Spatial analysis of ship strike risk for Rice’s whale in the Gulf of Mexico

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## 1 Abstract

Since release of the Biological Opinion on oil and gas activities in the Gulf of Mexico (NMFS 2020) that used a published density surface model (Roberts et al. 2016) to describe the distribution of the critically endangered Rice’s whale (*Balaenoptera ricei*), a new density surface model (Litz et al. 2022) has been made available. Importantly, this model extends the distribution of Rice’s whale beyond its initial core habitat in the Eastern Gulf of Mexico to the West, where it had previously only been acoustically detected (Soldevilla et al. 2022). This report replicates the Biological Opinion’s ship strike analysis using the newer Rice’s whale distributional model. Given the wider distribution of Rice’s whale, an alternative new Whale Area is suggested to reduce ship strike risk with the Rice’s whale based simply on location (25.5º N and higher) and depth (100 to 400 m).

## 2 Whale Densities

The new density surface model (Litz et al. 2022) uses approximately 40 km2 hexagons as its spatial unit to describe number of individuals per 40 km2 in a Lambert Conformal Conic projection, whereas the original model (Roberts et al. 2016) used 100 km2 cells in a custom equal area Albers projection to describe number of individuals per 100 km2. The spatial unit for this new analysis is also 100 km2 cells but in the web Mercator projection (EPSG:3857) in order to readily map results online with common “slippy” basemaps, like the Esri Ocean Basemap. All layers were clipped to the study area of the U.S. Exclusive Economic Zone (EEZ) within the Gulf of Mexico.

Normally converting polygons to raster extracts only the centroid point of the raster cell from the underlying polygon. In order to capture the entirety of the underlying geometric densities, a vector-based intersection was first performed on all layers (whale hexagons, ship cells, and new units) before summarizing to the raster cell as area-weighted means.

In order to adjust for slight differences from projecting coordinate reference systems and rounding errors, the new 100 km2 whale density grid was adjusted so the sum of individuals predicted throughout the study area is equal to 51.3, the most recent abundance estimate (Garrison, Ortega-Ortiz, and Rappucci 2020) from the same 2017 and 2018 surveys as the new density model (Litz et al. 2022) was derived.

Compared to the original distribution ([Figure 1](#fig-map-whales-old)), the whales are now concentrated along the strip from 100 to 400 m extending into the Western Gulf of Mexico ([Figure 2](#fig-map-whales-new)).

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| Figure 1: Map of previous whale densities (Roberts et al. 2016) as 100 km2 cells used by (NMFS 2020) showing the dominance in the northeastern corner of the Gulf of Mexico. The original Whale Area (p. 292 of NMFS 2020) is depicted by the pink outline polygon for vessel slowdown and nighttime avoidance. Depth contours are shown in dash blacked lines for 100 m (finer) and 400 m (thicker). |

The original Whale Area is described (p. 292 of NMFS 2020) as:

This opinion defines the Bryde’s whale area to include the area from 100- to 400- meter isobaths from 87.5° W to 27.5° N as described in the status review (Rosel 2016) plus an additional 10 km around that area.

There was only a tiny marginal improvement in capturing additional whale densities by adding the 10 km buffer used to create the original Whale Area (pink outline in [Figure 1](#fig-map-whales-old)). In generating the new Whale Area, the ease of navigation with simpler description in terms only of a southern limit and depth range outweighed this marginal improvement (red outline in [Figure 2](#fig-map-whales-new)). This new Whale Area captures 94% of the population from the new density estimates (Litz et al. 2022) compared to only 52% of the original Whale Area ([Table 1](#tbl_whale_densities)).

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| Figure 2: Map of new whale densities (Litz et al. 2022) as 100 km2 cells showing a distribution throughout the region. The newly recommended Whale Area is depicted by the red outline polygon for vessel slowdown and nighttime avoidance using similar logic as to (NMFS 2020). Depth contours are shown in dash blacked lines for 100 m (finer) and 400 m (thicker). |

Table 1. Table of new whale densities (Litz et al. 2022) summarized by total study area (U.S. Gulf of Mexico), previous Whale Area (NMFS 2020) and newly proposed Whale Area.

| Item | # | % |
| --- | --- | --- |
| Whales in Study (U.S. Gulf of Mexico) | 51 | 100% |
| Whales in Original Whale Area (NMFS, 2020) | 27 | 52% |
| Whales in New Whale Area | 48 | 94% |

## 3 Vessel Traffic

In order to evaluate the threat of ship strike to Rice’s whales, we used the same AIS data from 2014 to 2018 as the Biological Opinion (NMFS 2020). This data is based on a grid of cells ~126 km2 in Albers equal area projection. Traffic in terms of kilometers (km) traversed within a cell was differentiated based on speed (≤ 10 knots or > 10 knots) and type (oil & gas or all types). In order to produce maps similar to the original Biological Opinion (NMFS 2020) showing spatial variation, colors were assigned to the Jenks natural breaks of the distribution of values (Figures [3](#fig-ships-avg-all-gt01), [4](#fig-ships-avg-boem-gt01), [5](#fig-ships-avg-all-gt10), [6](#fig-ships-avg-boem-gt10)).

