Gulf of Mexico Marine Assessment Program for Protected Species (GOMMAPPS): Seabird Surveys in the Northern Gulf of America, 2017–2020



U.S. Department of the Interior Bureau of Ocean Energy Management Gulf of America OCS Region New Orleans Office New Orleans, LA



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December 2024

Authors:

Jeffrey S. Gleason Allison L. Sussman Kayla L. Davis J. Christopher Haney Kathy M. Hickson Patrick G.R. Jodice James E. Lyons Pamela E. Michael Yvan G. Satge Emily D. Silverman Elise F. Zipkin R. Randy Wilson

Prepared under BOEM Intra-Agency Agreement No. M17PG00011 by U.S. Fish and Wildlife Service Migratory Birds Program/Science Applications 1875 Century Blvd NE Atlanta, GA 30345

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DISCLAIMER

This study was funded, in part, by the US Department of the Interior, Bureau of Ocean Energy Management (BOEM), Environmental Studies Program, Washington, D.C., through Intra-Agency Agreement Number M17PG00011 with the US Fish and Wildlife Service. This report has been technically reviewed by BOEM, and it has been approved for publication. The views and conclusions contained in this document are those of the authors, do not necessarily represent the views of the US Fish and Wildlife Service, and should not be interpreted as representing the opinions or policies of the US Government but do reflect the views of the US Geological Survey. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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CITATION

Gleason JS, Sussman AL, Davis KL, Haney JC, Hixson KM, Jodice PGR, Lyons JE, Michael PE, Satgé YG, Silverman ED, Zipkin EF, Wilson RR (US Fish & Wildlife Service, Atlanta, GA). 2025. Gulf of Mexico Marine Assessment Program for Protected Species (GOMMAPPS): seabird surveys in the northern Gulf of America, 2017–2020. New Orleans (LA): US Department of the Interior, Bureau of Ocean Energy Management. 301 p. Obligation No.: M17PG00011. Report No.: BOEM 2025-026.

ABOUT THE COVER

An adult brown booby (*Sula leucogaster*) in pursuit of a flying fish (family Exocoetidae) across the Gulf of America ocean surface in September 2018. Photo credit: S. Paxton.

ACKNOWLEDGMENTS

We would like to acknowledge the following seabird observers for their participation on the seabird vessel surveys: Jonathan Andrew, Dan Bauer, Peter Blank, Dawn Breese, Lisa Hug, Matthew Love, Michelle McDowell, Nicholas Metheny, Mark Oberle, Jim Panaccione, and Stormy Paxton. We thank the following USFWS pilot-biologists (Division of Migratory Bird Management, Branch of Migratory Bird Surveys): Stephen Earsom, Mark Koneff, and James Wortham, for their support and professionalism in ensuring that all low-level aerial surveys were completed safely. We wish to acknowledge all the aerial survey observers that participated: Kayla Davis, Dean Demarest, Barret Fortier, Wade Harrell, Pat Stinson, Allison Sussman, Robert Wheat, Randy Wilson, and Nick Wirwa. The USFWS, Branch of Migratory Bird Surveys provided Kodiak amphibious aircraft and pilot-biologists (Jim Wortham, Steve Earson, and Mark Koneff). The USFWS National Wildlife Refuge System provided qualified observers for both aerial and vessel surveys, USFWS Ecological Services provided GIS support, and the USFWS Migratory Bird Program provided administrative support. We want to thank all of USFWS administrative staff and leadership for their support throughout the project. We wish to thank all the NOAA staff, vessel crew members, particularly the Chief Scientists and IT support on each of the respective vessels/legs for their assistance. Without their support and assistance, the seabird vessel surveys would not have been possible. Finally, we would like to thank the BOEM contracting officers/project leads Pat Roscigno. Rebecca Green, and Melanie Damour given the challenges of such a large, multi-faceted, complex project, as well as their commitment, patience, and understanding during the writing and review process. We appreciate the constructive reviews provided by Tim White (BOEM) and Jeri Wisman (BOEM) on an earlier draft version of this report. This report benefitted from reviews by Dan Collins (USFWS) and Neal Niemuth (USFWS).

