BIOLOGY: INTEGRATING CORE TO ESSENTIAL VARIABLES (Bio-ICE)

TASK TEAM REPORT FOR MARINE MAMMALS

TABLE OF CONTENTS

Task Team Co-Chairs

Gabrielle Canonico, NOAA, Integrated Ocean Observing System

Laura Lorenzoni, National Aeronautics and Space Administration

Marine Mammal Subgroup Chair

Samantha Simmons, Marine Mammal Commission

Membership *(in alphabetical order)*

Abby Benson, U.S. Geological Survey

Mathew Biddle, NOAA, Integrated Ocean Observing System

Maggie Chory, Consortium for Ocean Leadership

Kruti Desai, Consortium for Ocean Leadership

Masha Edmondson, Consortium for Ocean Leadership

Jason Gedamke, NOAA, National Marine Fisheries Service

Stacie Hardy, NOAA, National Marine Fisheries Service

Margaret E. Hunter, U.S. Geological Survey

Anu Kumar, U. S. Navy

Brian D. Melzian, U.S. Environmental Protection Agency

Keith Mullin, NOAA, National Marine Fisheries Service

Kim Parsons, NOAA, National Marine Fisheries Service

James Price, Bureau of Ocean Energy Management

Shannon Rankin, NOAA, National Marine Fisheries Service

Patricia Rosel, NOAA, National Marine Fisheries Service

Heather Spence, Department of Energy, Water Power Technologies Office

Sofie Van Parijs, NOAA, National Marine Fisheries Service

Michael Weise, Office of Naval Research

Suggested citation: Simmons, S.E., A. Benson, M. Biddle, G. Canonico, M. Chory, K. Desai, M. Edmondson, J. Gedamke, S.K. Hardy, M.E. Hunter, A. Kumar, L. Lorenzoni, B.D. Melzian, K. Mullin, K.M. Parsons, J. Price, S. Rankin, P.E. Rosel, H.R. Spence, S.M. Van Parijs, and M.J. Weise. 2022. Interagency Ocean Observation Committee (IOOC) Biology: Integrating Core to Essential Variables (Bio-ICE) Task Team Report for Marine Mammals.

BACKGROUND AND RATIONALE

Marine mammals are wide-ranging, relatively long-lived organisms that play a crucial role in maintaining healthy ocean ecosystems. Often referred to as ecosystem engineers and sentinel species in marine ecosystems, these charismatic megafauna feed at a variety of trophic levels, affecting food web dynamics and cycling of chemicals and nutrients in the water column as well as in benthic habitats, both nearshore and in the deep ocean. An understanding of their abundance and distribution is an essential starting point for evaluating their role in ocean ecosystems. Accordingly, marine mammals have been included among key variables to monitor in ocean observing systems, from core variables[1] for the U.S. Integrated Ocean Observing System (IOOS) to an Essential Ocean Variable (EOV)[2] for the Global Ocean Observing System (GOOS). They also contribute to several Essential Biodiversity Variables (EBVs)[3] for the Group on Earth Observations Biodiversity Observation Network (GEO BON). Further, evaluation of the health of marine mammal populations will help deliver societal benefits by contributing to the UN Decade of Ocean Science for Sustainable Development; informing reporting activities such as the World Ocean Assessment; and supporting achievement of Sustainable Development Goal 14, the post-2020 framework for the Convention for Biological Diversity, and a new treaty for conservation and sustainable use of marine biodiversity beyond national jurisdiction.

In the U.S., the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (FWS) are required to produce stock assessments for marine mammals under the Marine Mammal Protection Act (MMPA, 16 U.S.C. §1371 *et seq.*). Stock assessment analyses require accurate, up-to-date information on abundance and distribution to inform appropriate management and/or conservation measures. Despite the availability of information on abundance and distribution within the stock assessment reports,[4] availability and accessibility of the underlying data to the broader ocean observing community and contribution to EOVs remain inconsistent.

GOAL

The goal of this Interagency Ocean Observation Committee task team was to advance the integration of existing biological observations from local, regional, and federal sources using best practices to inform national needs and ultimately feed seamlessly into the Global Ocean Observing System, as appropriate. To accomplish this goal the subgroup focused on marine mammals to:

1. Reconcile the IOOS core biological variables with GOOS EOVs and the GEO BON EBVs, identifying where there are clear synergies in terms of spatial and temporal observing requirements and existing observation infrastructure and delivery including best practices/standards.
2. Identify and improve pathways for data flow for observations of these variables from Federal sources, such as the stock assessments conducted by NMFS and FWS, into IOOS with a focus on identifying and implementing best practices surrounding standardized data collection and delivery adhering to the FAIR[5] and CARE[6] data principles, as appropriate.

1 https://ioos.noaa.gov/about/ioos-by-the-numbers/
2 https://goosocean.org/eov
3 https://geobon.org/ebvs/what-are-ebvs/
4 https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-species-stock
5 https://www.go-fair.org/fair-principles/
6 https://www.gida-global.org/care

BUILDING A FIT-FOR-PURPOSE SYSTEM

To meet the goals of the Framework for Ocean Observations (IFSOO 2012), biological observations, such as those on marine mammal abundance and distribution, should meet the requirements of end users to ensure the observing system is fit for purpose. The task team used the current GOOS specification sheet[7] and identified marine mammal information and derived products required by the agencies, primarily to meet the provisions and purposes of the MMPA, the Endangered Species Act, and the National Environmental Policy Act (Table 1). These products are needed--provide information for baseline assessment of marine mammal stocks, risk and impact assessments, and identification of important areas for marine mammals or to make decisions about siting of alternative energy infrastructure or other human activities.

Requirement or derived product	Temporal resolutions	Spatial resolutions	Management unit	Agency
Abundance (minimum population estimate)	Seasonal, annual, interannual, ideally every 1 to 3 years depending on stock status	0.1 km to 10 km, best available	Stock	Navy, BOEM, DOE WPTO, NMFS, FWS
Distribution and occupancy	Seasonal, annual, interannual, ideally every 1 to 3 years depending on stock status	0.1 km to 10 km, 10 km to 1,000 km, best available	Stock, population	Navy, BOEM, DOE WPTO, NMFS, FWS
Current population trend	Seasonal, annual, interannual, ideally every 1 to 3 years depending on stock status	Best available	Stock	Navy, BOEM, NMFS, FWS
Migration pathways or corridors	Seasonal, annual, interannual	0.1 km to 10 km, best available	Stock, population	Navy, BOEM, DOE WPTO
Hotspots	Seasonal, annual, interannual	0.1 km to 10 km, best available	Stock, population	Navy, BOEM, DOE WPTO
Utilization distributions (relative occupation of home range)		0.1 km to 10 km, best available	Stock, population	Navy, DOE WPTO,
Density	Seasonal, annual, interannual	10x10 km, best available	Stock	Navy, BOEM
Geographic range	Seasonal	01.km to 10 km, 10 km to 1,000 km	Stock	DOE WPTO, NMFS, FWS
4-D Movements		0.1 km to 10 km, best available	Individual	Navy, DOE WPTO
Current net productivity rate	Annual (it is an annual rate), best available	Best available	Individual, stock	Navy, NMFS, FWS
Maximum net productivity rate	Annual (it is an annual rate), best available	Best available	Individual, stock	Navy, NMFS, FWS
Detection rates/cue rates		0.1 km to 10 km, Best available	Stock, population	Navy, DOE WPTO
Home range		Best available	Stock, population	Navy
Potential Biological Removal	Every 1 to 3 years depending on stock status (ideally)		Stock	NMFS, FWS
Habitat Utilization	Seasonal, annual, interannual	Best available		BOEM, NMFS, FWS

TABLE 1: Federal agency requirements for marine mammal information that should be available from a fit-for-purpose observing system, based on observations made to deliver the marine mammal abundance and distribution EOV.