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| Figure 3: Map of annual average traffic (km) for all vessel types at all speeds from AIS data (2014 to 2018). Depth contours are shown in dash blacked lines for 100 m (finer) and 400 m (thicker). |

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| Figure 4: Map of annual average traffic (km) for oil and gas vessels at all speeds from AIS data (2014 to 2018). Depth contours are shown in dash blacked lines for 100 m (finer) and 400 m (thicker). |

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| Figure 5: Map of annual average traffic (km) for all vessel types > 10 knots from AIS data (2014 to 2018). Depth contours are shown in dash blacked lines for 100 m (finer) and 400 m (thicker). |

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| Figure 6: Map of annual average traffic (km) for oil and gas vessels > 10 knots from AIS data (2014 to 2018). Depth contours are shown in dash blacked lines for 100 m (finer) and 400 m (thicker). |

## 4 Vessel Risk to Whales

The vessel risk () to whales is calculated as a simple multiplication of number of whales () and km of vessel traffic () ([Equation 1](#eq-risk)).

This risk () can be further differentiated by vessel () type and speed (Figures [7](#fig-risk-avg-all-gt01), [8](#fig-risk-avg-boem-gt10); Table [2](#tbl-risk-overview)).

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| Figure 7: Map of risk (# whales \* km vessel traffic) for all vessels at all speeds. Depth contours are shown in dash blacked lines for 100 m (finer) and 400 m (thicker). |

Table 2. Vessel strike risk (# whales \* km vessel traffic) to Rice’s whales for oil and gas vessels compared with all vessels.

|  | Vessel Strike Risk | | |
| --- | --- | --- | --- |
| Year | All Vessels | Oil & Gas | % |
| All speeds | | | |
| 2015 | 92,849 | 38,428 | 41% |
| 2016 | 85,323 | 33,280 | 39% |
| 2017 | 86,236 | 33,858 | 39% |
| 2018 | 100,326 | 38,668 | 39% |
| Avg | 91,183 | 36,059 | 40% |
| > 10 knots | | | |
| 2015 | 71,621 | 23,153 | 32% |
| 2016 | 67,878 | 21,519 | 32% |
| 2017 | 68,494 | 21,909 | 32% |
| 2018 | 79,759 | 25,209 | 32% |
| Avg | 71,938 | 22,948 | 32% |

Finally, we can evaluate the risk reduction of the original Whale Area proposed in the Biological Opinion (NMFS 2020) compared with the newly proposed Whale Area encompassing the wider Gulf of Mexico([Table 3](#tbl-risk-reduction-by-areas)).

Table 3. Reduction of vessel strike risk (# whales \* km vessel traffic) to Rice’s whales with enforcement of original (NMFS 2020) and new Whale Areas. All percentage (%) reductions are compared to All Vessels for given speeds.

|  | Risk Reduction by Area | | | |
| --- | --- | --- | --- | --- |
| Year | Original | % | New | % |
| All speeds - All vessels | | | | |
| 2015 | 11,025 | 12% | 86,016 | 93% |
| 2016 | 10,963 | 13% | 79,186 | 93% |
| 2017 | 10,343 | 12% | 80,252 | 93% |
| 2018 | 11,956 | 12% | 93,215 | 93% |
| Avg | 11,072 | 12% | 84,667 | 93% |
| All speeds - Oil & Gas vessels | | | | |
| 2015 | 2,516 | 3% | 34,977 | 38% |
| 2016 | 1,827 | 2% | 30,287 | 35% |
| 2017 | 2,175 | 3% | 31,073 | 36% |
| 2018 | 1,520 | 2% | 35,309 | 35% |
| Avg | 2,010 | 2% | 32,911 | 36% |
| > 10 knots - All vessels | | | | |
| 2015 | 7,842 | 11% | 66,483 | 93% |
| 2016 | 8,194 | 12% | 63,161 | 93% |
| 2017 | 7,644 | 11% | 63,856 | 93% |
| 2018 | 9,105 | 11% | 74,307 | 93% |
| Avg | 8,196 | 11% | 66,952 | 93% |
| > 10 knots - Oil & Gas vessels | | | | |
| 2015 | 949 | 1% | 21,089 | 29% |
| 2016 | 659 | 1% | 19,655 | 29% |
| 2017 | 721 | 1% | 20,145 | 29% |
| 2018 | 450 | 1% | 23,116 | 29% |
| Avg | 695 | 1% | 21,001 | 29% |

## 5 Reproducible Results

This report was produced using the principles of reproducible research (Lowndes et al. 2017) with the R programming language (R Core Team 2023). Statistical analysis were performed using the libraries and methods of the [tidyverse](https://www.tidyverse.org/) (Wickham et al. 2019) and spatial features [sf](https://r-spatial.github.io/sf/index.html) (Pebesma 2018) output to a [Quarto](https://quarto.org/) document (Allaire 2022). All source code is available in the Github repository [github.com/ecoquants/ricei](https://github.com/ecoquants/ricei). The interactive version of this report is available at [ecoquants.com/ricei](https://ecoquants.com/ricei).

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