OCS Study
BOEM 2021-011

Identifying Past Studies and Prioritizing Research Gaps in Support of the Gulf of Mexico Assessment Program for Protected Species (GOMMAPPS)

U.S. Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico Regional Office

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DISCLAIMER

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ABOUT THE COVER

The GoMMAPPS logo is property of BOEM.

Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

Short Form	Long Form
AMAPPS	BOEM Atlantic Marine Assessment Program for Protected Species
BOEM	Bureau of Ocean Energy Management
CC-BY	Creative Commons–attribution needed
CC-BY-NC	Creative Commons–attribution needed–non-commercial use only
DIVER	NRDA DWH Data Integration Visualization Exploration and Reporting application
DOI	United States Department of the Interior
DWH	*Deepwater Horizon*
EEZ	exclusive economic zone
ERMA-GOM	NOAA Environmental Response Management Application for the Gulf of Mexico
ESPIS	BOEM Environmental Studies Program Information System
FWRI	Florida Fish Wildlife Research Institute
GCMD	National Aeronautics and Space Administration Global Change Master Directory
GOMAMN	Gulf of Mexico Avian Monitoring Network
GoMMAPPS	Gulf of Mexico Marine Assessment Program for Protected Species
Gulf	Gulf of Mexico
InPort	NOAA NMFS InPort: Enterprise Data Management Program
ITIS	Integrated Taxonomic Information System
LMMSTRP	Louisiana Marine Mammal and Sea Turtle Rescue Program
NASA	National Aeronautics and Space Administration
NCEI	NOAA National Centers for Environmental Information
NGDC	NOAA National Geophysical Data Center (former name of NCEI)
NMFS	NOAA National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NODC	NOAA National Oceanographic Data Center
NRDA	*Deepwater Horizon* Natural Resource Damage Assessment
OBIS	Ocean Biogeographic Information System
OBIS-SEAMAP	OBIS-Spatial Ecological Analysis of Megavertebrate Populations
OBIS-USA	OBIS-United States of America
OCS	outer continental shelf
RID	data repository identification code
SEAMAP	Southeast Area Monitoring and Assessment Program
SEFSC	NOAA NMFS Southeast Fisheries Science Center
ServCat	USFWS Service Catalog
SID	study identification code
STAT	satellite tracking and analysis tool
TAMUG	Texas A&M University at Galveston
TESTR	Palm Beach Atlantic University Trophic Ecology and Sea Turtle Research Lab
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey

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- US Geological Survey (USGS): Kristen Hart, Katherine Wesenberg, and the USGS Publications Warehouse Technical Team

1 Introduction

1.1 Background

The United States (US) Gulf of Mexico (Gulf) is a heavily used and industrialized basin, supporting oil and gas exploration and development, commercial and recreational fishing, shipping, military operations, and tourism. The Gulf is also important for many marine mammal, seabird, and sea turtle species, many of which are protected under the Marine Mammal Protection Act of 1972, Migratory Bird Treaty Act of 1918, and Endangered Species Act of 1973 (Appendix 1, Brenner et al. 2016b). Spatial and temporal data on marine mammal, seabird, and sea turtle species within the Gulf is currently uneven between and within taxa (Love et al. 2015).

The mission of the Bureau of Ocean Energy Management (BOEM) is to manage development of US Outer Continental Shelf (OCS) energy and mineral resources in an environmentally and economically responsible way. BOEM uses the best available scientific information to properly mitigate and monitor for impacts on the environment. The identification and elimination of information gaps about the distribution and abundance of marine mammals, seabirds, and sea turtles is of high importance to this mission. For the purposes of this project, seabirds are defined as coastal, offshore, or pelagic species of birds which have their usual habitats and food sources in the sea.

Research on marine mammals, sea turtles, and seabirds in the Gulf has been conducted using a variety of methods (Jefferson and Schiro 1997; Davis et al. 2000a; The National Academies of Sciences, Engineering, and Medicine 2017). Information on abundances, from sightings or captures during dedicated surveys (e.g., onboard ships, planes, or from shore), opportunistic encounters (e.g., during non-systematic studies or incidental captures), systematic mark-recapture studies, telemetry tags (e.g., satellite, acoustic), signal detections using fixed and passive acoustic arrays, and genetic samples (e.g., environmental, mitochondrial, and nuclear DNA analyses), has been collected to give insights into marine species distribution and abundance (Webster et al. 2002, Fujioka et al. 2014, Brenner et al. 2016b). These data have also been used in marine mammal stock assessments (e.g., Waring et al. 2013, 2015, 2016), to describe distribution and migration patterns (e.g., Brenner et al. 2016b, Lamb 2016), and to analyze diversity and phylogenetic relationships (e.g., Rosel and Wilcox 2014, Rosel et al. 2016).

Living marine resource data collected from the Gulf are inconsistently collated. In some cases, agencies organize large databases for internal use or for sharing data among specific stakeholders and/or collaborators, and in other cases data are made available in public repositories. Current databases and public repositories vary in their degree of detail (Contreras and Reichman 2015, Kalyvas et al. 2017). Although complications may arise when information is brought together across disciplines, the rewards for a properly managed data collection is great. Proper data management can ease the ability to reproduce study results and can provide greater access to research knowledge, both of which may promote funding opportunities for future research (Reichman et al. 2011). Federal agencies recognize their role as scientific data stewards and the importance of public access to research results. To date, the US federal government has been involved as the lead agency, collaborator, and/or funder of much of the marine protected species research in the Gulf of Mexico OCS. Some of the data derived from this research may be at risk of being lost if they are not managed or shared properly (Bjorndal et al. 2011).

The Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) is a partnership program between BOEM, the National Oceanic and Atmospheric Administration (NOAA), the US Fish and Wildlife Service (USFWS), and the US Geological Survey (USGS). Part of this program is the identification of data gaps. To this end, data repositories were reviewed to identify existing, relevant information from completed and ongoing studies.

Another part of the GoMMAPPS effort is field research planned for 2017–2020 to assess marine mammal, sea turtle, and seabird species from the near shore to the US exclusive economic zone (EEZ) in the northern Gulf (Rosel et al. 2016). Activities planned for GoMMAPPS would support quantifying and understanding long-term trends in species abundance and distributions as they are related to various anthropogenic and natural stressors (BOEM 2016). Key tasks include:

1) aerial-based visual line transect surveys over continental shelf waters,
2) ship-board surveys from the continental shelf to US EEZ,
3) satellite tracking of tagged animals,
4) collecting environmental and passive acoustic data from towed arrays,
5) performing genetic analyses for composition and connectivity from biopsy samples, and
6) developing spatially- and temporally-explicit species density and habitat models (Green 2016, Rosel et al. 2016).

With regard to marine mammals, sea birds, and sea turtles, the Gulf is relatively data poor when compared to other US OCS regions (Kot et al. 2010). To be more specific, it is generally recognized that limited information exists within the US Gulf for seabirds, marine mammals outside of the summer season (Best et al. 2012, Roberts et al. 2016), and male and juvenile sea turtles (Hughes and Landry 2016, Lamont et al. 2015, Shaver et al. 2013, Shaver et al. 2017, SEFSC 2016b). The GoMMAPPS research efforts would contribute key data products to the understanding of species in the region. For example, gathering data to strategically fill gaps is critical for producing new or improved habitat and/or species density models (Best et al. 2012, Roberts et al. 2016).

All data products derived from the GoMMAPPS partnership program will be publicly available (Green 2016). The final GoMMAPPS project synthesis is planned for 2020–2021; partners and other stakeholders will be made aware of the project completion for better data discovery and dissemination (Green 2016).

1.2 Project Goals and Objectives

The GoMMAPPS project objectives covered in this document include identifying research gaps in relevant existing literature, providing recommendations for efficiently disseminating information to improve survey design, facilitating involvement across multiple stakeholders, and promoting the discovery of and access to relevant study data. Key tasks to achieve these objectives included:

1) completing an initial literature review of past studies relevant to the distribution and abundance of marine mammals, seabirds, and sea turtles in the US Gulf EEZ,
2) building a prototype data model containing metadata and geospatial footprints from task 1 that are standardized and organized for assessing and managing the GoMMAPPS research priorities and efforts,
3) summarizing past data coverage spatially, temporally, and by taxa to highlight research gaps, and
4) outlining recommendations for data hosting and management tools to support the GoMMAPPS outreach, education, and stakeholder engagement.

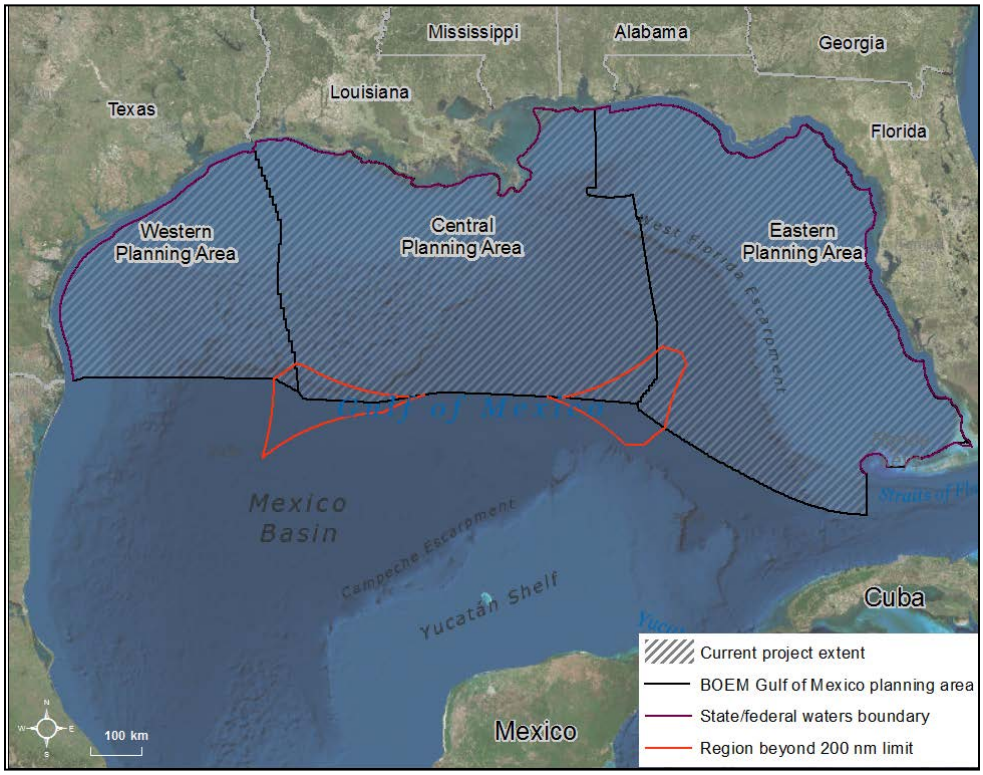


Figure 1. Project extent.
Within the Gulf of Mexico's Outer Continental Shelf, in support of the GoMMAPPS activities (Paskevich 2006; BOEM 2013, 2015; GADM 2015; Esri et al. 2016; VLIZ 2016; Esri et al. 2017).

1.3 Report Organization

This report has six sections with associated figures and tables and five appendices. The first section, including this paragraph, is an introduction to the project and provides background information, project goals, and objectives. The second section describes the methods used for data mining. The third section describes the results of executing the methodology described in the second section. The fourth section discusses the data sources identified, compares the repositories searched, includes recommendations for future data collection, and provides considerations for data dissemination. The fifth section is the conclusion. The sixth section is the works cited. The appendices include a species list, information on the data entry form for the GoMMAPPS database, a Standard Operating Procedures (SOP) for the creation of geofootprints, a data dictionary, and list of works consulted as part of this study but not cited in this document.

2 Methods

This section provides background information on the methods used to identify relevant data repositories, studies, and derived data as part of the greater Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) effort.

2.1 Defining Relevant Data

The data gathering phase of the GoMMAPPS initiative involved identifying relevant existing information for marine mammals, seabirds, and sea turtles in the Gulf of Mexico (Gulf). These data are diverse and include such types as visual observations, acoustic recordings, tissue samples, telemetry studies, and genetics. In addition to species and/or taxa data, extensive habitat and environmental data were gathered on oceanographic conditions, temperature, salinity, and chlorophyll concentrations. Data relevant to the GoMMAPPS effort were compiled by extracting information from relevant data repositories (Table 1). The determination of data relevancy was narrowed using several focal points. The spatial focus was the Bureau of Ocean Energy Management (BOEM) Gulf Western, Central, and Eastern Planning Areas but also included some other US federal waters and international waters when studies in these areas were deemed relevant (e.g., the Atlantic Marine Assessment Program for Protected Species [AMAPPS]). Focus was also placed on the inclusion of data which is readily available, or few hurdles exist for a user to obtain the data. Completed studies and active studies with interim published products were also considered. Information supplemental to what was identified through relevant data repositories was provided by the National Atmospheric and Oceanic Administration (NOAA) for marine mammals, US Fish and Wildlife Service (USFWS) for seabirds, and US Geological Survey (USGS) for sea turtles.

A total of 87 species were chosen for inclusion as part of the data gathering phase of the GoMMAPPS effort (Appendix 1). Of these, 29 were marine mammal species (Infraorder: Cetacea) (Tucker and Associates 1989, Felder and Camp 2009) and five were sea turtle species (Zug 2009, Brenner et al. 2016b). At least 491 species of birds are present in the Gulf (Felder and Camp 2009, Brenner et al. 2016b). The families that occur in ocean habitats (artificial aquatic/marine, marine coastal/supratidal, marine intertidal, marine neritic, or marine oceanic) of US territorial waters according to Birdlife International's definition of "seabirds" were Alcidae, Anatidae, Diomedeidae, Fregatidae, Hydrobatidae, Laridae, Oceanitidae, Pelecanidae, Phaethontidae, Phalacrocoracidae, Podicipedidae, Procellariidae, Scolopacidae, Stercorariidae, and Sulidae (BirdLife International 2010). Duncan and Havard (1980) also list Phalaropodidae. The 36 seabird species listed by Gallardo et al. (2009) as present in pelagic habitat permanently or ephemerally within the Gulf were identified for inclusion. Additional sources were used to identify other bird species that are known to occur in the Gulf Outer Continental Shelf (OCS) and/or US federal waters (Ribic et al. 1997, Lamb 2016, Lamb et al. 2017, P. Jodice, personal communication, 2017). These included two species from Pelecanidae (*Pelicanus occidentalis* and *Pelecanus erythrorhynchos*) and nine from Laridae (*Chlidonias niger*, *Chroicocephalus philadelphia*, *Hydroprogne caspia*, *Larus argentatus*, *Larus atricilla*, *Larus argentatus*, *Sternula antillarum*, *Thalasseus sandvicensis*, and *Rynchops niger*). Although not typically described under the definition of "seabird", *Rynchops niger* is described by Gallardo et al. (2009) as mostly using habitats nearshore, such as bays, beaches, shorelines, and islands. Three species (*Calonectris borealis*, *Thalasseus maximus*, and *Pterodroma feae*) not mentioned by Gallardo et al. (2009) were also included in this assessment. In total, 53 bird species were identified for inclusion in the GoMMAPPS data gathering phase.

2.2 Overview of Relevant Data Repositories

The relevant data repositories identified in the data gathering phase of the GoMMAPPS effort are listed in Table 1. These publicly available data repositories were recognized as potentially containing large amounts of data relevant to GoMMAPPS and were queried based on spatial, temporal, and/or text filters available online. Data repositories were queried in June and July 2017 and information on relevant data combined into a GoMMAPPS database (see Table 2 for further details).

Table 1. Large Data Repositories Inventoried for Data Relevant to the GoMMAPPS Effort

For more information on relevant data found within these repositories, use the data repository identification code (RID) along with Table 2.

