NOAA SEFSC Cetacean and Sea Turtle Spatial Density Models for the Gulf of Mexico Additional Information and Data Dictionary

Dataset title: Cetacean and sea turtle spatial density model outputs from visual observations using line-transect survey methods aboard NOAA vessel and aircraft platforms in the Gulf of Mexico.

Responsible Persons: Litz, Jenny; Aichinger Dias, Laura; Rappucci, Gina; Martinez, Anthony; Soldevilla, Melissa; Garrison, Lance; Mullin, Keith.

Related Funding Agencies: U.S. Department of Interior (DOI), Bureau of Ocean Energy Management (BOEM), the U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC), NOAA Office of Response and Restoration (ORR), United States Navy and the NOAA RESTORE Science Program.

Related Projects and/or Programs: Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS), University of Miami’s Cooperative Institute for Marine and Atmospheric Studies (CIMAS).

Dates: Start: 2003-06-12

End: 2019-07-31

Platforms: NOAA Ship *Gordon Gunter* or NOAA Ship *Pisces* and NOAA DeHavilland DHC-6 Twin Otter.

Sea Areas or Regions: United States of America, Gulf of Mexico.

Data Types:

**Parameter or Variable**: CETACEANS, SEA TURTLES, VISUAL OBSERVATIONS, DISTANCE SAMPLING, LINE-TRANSECT SURVEY.

**Observation Category**: In Situ/Laboratory Instruments, SPECIES DISTRIBUTION MODELS, POPULATION ABUNDANCE.

**Sampling Instrument**: AIRCRAFT, LINE-TRANSECT SURVEY, DISTANCE SAMPLING, INCLINOMETERS, BIG EYE BINOCULARS, SHIPS.

**Sampling and Analyzing Method**: The goal of this research was to develop Gulf-wide cetacean and sea turtle spatial density models (SDMs) based on line-transect surveys conducted in the U.S. waters of the Gulf of Mexico.

Surveys used to develop the SDMs for species occupying continental shelf and oceanic waters of the Gulf of Mexico were conducted during the GoMMAPPS project and comparable-prior-year surveys. Aerial survey data from seasonal surveys conducted during 2011/2012 and 2017/2018 (GoMMAPPS Surveys) were used to develop SDMs for cetacean and sea turtle species over the continental shelf. Data collected from vessel surveys, including the two-team surveys conducted during summer 2017, winter 2018, and summer/fall 2018 (GoMMAPPS Surveys) and 2003, 2004, and 2009 (that included only one survey team), were used to develop SDMs for cetaceans in oceanic waters. In addition, for Rice’s whales, surveys conducted in 2018 and 2019 were also used in developing the SDMs specific for this species.

Habitat-based species distribution models were developed using a generalized additive modeling (GAM) framework to determine the relationship between cetacean and sea turtle abundance and environmental variables. Samples for modeling were created by summarizing survey effort and environmental variables with a hexagon grid developed by the Environmental Protection Agency expanded to fit the entire Gulf of Mexico. The grid was created in a Lambert azimuthal equal area projection and the area of each hexagon is 40 km2. For all hexagons that contained survey effort segments, cetacean and sea turtle density was calculated using total number of animals observed, segment effort length and average sighting condition covariates in the hexagon, and the parameters estimated in distance sampling abundance models.

Oceanographic variables were used as dynamic covariates in SDMs and were obtained from multiple sources that included both remotely sensed data and hydrographic model output. Data products were obtained from their respective sources at varying temporal and spatial resolutions. To develop the explanatory variables for the SDMs, we summarized each data source spatially by overlaying the hexagon grid and calculating the average variable for each cell at the highest temporal resolution available. These data were then matched to the survey effort data so that each trackline segment in each grid cell. The survey effort segments were the sampling unit in the spatial density models (SDMs). For prediction maps, we developed monthly averages of the gridded data for all survey years from 2003-2018.

Species were visually identified to the lowest taxonomic level possible. For sea turtles, oceanic dolphins and small whale species, sightings that could not be identified to the species level were apportioned among the identified species based upon spatial density models (SDMs) for these taxa groups (Hardshell sea turtle, Unidentified Stenellid Dolphins, Unidentified Dolphins, and Unidentified Small Whales). In addition, for beaked whales species, genera *Ziphius* and *Mesoplodon*, very few sightings could be identified to species, and therefore all species were combined into a common "beaked whale" category for this analysis. Likewise, killer whales, false killer whales, pygmy killer whales, and melon-headed whales were combined into a “Blackfish” category, given the relatively infrequent encounters with these species and difficulty to identify them to species level. The final resulting SDMs therefore account for both identified and unidentified sightings.