7 https://goosocean.org/index.php?option=com_oe&task=viewDocumentRecord&docID=17511

IMPROVEMENTS: FROM DATA COLLECTION TO DELIVERY OF INFORMATION

Despite the information on abundance and distribution available in the stock assessment reports, the availability of and accessibility to the original data, delivery of information and other products to the broader ocean observing community, and contribution to the EOVs and EBVs remains inconsistent. To improve this situation, and better realize the FAIR data principles, the team developed preferred and alternative data flow pathways (Box 1) based on four methods that can be used to collect data on the abundance and distribution of marine mammals: line-transect vessel and aerial surveys, photo identification (photo-ID) capture-mark-recapture, passive acoustic monitoring, and the use of environmental DNA. To be successful, the data flow pathways must ensure that the data are provided in aggregated, standardized, and easily manipulable ways, ideally, they would be applicable to other EOVs as well.

One globally-recognized way to standardize data is to use the Darwin Core data standard. Darwin Core is a standard glossary of terms used for sharing and integration of biological diversity data (Wieczorek et al. 2012). Darwin Core was originally designed for natural history collection data but has grown in use and applicability with its adoption by global biodiversity data aggregator repositories like the Ocean Biodiversity Information System (OBIS) and the Global Biodiversity Information Facility (GBIF). Further, Darwin Core has been adopted by GOOS. Once data are standardized, they can be integrated into global aggregation systems like OBIS and can easily be reused by data analysts all over the world to answer scientific questions and create products useful to managers, conservationists, and other stakeholders.

BOX 1

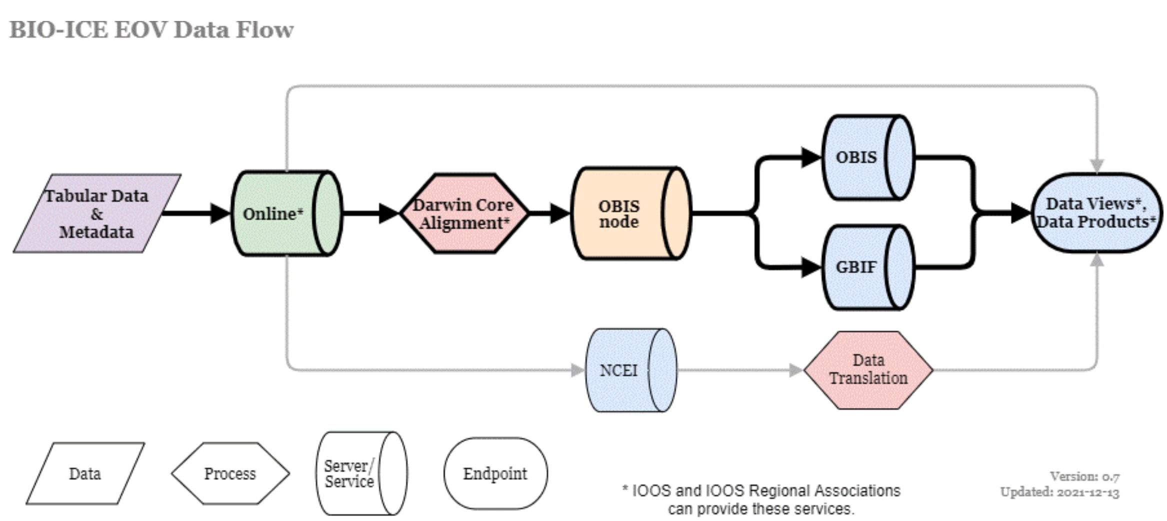

FIGURE 1: Data flow diagram depicting preferred (black lines) and alternative (gray lines) data flows for marine mammal observation data to make abundance and distribution visualizations and derived products publicly available and better realize the FAIR data principles.

BOX 1 *(Continued)*

The perspective of Figure 1 is from the data originator (the person/group that created the data) and the steps are defined below:

- **Tabular Data & Metadata -** These are the post-collection observations in an electronic format. that may have some scientific QA/QC already performed.
- **Online -** Data are available through some online platform. This might be through a project or program platform, or through another entity's service (like NCEI's archive services or an IOOS Regional Association).
- **Darwin Core Alignment -** The process of translating the post-collection observations into a community agreed-upon standard. This process can be facilitated by IOOS and the IOOS Regional Associations through their data management capabilities.
- **OBIS node -** Once data follow the Darwin Core standard, they can be included in OBIS nodes (OBIS SEAMAP or OBIS-USA are recommended for marine mammal observations) which share the data with global aggregators OBIS and GBIF.
- **OBIS/GBIF -** Data made accessible to global aggregators is integrated with other datasets around the world to provide increased interoperability and reusability of observational data.
- **Data Views/Products -** Observations available online can feed into defined data views and products to communicate status and trends on EOVs. The IOOS Office and Regional Associations can provide these products and views.
- **NCEI -** (alternative data pathway) NCEI is used as an example in the figure to represent repositories that allow but do not require the submitted data to follow community agreed standards (e.g., Darwin Core) when accepting data into their collection. If community agreed standards are not followed this path may require the producer of the data view or product to perform data translation to make the data ingestible into the platform of choice. Typically this requires significant effort, unique to each dataset, and does not create data that can be integrated with other datasets.
- **Data Translation -** (non-preferred) When data do not follow community agreed-upon standards there is a data translation step needed to make an appropriate data viewer/product, but often this does not allow the data to be reused by others.

The data flow starts on the left with tabular data and metadata in the format that is most useful for the project for which the data were collected. The data are then put online in the project-specific format so they are publicly accessible. To improve reuse and interoperability of the data, they are then aligned to the data standard Darwin Core. Once the data are standardized to Darwin Core, they can be included in an OBIS node (for marine mammals in the U.S., OBIS SEAMAP or OBIS-USA are recommended). The OBIS node then makes the data available to the global aggregators OBIS and GBIF. Once appropriate datasets are aggregated together data viewers and other data products can be developed to assess marine mammal abundance and distribution across projects.

The observation requirements (i.e., what defines the data collected in Tabular Data & Metadata box) are identified by the agency and through groups like IOOS, GOOS, and GEO BON, and feed into the determination of what tabular data and metadata should be collected. It should be noted that each of the arrows in the diagram represent an iterative process that can bring the process back to an earlier step. The bolded boxes and arrows indicate the preferred process a data provider should strive to achieve. However, alternative pathways that are currently used are also depicted in the diagram. Finally, to reduce the complexity of the diagram, some interagency data flows are not depicted (for example, OBIS-USA submitting data for long-term archival at the National Centers for Environmental Information, NCEI).

DATA COLLECTION METHODS

There are many ways to collect information on marine mammal abundance and distribution. For example, Hammond et al. (2021) provides a good review on methods for estimating marine mammal abundance. The remainder of this report focuses on four methods – line-transect vessel and aerial surveys, photo-ID capture-mark-recapture, passive acoustic monitoring, and the use of environmental DNA – three of which are already widely used with established best practices to deliver information for the U.S. marine mammal stock assessment reports as required under section 117 of the MMPA. The emerging field of environmental DNA is also included because it holds great promise for efficient future assessment of distribution and likely abundance. The report describes each method, identifies appropriate best practices – including whether submissions were made to the Ocean Best Practices System (OBPS)[8] – and illustrates the progress through the data flow pathway (Box 1) for any data use cases, and provision of information to the GOOS BioEco metadata portal on the federal monitoring effort. Additionally, the team identified a total of 17 EBVs that can be informed, either directly or indirectly,by the collection of observations and delivery of information on marine mammal abundance and distribution. Illustrations of the connections between observations or sub-variables, EOVs, derived products, and EBVs for both photo-ID and passive acoustic monitoring are given in Figures 2 and 3 at right.