RID	Repository	Organization	Query Type	Download Formats	Reference
1	ERMA®-GOM (Emergency Response Management Application®-Gulf of Mexico)	NOAA Office of Response and Restoration	Text, Spatial	pdf; shapefile, wms	(NOAA 2016, NOAA ORR 2015)
2	ESPIS (Environmental Studies Program Information System)	BOEM Environmental Studies Program	Text, Temporal	pdf	(Rasser et al. 2015, ESPIS 2019)
3	InPort	National Marine Fisheries Service (NMFS)	Text, Temporal, Spatial	pdf	(Sender et al. 2013, NMFS 2017)
4	OBIS-SEAMAP (Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations)	Duke University Marine Geospatial Ecology Lab	Text, Temporal, Spatial	csv; kml; shapefile; wms; xml	(Halpin et al. 2006, Halpin et al. 2009, OBIS 2019)
5	Publications Warehouse	USGS	Text, Temporal	ris	(USGS 2006)
6	ServCat* (Service Catalog)	USFWS	Text, Temporal, Spatial	csv; database; pdf; shapefile	(USFWS 2011)

*No datasets were identified as relevant within search results.

The ERMA®-GOM contains real-time and static datasets collated from a variety of sources to support emergency responders and environmental stakeholders (NOAA 2016, NOAA ORR 2015). Data layers relevant to marine mammals, seabirds, and sea turtles were selected manually via the table of contents of the ERMA®-GOM mapping interface. The Esri® ArcMap 10.2.2 Intersect Tool was used to double check that the extent of these shapefiles fell within the focus area for GoMMAPPS. Those that did not were discarded. Shapefiles associated with studies that used research methods outside of those proposed for the GoMMAPPS effort were also discarded. Metadata for relevant layers created for and by the Ocean Conservancy GAP Analysis (M. Love, personal communication, 2017) was also reviewed.

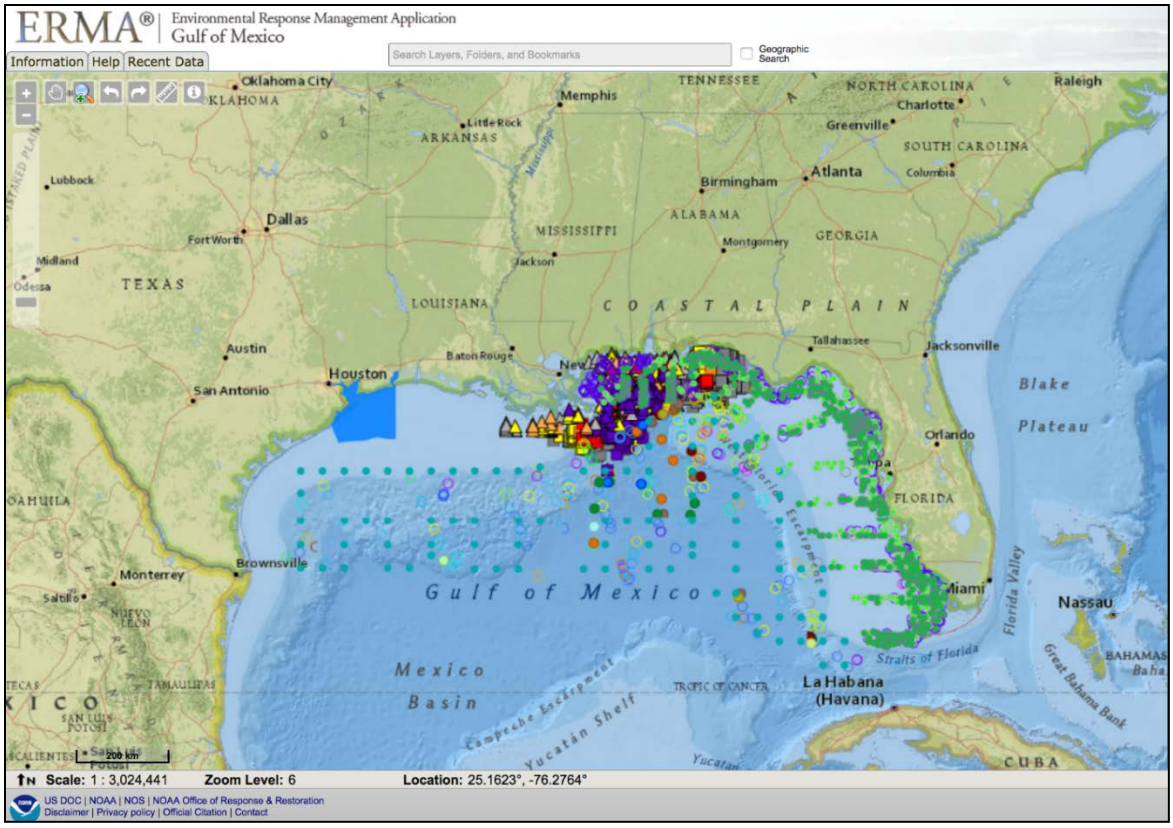


Figure 2. Screenshot of the extent of relevant data sets found on ERMA®-GOM after the results of the initial query for marine mammal, seabird, and sea turtle layers were reviewed.

The Environmental Studies Program Information System (ESPIS), which catalogs the BOEM Environmental Studies Program's studies, metadata, and reports (Rasser et al. 2015), was queried on June 20, 2017 by identifying the shapefiles that intersect the GoMMAPPS spatial focus. Although the ESPIS study footprints are available publicly as an Esri® ArcGIS Map service, the latest version of these shapefiles was obtained through Quantum Spatial, Inc. and used with permission (Figure 3).

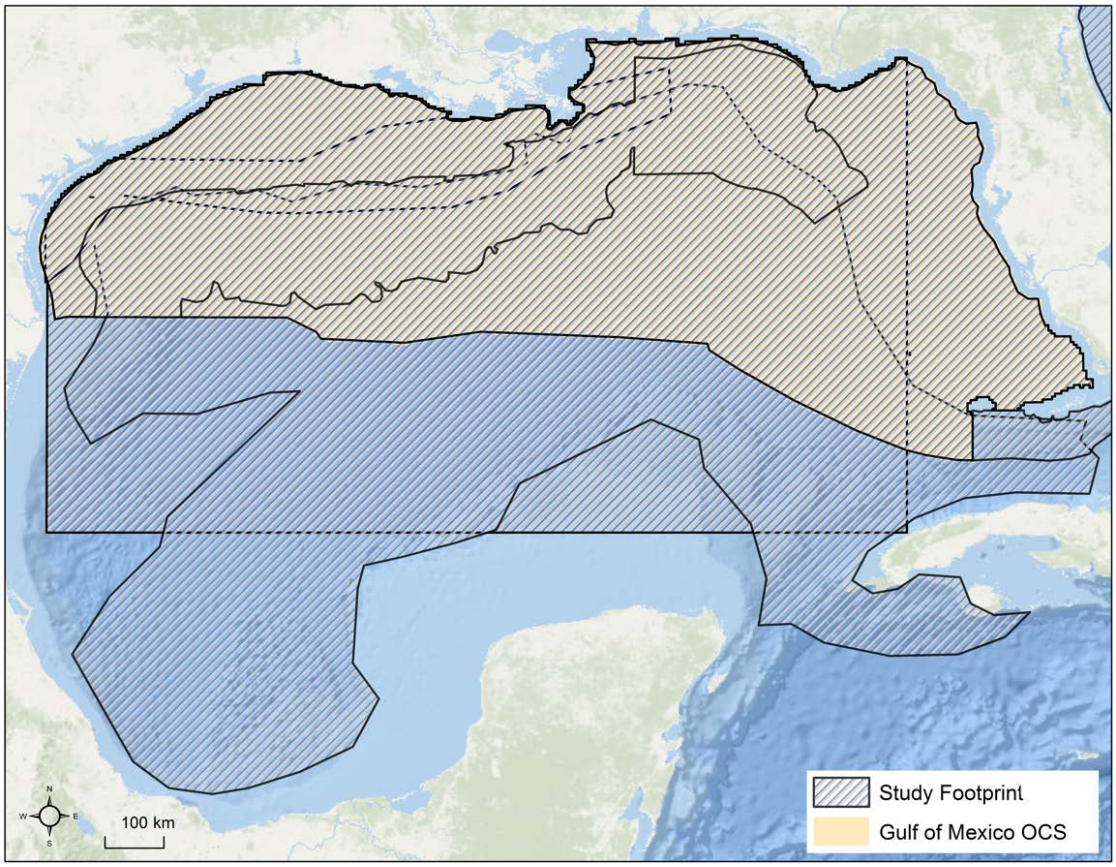


Figure 3. Relevant study footprints found on the Environmental Studies Program Information System (ESPIS).
(BOEM 2013, Esri et al. 2017)

The Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations database (OBIS-SEAMAP) is a spatially referenced online database aggregating marine mammal, seabird, sea turtle, ray, and shark data collected from across the globe (Halpin et al. 2006, Halpin et al. 2009). It was queried on June 20, 2017 using the online mapping interface to subset relevant datasets within the US Gulf of Mexico exclusive economic zone (EEZ) (Figure 4). The following search terms were entered in the quick search box: for marine mammals ('Cetacea'), for seabirds ('Alcidae', 'Diomedeidae', 'Fregatidae', 'Hydrobatidae', 'Laridae', 'Oceanitidae', 'Pelecanidae', 'Phaethontidae', 'Procellariidae', 'Scolopacidae', 'Stercorariidae', 'Sulidae'), and for sea turtles ('Testudines'). All records for these taxa, as well as any applicable child taxa (according to the Integrated Taxonomic Information System [ITIS]), were selected. The OBIS-SEAMAP repository contained some relevant datasets that were not available for public use, and permission was needed from the original data provider.

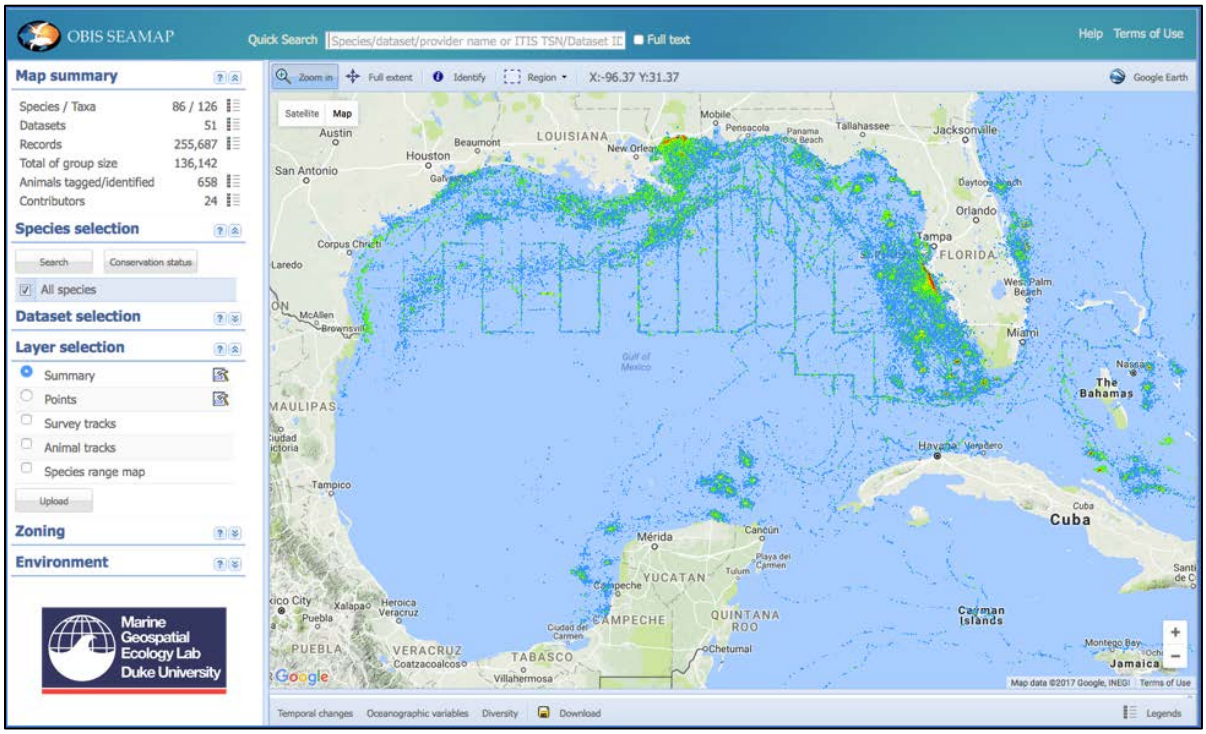


Figure 4. Screenshot of the relevant datasets on the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations database (OBIS-SEAMAP).

Online organizational catalogs housing recent studies by members of the GoMMAPPS taxa working groups were queried for relevant studies (Table 1). These catalogs included:

1) the NOAA National Marine Fisheries Service (NMFS) InPort: Enterprise Data Management Program for marine mammals and sea turtles (NMFS 2017);
2) the USFWS Service Catalog (ServCat) (USFWS 2011) mainly for seabirds; and
3) the USGS Publications Warehouse (USGS 2006) for sea turtles.

In general, these catalogs were mainly developed to facilitate data discovery by presenting metadata, general study footprints, and study contacts. They were most useful for obtaining textual details on relevant studies such as study scope and methods, in addition to information related to on-going, unpublished research. When available within these catalogs, spatial footprints often represented bounding boxes that were too broad to be used for a gap analysis. Furthermore, these spatial footprints may have

been developed without input from principal investigators and therefore may be inappropriate for determining actual spatial coverage (K. Hart and K. Wesenberg, personal communication, 2017).

The NMFS InPort allows users to explore the NOAA's completed and on-going studies (NMFS 2017, Sender et al. 2013). When queried on July 10, 2017, 14 studies related to marine mammals and 26 related to sea turtles were found. The following search terms were used: 1) "'marine mammal' AND 'Gulf of Mexico'"; 2) "'whale' AND 'Gulf of Mexico'"; 3) "'turtle' AND 'Gulf of Mexico'"; 4) "'bird' AND 'Gulf of Mexico'". After these queries, the NMFS Southeast Fisheries Center (SEFSC) Metadata Library (via InPort) was used to identify additional relevant studies. Study information available to the public included textual metadata, general bounding boxes representing the study footprint (if available), and related files for download (mainly pdfs for reference). Although the spatial resolution of the study footprints was low in these cases, details in the associated metadata were useful.

The USFWS ServCat (USFWS 2011) is a catalog that helps the public find USFWS studies and relevant documents. Metadata, pdfs, and simple study footprints can be archived and shared (USFWS 2011). After querying ServCat on June 16, 2017, using "Gulf of Mexico" as the text within the "search text" quick search option, 15 reports were returned, and none were determined as relevant to the current project. Although ServCat can archive different data formats in the system (USFWS 2012), these results provided only downloadable pdfs of publications.

The USGS Publications Warehouse (USGS 2006), a catalog of publications authored by USGS scientists, was queried on June 9, 2017 using the text string "'Gulf of Mexico' and 'turtle'" (Figure 5). Subsequent searches on July 12, 2017 for marine mammals (using search string "'Gulf of Mexico' and 'marine mammal'") and seabirds (using search string "'Gulf of Mexico' and 'bird'") were completed, but neither of these yielded relevant information.