Prediction maps were developed for each species or species group based upon the monthly averaged oceanographic conditions during 2015 - 2019. The appropriate SDM was used to predict animal density in each 40 km2 spatial cell for either shelf or oceanic waters for each month. The coefficient of variation (CV) of the density estimate (based upon uncertainty in the GAM model fit) is used to display the level of precision of the model and identify regions of high density and high uncertainty where model extrapolation is less reliable. Abundance estimates for each month are the sum of predicted abundance in each spatial cell. These estimates vary in response to dynamic oceanographic variables.

**Data Quality Method**: SDMs include a combination of two modeling approaches to address potential sources of bias and develop species-habitat relationships that are used to develop spatially and temporally explicit predictions of animal density. For aerial surveys, two survey teams were used in all surveys, and a combined MRDS model was developed to estimate detection probability in the survey strip. In the case of vessel surveys, a detection probability function was estimated using data from the flying bridge survey team for all surveys (2003-2018) using multiple covariate distance (MCDS) function models. While the probability of detection on the trackline was developed using MRDS methods from the 2017-2018 surveys.

For each species or species group, the best multiple covariate distance sampling (MCDS) model was selected by first examining the distribution of perpendicular sighting distances (PSD) and selecting an appropriate right truncation distance and key function. Then, all combinations of detection covariates were considered, and the model with the lowest AIC was selected. For the MCDS model, the relationship between group size and detection distance was examined, and the log of group size was included as a covariate where there was a statistically significant correlation. Following selection of the MCDS portion of the model, detection probability covariates were considered for inclusion in the MRDS model along with distance from the trackline and observer platform (flying bridge or bridge wings).

Following the selection of the best MRDS model, the second component of the SDM was implemented to develop species-habitat relationships. The sampling units for the SDM model were the segments of “on-effort” trackline within each grid cell for each survey. For each segment, the searched area was calculated as the product of the segment length, the surveyed strip width (based on the truncation distance from the MRDS model) and the estimated detection probability within the segment predicted from the MRDS model and the appropriate detection probability covariates on the survey strip. This searched area was included as an offset term in the SDM. The response variable was the total number of a particular species (or species group) observed on a given segment. A GAM was used to quantify the effect of habitat variables on animal density using a log count model assuming a Tweedie error distribution to account for overdispersed (i.e., zero-inflated) count data. An initial GAM model was fit using all available oceanographic and physiographic variables. A reduced model was then selected including only model terms with p-value < 0.2. This reduced model was compared to the full model using AIC to ensure selection of the best fitting, most parsimonious model. Model fit was assessed through the examination of randomized quantile residuals and the associated Q-Q plot for deviance residuals.

While the two-team approach accounts for the likelihood of detection on the trackline of groups that are available at the surface, it does not account for those that are underwater while in the viewing area of the vessel (beaked and sperm whales). For these two taxa, we applied an additional correction for availability. Tag data that recorded sperm whale or beaked whale dive-surface behavior were reviewed to obtain estimated dive and surface durations. The resulting correction factor was included in the SDM to obtain an unbiased estimate of sperm whale and beaked whale density and abundance.

Abstract: Based on ship-based and aerial line-transect surveys conducted in the U.S. waters of the Gulf of Mexico between 2003 and 2019, the Southeast Fisheries Science Center (SEFSC) developed spatial density models (SDMs) for cetacean and sea turtle species for the entire Gulf. SDMs were developed using a generalized additive modeling (GAM) framework to determine the relationship between species abundance and environmental variables (monthly averaged oceanographic conditions during 2015 - 2019). A total of 19 SDMs were developed for individual or groups of species, including:

1. Beaked whales (*Ziphius* and *Mesoplodon* spp.);
2. Pygmy or Dwarf sperm whales (*Kogia* spp.);
3. Blackfish (*Orcinus orca, Peponocephala electra, Feresa attenuata* and *Pseudorca crassidens* combined);
4. Pilot whales (*Globicephala* sp.);
5. Risso’s dolphin (*Grampus griseus*);
6. Clymene dolphin (*Stenella clymene*);
7. Spinner dolphin (*Stenella longirostris*);
8. Striped dolphin (*Stenella coeruleoalba*);
9. Pantropical spotted dolphin (*Stenella attenuata*);
10. Oceanic Atlantic spotted dolphin (*Stenella frontalis*);
11. Shelf Atlantic spotted dolphin (*Stenella frontalis*);
12. Oceanic Common bottlenose dolphin (*Tursiops truncatus*);
13. Shelf Common bottlenose dolphin (*Tursiops truncatus*);
14. Sperm whale (*Physeter macrocephalus*);
15. Rice’s whale (*Balaenoptera ricei*);
16. Green sea turtle (*Chelonia mydas*);
17. Kemp's Ridley sea turtle (*Lepidochelys kempii*);
18. Leatherback sea turtle (*Dermochelys coriacea*) and;
19. Loggerhead sea turtle (*Caretta caretta*).

Models were extrapolated beyond the U.S. Gulf of Mexico to provide insight into potential high density areas throughout the Gulf. However, extrapolations of this type should be interpreted with caution.

Dataset Author List: Litz, Jenny; Aichinger Dias, Laura; Rappucci, Gina; Martinez, Anthony; Soldevilla, Melissa; Garrison, Lance; Mullin, Keith; Barry, Kevin; Foster, Marjorie.

Purpose: The primary goal was to create spatial density models for cetaceans and sea turtles in the Gulf of Mexico.

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Keywords:

*UNITED STATES OF AMERICA*

*GULF OF MEXICO*

*DOC/NOAA/NMFS/SEFSC*

*DOI/BOEM*

*GoMMAPPS*

*Gulf of Mexico Marine Assessment Program for Protected Species*

*SHIPS*

*SIGHTING*

*SURVEY – BIOLOGICAL*

*BIOLOGICAL DATA*

*IN SITU/LABORATORY INSTRUMENTS*

*LINE TRANSECT SAMPLING*

*DISTANCE SAMPLING*

*VISUAL ESTIMATE*

*VISUAL OBSERVATIONS*

*BIG EYE BINOCULARS*

*INCLINOMETERS*

*MAMMALS*

*CETACEANS*

*DOLPHIN*

*MARINE MAMMALS*

*SPECIES DISTRIBUTION MODELS*

*POPULATION ABUNDANCE*

*ATMOSPHERIC/OCEAN INDICATORS*

*INDICATOR SPECIES*

*SPECIES/POPULATION INTERACTIONS*

*SEA TURTLES*

*NOAA TWIN OTTER*

*AIRCRAFT*

*Shapefile*

Dataset content and format

Esri shapefiles are provided by species or groups of species.

Files:

| **Files** | **Definition** |
| --- | --- |
| species\_Monthly\_Density | Monthly prediction based on identified species; this model accounts for both statistical uncertainty and interannual environmental variability. |
| species\_Monthly\_Density\_wUnids | Monthly prediction based on identified species and the proportion of unidentified species, which were inferred to be of that species; this model accounts for both statistical uncertainty and interannual environmental variability. |
| species\_Monthly\_Density\_Unclipped | Monthly prediction based on identified species; this model accounts for both statistical uncertainty and interannual environmental variability. Nearshore cells may include land areas; clip as needed and according to projection used. |
| species\_Monthly\_Density\_wUnids\_Unclipped | Monthly prediction based on identified species and the proportion of unidentified species, which were inferred to be of that species (if applicable); this model accounts for both statistical uncertainty and interannual environmental variability. Nearshore cells may include land areas; clip as needed and according to projection used. |
| Oceanic | From shelf break waters (~200m) and deeper; Gulf-wide |
| shelf | From shelf break waters (~200m) to the shoreline; Gulf-wide |

Column headers:

| **Field** | **Definition** |
| --- | --- |
| HEXID | Unique identifier for each cell within the hexagon grid |
| month\_n | Number of animals per 40 km2 cell by month; -9999 indicates not applicable. |
| month\_se | Standard error of month\_n; -9999 indicates not applicable. |
| month\_cv | Coefficient of variation: month\_se/month\_n; -9999 indicates not applicable. |