This study was funded by the US Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program through Intra-Agency Agreement M17PG00011 with the US Department of Interior, US Fish and Wildlife Service via an Intra-Agency Agreement 4500108172-F17IA00005 with the US Geological Survey, South Carolina Cooperative Fish and Wildlife Research at Clemson University, and through a Cooperative Agreement F17AC00575 with Michigan State University.

Contents

Cor	ntents		vi
List	of Figures		viii
List	of Tables		xv
List	of Abbreviatio	ns and Acronyms ¹	xvii
Intr	oduction		
	1.1	Regulatory Nexus and Project Goals	21
2	Study Area		23
	2.1	Gulf Habitats, Physical Oceanography, and Planning Areas	23
	2.2	Historical Seabird Surveys	26
3	Aerial Seabird	Surveys	29
	3.1	Data Collection Schedule	29
	3.1.1	1 Aerial Survey Spatial Coverage	29
	3.2	Characterizing Marine Birds	42
	3.3	Aerial Survey Analytical Methods	47
	3.4	Aerial Survey Results	52
	3.4.7	1 2018 – 2020 Aerial Survey Results	58
4	Vessel-based	Seabird Surveys: Methods	70
	4.1	Vessel Survey Protocols, Data Collection, and Data Screening	86
	4.2	Seabird Response Metrics and Habitat Variables	87
	4.3	Modeling Distribution and Abundance of Seabirds	88
	4.4	Seabird Community Metrics	89
	4.5	Macro-scale Exposure of Seabirds to Oil Platforms	93
	4.6	Review of Previous Surveys and Compilations of Seabird Observations in the Northern	Gulf93
5	Vessel-based	Seabird Surveys: Results	94
	5.1	Survey Effort	94
	5.2	Fauna Observed in the Northern Gulf	100
	5.3	Species Accounts: Abundance, Distribution, and Predicted Occurrence	126
	5.4	Individual Species Accounts	137
	5.4.	1 Audubon's shearwater	137
	5.5	Conservation Status of Focal Seabirds	180
	5.6	Summary of Habitat Relationships	181
	5.7	Comparisons of Habitat Relationships among Related Species	182
	5.8	Spatial Overlap of Suitable Habitat with Oil Platforms	184
6.	Conclusions a	Ind Future Directions	186
	6.1	GOMMAPPS Seabird Data: Regulatory Decision-making in the Northern Gulf	186
	6.2	Seabirds: Remaining Data Gaps	189
	6.3	Additional Information Needs	192
	6.4	Current and Planned Bird-related Monitoring and Research in the Northern Gulf	194

Works Cited .			197
Appendix A. vessel (V	/)-bas	List of all vertebrates detected and identified to species from both aerial (ed survey platforms as part of the GOMMAPPS, 2017– 2020	A) and 221
Appendix B. metrics a	as par	Trackline maps for seabird vessel surveys with associated effort-based t of the GOMMAPPS, 2017 – 2019.	226
	Survey	r B21702	227
S	Survey	r: PI1706	228
S	, Survey	r: GG1707	229
S	Survey	r: GG1708	230
S	Survey	r: GG1709	231
5	Survey	r: GG1801	232
\$	Survey	r: GG1802	233
\$	Survey	r: GG1803	234
\$	Survey	/: O21804	235
S	Survey	r: O21805	236
S	Survey	r: PC1805	237
Ş	Survey	r: GG1804	238
Ş	Survey	r: O21901	239
Ş	Survey	r: PC1905	240
Appendix C.		Spatial distribution of non-marine avifauna detections during seabird ves	sel
surveys	as pai	rt of the GOMMAPPS, 2017 - 2019	241
l	Landbi	ras	242
ſ	Rapior	S	252
	Shore	a Diada	
, i	Watarf		204
Appendix D.	valen	Spatial Distribution Map of Seabird Detections	256
Appendix E. for this S	Study	Publications, Data Releases, and other Materials Resulting from Data Col 296	lected
E	E.1	Peer-reviewed publications	296
E	E.2	Peer-reviewed publications in review	296
E	E.3	Peer-reviewed publications in preparation	296
E	E.4	Theses	296
E	E.5	Conference presentations	297
E	E.6	Data releases	300
	NOA	A NCEI	301