Line-Transect Vessel and Aerial Surveys

Line-transect survey methods have been used for years to estimate the density of a wide variety of terrestrial and marine animals (Buckland et al. 2001, Buckland et al. 2004, Buckland et al. 2015). The abundance of the animal is estimated by extrapolating the density in the area surveyed to the entire area of interest. In the most basic application, the method involves an observer moving through an area in a straight line, or transect, searching for the target animal, where the length of the transect searched is measured. When a sighting is made, the perpendicular distance from the transect line to the location where the animal was first sighted is measured, known as the perpendicular sighting distance (PSD). The central assumption of line transect methods is that all animals/groups on the transect line (i.e., PSD = 0) are sighted with certainty (i.e., probability = 1). The PSDs are used to model the probability of sighting an animal based on distance alone. That is, the probability usually decreases with increasing PSD according to some function that can be modeled (i.e., "sighting function"). The sighting function, transect length, and number of animals sighted are used to estimate density.

Visual cetacean line-transect surveys are conducted from platforms such as small boats, large ships, and aircraft using teams of observers that search for cetacean groups along and on both sides of the transect line. Surveys on each platform type are implemented using methods customized for that platform that meet the assumptions of line-transect theory. Methods on each platform may be tailored further depending on analytical approaches (e.g., passing vs closing mode, one or two independent observer teams). In addition to the transect and PSD data, a wide variety of ancillary data used during data analysis to estimate density are also collected, including species identification, group size, behavior, and survey conditions.

Aerial surveys are conducted from platforms such as helicopters, fixed-wing aircraft, and unoccupied aircraft using either a team of observers that are searching for marine mammals or instrument-based approaches where images are taken from cameras mounted beneath the plane. Instrument-based surveys allow researchers to conduct survey effort while eliminating some in-flight challenges (e.g. observer fatigue, safety), result in a permanent record of the survey and flight area, and allow for the application of one or more approaches for detecting animals (e.g. image review, hotspot detection, machine learning detection models). For some marine mammal species, aerial surveys have expanded

8 https://www.oceanbestpractices.org/ All task team submissions were indexed with the terms "BioICE" and "IOOS Marine Life" for easy extraction/reference and potential inclusion in subsequent collections or communities.

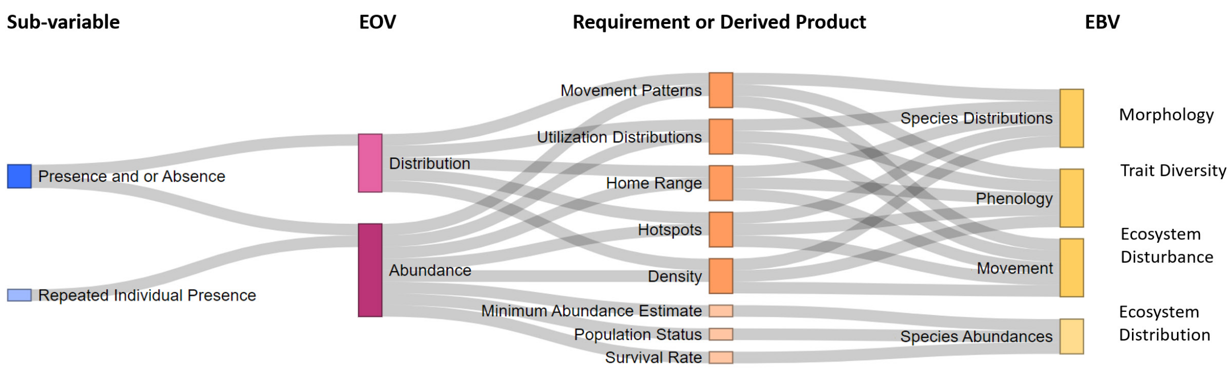

FIGURE 2: Sankey diagram illustrating the connections from data collection to delivery of information for photo-ID. Nodes with darker colors within a category have more connections. The EBVs listed on the right hand side, without any connections, are EBVs that can be informed by virtue of the method used without having a direct connection into determining marine mammal abundance or distribution. An interactive version, where different connections can be highlighted by hovering over the figure, is available *here*.

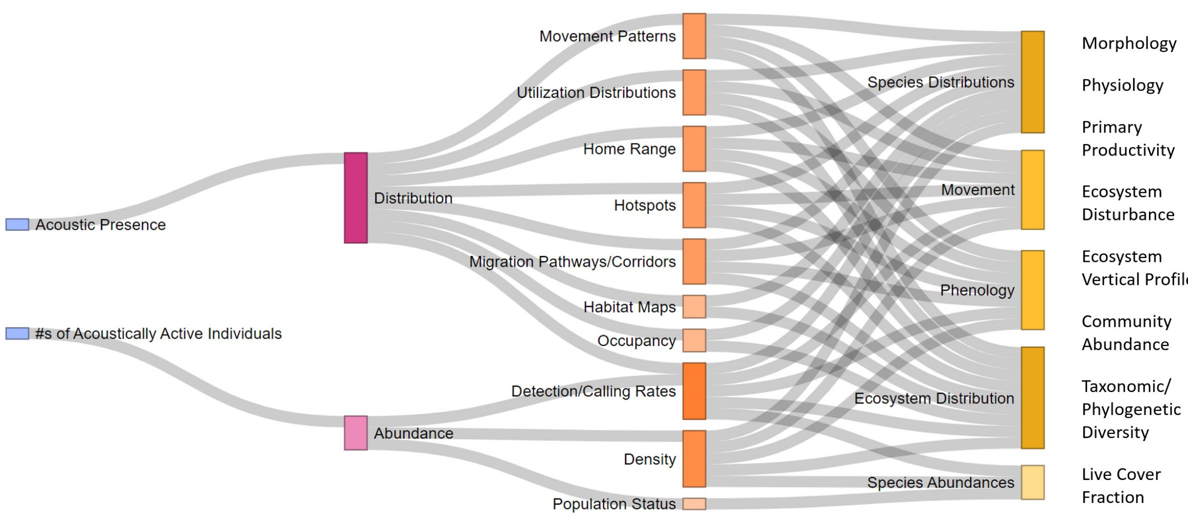

FIGURE 3: Sankey diagram illustrating the connections from data collection to delivery of information for passive acoustic monitoring. Nodes with darker colors within a category have more connections. The EBVs listed on the right-hand side, without connections in the diagram, are EBVs that can be informed by virtue of the method used without having a direct connection into determining marine mammal abundance or distribution. An interactive version, where different connections can be highlighted by hovering over the figure, is available *here*.

beyond traditional line-transect methodologies to include hierarchical polygon-based efforts as well (Conn et al. 2012, Martin et al. 2015). While the specific methods for how these surveys are conducted varies and are substantially different from line-transect surveys, the resulting counts from these flights can similarly be modeled to estimate species abundance.

There are a number of challenges associated with the line-transect survey method. The central assumption that each animal/group on the transect line is sighted with certainty can be violated in primarily two ways: (1) groups on the transect are missed by observers (perception bias) and (2) groups on the transect line are below the surface and cannot be seen by observers (availability bias). There are methods for estimating perception bias that can be employed during the survey that include independent observers and two-team approaches for perception bias. Availability bias can be estimated independently with tagging studies that provide data to estimate dive times. In the case of visual vessel surveys that include acoustic line-transect surveys, the two methods can be combined to estimate visual availability bias for some species. Line-transect surveys are used to estimate the density of cetacean groups. Therefore, an estimate of group size for each species must be made independently. The size of each group encountered can be estimated during the visual survey by observers but can be potentially biased by a number of factors. Group size, environmental conditions (e.g., sea state), and animal behavior affect the sightability of each group and must be considered. Finally, during multi-species cetacean surveys, each species must be identified. Accurate species identification depends on a number of factors that include behavior, experience of the observers, and distance from the survey platform.

An extensive[9], searchable bibliography of Distance Sampling papers using a wide-variety of applications can be found at *https://distancesampling.org/dbib.html*

Data use case: Line-transect survey data for cetaceans that were collected as part of the Gulf of Mexico Marine Assessment Program for Protected Species.