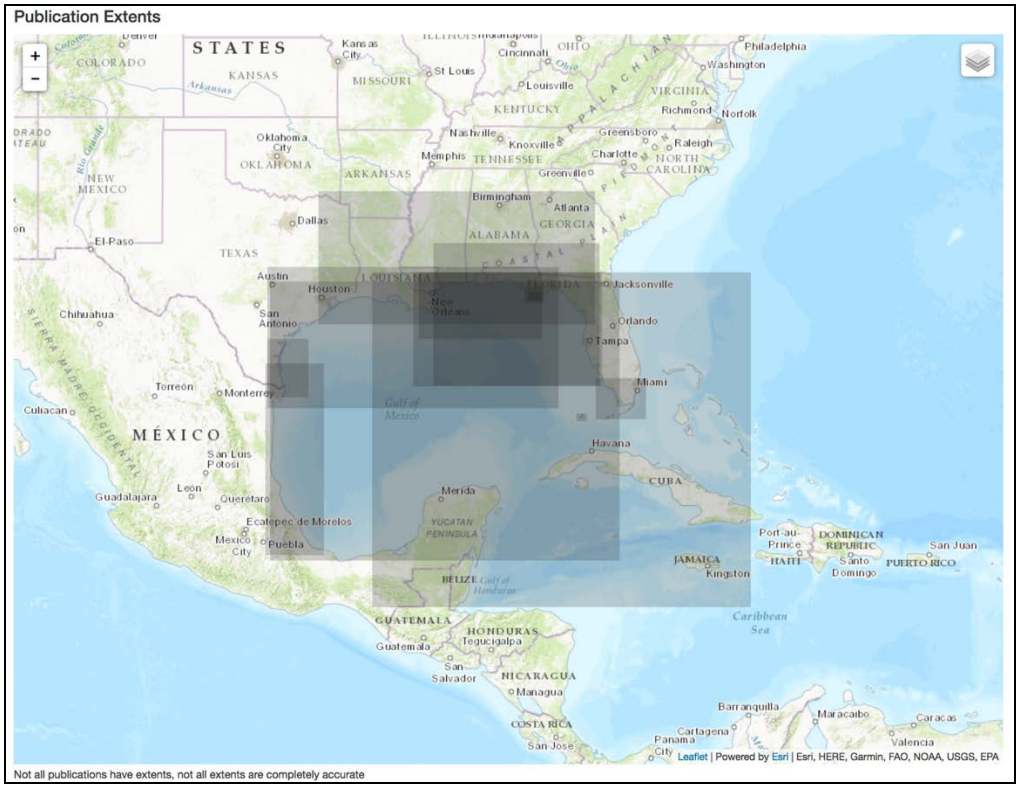


Figure 5. Screenshot of relevant sea turtle data sets from the US Geological Survey (USGS) Publications Warehouse.

(USGS 2006)

2.3 Storing Relevant Study Information and Identifying Gaps

Studies identified as relevant to the GoMMAPPS effort were reviewed to extract details such as target taxa, years fieldwork was performed, and data collection methods (see Appendix 7.4 for details). Useful study information that could not be gleaned from data repositories was obtained by reviewing peer-reviewed papers, grey literature (unpublished reports or reports published in a non-commercial form such as government reports), presentations, and websites associated with the study.

Non-spatial study information was entered into a Microsoft® Access (.accdb) relational database (referred to as the "GoMMAPPS database" throughout this report) and spatial information was stored in a geodatabase created with Esri® ArcGIS® 10.5 (Figure 6). To enhance the user experience and minimize data entry errors, data entry forms were created.

The geodatabase provides spatial information on study extents and data product extents in the form of feature datasets called footprints. Attributes for these footprints can be found in Appendix 7.4. Readily available spatial data created as part of the study was used as much as possible. If spatial data associated with a study was not readily available, other methods were employed for footprint generation (see section 7.3). This information was stored in the GenMethod attribute of each footprint (see Data Dictionary, section 7.4).

This review was also useful in the identification of existing data gaps.

2.4 GoMMAPPS Database

As mentioned in section 2.3, relevant, non-spatial study information were entered into a Microsoft® Access (.aacdb) relational database as part of this exercise (see Figure 6). The Data Dictionary (Appendix 7.4) provides details on allowed values for each field in the database (Appendix 7.4). Though the Data Dictionary fully explains the values in most of the database fields, the remaining paragraphs in this section provide additional details needed to fully understand the information in the GoMMAPPS database.

The Aquatic Setting field has four options: Coastal, Nearshore, Offshore, and/or Oceanic. These choices are borrowed from Coastal and Marine Ecological Classification Standard (CMECS) subsystem classifications, which in turn is based on FGDC-STD-018-2012 (Federal Geographic Data Committee 2012). In the CMECS classification scheme, the Coastal subsystem is part of the Estuarine system, and Nearshore, Offshore, and Oceanic are part of the marine system.

The Estuarine system is defined by FGDC-STD-018-2012 as follows: "This System includes tidally influenced waters that (a) have an open-surface connection to the sea, (b) are regularly diluted by freshwater runoff from land, and (c) exhibit some degree of land enclosure. The Estuarine System extends upstream to the head of tide and seaward to the mouth of the estuary. Head of tide is defined as … the inland or upstream limit of water affected by a tide of at least 0.2 foot (0.06 meter) amplitude. The mouth of the estuary is defined by an imaginary line connecting the seaward-most points of land that enclose the estuarine water mass at Mean Lower Low Water." The Estuarine Coastal subsystem is defined as the area "… from the supratidal zone at the land margin up to the 4 meter depth contour in waters that have salinity greater than 0.5 (during the period of average annual low flow)."

Nearshore, Offshore, and Oceanic subsystems are part of the Marine system. According to FGDC-STD-018_2012, "The Marine System is defined by salinity, which is typically around 35, although salinity can measure as low as 0.5 during the period of average annual low flow near fresh outflows. This system has little or no significant dilution from fresh water except near the mouths of estuaries and rivers. The Marine System includes all non-estuarine waters from the coastline to the central oceans. The landward

boundary of this system is either the linear boundary across the mouth of an estuary of the limit of the supratidal splash zone affected by breaking waves. Seaward, the Marine System includes all ocean waters."

The definitions for Nearshore, Offshore, and Oceanic, according to FGDC-STD-018_2012, are as follows: "The Marine Nearshore Subsystem extends from the landward limit of the Marine System to the 30 meter depth contour."; "The Marine Offshore Subsystem extends from the 30 meter depth contour to the continental shelf break, as defined by the maximum slope discontinuity with a rapid change in gradient of 3 or greater at the outer edge of the continental shelf."; and "The Marine Oceanic Subsystem represents the open ocean, extending from the continental shelf break to the deep ocean. Water depths typically range from 100–200 meters at their shallowest at the shelf break to over 11,000 meters at the deepest point in the ocean."

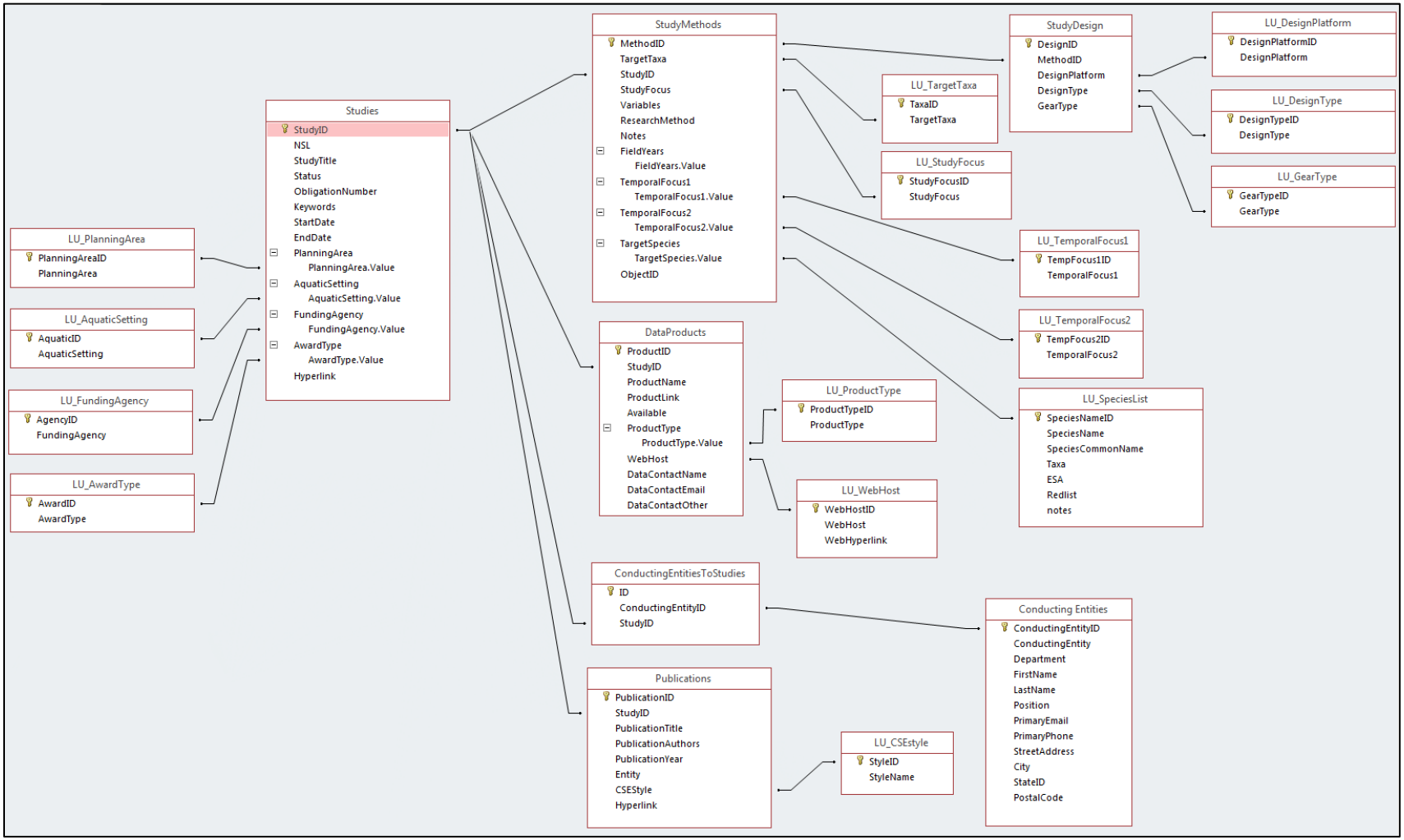


Figure 6. Logical data model of tables and their relationship in the GOMAPPS database.
The Study Footprints and Data Product Footprints are related to this data structure through the StudyID and ProductID, respectively. More information on the attributes in these layers is included in the Data Dictionary (Appendix A.4).

3 Results

3.1 Data Repository Review Results

To recap, the data repositories inventoried were determined to have the potential to contain information related to studies relevant to the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS). These repositories allowed the user to query based on text inputs and, in some cases, could also be queried using alternative methods. For example, the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) application allowed queries for a specific taxonomic group (e.g., species, genus, family, etc.), data type/platform (e.g., visual sightings from vessels/aircraft/land, telemetry tagged animals, mobile or stationary passive acoustic detections, and long-term shore-based surveys), biogeographic or jurisdictional regions, and temporal ranges (e.g., year, year and month, seasons). Of the repositories that could be queried temporally, time periods were pre-defined as either year of the publication/product, overall timeline of the study, or time of data collection. When spatial queries were available, they were often generalized and/or overestimated. The NOAA Environmental Response Management Application for the Gulf of Mexico (ERMA-GOM) and OBIS-SEAMAP were exceptions; both repositories offered the ability to query on higher resolution spatial data contributed directly from researchers.

After the identification of potentially relevant data sources from data repositories, these were further scrutinized to solidify their relevance to GoMMAPPS. Additional datasets were also contributed by taxa experts. The results of this exercise were that 51 studies and/or research projects related to the distribution and abundance of marine mammals, seabirds, and sea turtles in the GoM were entered into the database (Table 2). The ongoing GoMMAPPS effort was entered into the database as the 51st study.

Studies were defined as research conducted with a distinct objective, often involving a single organization or group. In a few instances, this process involved contacting principal investigators to ensure the data entered to the GoMMAPPS database were correct and complete. In most cases, the available data products associated with each study were identified in one of the inventoried data repositories. However, there were a few exceptions. In the GoMMAPPS database, five data products were identified through the NOAA National Centers for Environmental Information (NCEI), two were identified through the National Aeronautics and Space Administration (NASA) Global Change Master Directory (GMCD), 58 came from Seaturtle.org, and three came from the Smithsonian National Museum of Natural History. There were four additional data products which were discovered directly from their project websites or obtained through personal communication (J. Brenner and P.Tuttle, personal communication).

The information presented in the GoMMAPPS database and the associated Esri ArcGIS® geodatabase should be considered a starting point for referencing research in the Gulf of Mexico (Gulf) for marine mammals, seabirds, and sea turtles. A review of study metadata revealed that further relevant information is likely to exist within additional repositories that were not a part of this exercise or by interviewing principal investigators. Noted repositories that may helpful with data discovery and dissemination, should they be inventoried in the future, include:

1) The Bureau of Ocean Energy Management (BOEM) and NOAA MarineCadastre.gov (Taylor et al. 2012),
2) Max Planck Institute for Ornithology Movebank (Wilkelski and Kays 2017),
3) Global Change Master Directory (GCMD) (NASA 2016),
4) NCEI/ NOAA National Oceanographic Data Center (NODC) (NOAA 2017),

5) International Ocean Biogeographic Information System (OBIS) and affiliated OBIS-USA regional node (Grassle 2000, Halpin et al. 2006, Halpin et al. 2009), and
6) seaturtle.org/ Satellite Tracking and Analysis Tool (STAT) (Coyne and Godley 2005).

Most often, supplementary information could be found by searching within organizations known to have conducted specific research or participated in large studies. Organizational data repositories that were noted for containing significant details, but were not systematically inventoried as part of this exercise, included:

1) Duke University's OBIS-SEAMAP Model Repository (OBIS 2019), which currently hosts Duke University's marine life model outputs and metadata,
2) the National Marine Fisheries Service (NMFS) Authorizations and Permits for Protected Species Database (NOAA NMFS 2019), an online application system where applications to and/or permits from NOAA can be searched and reviewed,
3) the Southeast Fisheries Science Center (SEFSC) Cruise Reports (NOAA Southeast Fisheries Science Center 2017), a searchable collection of research vessel cruise reports, and
4) the US Geological Survey (USGS) ScienceBase-Catalog (USGS 2019), a searchable data catalog of communities, studies, datasets, and metadata for USGS researchers and collaborators.

The results of this data search revealed a noticeable gap in seabird data versus what was available for sea turtles or marine mammals. BirdLife International currently is the largest online collection of seabird tracking data (BirdLife International 2004, Lascelles et al. 2016), yet was extremely data-limited in the Gulf (for example, when queried by the Gulf region of interest on July 24, 2017, only five datasets with nine tracks for four species resulted). Some recently collected information for seabird surveys conducted for the *Deepwater Horizon* Natural Resource Damage Assessment (NRDA) were available in the NRDA Administrative Record (USDOI n.d.), a searchable document repository for the NRDA effort. Information on long-term seabird monitoring projects have also been collected in the Gulf of Mexico Avian Monitoring Network (GOMAMN), an approach to coordinating data updates and collections on birds for an interactive bird monitoring website (A. Baldera, personal communication, 2017). Also, some data on abundance and distribution of seabirds in the Gulf can be found on individual project websites, such as the USGS–South Carolina Cooperative Research Unit and Clemson University's Project Pelican (SCCFWRU 2019) and the Nature Conservancy's Gulf of Mexico Migratory Blueways (Nature Conservancy n.d., 2016).

Table 2. List of Relevant Data Sources Identified

The RID indicates the data repository where the information was obtained (see Table 1). For more details on studies, use the Study ID (SID) in conjunction with Table 3. The Study Title within the database may not include the associated references cited within () in the table below. These references were added here in Table 2 to provide additional context for readers of this report that may not be examining the database concurrently.

