic, the remaining data gaps, and the available resources for addressing those data gaps. Developing a strategy that will provide decision makers with robust, science-based data and analysis to address the data gaps will require a significant, multi-year effort. Under the best circumstances (i.e., here, under normal or “baseline” salinity conditions), studies on wild dolphins are challenging and, especially when factoring in health, take time and collaborations to generate appropriate sample sizes. The challenge increases when the study also requires data from dolphins in more specific cohorts/conditions (i.e., here, dolphins with a variety of exposure durations/severities and a variety of effects—to build/update the dose-response curves).

Given those difficulties, it will be critical to integrate and synthesize data across as many different efforts as possible (from Louisiana, the Southeast U.S., and potentially internationally), including: 1) past efforts, 2) future studies under programs outside of this LA marine mammal monitoring and adaptive management effort, 3) opportunistic studies that arise and offer valuable chances to collect relevant data, and 4) studies designed and conducted specifically to support this effort. The [LA BND Monitoring Plan](#) provides recommendations for coordinated field efforts to monitor the dolphin populations across Louisiana, and the overarching planning needs (Section 2) and the specific activities therein offer a solid framework that can integrate the freshwater-specific tools discussed in this report. I.e., the Monitoring Plan and this Freshwater Strategy should ideally be considered as one, unified effort, saving time and resources, and ensuring that decision makers get the best-available information as soon as possible.

In the near-term (e.g., the next three years), what are the priority actions needed to better our understanding of freshwater exposure and effects on Louisiana dolphins? We recommend the following:

1. Establish the infrastructure for the overarching planning needs in Section 2 of the [LA BND Monitoring Plan](#).
2. Identify, as early as possible, known or predictable large freshwater inputs into Louisiana basins (e.g., from the Bonnet Carré Spillway, the Bohemia Spillway, and Mardi Gras Pass, and naturally occurring cuts in the Mississippi River) and deploy field crews for monitoring salinity levels/freshwater exposure and dolphin distributions/health status before, during, and after freshwater inundation events. Similarly, identify subpopulations of dolphins that likely experience seasonal freshwater exposures based on their home ranges (e.g., near river inputs or in the northern portions of Barataria Bay) for targeted research efforts.
3. Integrate the protocols/tools from Section 4 of this document to any future dolphin studies in Louisiana or, if possible, nearby states—whether as part of Louisiana marine mammal monitoring and adaptive management activities (e.g., the field activities recommended in the [LA BND Monitoring Plan](#)) or by collaborating with scientists with other programs/funding.
4. Ensure that Stranding Network Partners in Louisiana have the training and resources they need to 1) fully integrate the freshwater-related protocols/tools into their routine activities and 2) respond to as many cases as possible across Louisiana (especially cases with possible freshwater exposure).
5. Convene subject matter expert groups to further develop this plan and the recommendations made within it, including the specific protocols/tools identified in [Section 4](#).

This report/plan is meant to be a living document with consistent efforts to review and update the material within. Whenever new, significant datasets or studies become available, they should be integrated into this document (and the associated [data repository/dictionary](#)), and the recommendations herein should be updated. Otherwise, given the rapidly changing coastal environment in Louisiana, we recommend that NOAA and the Louisiana marine mammal monitoring and adaptive management group identify and work with subject matter experts to review and update the document annually.

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