Completed data flow steps (Box 1):

- **Online -** Full survey tabular data and metadata available online through NCEI. https://www.ncei.noaa.gov/archive/accession/0241032
- **Darwin Core Alignment -** Completed initially for a subset of the data sent to OBIS SEAMAP and now completed for the full dataset available at NCEI .
- **OBIS node -** Subset of the data sent to OBIS SEAMAP
- **OBIS -** Available in OBIS, through facilitation by OBIS SEAMAP. https://obis.org/dataset/322e289f-10c8-4e53-b7c6-705ff3c4a788
- **GBIF -** Available in GBIF, through facilitation by OBIS SEAMAP. https://www.gbif.org/dataset/5af68f8f-689b-4c4f-bdfd-75f060a2111b
- **Data Views/Products -** e.g. OBIS SEAMAP's Cetacean Density Mapping Tool. https://seamap.env.duke.edu/models/mapper/USECGOM

In addition to the data flow steps, three entries representing abundance and distribution surveys of cetaceans in U.S. waters of the Gulf of Mexico and waters off the Southeast United States, as well as Bering-Okhotsk Sea seal surveys are pending submission to the GOOS BioEco metadata portal.[10] The portal is still under development but will serve as the GOOS dashboard for monitoring programs providing information on the BioEco EOVs.

Next steps: identification and submission of best practices and data standards to the OBPS for line-transect survey methods across the various platforms, increasing the number of survey datasets that are available through the data flow pathway, and adding additional survey or monitoring efforts to the GOOS BioEco metadata portal that reflect the full scope of effort put forth by NMFS and FWS to deliver information on marine mammal abundance and distribution using line-transect surveys.

Photo-identification, Capture-Mark-Recapture

Capture-Mark-Recapture (CMR) is a long-standing tool for estimating density and abundance of wild populations. The method can involve physically capturing and marking the study animals for later identification and "recapture," or can rely on natural markings on animals. Humpback whales, for example, have unique pigmentation patterns on the ventral sides of the flukes; common bottlenose dolphins often have unique nicks and notches in their dorsal fins. These unique, natural markings allow researchers to identify individuals. Through vessel-based surveys and photography, photo-identification (photo-ID) of individuals is possible and this information can be used for CMR-based abundance estimation. This method, in addition to providing estimates of density and abundance, can also be used to estimate

9 Bibliography contains over 1,500 citations from 1882 to 2021
10 GOOS BioEco Metadata Portal (bioeco.goosocean.org)

key demographic parameters in a population, and provide information on population distribution and movement of individuals, at least within the bounds of the survey area (Fig. 2). Hammond et al. (2021) provides a broad overview of CMR methods for marine mammals.

Data from photo-ID CMR may also indirectly provide information on ecosystem disturbance, as it could potentially provide an indicator of disturbances via changes in habitat use, and of ecosystem distribution, as it could potentially provide information about the boundaries of discrete ecosystem units, depending on how those units are defined. Other potential derived products include identification of hotspots, home ranges, movement patterns, and utilization distributions (relative occupation of home range) (Fig. 2).

Photo-ID CMR entails assumptions that can be challenging to meet in practice and, like all methods, proper survey design is critical. If the species is not well marked, or only a very small fraction of the population is marked, uncertainty in the abundance estimate may be high. If the likelihood of re-encountering marked individuals is very small, the method will not perform well. If the photo-ID survey area encompasses only a very small portion of the population's range, an underestimate of the true population abundance is likely. Finally, there are a variety of underlying assumptions of the CMR analyses that must be met or otherwise addressed.

Photo-ID CMR and CMR methods can be applied to both a variety of marine mammal species, including cetaceans, pinnipeds and sirenians as well as other respective groups. For pinnipeds, CMR can be performed using applied or natural marks, and can be conducted from land or potentially via aerial surveys. For cetaceans, photo-ID CMR is commonly used for delphinids, particularly bottlenose dolphins. The method can be broken into three steps: 1) vessel-based field surveys to collect photographs, 2) photo analysis (image processing and quality control, sorting, and matching), and 3) statistical analyses to obtain abundance and/or survival estimates. Each of these three steps has unique best practices. Because this method has most commonly been applied to bottlenose dolphins, many of the best practices are focused on this species, but are also more broadly applicable. For the first step, Rosel et al. (2011) describe best practices for appropriate survey design and data collection in the field. They also provide some best practices for early stages of step 2. Step 2 involves photo-processing and photo-analysis, and ultimately construction of a database of the individual photos and, importantly, their associated metadata. There are several documents describing best practices for this step, for example, Adams et al. (2006), Melancon et al. (2011), Urian et al. (2015), and Thompson et al. (2021). There are currently no best practices documents focused on step 3, the statistical analysis of the photo-ID data to generate density, abundance, and/or survival estimates. Many different methods have been developed, due in part to the variety of conditions and attributes a particular population or habitat presents, and also due to continued advancements in the types of analytical tools, including, for example, spatial capture-recapture tools that can be brought to bear on the question. Balmer et al. (2019) and Tyne et al. (2014) provide some examples of good analytical practices for photo-ID CMR abundance estimation. McDonald et al. (2017) and Glennie et al. (in press) provide examples of more advanced statistical analyses that have more recently been developed.

Data use case: A CMR photo-ID dataset for common bottlenose dolphins is available in NCEI. The abundance estimate generated by this dataset is in Conn et al. (2011).

Completed data flow steps (Box 1):

- **Online -** Tabular data and metadata available online through NCEI: https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:0237742
- **Darwin Core Alignment -** Completed by OBIS SEAMAP.
- **OBIS node -** The data have been shared with the OBIS SEAMAP through the Gulf of Mexico Dolphin Identification System (GoMDIS).

Missing from flow:

- **OBIS/GBIF -** As of now these data are not shared with global data aggregators, however, activity is underway to accomplish this task.
- **Data Views/Products -** None available.

In addition to the data flow steps, an entry representing dolphin CMR surveys in the Gulf of Mexico is pending submission to the GOOS BioEco metadata portal. The portal is still under development but will serve as the GOOS dashboard for monitoring programs providing information on the BioEco EOVs.

Next steps: identification or development and submission of best practices and data standards to the OBPS for step 3, the statistical analysis of the photo-ID data to generate density, abundance, and/or survival estimates for photo-ID CMR; increasing the number of CMR datasets that are available through the data flow pathway; and adding additional survey or monitoring efforts to the GOOS BioEco metadata portal that reflect the full scope of effort put forth by NMFS and FWS to deliver information on marine mammal abundance and distribution using photo-ID CMR.

Passive Acoustic Monitoring

Passive Acoustic Monitoring (PAM) involves the recording of underwater sounds, both biological and anthropogenic (man made). PAM allows for the understanding of species presence, distribution, abundance and behavior, measurements of ambient ocean noise levels and how anthropogenic sounds may impact species' ability to communicate effectively. PAM is valuable where the species in question are producing sounds but does not provide information when species are quiet, therefore the underlying assumption with this technique is that it can determine presence but not absence. This technology is in the process of transitioning from a development technology to a more broadly operational technology for a wide range of applications. The technology will continue to change rapidly at all points in the data collection and analytical process. As a result, Standard of Practices (SOP) for data collection, data processing, and analysis remain limited but there are a number of review papers that provide a great starting point.

PAM Data Collection/Design may consider archival and/or real-time sensors applied over a range of spatial and temporal scales (Van Parijs et al. 2009). PAM applications for monitoring and mitigation of potential impacts have evolved significantly over recent years. Van Parijs et al. (2021) focusses on providing recommendations on PAM best practices for monitoring and mitigation in relation to wind energy development. The paper provides SOP that address PAM capabilities and techniques needed to promote efficient, consistent, and meaningful data collection efforts on local and regional scales required by federal and state regulators, the offshore wind industry, and environmental advocates.

PAM Data Analyses & Validation approaches vary based on the target species and call type. Kowarski et al. (2021) undertook a literature review of baleen whale PAM analysis methods using large datasets and provided recommendations to encourage robust research methods that are comparable across studies and sectors, achievable across research groups, and consistent with previous work. Baumgartner et al. (2020) provides detailed information on the PAM validation and analyses processes for novel approaches that include real time PAM data collection and rapid reporting of acoustic detections to mitigate impacts of ship strikes.