Study ID	Organization	Study Title	Repository ID
1	Louisiana State University; DOI	Interactions between migrating birds and offshore oil and gas structures off the Louisiana coast (ESPIS Interactions)	2
2	Florida Fish and Wildlife Conservation Commission; NOAA	Florida loggerhead migrations (Schroeder 2016)	4

Study ID	Organization	Study Title	Repository ID
3	NOAA; Texas A&M University; Oregon State University	Distribution and abundance of marine mammals in the North-Central and Western Gulf of Mexico (GulfCet I) (Davis et al. 1994a, 1994b, 1994c, Davis & Fargion 1996)	2
4	Cayman Islands Department of Environment; UK Overseas Territories Conservation Forum; University of Exeter in Cornwall	Cayman Islands 2005: green turtles (Blumenthal 2016)	4
5	Texas A&M University at Galveston (TAMUG) Sea Turtle and Fisheries Ecology Research Lab	TAMUG Sea Turtle and Fisheries Ecology Research Lab's sea turtle tracking (Seney 2013)	4
6	Florida Fish and Wildlife Conservation Commission & Mote Marine Laboratory	FWC-Mote Florida loggerheads (Tucker 2016)	4
7	Florida Fish and Wildlife Conservation Commission	FWRI EPDC nonneonate sea turtle observations (Hirama et al. 2014)	4
8	NOAA; Texas A&M University at Galveston	Coastal and Marine Ecosystem Program: distribution and abundance of marine mammals in the Gulf of Mexico (GulfCet II) (ESPIS Coastal, Davis et al. 1997, 2000a, 2000b)	2; 4
9	Institute for Marine Mammal Studies	Institute of Marine Mammal Studies Kemp's ridley sea turtle tracking (Coleman 2017)	4
10	Mote Marine Laboratory; Florida Fish and Wildlife Conservation Commission/NOAA; University of South Florida; Collecte Localisation Satellites (CLS)	Casey Key loggerheads (MML 2005–2006, 2007, 2008, 2009, 2010, 2011, 2012-2013)	4
11	NOAA	Sperm whales and bottlenose dolphins in the Gulf of Mexico (ESPIS Sperm whales)	2
12	USGS	Eastern brown pelicans: dispersal, seasonal movements, and monitoring of PAHs and other contaminants in the northern Gulf of Mexico (ESPIS Eastern)	2
13	USGS; USFWS	Compendium of marine bird data for offshore renewable energy decision making (Bigger 2015)	2
14	Florida Fish and Wildlife Conservation Commission	Movements and habitat associations of neonate sea turtles (Mansfield 2011)	

Study ID	Organization	Study Title	Repository ID
15	Texas A&M University; Scripps Institution of Oceanography; Oregon State University; University of Durham; University of St Andrews; Woods Hole Oceanographic Institution	Deepwater Program: cooperative research on sperm whales and their response to seismic exploration in the Gulf of Mexico – (Sperm Whale Seismic Study [SWSS]) (ESPIS Deepwater Program: Cooperative)	2
16	Texas A&M University; Oregon State University; Scripps Institution of Oceanography; University of Colorado; University of Durham; University of South Florida; University of St Andrews-Woods Hole Oceanographic Institution	Deepwater Program: sperm whale seismic study–part II (SWSS II) (ESPIS Deepwater Program: Sperm whale)	2
17	USGS	Discerning behavioral patterns of sea turtles in the Gulf of Mexico to inform management decisions (ESPIS Discerning, Mallindine 2017)	
18	LGL Limited–Environmental Research Associates/Colombia University	Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's seismic testing and calibration study in the Northern Gulf of Mexico, November 2007 – February 2008 (Holst and Smultea 2008, Holst et al. 2014)	4
19	National Park Service; NOAA; Texas A&M University at Galveston	TAMUG Tropic Ecology & Sea Turtle Research Lab's sea turtle tracking (Reich 2018)	4
20	Audubon Nature Institute Aquatic Center; Louisiana Department of Wildlife & Fisheries	Louisiana Marine Mammal & Sea Turtle Rescue Program-–Kemp's ridley tracking (Mullins 2017)	4
21	NOAA	Gulf of Mexico coastal biopsy surveys–NRDA (SEFSC 2016a)	3

Study ID	Organization	Study Title	Repository ID
22	Geological Survey of Alabama; Alabama Department of Conservation and Natural Resources; Florida Fish and Wildlife Conservation Commission; Florida Department of Environmental Protection; Louisiana Department of Natural Resources; Louisiana Coastal Protection and Restoration Authority; Louisiana Oil Spill Coordinator's Office; Louisiana Department of Environmental Quality; Louisiana Department of Wildlife and Fisheries; Mississippi Department of Environmental Quality; Texas Parks and Wildlife Department; Texas Commission on Environmental Quality; Texas General Lands Office; USDA/US Department of the Interior; US EPA	Deepwater Horizon MC 252 Incident-NRDA Working Group (USGS Natural)	1
23	USGS	Buck Island turtles (Hart 2017a)	4
24	The Ocean Conservancy	The Ocean Conservancy's Gulf of Mexico ecosystem and gaps analysis after the Deepwater Horizon spill (Love et al. 2015)	1
25	The Nature Conservancy	Migratory species corridors in the Gulf of Mexico (Brenner 2016a, 2016b; Nature Conservancy 2016)	
26	U.S. Navy	The United States Navy, Naval Surface Warfare Center - Panama City Division Marine Species Monitoring Plan (NSWC PCD 2013)	4
27	GeoCet Group, LLC.	Seismic survey mitigation measures and marine mammal observer reports (Barkaszi et al. 2012a, 2012b).	2
28	NOAA	Sperm whale acoustic prey study (SWAPS) (Garrison et al. 2018)	
29	HDR, Inc.	Passive Acoustic Monitoring (PAM) Program for the Northern Gulf of Mexico (BOEM ongoing)	
30	Mote Marine Laboratory/Turtle Hospital	Turtle Hospital and Mote Marine Laboratory Sea Turtle Conservation and Research Program turtle tracking (Moretti and Tucker 2016)	4

Study ID	Organization	Study Title	Repository ID
31	Florida Fish and Wildlife Conservation Commission; NOAA; University of Central Florida	Tracking the sea turtle “lost year””/juveniles in the Gulf of Mexico (SEFSC 2016b)	3
32	Cherokee Nations Technology Solutions; University of Florida; USGS	Home range and habitat use of juvenile green turtles (Chelonia mydas) in the northern Gulf of Mexico (Lamont et al. 2015)	
33	National Park Service; USGS	Satellite tracking Everglades loggerheads (Hart 2017c)	
34	Duke University	Habitat-based cetacean density models for the US Atlantic and Gulf of Mexico (Roberts 2016, Roberts et al. 2016)	
35	NOAA	Gulf of Mexico sperm whale surveys–Sperm Whale Pilot Study 2000 (SWY2K) (Roden 2000, Roden and Mullin 2000)	4
36	NOAA	Abundance of cetaceans in the oceanic Northern Gulf of Mexico from 2003 and 2005 ship surveys (Mullin 2007)	
37	USGS	Tracking sea turtles from the Dry Tortugas (Hart 2017b)	
38	USGS	Green sea turtles (Chelonia mydas) of Everglades National Park: habitat associations and genetic analysis (Hart and Fujisaki 2010)	
39	Cherokee Nations Technology Solutions; National Park Service; University of Florida/USGS	Movement mysteries unveiled: spatial ecology of juvenile green sea turtles (Shaver et al. 2013)	
40	Indiana University–Purdue University Fort Wayne	Characterization of the juvenile green turtle (Chelonia mydas) microbiome throughout an ontogenetic shift from pelagic to neritic habitats (Price 2016, Price et al. 2017)	
41	Duke University Marine Laboratory; North Carolina Wildlife Resources Commission	North Carolina long-term sea turtle monitoring project (Coyne 2016)	
42	Gladys Porter Zoo; National Park Service	Padre Island National Seashore Kemp's Ridley Tracking Program (Shaver et al. 2017)	
43	National Park Service; USFWS; USGS	Satellite tracking adult male Kemp's Ridley sea turtles (Shaver et al. 2005)	
44	National Park Service	Padre Island National Seashore National Park Service- Rancho Nuevo, Mexico Kemp's Ridley Tracking (NPS 2010-2011)	
45	National Park Service	Padre Island National Seashore National Park Service- Veracruz, Mexico Kemp's Ridley Tracking (NPS 2012-2013, 2014, 2015, 2016)	

Study ID	Organization	Study Title	Repository ID
46	NOAA; University of Miami	Seasonal migrations of immature Kemp's ridley turtles along the West Coast of Florida (Schmid and Witzell 2006)	
47	Chicago Zoological Society; Mote Marine Laboratory	Sarasota Dolphin Research Program (Wells 2010)	
48	Geo-Marine, Inc.	US Navy OPAREA density estimate (NODE) for the GOMEX OPAREA (DoN 2007)	
49	NOAA; USFWS	Atlantic Marine Assessment Program for Protected Species (AMAPPS and AMAPPS II) (NMFS 2016)	4
50	NOAA	SEFSC GoMex Surveys (not including those listed under GulfCet I and II) (Garrison 2013a–2013j)	4
51	NOAA; USFWS; USGS	Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) (Gleason and Wilson 2017)	

3.2 Summary of Studies and Data Gaps

The study design types identified for this GoMMAPPS initiative (acoustic monitoring, genetics, line transects, point counts, strip transects, and telemetry and/or tracking) have been conducted on all taxa, with one exception: no studies were identified involving birds and acoustic monitoring. Acoustic monitoring, for the purpose of this exercise, describes passive and active acoustic monitoring carried out with the aid of in-water acoustic tracking arrays, acoustic transmitters and receivers, and hydrophones. Acoustic monitoring is typically used to track animals in-water. It is common in scientific literature for these methods to be used for investigations about marine mammals. Bird studies that involved the recording and/or interpretation of bird calls may be listed as line transects, point counts, or strip transects. It was common for sea turtle studies to use satellite tracking to investigate distribution and behavior. Seabird and sea turtle sightings were sometimes collected opportunistically during marine mammal surveys, but it is important to note that these types of data are of poor use for density and habitat modeling. The study design type with the least amount of information came from strip transects.

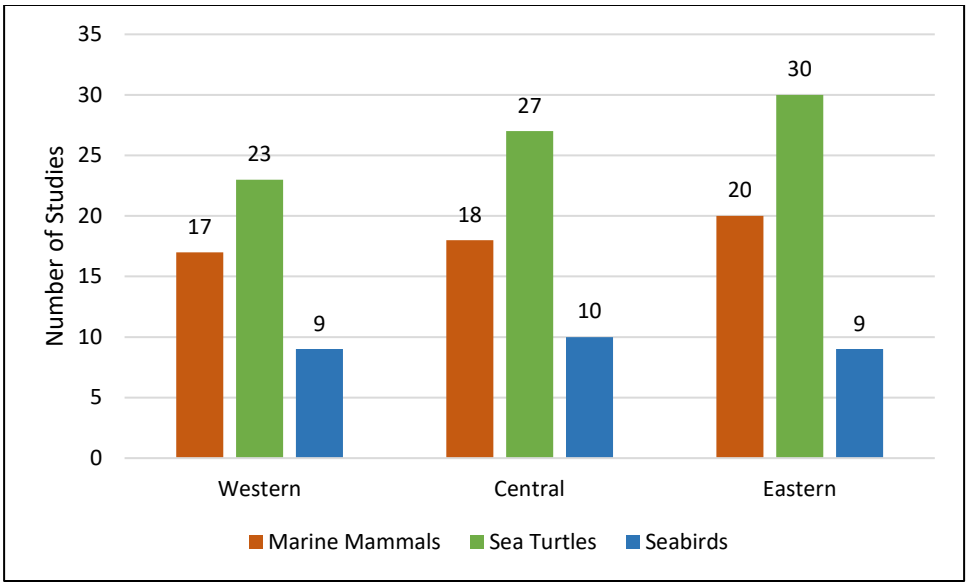
The results of this exercise indicate that data gaps exist spatially and temporally within the Gulf for all taxa investigated. These gaps varied between taxa (Figure 7). Eight studies were found to collect data on all taxa, within all planning areas, and over all seasons (Table 3). Twenty-four collected either marine mammal, seabird, and/or sea turtle data within all three regions of the Gulf. More than half of the studies (n = 41) collected either marine mammal, seabird, and/or sea turtle data within all four seasons.

Of the 51 studies, data on turtles were collected most often, followed by marine mammals, and then seabirds. Eight studies collected data for all three taxa. Seabird data were the most limited not just in the number of studies but also by the percentage of species on which data were gathered. Eleven studies were found to collect data on seabirds, nine of which specifically targeted seabirds as opposed to collecting data opportunistically. Data for all sea turtle species found in the Gulf were represented, which was not the case for marine mammals or seabirds.

Many studies overlapped more than one BOEM planning area in the Gulf. However, in review of the studies identified in this exercise, some trends in spatial data coverage were observed. Overall, more studies collected data within the central region and eastern planning areas compared to the western region (Figure 7a). When this trend is examined by taxa, sea turtles and marine mammals also followed this trend. Data on seabirds, however, was most abundant in the central region, followed by the western and then eastern regions.

Finally, temporal trends in data collection were also examined. When studies were summarized by the season of data collection (winter: December–February, spring: March–May, summer: June–August, and fall: September–November), it became apparent that most data collection occurred in the summer (n = 48) followed by the fall (n = 46), winter (n = 44), and spring (n = 43) (Figure 7b). This trend was similar among marine mammal studies. Sea turtle studies were most commonly carried out during the summer and fall followed by spring, and lastly winter. Seabirds showed a trend for the most studies carried out in summer followed by fall and spring with an equal number, and winter with the fewest. Of all taxa, sea turtles were found to have the best temporal coverage.

a)



b)

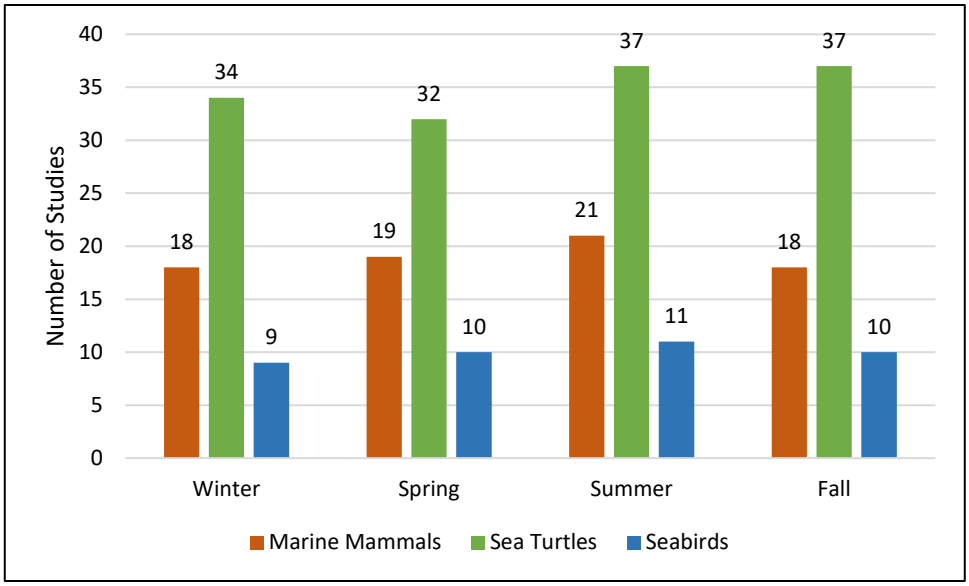


Figure 7. Summary of the number of marine mammal, sea turtle, and seabird studies that collected data.