List of Figures

Figure 2.1.	Study area map of the northern Gulf including Texas, Louisiana, Mississippi, Alabama, and Florida
Figure 3.1.	Sampling design used for the USFWS aerial surveys (2018 – 2020) using Environmental Protection Agency 40 km ² hexagons including Texas, Louisiana, Mississippi, Alabama, and Florida state boundaries
Figure 3.2.	Sampling design employed for the USFWS aerial surveys using Environmental Protection Agency 40 km ² hexagons during the 2017 pilot field season off the Louisiana coast
Figure 3.3.	Planned USFWS aerial transect surveys during the 2017 pilot field season off the Louisiana coast near the Mississippi River mouth
Figure 3.4.	Six boxes representing the seat rotation as part of the double observer protocol used during USFWS aerial surveys
Figure 3.5.	Depiction of USFWS aircraft flying at ~61 m (200') showing the visible strip width of 200 m out the left-hand side of the aircraft (as the aircraft approaches)
Figure 3.6.	Linear regression plot of waterbird counts from front and rear same-side observers during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana coast
Figure 3.7.	Depiction of USFWS aircraft flying 3, ~11.5 km transect segments (red lines) within a 'cluster' of 3, 40 km ² hexagons (blue outline) with arrows on each end representing turns to go back on transect within the hexagon 'cluster'
Figure 3.8.	Planned aerial survey plots ($n = 180$) as part of the GOMMAPPS summer 2018 and winter 2018 – 2020 surveys with map of the US Gulf of America coastline of Texas, Louisiana, Mississippi, Alabama, and Florida
Figure 3.9.	Triad of graphs for hourly sea-surface temperature (SST; °C, top set of plates) averaged over each day for the winter survey periods for 2018 (a), 2019 (b), and 2020 (c), respectively; hourly sea-surface height (SSH; in m, middle set of plates) averaged over each day for the winter survey periods for 2018 (d), 2019 (e), and 2020 (f), respectively; and hourly sea-surface salinity (SSS, bottom set of plates) averaged over each day for the winter survey periods for 2018 (d), 2020 (i), respectively
Figure 3.10.	Graphic depicting hourly sea-surface temperature (SST; °C) averaged over each day for the summer 2018 survey period (2018 July 11-20) as measured by the Hybrid Coordinate Ocean Model (HYCOM) in the northern Gulf
Figure 3.11.	Graphic depicting hourly sea-surface height (SSH; in m) averaged over each day for the summer 2018 survey period (2018 July 11-20) as measured by the Hybrid Coordinate Ocean Model (HYCOM) in the northern Gulf
Figure 3.12.	Graphic depicting hourly sea-surface salinity (SSS) averaged over each day for the summer 2018 survey period (2018 July 11–20) as measured by the Hybrid Coordinate Ocean Model (HYCOM)
Figure 3.13.	Histograms (a) of all species combined flock sizes per aerial survey unit (40-square km hexagons) and of all species combined flock sizes (>0) aerial survey unit (40 km2 hexagons) for 2018, 2019, and 2020 winter surveys (b)
Figure 3.14.	Histograms (a) of all species combined flock sizes per aerial survey unit (40-square km hexagons) and of all species combined flock sizes (>0) per aerial survey unit (40 km ² hexagons) for 2018 summer survey (b)
Figure 3.15.	Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for all marine bird species combined during winter aerial surveys, 2018 – 2020.