PAM Metadata Standards are essential for compiling disparate long-term data sets to address ecological questions on varying time scales. Roch et al. (2016) outline the need and propose a solution to standardize metadata to provide consistency and transparency across efforts. Different PAM devices require specialized data standards and protocols still in development, such as the current effort to create an American National Standard for towed array operations[11].

11 https://asastandards.org/s3sc1wg3/

PAM Applications and analyses can address ecological, behavior and impact level questions, just to name a few. Marques et al. (2013) focuses on the potential of using PAM to estimate animal density of certain marine mammal species. A review that covers a range of other PAM applications can be found in Van Parijs et al. (2009). All of these review papers are available in the OBPS.

Data use case: Passive acoustic data from the endangered North Atlantic right whale presents a prime example of what is possible through joint collaborative efforts to answer large scale questions such as changes in distribution or occupancy of a large migratory marine mammal across an ocean basin. Davis et al. (2017) presents a study in which 36 collaborators shared access to their data to allow for a cohesive and comparable analysis of North Atlantic right whale acoustic distribution throughout the western Atlantic Ocean across a 10-year time period. This effort highlighted the need for structured metadata templates to allow for other future data sharing[12]. In addition, public sharing of the data is important through data portals such as the *GOOS BioEco metadata portal*[13] or the historical Passive Acoustic Cetacean Map[14]. Similarly, PAM recordings require long term storage which can be achieved through contributing data recordings to NOAA's National Center for Environmental Information[15].

Completed data flow steps (Box 1):

- **Data Views/Product -** Data can be visualized in the Passive Acoustic Cetacean Map portal *https://apps-nefsc.fisheries.noaa.gov/pacm/#/narw*

In progress:

- **Online -** Data are not currently available online but working with NCEI.
- **Darwin Core Alignment -** Crosswalk to Darwin Core performed by Abby Benson as part of the work of this sub-task team.
- **OBIS node -** Data will be shared with OBIS-USA once crosswalk is complete and data are available.
- **OBIS/GBIF -** Once shared with OBIS-USA these data will be shared with OBIS and GBIF.

In addition to the data flow steps, two entries representing NOAA's Ocean Noise Reference Station Network and the acoustic presence of cetaceans in the Western North Atlantic are pending submission to the GOOS BioEco metadata portal. The portal is still under development but will serve as the GOOS dashboard for monitoring programs providing information on the BioEco EOVs.

Next steps: identification and submission of additional or revised best practices and data standards to the OBPS for passive acoustic monitoring, increasing the number of acoustic datasets that are available through the data flow pathway, and adding additional passive acoustic monitoring efforts to the Passive Acoustic Cetacean Map, NCEI, and GOOS BioEco metadata portal.

Environmental DNA

The use of environmental DNA (eDNA) in the marine environment is still a nascent technology and methods for interpreting eDNA detections (and negative or non-detections) in an open marine environment are evolving. However, there are relatively few publications to date that have successfully applied eDNA to marine mammals (Baker et al. 2018; Foote et al. 2012; Hunter et al. 2018; Juhel et al. 2021; Parsons et al. 2018; Qu & Stewart 2019; Szekely et al. 2021; Visser et al. 2021). To date, most eDNA studies targeting marine mammals have focused on detection as an indicator of distribution as there are several unresolved challenges to the use of eDNA methods for estimating abundance. Much remains unknown about eDNA shedding rates in marine mammals (for both live animals and carcasses), as well as marine mammal eDNA degradation, dispersion and transport in currents, and the influence of biotic and abiotic factors on the movement of eDNA in the marine environment. In addition, while

12 https://www.fisheries.noaa.gov/resource/document/passive-acoustic-reporting-system-templates
13 https://bioeco.goosocean.org
14 https://apps-nefsc.fisheries.noaa.gov/pacm/#/
15 https://ngdc.noaa.gov/mgg/pad/

positive detections can be used to confirm species presence, negative detections do not necessarily imply absence from a sampled region. Potential derived products from detection/non-detections of eDNA include estimating detection and occupancy rates through three-level occupancy models (Hunter al. 2015, Schmidt et al. 2013, Strickland & Roberts 2019) and using real-time eDNA monitoring to investigate movements/migration.

To date, the use of eDNA data to estimate abundance is still a general topic of discussion in the field (Lacoursiere-Roussel et al. 2016, Rourke et al. 2021, Shelton et al. 2019, Yates et al. 2019) and estimates of abundance or biomass using eDNA have focused primarily on fish species (e.g. Rourke et al. 2021, Stoeckle et al. 2021, Yates et al. 2021). Several studies have found close correlations between eDNA concentration and biomass estimates using species-specific quantitative assays, especially in closed or semi-closed systems where environmental covariates (water/current speed and mixing, temperature, microbial degradation, etc.) can be measured and integrated into a model framework. However, the suite of biotic and abiotic factors affecting eDNA estimates are both species- and habitat-specific, making broad standardization of the method difficult. Therefore, additional technological advances and empirical modeling are needed to support eDNA-data application for less abundant marine species, such as marine mammals.

The large number of environmental and species-specific covariates can make data interpretation and comparison challenging. Particularly challenging are eDNA detections of rare species and habitats that are extensive, open and deep, as is the case for many marine mammals. As eDNA fate and transport models evolve, insights into key variables for parameterizing eDNA abundance estimation models should continue to improve. In addition, bioinformatic approaches are expected to continue to evolve to support estimates of relative abundance, distribution models, and interpretation of negative detections. Population genetic methodologies are advancing, and individual identification and effective population size (Ne) derived from eDNA data could potentially be used as indicators to inform changes in abundance in the future (Parsons et al. 2018).

While eDNA methods have rapidly expanded to date, the progression of standardization of methods and best practices across studies is still evolving. Certain field and laboratory methods used for eDNA detection are variable depending on target taxa or species, sample types (fresh vs. saline water; surface vs. depth; turbid vs. clear), collection methods, sampling location (shore vs. pelagic), and environmental covariates (temperature, UV, wind action, etc.). Therefore, standardized broad-sweeping protocols have been difficult to develop and there is currently no best practice protocol to register in OBPS.

A number of groups have developed best practices primarily covering broad, high-level topics, or focusing on one of the many processes within an eDNA study (field collection, water filtration, DNA extraction, assay design/execution, data analysis, interpretation/statistics). Thalinger et al. (2021) developed a five-level scale to determine the level of assay optimization, validation, and statistical interpretation needed to identify whether an eDNA assay meets criteria for operational readiness. Although, the authors note, “The placement of assays on this 5-level scale is not straightforward, since each … contains variables associated with either rudimentary or substantial validation and reporting.” Abbott et al. (2021) through Fisheries and Oceans Canada published guidance on eDNA related to invasive and at-risk species on sampling, detection, and analysis for managers and proposed a reporting template and minimum data requirements for eDNA studies. The array of both environmental and process-based factors affecting eDNA workflows have been highlighted across a number of publications (Burian et al. 2021, Dickie et al. 2018, Furlan et al. 2016, Kumar et al. 2021, Klymus et al. 2020, Mathieu et al. 2020, Piggott 2016, Trujillo-Gonzalez et al. 2021), emphasizing the value of pilot studies that allow direct evaluation of assay sensitivity, efficacy of sampling protocol in a given environment, and laboratory competency prior to embarking on new eDNA sampling campaigns. More work is being done to develop standard protocols by numerous groups, including the European

AquaNET and the U.S. Geological Survey for display of eDNA data on a public-facing database (Ferrante et al., In press). To date, no marine mammal eDNA datasets aimed at determining abundance or wide-scale distribution maps have been published.

Data use case: While no specific use case was identified for eDNA, there has been notable activity in this area associated with Darwin Core and making these data available to global aggregators. A guide to publishing DNA-derived data was added to OBPS (Andersson et al. 2020). In conjunction with this publication, a new extension to Darwin Core specifically for DNA-derived data was published[16]. The guide and extension have supported the publication of eDNA data to global aggregators while ensuring the necessary ancillary information is included when the data are shared.