Chart a) in the western, central, and eastern BOEM Gulf of Mexico planning areas, and Chart b) during the winter, spring, summer, and fall. Data from studies could be represented across multiple categories. For a visual representation of the BOEM Gulf planning areas, see Figure 1. *Figure 7a does not include a count of studies which overlap the South Atlantic, Mid-Atlantic, and/or North Atlantic BOEM planning areas. A thorough examination of studies in the Atlantic which overlap BOEM planning areas was not performed as part of this exercise.

Table 3. Summary of Relevant Studies along with Associated Taxa, Gulf of Mexico Region, and Season

1=data collected within the project extent, blank=no data available in the project extent. See Table 2 for more information on studies by Study ID (SID).

Study ID (SID)	Taxa Studied			Gulf of Mexico Region			Season Studied			
	Marine Mammal	Sea Turtle	Seabird	Western	Central	Eastern	Winter	Spring	Summer	Fall
1			1	1	1		1	1	1	1
2		1		1	1	1	1	1	1	1
3	1	1	1	1	1		1	1	1	1
4		1				1	1	1	1	1
5		1		1	1		1	1	1	1
6		1				1	1	1	1	1
7		1			1	1			1	
8	1	1	1	1	1	1	1	1	1	1
9		1		1	1	1	1	1	1	1
10		1		1	1	1	1	1	1	1
11	1			1	1	1	1	1	1	1
12			1	1	1	1	1	1	1	1
13			1	1	1	1	1	1	1	1
14		1				1			1	1
15	1			1	1	1		1	1	
16	1			1	1	1	1	1	1	1
17		1		1	1	1	1	1	1	1
18	1	1		1			1		1	1
19		1		1	1	1	1	1	1	1
20		1			1		1			1
21	1			1	1	1				
22	1	1	1	1	1	1	1	1	1	1
23		1			1	1	1	1	1	1

Study ID (SID)	Taxa Studied			Gulf of Mexico Region			Season Studied			
	Marine Mammal	Sea Turtle	Seabird	Western	Central	Eastern	Winter	Spring	Summer	Fall
24	1	1	1	1	1	1	1	1	1	1
25	1	1		1	1	1	1	1	1	1
26	1	1			1	1	1	1	1	1
27	1	1		1	1	1	1	1	1	1
28	1			1	1	1	1	1	1	
29	1			1	1	1	1	1	1	1
30		1				1	1	1	1	1
31		1		1	1	1	1	1	1	1
32		1				1	1			1
33		1		1	1		1	1	1	1
34	1					1	1	1	1	1
35	1	1	1		1	1			1	
36	1			1	1	1	1	1	1	1
37		1				1	1	1	1	1
38		1				1	1	1	1	1
39		1		1			1	1	1	1
40		1			1	1			1	1
41		1				1	1	1	1	1
42		1		1	1	1	1	1	1	1
43		1		1	1		1	1	1	1
44		1		1	1		1	1	1	1
45		1		1	1		1	1	1	1
46		1				1	1	1	1	1
47	1					1	1	1	1	1
48	1	1		1	1	1	1	1	1	1

Study ID (SID)	Taxa Studied			Gulf of Mexico Region			Season Studied			
	Marine Mammal	Sea Turtle	Seabird	Western	Central	Eastern	Winter	Spring	Summer	Fall
49	1	1	1			1	1	1	1	1
50	1	1	1	1	1	1		1	1	1
51	1	1	1	1	1	1	1	1	1	1
Studies (n)	22	39	11	33	37	41	44	43	48	43
Studies (%)	43.14	76.47	21.57	64.71	72.55	80.39	86.27	84.31	94.12	90.20

4 Discussion

4.1 Data Repositories

The results of this inventory should be considered as a first review of relevant studies for marine mammals, sea turtles, and seabirds that have been conducted within the US Gulf of Mexico (Gulf) Outer Continental Shelf (OCS), based on querying select data repositories. The degree to which study data were distributed ranged from a small number of scientists to publicly shared and easily discovered through multiple outlets (e.g., print media, online resources, open-access references, popular data repositories, etc.). Furthermore, usefulness ranged from a vague description of research to highly detailed metadata included with data available for download in multiple formats (e.g., tables, GIS files, notes).

For studies that were identified as relevant to the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS), a moderate amount of effort was required by individual researchers, institutions, partners, and/or other stakeholders in the preparation and uploading of study data to the repositories examined (see Table 1). It is likely that this methodology missed some relevant studies and associated data. More recent studies tended to make a greater effort to organize data in online repositories than earlier ones. However, regardless of the year data were gathered for a study, pressures exist to disseminate data through online repositories as well as against data dissemination through online repositories. For example, Kim and Stanton (2012) found that the effort researchers perceived for the entry of data into repositories hindered data sharing among scientists but they were motived to share due to pressure from publishing in journals, other collaborators, and by the potential for gaining individual career benefits. Interestingly, the relationship between the availability of data repositories and level of data sharing was not found to be straightforward, but depended on a number of factors, such as the researchers' perceived career benefit, perceived effort necessary to enter data to repositories, scholarly altruism, as well as institutional pressures, such as regulative pressure from journals and normative pressure within a given discipline (Kim 2013). While some institutions currently work on revised plans and requirements to encourage scientists to share data (P. Jodice and D. Byrne, personal communication, 2017), the availability of information in widely shared data repositories should continue to improve in the future. It should be noted that along with the vast amounts of data collected and entered into online repositories comes a responsibility to maintain data quality, which will enable addressing broader questions through big data studies (Hampton et al. 2013), in future applications.

It is understandable that when large-scale scientific research studies involved multiple partners, project components and objectives, methods, and analyses products, a coordinated effort to organize, present, and archive all results and outcomes can be a challenge. When relevant studies were reviewed in terms of availability and accessibility of products within these data repositories, many relatively smaller-scaled studies were able to give more information within specialized data repositories (e.g., satellite tracked sea turtles in peer-reviewed literature, maps, datasets on the seaturtle.org and/or satellite tracking and analysis tool [STAT]) while larger-scaled studies (e.g., the A BOEM Atlantic Marine Assessment Program for Protected Species [AMAPPS]) disseminated information across various data repositories (e.g., seaturtle.org/STAT, Ocean Biogeographic Information System-Spatial Ecological Analysis of Megavertebrate Populations [OBIS-SEAMAP]), depending on the suitability of the data repository to receive data products and objectives of each study component (e.g., telemetry data, reports, tables). Many of the identified studies relevant to GoMMAPPS involved several different institutions; this can result in data being housed in multiple places, either as duplicate copies or as unique components. A fundamental way to communicate the results of a study and help prevent loss of valuable information in the future is to document and archive all study data in a single location that is logical and accessible. If multiple repositories are used, data organization and discovery would be more efficient and easier among all

databases if reference information is included that links data repositories and clearly defines the study (e.g., using a standard title and description). When data are shared in an accessible repository, standardizing the practice to include specific links and/or unique dataset identification codes, along with the name of an associated data repository within any data products (e.g., publications, metadata) should be emphasized. Methods to access the data (e.g., permissions) and allowable uses (e.g., analyses) should also be made transparent to guide users to properly handle information (e.g., attribution).

4.2 Field Data Collection Recommendations

This review of data repositories for information relevant to the GoMMAPPS effort indicated that data have been unevenly collected across methodologies, taxa, BOEM planning areas, and seasons. For example, there seems to be a dearth of information on seabirds in comparison to the other two taxa evaluated. Studies on marine mammals and seabirds tended to lean toward the line transect study design and sea turtle data were gathered using primarily satellite tagging.

The authors recommend that field data collection methodologies as part of the GoMMAPPS initiative support the estimation of distribution, abundance, and/or behavior for the target taxa. Within these broad categories, behavioral studies on marine mammals and sea turtles, and studies in any category for seabirds, would be the most beneficial for filling data gaps. However, when determining the best way to collect information for target species, available resources for sampling efforts, species' life histories, and the limitations of current technology must also be considered. For example, it is generally more difficult and expensive to sample further offshore, especially for large, highly mobile animals such as marine mammals, seabirds, and sea turtles (Kot et al. 2010). Though there can be trade-offs between sampling methodologies that seek to examine any animal of concern, studies that use satellite tags or collect genetic samples are generally more expensive and invasive than observational surveys. For example, a few studies show that, relative to seabirds and sea turtles, marine mammals typically return less data from shorter durations and individuals were more negatively impacted physically by the current technology used to tag them (Reeves 1998, Robbins et al. 2013). Although it was outside of the scope of this project to prioritize an exhaustive list of sampling methods, this exercise is recommended for the future benefit of the GoMMAPPS research objectives.

When prioritizing by region, directing future research towards the western BOEM Gulf planning area is recommended for filling existing spatial data gaps. For sea turtles and seabirds, most spatial gaps appear to exist in areas far offshore. However, due to the low number of seabird studies overall, any future abundance, distribution, and/or behavior studies would be useful for filling in these spatial data gaps. A more thorough investigation of data coverage with the support of taxa experts and higher resolution spatial data would further guide important areas to study within these regions.

In terms of seasonality, the fewest number of studies evaluated in this exercise collected data in the spring months, closely followed by the winter months. Other analyses have also concluded an uneven distribution of seasonal data collection as well. In particular, Roberts (2016) found an uneven seasonal coverage in the Gulf for cetacean surveys; Kot et al. (2010) found the greatest number of surveys conducted for marine mammals, seabirds, or sea turtles in the summer and fall months within the OBIS-SEAMAP repository. The OBIS-SEAMAP database has been acknowledged to have global gaps in data coverage, but available marine megafauna data from dedicated surveys, telemetry, and opportunistic records within the US Atlantic and Gulf were very well represented (Kot et al. 2010). Therefore, directing efforts to study the distribution, abundance, and behavior of these taxa towards the winter and spring would aid in evaluating seasonal movements and/or migrations, if present, and contribute to the development of spatially- and temporally-explicit species density and habitat models.

4.3 Data Dissemination Recommendations

Appropriate data repositories should be identified as applicable, flexible, and should enlist best practices for archiving information for long-term data management and stewardship (Byrne 2014). For US federally-funded research, data repositories are identified in advance and specific departments or agencies separate from the data producer are tasked with data stewardship (D. Byrne, personal communication, 2017). Some active data repositories, such as the NOAA National Centers for Environmental Information (NCEI) or OBIS-SEAMAP, can assist principal investigators with developing workflows for efficient project data transfer and archiving (D. Byrne and E. Fujioka, personal communication, 2017). Close communication among data providers and data stewards would improve the approach to both meeting researcher needs and fulfilling repository missions.

Many data repositories focus on representing a comprehensive collection of data for a specific research focus. Currently, numerous efforts are being made within and across institutions and agencies to standardize project data management protocols so that different types of data can be archived efficiently and accurately. Further efforts to standardize repositories would benefit subsequent uses of the information.

Because the distribution, abundance, and behavior of marine mammals, seabirds, and sea turtles are often studied using a variety of methodologies, the flexibility of data housing within the database is extremely useful. Housing diverse data sets in one location saves researchers time and effort when searching for information based on a geographic, temporal, and/or taxa of interest (Fujioka et al. 2014). A data repository's ability to centralize archived data gathered by different platforms, often resulting in data organized in multiple formats, was identified as an asset for reviewing past research. All repositories searched and mentioned in this document had the potential to offer at least text, references, and URLs to information about aerial and ship-board surveys, satellite tracked animals, passive acoustic data from towed arrays, genetic analysis, and density and habitat models. When choosing a suitable data repository for the diverse products that are anticipated for the GoMMAPPS, the capacity to support multiple formats should be considered.

For the repositories extensively searched as part of this exercise, only the NOAA Environmental Response Management Application for the Gulf of Mexico (ERMA-GOM), OBIS-SEAMAP, and the USFWS Service Catalog (ServCat) were shown to offer downloads that included GIS data available to the public. Several repositories which were mentioned in this text but were not thoroughly searched (e.g., the NCEI, Movebank, and MarineCadastre.gov) offered associated GIS shapefiles or tabular data useful for this gap analysis. When high resolution data were available for a study, not all repositories had the objective nor mechanism to store these large data files. The goals of data repositories were also typically difficult to find without directly contacting the lead organization, so it was unclear whether all repositories had the capabilities or future plans to offer GIS or other raw data products. It is also possible that many data repositories have the potential for archiving more detailed, high resolution data but contributors were not fully using these capabilities. Data repositories that currently provide the capability for public downloads of multiple data formats, including GIS, should be considered when choosing a suitable data repository for GoMMAPPS data.

Other important points to consider are the level of detail offered within publicly available data in repositories (e.g., existing exemptions or embargoes for public dissemination, proprietary information, etc.) and the data repository's storage capability (e.g., database transfer and/or archival size limits, inflexible data models and/or schemas resulting in data loss, etc.). Data coverage and gaps were assessed using the information that was either currently available to the public or had been given directly by principal investigators when requested. The specific reasons that other data products developed by past research studies were inaccessible or unavailable to the public were beyond the scope of this exercise. A convenient technique for extracting information across methods for the gap analysis was by using

metadata files (e.g., detailed reports) linked to GIS shapefiles. These metadata files contained information such as the spatial location, date, and taxa (identified to the lowest level possible) studied. A centralized location for these details can support more advanced queries if tools are available for users. Though all GIS data from the OBIS-SEAMAP repository contained details on the location, taxa, and date, only some datasets on the ERMA-GOM contained those details. For the ERMA-GOM and BOEM Environmental Studies Program Information System (ESPIS) data repositories, GIS data could represent general footprints of studies delineated by those outside of the original researchers, based the description of the study coverage and not necessarily the specific locations of data collection (S. Eastman, M. Love, and A. Ramirez, personal communication, 2017). For OBIS-SEAMAP, GIS shapefiles were either directly contributed by the researchers or created with data provided directly from the researchers (e.g., CSV files), both of which were created with or approved by the original providers.

Collaborative efforts for big-data projects often build on historic collections and can create the impetus to clean, standardize, and organize data to increase quality and cultivate better data management and sharing standards. Several reviews and studies involving marine mammal, seabird, and sea turtles in the Gulf region have already compiled data from various sources, sometimes including expert opinion and previously unpublished data, resulting in comprehensive overviews of data gaps and coverage (see DoN 2007; Best et al. 2012; Waring et al. 2013; Waring et al. 2015; Brenner et al. 2016b, Roberts et al. 2016; Waring et al. 2016; M. Lettrich, personal communication, 2017). Including information about these data compilation projects in repositories aids dissemination and reduces duplication of future historic data reviews and data collection efforts in the field. Furthermore, the opportunity to leverage the lessons-learned from these large-scaled efforts to collate past research on the distribution, abundance, and behavior of these taxa should be used to continue improvements to data management, quality, and long-term preservation.

Other data repositories hosting large collections but not inventoried comprehensively as part of this exercise may warrant more investigation in the future. One example of this type of repository is the *Deepwater Horizon* Natural Resource Damage Assessment (NRDA) Deepwater Horizon) Data Integration, Visualization, Exploration, and Reporting (DIVER) data repository, which collates biological and environmental data developed for assessing damage from the 2010 *Deepwater Horizon* oil spill in the Gulf (DIVER 2017). The DIVER data repository is an archive of all proposed, active, and funded studies related to the Deepwater Horizon Trustees' NRDA efforts. Another example is the seaturtle.org/STAT feature tracking site for sea turtles tagged and tracked within the Gulf. This website was highly effective in collating active data collection efforts, but updates relied on researchers uploading data and any use of the information presented was restricted without permission from the principal investigators. The international OBIS, OBIS-USA, and National Aeronautics and Space Administration (NASA) Global Change Master Directory (GCMD) repositories contained more advanced tools for queries on projects, including related web links to download data, metadata, and comprehensive data contact information for more details (Grassle 2000, Halpin et al. 2006, Halpin et al. 2009, NASA 2016). The National Oceanic and Atmospheric Administration (NOAA) and BOEM MarineCadastre.gov contained materials for on-going and completed projects, including related web links to download data, map services, story maps, and web-based and printed outreach materials such as one-pagers and fact sheets (Taylor et al. 2012).