Figure 3.16.	Marginal effects model plot of sea-surface temperature (SST) (dark blue line) and the 15- year average of SST (green line) each with associated 95% credible intervals for all marine bird species combined winter aerial surveys, 2018 – 2020
Figure 3.17.	Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on all marine bird species combined for winter aerial surveys, 2018 – 2020
Figure 3.18.	Winter predicted abundance model (a) and associated standard deviation of predictions (b) for all marine bird species combined winter aerial surveys, 2018 – 2020
Figure 3.19.	Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on northern gannet (NOGA; <i>Morus bassanus</i>) counts for winter aerial surveys, 2018 – 2020
Figure 3.20.	Marginal effects model plot of distance to shore (dark blue line) on northern gannet (NOGA; <i>Morus bassanus</i>) counts (2018 = blue line, 2019 = green line; light bands represent 95% credible intervals) during winter aerial surveys, 2018 – 2020
Figure 3.21.	Marginal effects model plot of sea-surface height (SSH; green line) on northern gannet (NOGA; <i>Morus bassanus</i>) counts (2018 = blue line, 2019 = green line; light bands represent 95% credible intervals) during winter aerial surveys, 2018 – 2020
Figure 3.22.	Marginal effects model plot of sea-surface salinity (SSS) on northern gannet (NOGA; <i>Morus bassanus</i>) counts (2018 = blue line, 2019 = green line; light bands represent 95% credible intervals) during winter aerial surveys, 2018 – 2020
Figure 3.23.	Winter predicted abundance model (a) and associated standard deviation of predictions (b) for northern gannets from winter aerial surveys, $2018 - 2020$. The survey area includes all 40 km^2 hexagons representing the entirety of the study area from the coastline out to roughly 50 nm line
Figure 3.24.	Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on gull and tern counts for winter aerial surveys, 2018 – 2020.
Figure 3.25.	Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for gulls and terns during winter aerial surveys, 2018 – 202067
Figure 3.26.	Marginal effects model plot of sea-surface temperature (SST) (dark blue line) and associated 95% credible intervals (light blue band) for gulls and terns during winter aerial surveys, 2018 – 2020
Figure 3.27.	Marginal effects model plot of sea-surface salinity (SSS) on gull and tern counts (blue line) with associated 95% credible intervals (light blue band) during winter aerial surveys, 2018 – 2020.
Figure 3.28.	Winter predicted abundance model (a) and associated standard deviation of predictions (b) for gulls and terns from winter aerial surveys, 2018 – 2020
Figure 3.29.	Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for all marine bird species combined 2018 summer aerial surveys.
Figure 3.30.	Marginal effects model plot of sea-surface temperature (SST) (dark blue line) and associated 95% credible intervals (light blue band) for all marine bird species combined counts 2018 summer aerial surveys
Figure 3.31.	Marginal effects model plot of sea-surface height (SSH) (dark blue line) and associated 95% credible intervals (light blue band) for all marine bird species combined counts 2018 summer aerial surveys