Next steps: development of best practices and data standards for targeted (species- or genera-specific) and metabarcoding eDNA applications; improved understanding of the fate and transport of marine mammal eDNA; and development and parameterization of models quantifying the effects of biotic and abiotic factors on eDNA detections in marine environments. Work focusing on quantifying abundance and individual identification will continue to advance for the field as a whole.

16 https://tools.gbif.org/dwca-validator/extension.do?id=http://rs.gbif.org/terms/1.0/DNADerivedData

SUMMARY

The task team leveraged existing infrastructure and information to improve the integration of fit-for-purpose marine mammal abundance and distribution information from federal sources into IOOS, GOOS and GEO BON data flow pathways. It was agreed that to streamline communications and data flow and to minimize confusion, the name of the IOOS core variable will be changed to match the EOV and now be known as "marine mammal abundance and distribution."

For each of the four focal methods, the team identified the derived products and EBVs that can be informed by collection of observations and delivery of information on marine mammal abundance and distribution (two examples are illustrated in Figures 2 and 3). In total the team determined that 17 of the 20 currently recognized EBVs can be informed either directly or indirectly by using the four methods that the team focused on for this effort. If other methods, for example biologging or telemetry, are considered in future efforts this number may increase.

Information for six federal monitoring and data collection efforts including line-transect surveys, photo-ID, and passive acoustic monitoring have been prepared for submission to the GOOS BioEco metadata portal. Initial datasets for each of these methods have also been mapped through the data flow pathway (Box 1 and see details for each method above), and 10 best practices, seven for acoustics and three for photo-ID, have been submitted to OBPS (see bolded citations in the references section).

Overall, the team's efforts have laid a solid foundation to reconcile one of the IOOS core variables with EOVs and EBVs, identify and improve pathways for data flow, and build the community around best practices for the focal methods. However, future efforts are needed to:

1. Reflect the true scope of federal monitoring efforts through the GOOS BioEco metadata portal.
2. Identify or develop additional best practices for collection of data and delivery of information on marine mammal abundance and distribution.
3. Ensure all federal marine mammal abundance and distribution datasets are integrated into the data pathway in Box 1.
4. Work with end users on the delivery of information from those datasets to ensure the system is fit-for-purpose.
5. Incorporate data and information from emerging technologies such as eDNA into the observing system.
6. Increase knowledge of and training opportunities around the Darwin Core data standard for federal data collectors. Ideally this could result in inclusion of Darwin Core in individual agency processes as a required part of federal data processing and archiving under the Presidential Memorandum on "Increasing Access to the Results of Federally Funded Scientific Research"[17].

ACKNOWLEDGMENTS

The authors would like to acknowledge additional contributions from Erin Mooreland and Karin Forney and the peer reviewers for constructive comments. The team would also like to thank Jay Pearlman and Pauline Simpson for input and guidance on submissions to the OBPS, Erin LaBrecque for assistance with producing Figures 2 and 3, and Jason Mallett for the graphic design of this report. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

17 https://www.whitehouse.gov/wp-content/uploads/2022/08/08-2022-OSTP-Public-Access-Memo.pdf

REFERENCES *(Citations in bold have been submitted to the OBPS)*

Abbott, C., Coulson, M., Gagné, N., Lacoursière-Roussel, A., Parent, G.J., Bajno, R., Dietrich, C., May-McNally, S. (2021). Guidance on the Use of Targeted Environmental DNA (eDNA) Analysis for the Management of Aquatic Invasive Species and Species at Risk. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/019. iv + 42 p.

Adams, J, Speakman, T, Zolman, E and Schwacke, L. (2006). Automating image matching, cataloging, and analysis for photo-identification research. Aquatic Mammals, 32(3): 374-384. *https://doi.org/10.1578/AM.32.3.2006.374*

American National Standard: Underwater Passive Acoustic Monitoring for Bioacoustic Applications. BSR/ASA S3/SC1WG3.2020. *https://asastandards.org/s3sc1wg3/*

Andersson, A. F., Bissett, A., Finstad, A. G., Fossøy, F., Grosjean, M., Hope, M., Jeppesen, T. S., Kõljalg, U., Lundin, D., Nilsson, R. N., Prager, M., Svenningsen, C., and Schigel, D. (2020). Publishing DNA-derived data through biodiversity data platforms. vol 1, Copenhagen: GBIF Secretariat. *https://doi.org/10.35035/doc-vf1a-nr22*

Baker, C.S., Steel, D., Nieukirk, S. and Klinck, H. (2018). Environmental DNA (eDNA) from the wake of the whales: Droplet digital PCR for detection and species identification. Front. Mar. Sci. 5:133. *https://doi.org/10.3389/fmars.2018.00133*

Balmer, B., Watwood, S., Quigley, B., Speakman, T., Barry, K., Mullin, K., Rosel, P., Sinclair, C. Zolman, E. and Schwacke, L. (2019). Common bottlenose dolphin (Tursiops truncatus) abundance and distribution patterns in St Andrew Bay, Florida, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 29(3): 486-498. *https://doi.org/10.1002/aqc.3001*

Baumgartner, M. F., Bonnell, J., Corkeron, P. J., Van Parijs, S. M., Hotchkin, C, Hodges, B. A., Bort Thornton, J., Mensi, B. L., and Bruner, S. M. (2020). Slocum gliders provide accurate near real-time estimates of baleen whale presence from human-reviewed passive acoustic detection information. Front. Mar. Sci. 7: 100. *https://doi.org/10.3389/fmars.2020.00100*

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. and Thomas, L. (2001). Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford, UK.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. and Thomas, L. (Editors) (2004). Advanced Distance Sampling. Oxford University Press, Oxford, UK.

Buckland, S. T., Rexstad, E., Marques, T. A. and Oedekoven, C. S. (2015). Distance Sampling: Methods and Applications. Springer, Heidelberg.

Burian, A., Mauvisseau, Q., Bulling, M., Domisch, S., Qian, S. and Sweet, M. (2021). Improving the reliability of eDNA data interpretation. Molecular Ecology Resources, 21(5): 1422-1433. *https://doi.org/10.1111/1755-0998.13367*

Conn, P. B., Gorgone, A. M., Jugovich, A. R., Byrd, B. L., & Hansen, L. J. (2011). Accounting for transients when estimating abundance of bottlenose dolphins in Choctawhatchee Bay, Florida. The Journal of Wildlife Management 75(3):569-579. *https://doi.org/10.1002/jwmg.94*

Conn, P. B., Laake, J. L., and Johnson, D. S. (2012). A hierarchical modeling framework for multiple observer transect surveys. PLoS 7(8): e42294. *https://doi.org/10.1371/journal.pone.0042294*

Davis, G. E., Baumgartner, M. F., Bonnell, J. M., Bell, J., Berchok, C., Bort Thornton, J., Brault, S., Buchanan, G., Charif, R. A., Cholewiak, D., Clark, C. W., Corkeron, P., Delarue, J., Dudzinski, K., Hatch, L., Hildebrand, J., Hodge, L., Klinck, H., Kraus, S., Martin, B., Mellinger, D. K., Moors-Murphy, H., Nieukirk, S., Nowacek, D. P., Parks, S., Read, A. J., Rice, A. N., Risch, D., Sirovic, A., Soldevilla, M., Stafford, K., Stanistreet, J. E., Summers, E., Todd, S., Warde, A., and Van Parijs, S. M. (2017). Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (Eubalaena glacialis) from 2004 to 2014. Sci Rep 7: 13460. *https://doi.org/10.1038/s41598-017-13359-3*

Dickie, I. A., Boyer, S., Buckley, H. L., Duncan, R. P., Gardner, P. R., Hogg, I. D., Holdaway, R. J., Lear, G., Makiola, A., Morales, S. E., Powell, J. R., and Weaver, L. (2018). Towards robust and repeatable sampling methods in eDNA-based studies. Mol Ecol Resour. 18(5): 940– 952. *https://doi.org/10.1111/1755-0998.12907*

Foote, A.D., Thomsen, P. F., Sveegaard, S., Wahlberg, M., Kielgast, J., Kyhn, L. A., Salling, A. B., Galatius, A., Orlando, L. and Gilbert, M. T. P. (2012). Investigating the potential use of environmental DNA (eDNA) for genetic monitoring of marine mammals. PLoS 7(8): e41781 *https://doi.org/10.1371/journal.pone.0041781*

Furlan, E. M., Gleeson, D., Hardy, C. M. and Duncan, R. P. (2016), A framework for estimating the sensitivity of eDNA surveys. Mol Ecol Resour 16: 641-654. *https://doi.org/10.1111/1755-0998.12483*

Ferrante, J. A., Daniel, W. M., Freedman, J. A., Klymus, K. E., Neilson, M. E., Passamaneck, Y., Rees, C. B., Sepulveda, A., and Hunter, M. E. (2002), Gaining decision-maker confidence through community consensus: identifying environmental DNA standards for data display on the USGS Nonindigenous Aquatic Species database. Management of Biological Invasions. In Press.