GoMMAPPS is modeled after the successful AMAPPS, which was initiated in 2010 as a collaboration among the BOEM, NOAA, USFWS, and US Navy (USFWS et al. 2010). Like the GoMMAPPS, the AMAPPS focused on collecting seasonal data on the abundance, distribution, and behavior of marine mammals, sea turtles, and seabirds throughout the US Atlantic exclusive economic zone (EEZ), providing spatially-explicit information to inform governmental decision makers with mandated responsibilities to protect living marine resources (USFWS et al. 2010, NMFS 2016). Using current habitat utilization models, the results from the AMAPPS will contribute to seasonal density maps of various species to inform stock assessments and other related tools for decision makers concerned with possible adverse impacts from offshore energy development, military readiness exercises, and other activities. The second phase (AMAPPS-II) continued this effort to collect data, update maps and density models, and explore other tools and technologies for estimating abundance and distribution in the US Atlantic EEZ (Green 2016, NMFS 2016). Currently, information and data from AMAPPS have been discovered through multiple data repositories, such as ESPIS, MarineCadastre.gov, OBIS-SEAMAP, and seaturtle.org/STAT. Given that the GoMMAPPS initiative is complementary, leveraging efforts and lessons-learned from the AMAPPS would be beneficial as data management and archive plans progress.

5 Conclusion

Collecting data on the distribution, abundance, and behavior of marine mammals, seabirds, and sea turtles in the Gulf of Mexico (Gulf) is the objective of the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) project. As part of this effort, information relating to survey methodology and design, geographic scope, taxa, and season of data collection were compiled from historic studies discovered through existing data repositories, recently published large reviews, and taxa experts. Over 50 studies using multiple methods to gather relevant marine mammal, seabird, and sea turtle data were summarized. In general, dedicated surveys were most often used to collect data on marine mammals and seabirds while tracking data from satellite telemetry tags was the leading method used for sea turtles in the Gulf. Because a considerable amount of information is needed to determine the distribution, abundance, and behavior of these taxa, it is especially important to strategically build upon historic knowledge and ongoing collaborative efforts. Results from this data inventory can facilitate future in-depth analyses on how, when, and where to prioritize research to fill gaps and therefore to better inform management and conservation decisions.

Strategic plans to fill research gaps may also reveal long-term trends in species abundance and distributions as they relate to various anthropogenic and natural stressors. In support of the GoMMAPPS planning phase, and to best fill in geographic, temporal, and taxonomic gaps for seabirds, sea turtles, and marine mammals, this analysis revealed the following priorities for data collection:

a. seabird abundance, distribution, and behavior in the Gulf,
b. marine mammal behavior in the Gulf,
c. sea turtle abundance in the Gulf,
d. seabird, sea turtle, and marine mammal data in the western Gulf region, and
e. seabird, sea turtle, and marine mammal data in the Gulf during the spring, fall, and winter months.

Multiple data sources and repositories that held information on relevant research studies were found online or were referenced within the published literature, but the quality and amount of details provided within the metadata along with the levels of accessibility to the research data varied greatly. The quality and amount of detail can be dependent on numerous factors, such as the main objectives of the data repository (e.g., catalog created for data discovery compared to raw data archiving), organizational data hosting (e.g., data are only included when collected by a specific organization), the contributors and/or collaborators' goals for data hosting (e.g., mandatory, voluntary, or for a greater purpose), and the amount of communication principal investigators have with the repository data stewards. Levels of accessibility through data sources and repositories may also be dependent on numerous factors, such as existing exemptions or embargoes for public dissemination, proprietary information, database transfer and/or archival size limits, and the limited resources for data owners to respond to requests. The repositories inventoried here had the capability of archiving various types of data, enabling data discovery and advanced queries, offering publicly accessible data for download and metadata contacts for more details. The GoMMAPPS goal for long-term data products storage and preservation could be met by using the existing services that data repositories offer, which may be maximized when data producers can work closely with the repository data steward to support the archival and discovery of data at the highest resolution possible.

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Appendixes

A.1 Species List

List of key marine mammals, seabirds and sea turtle species in the Gulf of Mexico included in this study (n = 88 species), with listed statuses under the US ESA and IUCN Redlist (IUCN 2018).

ESA categories: E = endangered, T = threatened, blank = not listed; Redlist categories: CR = critically endangered, EN = endangered, VU = vulnerable, NT = near threatened, LC = least concern, DD = data deficient.

	Common name	Scientific name	ESA	Redlist
Marine mammal (n = 29)				
	Minke whale	*Balaenoptera acutorostrata*		LC
	Sei whale	*Balaenoptera borealis*	E	EN
	Bryde's whale	*Balaenoptera edeni*		DD
	Blue whale	*Balaenoptera musculus*	E	EN
	Fin whale	*Balaenoptera physalus*	E	EN
	Common dolphin	*Delphinus delphis*		LC
	Northern right whale	*Eubalaena glacialis*	E	EN
	Pygmy killer whale	*Feresa attenuata*		DD
	Short-finned pilot whale	*Globicephala macrorhynchus*		DD
	Risso's dolphin	*Grampus griseus*		LC
	Pygmy sperm whale	*Kogia breviceps*		DD
	Dwarf sperm whale	*Kogia simus*		DD
	Fraser's dolphin	*Lagenodelphis hosei*		LC
	Humpback whale	*Megaptera novaeangliae*		LC
	Sowerby's beaked whale	*Mesoplodon bidens*		DD
	Blainville's beaked whale	*Mesoplodon densirostris*		DD
	Gervais' beaked whale	*Mesoplodon europaeus*		DD
	Killer whale	*Orcinus orca*		DD
	Melon-headed whale	*Peponocephala electra*		LC
	Sperm whale	*Physeter macrocephalus*	E	VU
	False killer whale	*Pseudorca crassidens*	E	DD
	Pantropical spotted dolphin	*Stenella attenuata*		LC
	Clymene dolphin	*Stenella clymene*		DD
	Striped dolphin	*Stenella coeruleoalba*		LC
	Atlantic spotted dolphin	*Stenella frontalis*		DD
	Spinner dolphin (long-snouted)	*Stenella longirostris*		DD

	Common name	Scientific name	ESA	Redlist
	Rough-toothed dolphin	*Steno bredanensis*		LC
	Bottlenose dolphin	*Tursiops truncatus*		LC
	Cuvier's beaked whale	*Ziphius cavirostris*		LC
Seabird (n = 54)				
	Little auk	*Alle alle*		LC
	Brown noddy	*Anous stolidus*		LC
	Greater shearwater	*Ardenna gravis*		LC
	Sooty shearwater	*Ardenna grisea*		NT
	Long-billed murrelet	*Brachyramphus perdix*		NT
	Cory's shearwater	*Calonectris borealis*		LC
	Scopoli's shearwater	*Calonectris diomedea*		LC
	Black tern	*Chlidonias niger*		LC
	Bonaparte's gull	*Chroicocephalus philadelphia*		LC
	Magnificent frigatebird	*Fregata magnificens*		LC
	Common gull-billed tern	*Gelochelidon nilotica*		LC
	Leach's storm-petrel	*Hydrobates leucorhous*		VU
	Caspian tern	*Hydroprogne caspia*		LC
	Herring gull	*Larus argentatus*		LC
	Laughing gull	*Larus atricilla*		LC
	Ring-billed gull	*Larus delawarensis*		LC
	Kelp gull	*Larus dominicanus*		LC
	Bonaparte's gull	*Larus Philadelphia*		LC
	Franklin's gull	*Larus pipixcan*		LC
	Northern gannet	*Morus bassanus*		LC
	Wilson's storm-petrel	*Oceanites oceanicus*		LC
	Band-rumped storm-petrel	*Oceanodroma castro*	E	LC
	Bridled tern	*Onychoprion anaethetus*		LC
	Sooty tern	*Onychoprion fuscatus*		LC
	American white pelican	*Pelecanus erythrorhynchos*		LC
	Brown pelican	*Pelecanus occidentalis*		LC
	Red-billed tropicbird	*Phaethon aethereus*		LC
	White-tailed tropicbird	*Phaethon lepturus*		LC
	Red phalarope	*Phalaropus fulicarius*		LC
	Red-necked phalarope	*Phalaropus lobatus*		LC
	White-chinned petrel	*Procellaria aequinoctialis*		VU
	Cape Verde petrel/Fea's petrel	*Pterodroma feae*		NT
	Black-capped petrel	*Pterodroma hasitata*		EN

	Common name	Scientific name	ESA	Redlist
	Stejneger's petrel	*Pterodroma longirostris*		VU
	Audubon's shearwater	*Puffinus lherminieri*		LC
	Manx shearwater	*Puffinus puffinus*		LC
	Black-legged kittiwake	*Rissa tridactyla*		VU
	Black skimmer	*Rynchops niger*		LC
	Long-tailed jaeger	*Stercorarius longicaudus*		LC
	South polar skua	*Stercorarius maccormicki*		LC
	Arctic jaeger/Parasitic jaeger	*Stercorarius parasiticus*		LC
	Pomarine jaeger	*Stercorarius pomarinus*		LC
	Roseate tern	*Sterna dougallii*	T[1]	LC
	Forster's tern	*Sterna forsteri*		LC
	Common tern	*Sterna hirundo*		LC
	Arctic tern	*Sterna paradisaea*		LC
	Least tern	*Sternula antillarum*	E[2]	LC
	Masked booby	*Sula dactylatra*		LC
	Brown booby	*Sula leucogaster*		LC
	Red-footed booby	*Sula sula*		LC
	Atlantic yellow-nosed albatross	*Thalassarche chlororhynchos*	EN	
	Royal tern	*Thalasseus maximus*		LC
	Sandwich tern	*Thalasseus sandvicensis*		LC
	Sabine's gull	*Xema sabini*		LC
Sea turtle (n = 5)				
	Loggerhead	*Caretta caretta*	T[3]	VU
	Green	*Chelonia mydas*	T[4]	EN
	Leatherback	*Dermochelys coriacea*	E	VU
	Hawksbill	*Eretmochelys imbricata*	E	CR
	Kemp's ridley	*Lepidochelys kempii*	E	CR

[1]*Sterna dougallii dougallii* is listed as "Threatened" in the Western hemisphere and adjacent oceans, including US (Florida, Puerto Rico, and Virgin Islands), where not listed as endangered under the ESA.

[2]*Sterna antillarum* is listed as "Endangered" in the US regions of AR, CO, IA, IL, IN, KS, KY, LA (Mississippi River and tributaries North of Baton Rouge), MS (Mississippi River), MO, MT, ND, NE, NM, OK, SD, TN, and TX (except within 50 miles of coast).

[3]Northwest Atlantic Distinct Population Segment is listed as "Threatened" under the ESA.

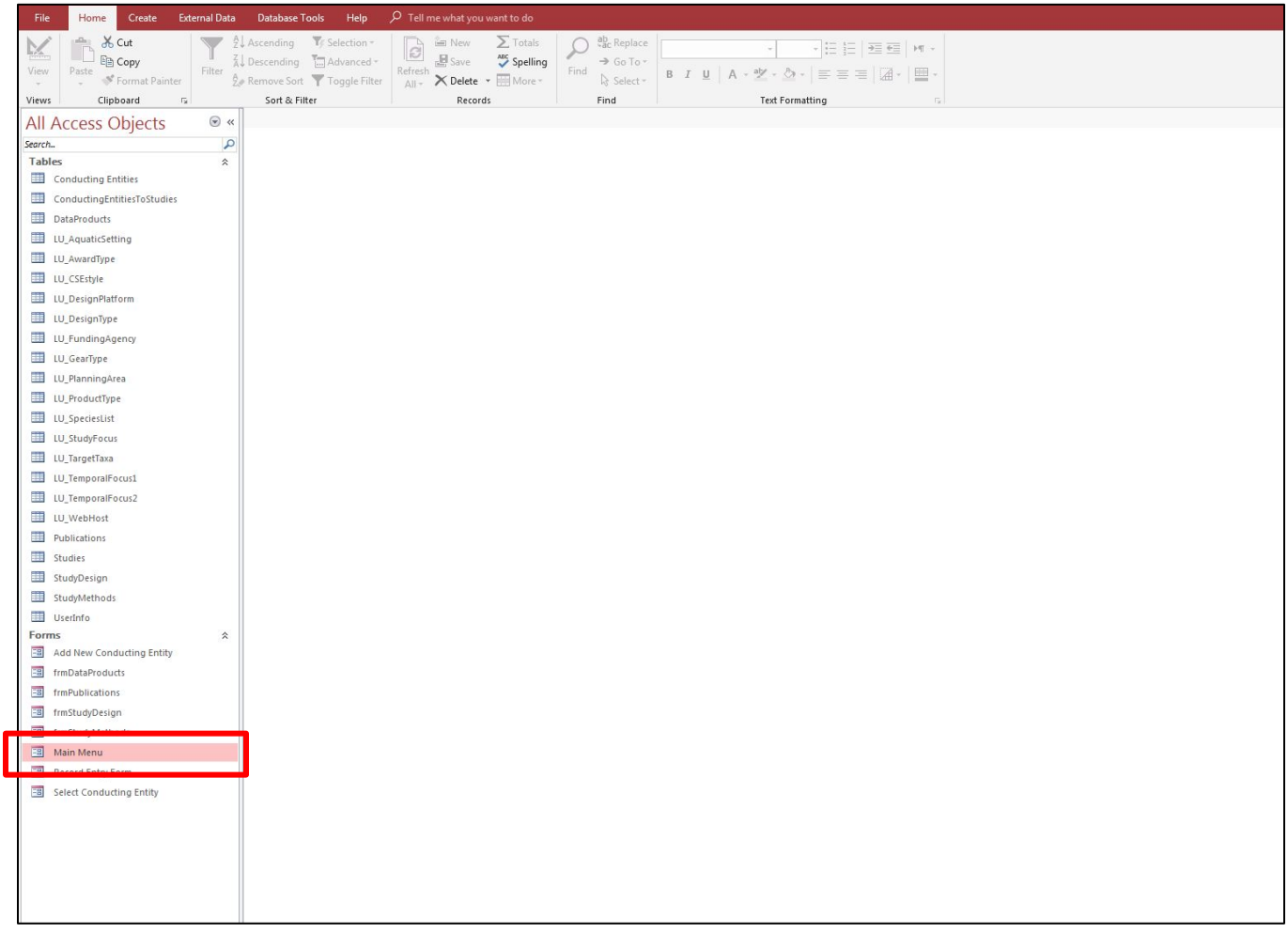
[4]North Atlantic Distinct Population Segment is listed as "Threatened" under the ESA.