Figure. 3.32	Marginal effects model plot of sea-surface salinity (SSS) on gull and tern counts (blue line) with associated 95% credible intervals (light blue band) for all marine bird species combined counts 2018 summer aerial surveys
Figure 3.33.	Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on all marine bird species combined counts for 2018 summer aerial surveys
Figure 3.34.	Summer predicted abundance model (a) and associated standard deviation of predictions (b) for all marine bird species combined 2018 aerial surveys76
Figure 3.35.	Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on all marine bird species combined counts for 2018 summer aerial surveys
Figure 3.36.	Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for brown pelican (BRPE; <i>Pelecanus occidentalis</i>) counts in 2018 summer aerial surveys
Figure 3.37.	Summer predicted abundance model (a) and associated standard deviation of predictions (b) for brown pelican (BRPE; <i>Pelecanus occidentalis</i>) 2018 aerial surveys79
Figure 3.38.	Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on gull and tern counts for 2018 summer aerial surveys80
Figure 3.39.	Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for gull and terns counts in 2018 summer aerial surveys
Figure 3.40.	Marginal effects model plot of sea-surface height (SSH) (dark blue line) and associated 95% credible intervals (light blue band) for gull and tern counts in 2018 summer aerial surveys. 82
Figure 3.41.	Summer predicted abundance model (a) and associated standard deviation of predictions (b) for gulls and terns from 2018 aerial surveys
Figure 4.1.	Tracklines (solid black lines) for GOMMAPPS seabird vessel surveys (2017 - 2019)84
Figure 4.2.	Histogram of the seabird community as a proportion of individuals of a given species in the four different distances zones (Zone $1 = 0 - 100$ m, Zone $2 = 100 - 200$ m, Zone $3 = 200 - 300$ m, Zone $4 = >300$ m as well as birds observed off or outside the transect boundary) from Program SEEBIRD (Vers. 4.3.7; Ballance and Force 2016) used for seabird vessel surveys (2017 – 2019)
Figure 5.1.	Cumulative trackline maps of survey effort (transect km surveyed) across the four calendar seasons (spring = March-May, summer = June-August, fall = September-November, winter =December-February) and three BOEM planning areas (Western, Central, and Eastern) for GOMMAPPS seabird vessel surveys (2017 – 2019)
Figure 5.2.	Histogram of allocation of survey effort based on number of survey days (top) and distance surveyed (bottom) by year across the three BOEM planning areas (Western, Central, and Eastern) for GOMMAPPS seabird vessel surveys (2017 – 2019)
Figure 5.3.	Histogram of allocation of survey effort based on number of survey days (top) and distance surveyed (bottom) by calendar month for GOMMAPPS seabird vessel surveys (2017 – 2019).
Figure 5.4.	Histograms of seabird species richness (top figure) and species diversity (bottom figure) for GOMMAPPS seabird vessel surveys (2017 – 2019)
Figure 5.5.	Histograms of flock sizes by species for seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Figure 5.6a.	Map of chlorophyll-a (mg/m ³) in the Gulf of America

Figure 5.6b.	Map of sea-surface salinity (SSS; indicative of water mass) in the Gulf of America
Figure 5.6c.	Map of sea-surface height (SSH in meters) in the Gulf of America
Figure 5.6d.	Map of sea-surface temperature (SST; °C) in the Gulf of America141
Figure 5.6f.	Map of eastward surface current velocity (m/s) in the Gulf of America
Figure 5.6g.	Map of northward surface current velocity (m/s) in the Gulf of America144
Figure 5.6h.	Map of absolute surface current velocity (m/s) in the Gulf of America
Figure 5.7a.	Plots of coefficient response curves for the predictor variable bathymetry (A) derived from MaxEnt models (Phillips et al. 2006) for seven species (Audubon's shearwater, band-rumped storm-petrel, bridled tern, common tern, parasitic jaeger, pomarine jaeger, Wilson's storm-petrel) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019 149
Figure 5.7b.	Plots of coefficient response curves for the predictor variable chlorophyll-a (B) derived from MaxEnt models (Phillips et al. 2006) for nine species (black tern, Bonaparte's gull, brown pelican, common loon, great shearwater, magnificent frigatebird, northern gannet, royal tern, and sandwich tern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.
Figure 5.7c.	Plots of coefficient response curves for the predictor variable current direction (C) derived from MaxEnt models (Phillips et al. 2006) for three species (black-capped petrel, bridled tern, and sooty tern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.
Figure 5.7d.	Plots of coefficient response curves for the predictor variable sea-surface height (D) derived from MaxEnt models (Phillips et al. 2006) for four species (Audubon's shearwater, brown noddy, parasitic jaeger, and sooty tern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Figure 5.7e.	Plots of coefficient response curves for the predictor variable sea-surface salinity (E) derived from MaxEnt models (Phillips et al. 2006) for twelve species (band-rumped storm-petrel, black tern, brown booby, brown pelican, Cory's shearwater, great shearwater, herring gull, laughing gull, masked booby, northern gannet, pomarine jaeger, and Wilson's storm-petrel) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Figure 5.7f.	Plots of coefficient response curves for the predictor variable sea-surface temperature (F) derived from MaxEnt models (Phillips et al. 2006) for four species (brown booby, brown noddy, common tern, and magnificent frigatebird) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Figure A-C 1	 Spatial distribution map of non-marine avifauna detections for landbirds (nine species of warblers and allies) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019. 242
Figure A-C2	. Spatial distribution map of non-marine avifauna detections for landbirds (nine species of warblers and allies) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019. 243
Figure A-C3	. Spatial distribution map of non-marine avifauna detections for landbirds (five species of blackbirds and allies) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019. 244
Figure A-C4	. Spatial distribution map of non-marine avifauna detections for landbirds (six species of aerial insectivores) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019. 245
Figure A-C5	. Spatial distribution map of non-marine avifauna detections for landbirds (four species) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Figure A-C6	. Spatial distribution map of non-marine avifauna detections for landbirds (three species of flycatchers) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019247