Glennie, R., Thomas, L., Speakman, T., Garrison, L., Takeshita, R., and Schwacke, L. (in press). Estimating spatially-varying density and time-varying demographics with open population spatial capture-recapture: a photo-ID case study on bottlenose dolphins in Barataria Bay, Louisiana, USA. Available at arXiv preprint arXiv:2106.09579.

Hammond, P. S., Francis, T. B., Heinemann, D., Long, K. J., Moore, J. E., Punt, A. E., Reeves, R. R., Sepúlveda, M., Sigurgsson, G. M., Siple, M. C., Víkingsson, G., Wade, P. R., Williams, R., and Zerbini, A. N. (2021). Estimating the abundance of marine mammal populations. Front Mar Sci 8:735770. *https://doi.org/10.3389/fmars.2021.735770*

Hunter, M. E., Oyler-McCance, S. J., Dorazio, R. M., Fike, J. A., Smith, B. J., Hunter, C. T., Reed, R. N., and Hart, K. M. (2015). Environmental DNA (eDNA) sampling improves occurrence and detection estimates of invasive Burmese pythons. PloS ONE, 10(4): e0121655. *https://doi.org/10.1371/journal.pone.0121655*

Hunter, M. E., Meigs-Friend, G., Ferrante, J. A., Kamla, A. T., Dorazio, R. M., Diagne, L. K., Luna, F., Lanyon, J. M., and Reid, J.P. (2018). Surveys of environmental DNA (eDNA): a new approach to estimate occurrence in Vulnerable manatee populations. Endangered Species Research, 35:101-111. *https://doi.org/10.3354/esr00880*

Juhel, J. B., Marques, V., Fernández, A. P., Borrero-Pérez, G. H., Martinezguerra, M. M., Valentini, A., Dejean, T., Manel, S., Loiseau, N., Velez, L., and Hocdé, R. (2021). Detection of the elusive Dwarf sperm whale (Kogia sima) using environmental DNA at Malpelo island (Eastern Pacific, Colombia). Ecology and Evolution, 11(7): 2956. *https://doi.org/10.1002/ece3.7057*

Kowarski, K. A., and Moors-Murphy, H. (2021). A review of big data analysis methods for baleen whale passive acoustic monitoring. Marine Mammal Science 37(2): 652-673. *https://doi.org/10.1111/mms.12758*

Kumar, G., Farrell, E., Reaume, A. M., Eble, J. A., and Gaither, M. R. (2021). One size does not fit all: Tuning eDNA protocols for high- and low-turbidity water sampling. Environmental DNA 00:1– 15. *https://doi.org/10.1002/edn3.235*

Klymus, K. E., Merkes, C. M., Allison, M. J., Goldberg, C. S., Helbing, C. C., Hunter, M. E., Jackson, C. A., Lance, R. F., Mangan, A. M., Monroe, E. M., Piaggio, A. J., Stokdyk, J. P., Wilson, C. C., and Richter, C. A. (2020). Reporting the limits of detection and quantification for environmental DNA assays. Environmental DNA. 2020; 2(3): 271– 282. *https://doi.org/10.1002/edn3.29*

Marques, T. A., Thomas, L., Martin, S. W., Mellinger, D. K., Ward, J. A., Moretti, D. J., Harris, D., and Tyack, P. L. (2013). Estimating animal population density using passive acoustics. Biological Reviews, 88(2), 287-309. *https://doi.org/10.1111/brv.12001*

Martin, J., Edwards, H. H., Fonnesbeck, C. J., Koslovsky, S. M., Harmak, C. W., and Danea, T. M. (2015). Combining information for monitoring at large spatial scales: First statewide abundance estimate of the Florida manatee. Biological Conservation 186: 44-51. *https://doi.org/10.1016/j.biocon.2015.02.029*

Mathieu, C., Hermans, S. M., Lear, G., Buckley, T. R., Lee, K. C., and Buckley, H.L. (2020). A systematic review of sources of variability and uncertainty in eDNA data for environmental monitoring. Frontiers in Ecology and Evolution 8:135. *https://doi.org/10.3389/fevo.2020.00135*

McDonald, T. L., Hornsby, F. E., Speakman, T. R., Zolman, E. S., Mullin, K. D., Sinclair, C., Rosel, P. E., Thomas, L., and Schwacke, L. H. (2017). Survival, density, and abundance of common bottlenose dolphins in Barataria Bay (USA) following the Deepwater Horizon oil spill. Endangered Species Research 33: 193-209. *https://doi.org/10.3354/ESR00806*

Melancon, R., Lane, S., Speakman, T., Hart, L., Sinclair, C., Adams, J., Rosel, P., and Schwacke, L. (2011). Photo-identification field and laboratory protocols utilizing FinBase version 2. NOAA Technical Memorandum NMFS-SEFSC-627. Retrieved from: *https://repository.library.noaa.gov/view/noaa/10475*

Lacoursière-Roussel, A., Rosabal, M., and Bernatchez, L. (2016). Estimating fish abundance and biomass from eDNA concentrations: variability among capture methods and environmental conditions. Molecular ecology resources, 16(6): 1401-1414. *https://doi.org/10.1111/1755-0998.12522*

Parsons, K. M., Everett, M., Dahlheim, M. and Park, L. (2018). Water, water everywhere: Environmental DNA can unlock population structure in elusive marine species. Royal Society open science 5(8): 180537. *https://doi.org/10.1098/rsos.180537*

Piggott, M. P. (2016). Evaluating the effects of laboratory protocols on eDNA detection probability for an endangered freshwater fish. Ecol Evol 6: 2739-2750. *https://doi.org/10.1002/ece3.2083*

Qu, C. and Stewart, K. A. (2019). Evaluating monitoring options for conservation: comparing traditional and environmental DNA tools for a critically endangered mammal. The Science of Nature, 106(3): 1-9. *https://doi.org/10.1007/s00114-019-1605-1*

Roch, Marie A., Batchelor, H., Baumann-Pickering, S., Berchok, C. L., Cholewiak, D., Fujioka, E., Garland, E. C., Herbert, S., Hildebrand, J. A., Oleson, E. M., Parijs, S. V., Risch, D., Sirovic, A., and Soldevilla, M. S. (2016). Management of acoustic metadata for bioacoustics. Ecological informatics 31: 122-136. *https://doi.org/10.1016/j.ecoinf.2015.12.002*

Rosel, P., Mullin, K., Garrison, L., Schwacke, L. H., Adams, J., Balmer, B., Conn, P., Conroy, M., Eguchi, T., Gorgone, A., Hohn, A., Mazzoil, M., Schwartz, C., Sinclair, C., Speakman, T., Urian, K., Vollmer, N., Wade, P., Wells, R. and Zolman, E. (2011). Photo-identification capture-mark-recapture techniques for estimating abundance of bay, sound and estuary populations of bottlenose dolphins along the U.S. East Coast and Gulf of Mexico: A workshop report. NOAA Technical Memorandum NMFS-SEFSC-621. Retrieved from: *https://repository.library.noaa.gov/view/noaa/4014*