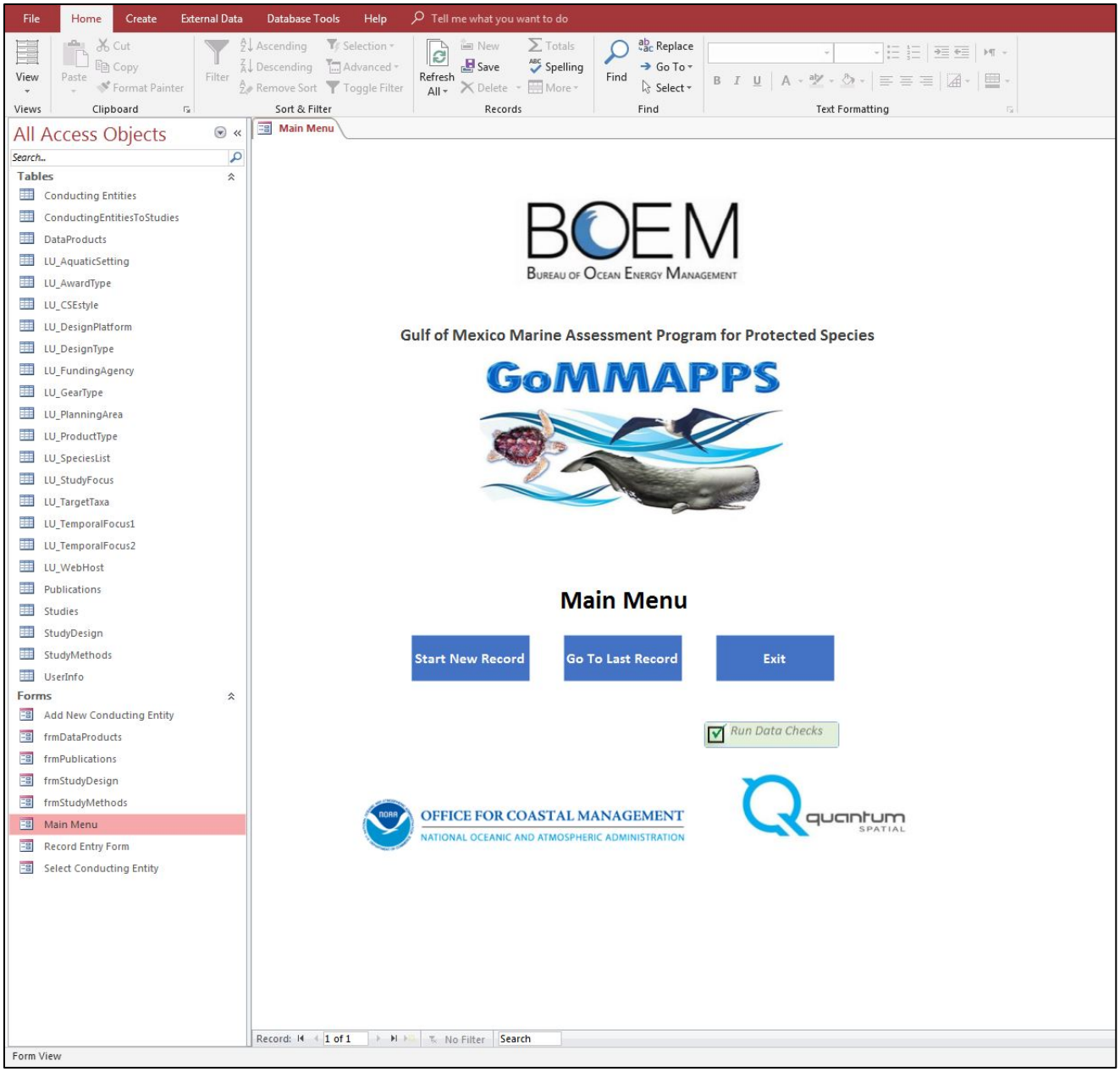
A.2. Database Entry Form

One of QSI's goals for the GoMMAPPS effort was to create a data inventory to inform the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) survey design. To accommplish this, six data repositories were reviewed. The results of this review are summarized in a Microsoft® Access® database and associated geodatabase (.gdb).

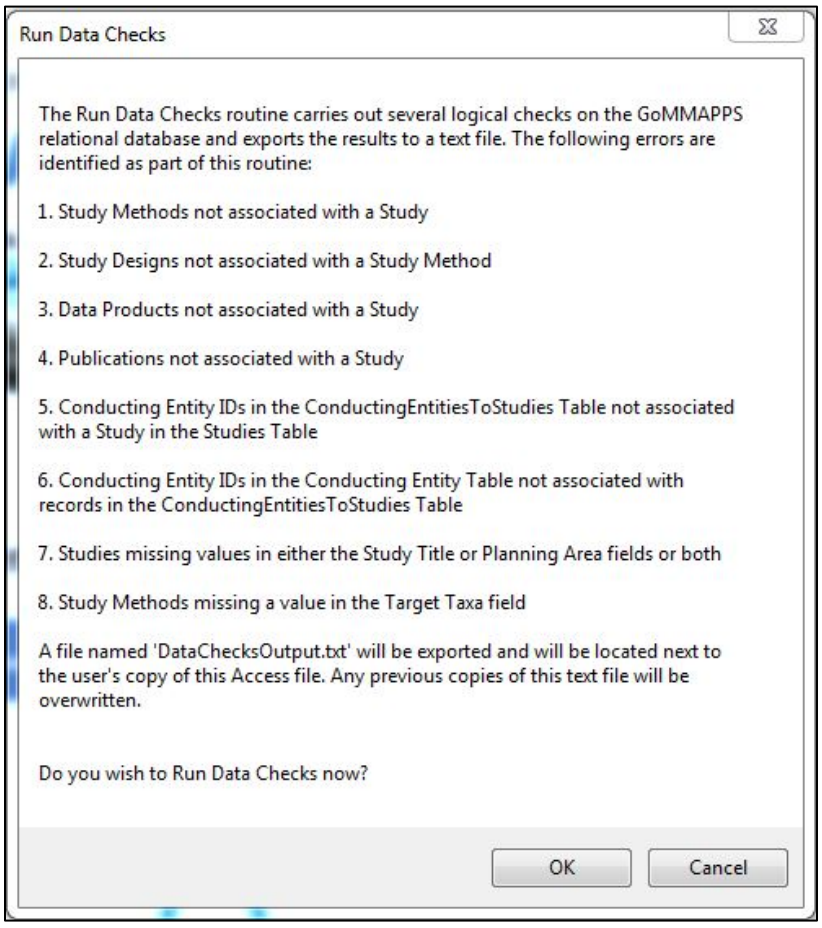
In addition to the database and associated geodatabase, QSI created a series of data entry forms within Microsoft® Access®. These data forms ease the viewing of study data, prevent some data entry errors, provide some checks on the integerity of data within the relational database, and provide a robust method of data entry for users with a variety of experience levels.

Data entry to the database starts with the user opening the Microsoft® Access® file and opening the Main Menu form:

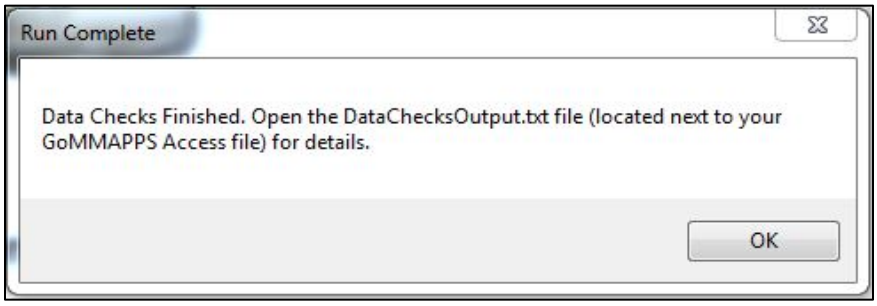



File
Home
Create
External Data
Database Tools
Help
Tell me what you want to do
View
Paste
Cut
Copy
Format Painter
Filter
Ascending
Descending
Remove Sort
Selection
Advanced
Toggle Filter
Refresh All
New
Save
Delete
Totals
Spelling
More
Find
Replace
Go To
Select
Views
Clipboard
Sort & Filter
Records
Find
Text Formatting
All Access Objects
Search...
Tables
Conducting Entities
ConductingEntitiesToStudies
DataProducts
LU_AquaticSetting
LU_AwardType
LU_CSEstyle
LU_DesignPlatform
LU_DesignType
LU_FundingAgency
LU_GearType
LU_PlanningArea
LU_ProductType
LU_SpeciesList
LU_StudyFocus
LU_TargetTaxa
LU_TemporalFocus1
LU_TemporalFocus2
LU_WebHost
Publications
Studies
StudyDesign
StudyMethods
UserInfo
Forms
Add New Conducting Entity
frmDataProducts
frmPublications
frmStudyDesign
frmStudyMethods
Main Menu
Record Entry Form
Select Conducting Entity
Main Menu
BOEM
Bureau of Ocean Energy Management
Gulf of Mexico Marine Assessment Program for Protected Species
GoMMAPPS
Main Menu
Start New Record
Go To Last Record
Exit
Run Data Checks
OFFICE FOR COASTAL MANAGEMENT
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
quantum
SPATIAL
Record:
1 of 1
No Filter
Search
Form View

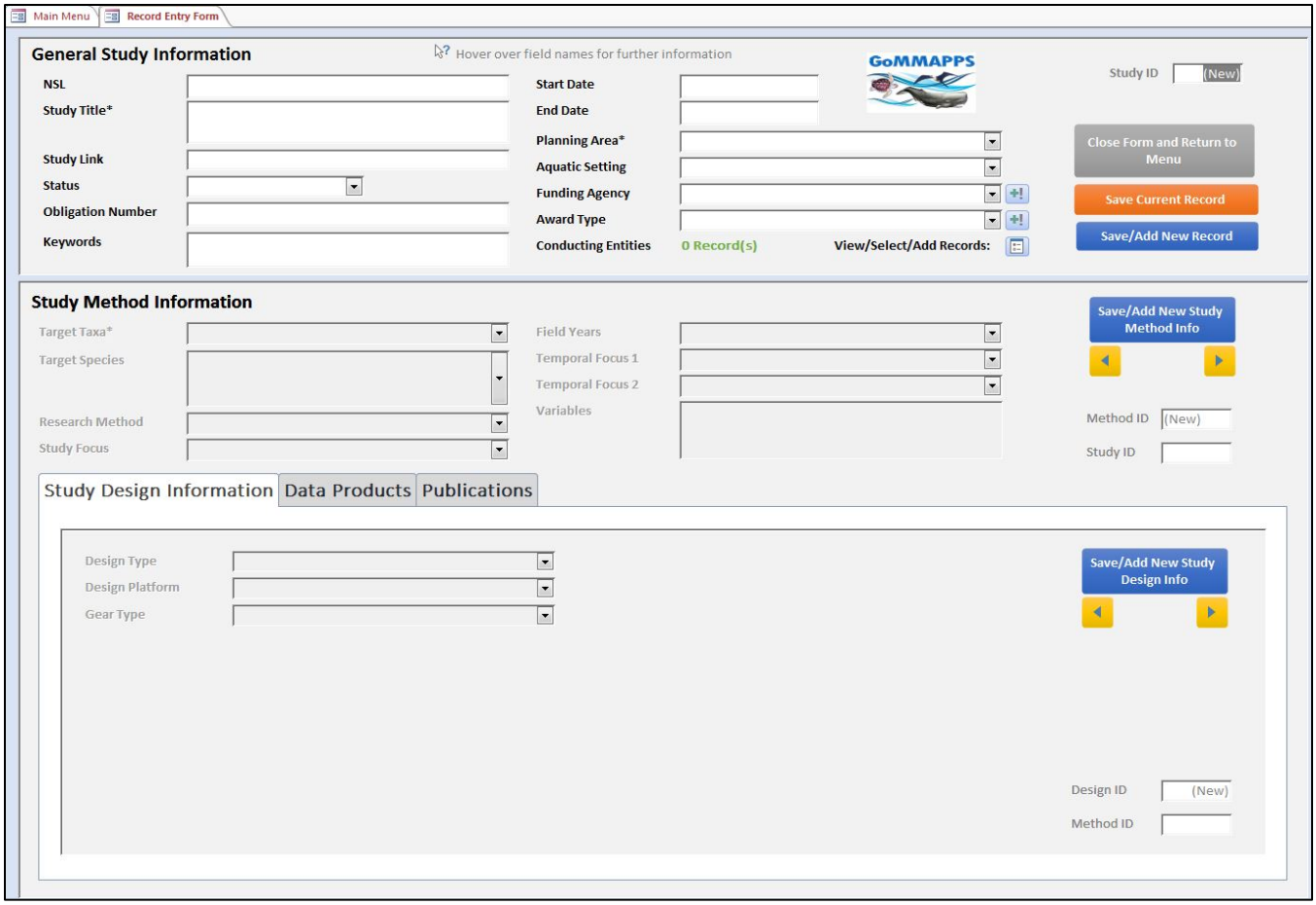
On the Main Menu form, the user is presented with 3 blue buttons and one green Run Data Checks button. The Exit button exits the form. The Run Data Checks button runs a series of logical checks on the relational database and exports the results to a text file which is exported next to the location of the database file. This process is not an exhaustive list of all possible logical checks.



If the user clicks OK, the following message box alerts the user once the process has been completed:

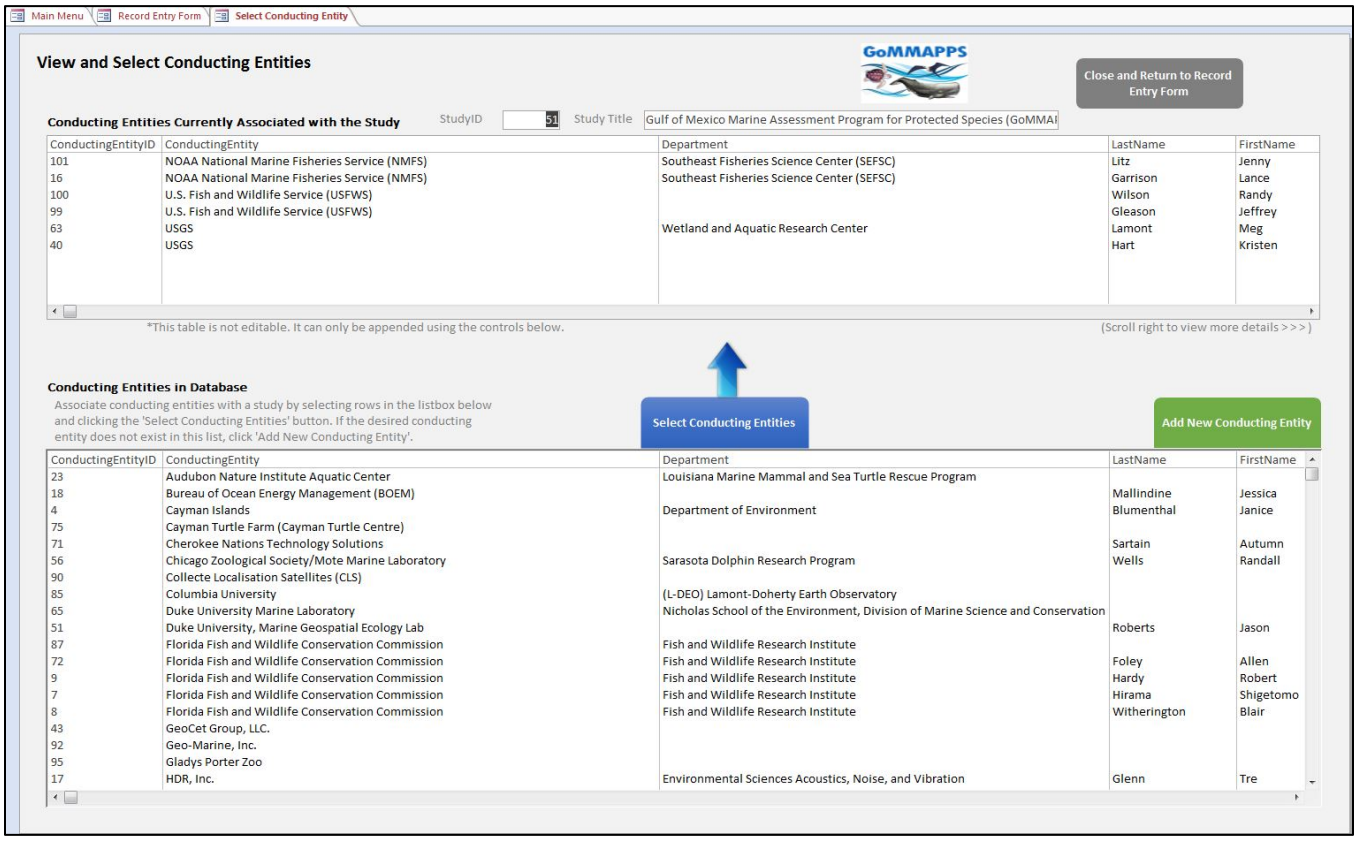


The Start New Record and Go To Last Record buttons on the Main Menu form link to the primary form used for data entry- the Record Entry Form. The Start New Record button will navigate to a new blank record and should appear similar to the image below:



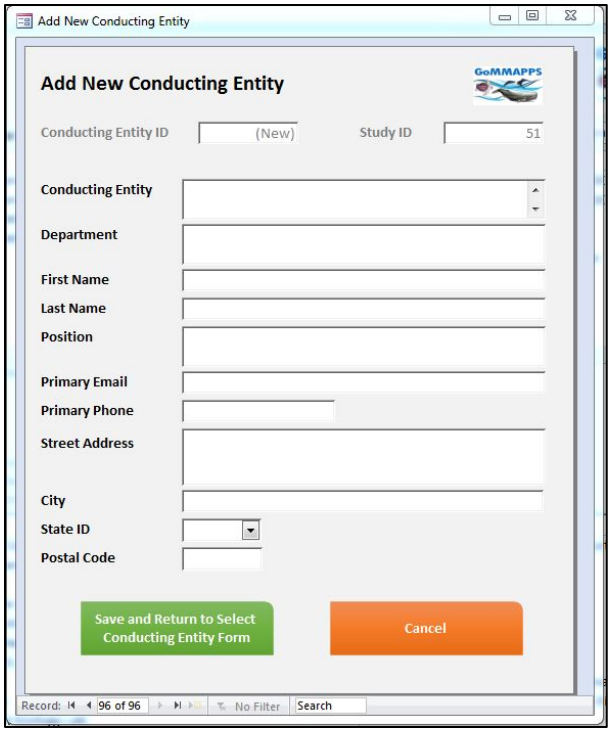
The Record Entry Form is linked to the following tables in the database: Studies, StudyMethods, StudyDesign, DataProducts, Publications, and ConductingEntities (along with various lookup tables that start with LU_...). Values on this form populate the appropriate fields in one or more of these tables. For further information on the fields in this form, see the Data Dictionary (Appendix A.4).