Figure A-C7. Spatial distribution map of non-marine avifauna detections for landbirds (five species) Figure A-C8. Spatial distribution map of non-marine avifauna detections for landbirds (five species of doves and pigeons) during seabird vessel surveys as part of the GOMMAPPS, 2017 - 2019. Figure A-C9. Spatial distribution map of non-marine avifauna detections for landbirds (unidentified Figure A-C10. Spatial distribution map of non-marine avifauna detections for landbirds (unidentified passerines) during seabird vessel surveys as part of the GOMMAPPS, 2017 - 2019........251 Figure A-C11. Spatial distribution map of non-marine avifauna detections for raptors (five species) Figure A-C12. Spatial distribution map of non-marine avifauna detections for shorebirds (10 species) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.253 Figure A-C13. Spatial distribution map of non-marine avifauna detections for wading birds (six species) during seabird vessel surveys as part of the GOMMAPPS, 2017 - 2019......254 Figure A-C14. Spatial distribution map of non-marine avifauna detections for waterfowl (two ducks and American coot) during seabird vessel surveys as part of the GOMMAPPS, 2017 - 2019. 255 Figure D-1. Spatial distribution of Audubon's shearwater detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 - 2019. Figure D-2. Spatial distribution of band-rumped storm-petrel detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 - 2019. 258 Figure D-3. Spatial distribution of black-capped petrel detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms Figure D-4. Spatial distribution of black tern (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird Figure D-5. Spatial distribution of Bonaparte's gull detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms Figure D-6. Spatial distribution of bridled tern detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 - 2019......263 Figure D-7. Spatial distribution of brown booby detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 - 2019......264

- Figure D-14. Spatial distribution of one petrel and one shearwater species (Fea's petrel, Manx shearwater) and unidentified *Pterodroma*, unidentified shearwater, unidentified large shearwater, and unidentified small shearwater detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 2019.

- Figure D-20. Spatial distribution of Leach's storm-petrel and identified storm-petrel detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 2019......280

- Figure D-33. Spatial distribution of Wilson's storm-petrel tern detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 2019.