Rourke, M. L., Fowler, A. M., Hughes, J. M., Broadhurst, M. K., DiBattista, J. D., Fielder, S., Wilkes Walburn, J., and Furlan, E.M. (2021). Environmental DNA (eDNA) as a tool for assessing fish biomass: A review of approaches and future considerations for resource surveys. Environmental DNA. *https://doi.org/10.1002/edn3.185*

Schmidt, B. R., Kery, M., Ursenbacher, S., Hyman, O. J. and Collins, J. P. (2013). Site occupancy models in the analysis of environmental DNA presence/absence surveys: a case study of an emerging amphibian pathogen. Methods in Ecology and Evolution 4(7): 646-653. *https://doi.org/10.1111/2041-210X.12052*

Shelton, A. O., Kelly, R.- P., O'Donnell, J. L., Park, L., Schwenke, P., Greene, C., Henderson, R. A. and Beamer, E. M. (2019). Environmental DNA provides quantitative estimates of a threatened salmon species. Biological Conservation, 237:383-391. *https://doi.org/10.1016/j.biocon.2019.07.003*

Stoeckle, M. Y., Adolf, J., Charlop-Powers, Z., Dunton, K. J., Hinks, G., and VanMorter, S. M. (2021). Trawl and eDNA assessment of marine fish diversity, seasonality, and relative abundance in coastal New Jersey, USA. ICES Journal of Marine Science, 78(1): 293-304. *https://doi.org/10.1093/icesjms/fsaa225*

Strickland, G. J. and Roberts, J. H. (2019). Utility of eDNA and occupancy models for monitoring an endangered fish across diverse riverine habitats. Hydrobiologia 826(1): 129-144. *https://doi.org/10.1007/s10750-018-3723-8*

Székely, D., Corfixen, N. L., Mørch, L. L., Knudsen, S. W., McCarthy, M. L., Teilmann, J., Heide-Jørgensen, M. P., and Olsen, M. T. (2021). Environmental DNA captures the genetic diversity of bowhead whales (Balaena mysticetus) in West Greenland. Environmental DNA 3(1): 248-260. *https://doi.org/10.1002/edn3.176*

Task Team for an Integrated Framework for Sustained Ocean Observing (IFSOO). A Framework for Ocean Observing. UNESCO 2012, IOC/INF-1284, *https://doi.org/10.5270/OceanObs09-FO*

Thalinger, B., Deiner, K., Harper, L. R., Rees, H. C., Blackman, R. C., Sint, D., Traugott, M., Goldberg, C. S., and Bruce, K. (2021). A validation scale to determine the readiness of environmental DNA assays for routine species monitoring. Environmental DNA 3(4): 823-836. *https://doi.org/10.1002/edn3.189*

Thompson, J. W., Zero, V. H., Schwacke, L. H., Speakman, T. R., Quigley, B. M., Morey, J. S., and McDonald, T. L. (2021). Automated recognition and identification of marine mammal dorsal fins using residual convolutional neural networks. Marine Mammal Science 38: 139-150. *https://doi.org/10.1111/mms.12849*

Trujillo-González, A., Villacorta-Rath, C., White, N. E., Furlan, E. M., Sykes, M., Grossel, G., Divi, U., and Gleeson, D. (2021). Considerations for future environmental DNA accreditation and proficiency testing schemes. Environmental DNA 3:1049–1058. *https://doi.org/10.1002/edn3.243*

Tyne, J. A., Pollock, K. H., Johnston, D. W., Bejder L. (2014). Abundance and survival rates of the Hawai'i Island associated spinner dolphin (Stenella longirostris) stock. PLoS ONE 9(1): e86132. *https://doi.org/10.1371/journal.pone.0086132*

Urian, K., Gorgone, A., Read, A., Balmer, B, Wells, R. S., Berggren, P., Durban, J., Eguchi, T., Rayment, W., and Hammond, P. S. (2015). Recommendations for photo-identification methods used in capture-recapture models with cetaceans. Marine Mammal Science 31: 298-321. *https://doi.org/10.1111/mms.12141*

Van Parijs, S. M., Clark, C. W., Sousa-Lima, R. A., Parks, S. E., Rankin, S., Risch, D., and Van Opzeeland, I. C. (2009). Management and research applications of real-time and archival passive acoustic sensors over varying temporal and spatial scales. Marine Ecology Progress Series 395: 21-36. *https://doi.org/10.3354/meps08123*

Van Parijs, S. M., Baker, K., Carduner, J., Daly, J., Davis, G. E., Esch, C., Guan, S., Scholik-Schlomer, A., Sisson, N. B., and Staaterman, E. (2021). NOAA and BOEM Minimum Recommendations for Use of Passive Acoustic Listening Systems in Offshore Wind Energy Development Monitoring and Mitigation Programs. Frontiers in Marine Science 8:760840. *https://doi.org/10.3389/fmars.2021.760840*

Visser, F., Merten, V. J., Bayer, T., Oudejans, M. G., de Jonge, D. S. W., Puebla, O., Reusch, T. B., Fuss, J., and Hoving, H. J. T. (2021). Deep-sea predator niche segregation revealed by combined cetacean biologging and eDNA analysis of cephalopod prey. Science Advances 7(14): p.eabf5908. *https://doi.org/10.1126/sciadv.abf5908*

Wieczorek, J., Bloom, D., Guralnick, R., Blum, S., Doring, M., Giovanni, R. (2012). Darwin core: an evolving community-developed biodiversity data standard. PLoS One 7(1): e29715. *https://doi.org/10.1371/journal.pone.0029715*

Yates, M.C., Fraser, D.J. and Derry, A.M. (2019). Meta-analysis supports further refinement of eDNA for monitoring aquatic species-specific abundance in nature. Environmental DNA, 1(1): 5-13. *https://doi.org/10.1002/edn3.7*

Yates, M. C., Glaser, D. M., Post, J. R., Cristescu, M. E., Fraser, D. J., and Derry, A .M. (2021). The relationship between eDNA particle concentration and organism abundance in nature is strengthened by allometric scaling. Molecular Ecology, 30(13): 3068-3082. *https://doi.org/10.1111/mec.15543*

APPENDIX A: ACRONYM LIST

ATN - *Animal Telemetry Network*

Bio ICE - *Biology: Integrating Core to Essential variables*

BOEM - *Bureau of Ocean Energy Management*

CARE - *Collective benefit, Authority to control, Responsibility, Ethics*

CBD - *Convention on Biological Diversity*

CITES - *Convention on International Trade in Endangered Species of Wild Fauna and Flora*

CMR - *Capture-Mark-Recapture*

DOE WPTO - *Department of Energy, Water Power Technologies Office*

EBV - *Essential Biodiversity Variable*

eDNA - *Environmental Deoxyribonucleic Acid*

EOV - *Essential Ocean Variable*

FAIR - *Findable, Accessible, Interoperable, Reusable*

FWS – *U.S. Fish and Wildlife Service*

GBIF - *Global Biodiversity Information Facility*

GEO BON - *Group on Earth Observations Biodiversity Observation Network*

GOOS - *Global Ocean Observing System*

IOOS - *Integrated Ocean Observing System*

MMPA - *Marine Mammal Protection Act*

NCEI - *National Centers for Environmental Information*

NMFS – *National Marine Fisheries Service*

NOAA - *National Oceanic and Atmospheric Administration*

OBIS - *Ocean Biodiversity Information System*

OBIS SEAMAP - *Ocean Biodiversity Information System, Spatial Ecological Analysis of Megavertebrate Populations*

OBIS-USA - *Ocean Biodiversity Information System United States of America*

OBPS - *Ocean Best Practices System*

QA/QC - *Quality Assurance/Quality Control*

PAM - *Passive Acoustic Monitoring*

Photo-ID - *Photo identification*

PSD - *Perpendicular Sighting Distance*

SOP - *Standards of Practice*