A separate form called Select Conducting Entity will open from the Record Entry Form when the user clicks the button next to **View/Select/Add Records** to the right of **Conducting Entities**.



This form is used to associate conducting entities with studies. The top section shows the conducting entities currently associated with the study. The bottom section shows all conducing entities currently in the database. Conducting entities can be associated with the study by clicking the conducing entity in the bottom section and then clicking the blue Select Conducting Entities button. Conducing Entities cannot be disassociated with a study using these forms, to prevent unintentional deletion of data by inexperienced users.

If a conducing entity for a study does not exist in the database, the user can add it by clicking the green Add New Conducting Entity button. The following mini-form pops up for data entry:



Once data are entered and the user clicks the green Save and Return to Select Conducing Entity Form button, the new conducting entity will be both added to the list of conducing entities in the database and associated with the current study.

A.3 Geofootprint Creation Standard Operating Procedure

The following Standard Operating Procedure (SOP) was used by the technical project team for the identification and creation of study footprints. All study footprint features are held within the DataProductFootprints and StudyFootprints feature classes. **The spatial reference system used for this exercise is GSC_North_American_1983, WKID: 4269 Authority: EPSG.**

Five different methods were used to create footprints, listed below. The amount of detail and data within a study or study's data product determined which method was used.

Methodology:

Two types of footprints were created as part of this exercise: study footprints and data product footprints. Study footprints are a geographic representation of the overall extent of a study, i.e. where the data was or is planned to be collected. In contrast, data product footprints are a geographic representation that show regions or sub regions within which a data product was created, i.e. some assessment was made about distribution and abundance for a particular taxon within the study extent. Studies which included only telemetry data were not considered to have a study footprint or any data product footprints.

Footprint Creation:

This section briefly describes the 5 methods used to define footprint creation. The time associated with identifying and locating footprint data sources must be considered with respect to the amount of time it takes to generate the data from scratch, as well as the desired final data accuracy. Further process details for each of these methods are included in the 'Description of Workflow' section immediately following this section.

1. GIS-Ready Boundary (preferred methodology)

This method uses an existing digital project boundary created as part of the original study. These data were provided directly by the principle investigators or downloaded from a publicly available data repository.

2. Geographic Coordinate Location

This method uses any form of geographic location characteristics referred to in the study report (e.g., latitude/longitude coordinates) to create a project boundary. This includes digitizing around listed sample locations.

3. Georectification

This method includes the georectification of a published map within the study report. The map must have enough detail to capture a minimum of four locations to be used for georectification.

4. Feature Interpolation

If the study report does not delineate a study area, then feature interpolation can be used to create the footprint. This method uses identifiable physical features (e.g., river bank, coastline, transportation networks, etc.) to approximate the project boundary based on descriptions included in the study. When a study area includes detailed features (e.g., coastlines), it may be too time inefficient to digitize according to this method.

5. Study Interpretation (not preferred)

If available maps and descriptions do not clearly indicate a study area and feature interpolation is not time efficient, study interpretation is the last resort for footprint creation. A government agency's planning area footprint may be available which corresponds to written descriptions and maps within the study. Otherwise, a generic shapefile can be made to represent the study area. This method will result in the least accurate boundary definition and is the least desirable.

Description of Workflow:

Review the study to determine which footprint methodology will be used in the production process.

1. GIS-Ready Boundary (preferred methodology)
    a. Search online data repositories and/or contact the data owner and download the digital data.
    b. Modify feature as necessary to fit the end data schema and end use. Some examples include converting a .kml or shapefile to a feature class, deleting extraneous attributes from an attribute table, creating multi-part features, or simplifying a boundary to speed up loading times. These examples are not a complete list of possible modifications.
2. Geographic Coordinate Location
    a. Plot point coordinates as a set of geographic points.
    b. Convert to polygon.
3. Georectification
    a. Digitally capture the map in jpeg or other similar format.
    b. Use a minimum of 4 locations to georectify map.
    c. Trace study area boundary as polygon.
4. Feature Interpolation
    a. Identify the map or written description that will be used to create the footprint as well as known physical features that can be used to define boundaries.
    b. Acquire an authoritative GIS source that depicts these physical features (eg. federal or state GIS basemap resources).
    c. Create polygon.
5. Study Interpretation (not preferred)
    a. Identify the information that will be used for the interpretation.
    b. Find an authoritative government (eg. federal, state, or local) planning area or other delineation that corresponds to the description.

Once the spatial information for the footprint is finished, attributes should be populated as described in the Data Dictionary (Appendix A.4).

A.4. Data Dictionary

This Data Dictionary describes each field on the GoMMAPPS database Record Entry Form, Add New Conducting Entity Form, and within the feature classes associated with the study footprints geodatabase. Field Names followed by * are required in the database. For further information on table relationships within this database, see the Logical Model Diagram (Figure 6).

Table 4. General Study Information Section

Field Name	Field Type	Description	Look-up Table	Values	Multiple Selections	Add Value
Study ID	Autonumber	Unique ID for the study (primary key)	-	1-n	N	-
NSL	Short Text	National Science Library Number	-	-	-	-
Study Title*	Long Text	Name of the study identified in the technical summary, final report, publication, thesis, etc	-	-	-	-
Study Link	Short Text	Hyperlink to information on the study online	-	-	-	-
Status	Short Text	The status of the study	LU_Status	Proposed, Active, Complete	N	-
Obligation Number	Short Text	Number associated with award type	-	-	-	-
Keywords	Long Text	Keywords associated with the study (separated by ",")	-	-	-	-
Start Date	Date	Date the study began	-	-	N	-
End Date	Date	Date the study ended	-	-	N	-
Planning Area*	Number (Displayed as Short Text)	BOEM planning areas in which the study was conducted	LU_PlanningArea	Eastern Gulf of Mexico, Central Gulf of Mexico, Western Gulf of Mexico, Atlantic OCS Regions	Y	-
Aquatic Setting	Number (Displayed as Short Text)	Description of the marine environment in which the study focuses, follows CMECS definitions (see section 2.4 for further written desc, ription)	LU_AquaticSetting	Coastal, Nearshore, Offshore, Oceanic	Y	N
Funding Agency	Number (Displayed as Short Text)	The agency that funded the study	LU_FundingAgency	(many)	Y	Y
Award Type	Number (Displayed as Short Text)	The type of award granted to conduct the study	LU_AwardType	Competitive Award, Cooperative Agreement, Interagency Agreement, Conducted In-House, Sole Source Award, USGS (USGS OCS Funds), Settlement	Y	Y

Field Name	Field Type	Description	Look-up Table	Values	Multiple Selections	Add Value
Conducting Entities	Database generated number	Display of the number of conducting entities associated with the study. Must click 'View/Select/Add Records" to add new conducting entity details or associate a current conducting entity with the study.	ConductingEntities ToStudies-Conducting Entities	1-n	Y	Y

Table 5. Study Method Information Section

Field Name	Field Type	Description	Look-up Table	Values	Multiple Selections	Add Value
Study ID	Autonumber	Unique ID for the study (foreign key)	-	1-n	N	-
Method ID	Autonumber	Unique ID for the study method (primary key)	-	1-n	N	-
Target Taxa	Number (Displayed as Short Text)	The taxa being studied	LU_TargetTaxa	Turtle, Bird, Mammal, Fish, Other	N	N
Target Species	Number (Displayed as Short Text)	Applicable species to the target taxa field	LU_SpeciesList	(many)	Y	N
Research Method	Short Text	Whether the study was 'Quantitative' or 'Qualitative'	-	Qualitative, Quantitative	N	N
Study Focus	Number (Displayed as Short Text)	Brief description of the question anticipated to be answered by the study	LU_StudyFocus	Distribution, Abundance, Behavior, Opportunistic	N	N
Field Years	Short Text	Year or range of years during which field work was conducted	-	1990 – 2030	Y	N
Temporal Focus 1	Number	The general temporal focus of the study	LU_TemporalFocus1	Daily, Weekly, Monthly, Seasonally, Annually, Irregular	Y	N
Temporal Focus 2	Number	The specific months during which the study was conducted	LU_TemporalFocus2	January, February, March, April, May, June, July, August, September, October, November, December	Y	N
Variables	Long Text	Covariates used in analyzing study focus	-	-	N	-

Table 6. Study Design Information Section

Field Name	Field Type	Description	Look-up Table	Values	Multiple Selections	Add Value
Method ID	Autonumber	Unique ID for the study method (foreign key)	-	1-n	N	-
Design ID	Autonumber	Unique ID for the study design (primary key)	-	1-n	N	-
Design Type	Number (Displayed as Short Text)	General description of how the study was/will be carried out to answer the study focus	LU_DesignType	Tracking, Line Transect, Strip Transect, Point Count, Acoustic, Genetics	N	N
Design Platform	Number (Displayed as Short Text)	The location from which the fieldwork component of the study was performed	LU_DesignPlatform	Aerial, Ship, Shore, Station, Tags	N	N
Gear Type	Number (Displayed as Short Text)	Main field gear used for data collection	LU_GearType	Trawler, Nets, Spear, Camera, Video, Acoustic Array, Acoustic Tow, PIT tags, Radio tags, Satellite tags, Optics (Binoculars/Scope), (TDR) Time-depth recording GPS tags, (D-Tags) Short-duration/Suction-cup/Digital tags, Dart Gun, Radar	N	N

Table 7. Data Products Section

Field Name	Field Type	Description	Look-up Table	Values	Multiple Selections	Add Value
Study ID	Autonumber	Unique ID for the study (foreign key)	-	1-n	N	-
Product ID	Autonumber	Unique ID for the data product (primary key)	-	1-n	N	-
Product Name	Short Text	The title of the data product	-	-	-	-
Product Type	Number (Displayed as Short Text)	Brief description of the data product type	LU_ProductType	Model, Imagery, Video, Archived Specimen Sample, Database	N	Y
Available	Yes/No (Boolean)	Boolean value indicating if the product is readily available for acquisition	-	Yes/No	N	-
Product Link	Short Text	A hyperlink to the final data product delivered as part of a completed study by the Principal Investigator (if available)	-	-	N	-
Web Host	Number	Name of the organization or entity hosting the virtual data product	LU_WebHost	(many)	N	Y
Data Contact Name	Short Text	Name of the individual who may be contacted for inquiries related to the data product	-	-	-	-
Data Contact Email	Short Text	Email of the individual who may be contacted for inquiries related to the data product	-	-	-	-
Data Contact Other	Short Text	Other information, such as a street address or phone number, which may be used to locate the individual who may be contacted for inquiries related to the data product	-	-	-	-

Table 8. Publications Section

Field Name	Field Type	Description	Look-up Table	Values	Multiple Selections	Add Value
Study ID	Autonumber	Unique ID for the study (foreign key)	-	1-n	N	-
Publication ID	Autonumber	Unique ID for the publication (primary key)	-	1-n	N	-
Publication Title	Long Text	Title of the publication	-	-	-	-
Publication Author(s)	Short Text	Authors of the publication	-	-	-	-
Entity	Short Text	Entity or entities that created the publication (eg. academic institutions, government agencies, or non-profit research institutions)	-	-	-	-
Publication Year	Number	Year of publication	-	1994-2018	N	-
Hyperlink	Short Text	Hyperlink to a copy of the publication	-	-	-	-
CSE Style	Number	Council of Science Editors documentation style	LU_CSEstyle	(many)	N	N

Table 9. Select Conducting Entity Form

Field Name	Field Type	Description	Look-up Table	Values	Multiple Selections	Add Value
Study ID	Autonumber	Unique ID for the study (foreign key)	-	1-n	N	-
Study Title	Long Text	Name of the study identified in the technical summary, final report, publication, thesis, etc	-	-	-	-
Conducting Entity ID	Autonumber	Unique ID for the conducting entity (primary key)	-	-	-	-
Conducting Entity	Short Text	Name of the conducting entity	-	-	-	-
Department	Short Text	Academic or government agency where the conducting entity sits	-	-	-	-
Last Name	Short Text	Last name of the individual who conducted the study	-	-	-	-
First Name	Short Text	First name of the individual who conducted the study	-	-	-	-
Position	Short Text	Professional position held by the individual who conducted the study	-	-	-	-
Primary Email	Short Text	Email of the individual or entity that conducted the study	-	-	-	-
Primary Phone	Short Text	Phone number for the individual or entity that conducted the study	-	-	-	-
Street Address	Short Text	Address for the conducting entity	-	-	-	-
City	Short Text	City where the conducting entity resides	-	-	-	-
State ID	Short Text	Two letter state code for the conducting entity	-	-	-	-
Postal Code	Number	Zip code for the conducting entity	-	-	-	-

Table 10. Field Descriptions for Associated Footprint Feature Classes

Field Name	Field Type	Description	Values
OBJECTID	Object ID	Unique ID automatically generated by ArcGIS	1-n
Shape	Geometry	Shape type automatically generated by ArcGIS	Polygon
DateCreated	Date	Date the polygon was created	-
StudyID	Long Integer	Study ID which corresponds to the shape (foreign key)	1-n
ProductFootprintID	Long Integer	Unique ID for each polygon (primary key)	1-n
Shape_Length	Double	Field automatically generated by ArcGIS	-
Shape_Area	Double	Field automatically generated by ArcGIS	-
ProductID	Short Integer	Product ID which corresponds to the shape (foreign key)	-
GenMethod	Short Integer	Method used to generate the shape (see section 7.3)	1, 2, 3, 4, 5
PlanningArea	Text	BOEM planning area which overlaps the data product or study footprint	Eastern Gulf of Mexico, Central Gulf of Mexico, Western Gulf of Mexico, Atlantic OCS Regions

A.5. Works Consulted

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