List of Tables

Table 3.1.	Summary of aerial seabird survey effort by year and season including number of hexagons sampled, proportion (%) of hexagons sampled, number of transects within hexagons sampled, and distance (km) flown while on transect within hexagons as part of the GOMMAPPS, 2018 – 2020
Table 3.2.	Summary comparison of two aerial survey designs: 3-hexagon cluster versus standard line transects during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana Coast.
Table 3.3.	Summary comparison (based on species counts) of two aerial survey designs: 3-hexagon cluster versus standard line transects during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana Coast
Table 3.4.	Summary of data matches between two observers recording data on the same side of the aircraft during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana Coast. 37
Table 3.5.	Mean and standard deviation (SD) for double-observer (same-side front and rear seat positions) number of records and counts of waterbird observations for both hexagons and transects during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana Coast.
Table 3.6.	Seasonal summary of survey effort for GOMMAPPS aerial seabird surveys, 2018 – 2020*43
Table 3.7.	Aircraft, pilot, and crew information for the GOMMAPPS aerial seabird surveys, 2018 – 2020.
Table 3.8.	Faunal classes of vertebrates observed during the GOMMAPP) aerial seabird surveys, 2018 – 2020
Table 3.9.	Species composition of birds observed during the GOMMAPPS aerial seabird surveys, 2018 – 2020
Table 4.1.	Summary of seabird vessel survey effort as a part of the GOMMAPPS, 2017 – 201985
Table 4.2.	Summary of all habitat covariates used in seabird species-specific MaxEnt models (MaxEnt; Phillips et al. 2006) from data collected by seabird vessel surveys, 2017 – 201991
Table 5.1.	Summary of seabird vessel survey effort across the three BOEM planning areas (Western, Central, Eastern) and calendar seasons as part of the GOMMAPPS, 2017 – 201997
Table 5.2.	Summary of various faunal classes based on number of detections, number of individuals, and species richness from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019. 101
Table 5.3a.	Summary of number of detections of non-avifauna by season and Bureau of Ocean Energy Management (BOEM) planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Table 5.3b.	Summary of number of individuals of non-avifauna by season and Bureau of Ocean Energy Management (BOEM) planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Table 5.4a.	Summary of bird taxonomic groups based on number of detections, number of individuals, and species richness from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019. 106
Table 5.4b.	Summary of number of detections for non-marine avifauna by season and BOEM planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Table 5.4c.	Summary of number of individuals for non-marine avifauna by season and BOEM planning area (Western, Central, Eastern) from the vessel-based marine bird component of the GOMMAPPS, 2017 – 2019

Table 5.5a.	Summary of number of detections by taxonomic group for non-marine avifauna by BOEM planning area (Western, Central, Eastern) and season from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Table 5.5b.	Summary of number of individuals by taxonomic group for non-marine avifauna by BOEM planning area (Western, Central, Eastern) and season from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Table 5.6a.	Summary of seabird observations with number of detections, number of individuals, and proportion of total individuals for seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.
Table 5.6b.	Summary of number of detections for marine avifauna by season and BOEM planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Table 5.6c.	Summary of number of individuals for marine avifauna by season and BOEM planning areas (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.
Table 5.7.	Summary of seabird taxonomic groups based on number of detections, number of individuals, and proportion of individuals from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Table 5.8.	Summary of number of individuals for respective seabird taxonomic groups by season and BOEM planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Table 5.9.	Summary of number and proportion of individuals (%) for all seabirds identified to species assigned to a breeding region, by season, and by BOEM planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019
Table 5.10.	Number of seabird species observed and identified to species from seabird vessel surveys as part of the GOMMAPPS and six historical seabird studies in the northern Gulf
Table 5.11.	Characterization of species-specific overlap with oil and gas platforms for the western and central BOEM planning areas, individually and combined
Table 5.12.	Percent contribution for each of nine predictor variables to final predictive models of species occurrence for 24 species of seabirds in the Gulf (seabird vessel survey data-only), 2017 – 2019.

List of Abbreviations and Acronyms¹

Short Form	Long Form				
AL	Alabama				
AMAPPS	Atlantic Marine Assessment Program for Protected Species				
asl	above sea-level: typically, in reference to aerial survey altitude				
AOU	American Ornithologists' Union				
AUC	area-under-curve				
BCR	Bird Conservation Region				
BOEM	Bureau of Ocean Energy Management				
BSEE	Bureau of Safety and Environmental Enforcement				
°C	degrees Celsius				
CCR	cold-core ring(s)				
CPA	Central Planning Area				
d	day(s)				
DAS	days-at-sea				
DO	double observer				
DOCD	Development Operations Coordination Document(s)				
DOI	U.S. Department of the Interior				
DWH	Deepwater Horizon (oil spill)				
EA	environmental assessment				
EEZ	Exclusive Economic Zone				
EIS	environmental impact statement				
EO	Executive Order				
EP	Exploration Plan(s)				
EPA	Eastern Planning Area				
ESA	Endangered Species Act				
ESP	Environmental Studies Program				
EPIS	Environmental Studies Program Information System				
FL	Florida				
FWCA	Fish and Wildlife Coordination Act				
GLM	generalized linear model				
Gulf	Gulf of America				
GOMAMN	Gulf of Mexico Avian Monitoring Network				
GOMMAPPS	Gulf of Mexico Marine Assessment Program for Protected Species				
GRTS	Generalized Random Tessellation Stratified				
hr	hour(s)				
HYCOM	Hybrid Coordinate Ocean Model				
IAA	intra-agency agreement				
km	kilometer(s)				
km2	square kilometer(s)				
ITM	Information Transfer Meeting				
LA	Louisiana				
LC	Loop Current				
LTCC	Louisiana-Texas Coastal Current				
m	meter(s)				
MBTA	Migratory Bird Treaty Act				
MI	Mississippi				

Short Form	Long Form			
MOU	Memorandum of Understanding			
mo	month(s)			
MSU	Michigan State University			
n	sample size			
NEPA	National Environmental Policy Act			
NOAA	National Oceanic and Atmospheric Administration			
NRDA	Natural Resources Damage Assessment			
O&G	oil and gas			
OCS	Outer Continental Shelf			
OCSLA	Outer Continental Shelf Lands Act			
OSRA	oil spill risk analysis			
OWED	Offshore Wind Energy Development			
QA/QC	quality assurance/quality control			
S	second(s)			
SSH	sea-surface height (meters or m)			
spp.	Species (plural; >1 species)			
SSS	sea-surface salinity (parts per thousand or ppt)			
SST	sea-surface temperature ([°] Celsius or °C)			
TX	Texas			
USFWS	US Fish and Wildlife Service			
USGS	US Geological Survey			
VOO	vessels of opportunity			
WCR	warm-core ring(s)			
WPA	Western Planning Area			
yr	year(s)			

¹ The four-letter American Ornithological Union codes used to identify the numerous bird species are not included in this List of Abbreviations. These four-letter codes are provided separately in Table 5.6a.

Introduction

The northern Gulf of America (formerly the Gulf of Mexico¹) (northern Gulf) is considered critically important to a large segment of North America's migratory bird populations during some point of their annual life cycle. An estimated ~500 species representing seven major taxonomic groups (landbirds, marsh birds, raptors, seabirds, shorebirds, wading birds, and waterfowl; Wilson et al. 2019a) are known to occur in the five Gulf of America (Gulf) coast states. In addition, an estimated ~300 species are known to breed across the span of the northern Gulf from Texas to Florida (Wilson et al. 2019a). Using observers on oil and gas platforms in the northern Gulf. (Russell 2005) identified 279 bird species during spring and fall migration (1998 - 2000). Horton et al. (2019) used weather surveillance radar (1995 - 2015) to estimate nearly 2.1 billion birds (mostly nocturnally migrating neotropical passerines) migrate through the region each spring enroute to their Nearctic breeding grounds. The northern Gulf region provides a diversity of habitats and ecological niches to breeding, staging, and wintering migratory birds (Burger 2017, 2018; Wilson et al. 2019a). The northern Gulf coastline represents a southern geographic terminus for all four major (Pacific, Central, Mississippi, and Atlantic) North American migratory flyways (Bellrose 1980). It is well understood that although the Gulf may represent an ecological barrier for some bird species (e.g., Buler and Moore 2011, Smolinksy et al. 2013, Buler et a. 2017), many species of birds continue their south-bound fall migration to wintering areas much farther to the south. Many species of Nearctic migrant landbirds appear to use either Trans-Gulf or Circum-Gulf migratory strategy (Rappole and Ramos 1994). Briefly, it is thought that most species of Nearctic migrant landbirds follow a Trans-Gulf migratory path in the fall, whereas in the spring they migrate back north following a more westerly Circum-Gulf path. From telemetry data it seems clear, that even within a given species, there tends to be some variability in migration timing and migratory behavior (e.g., Deppe et al. 2015) including for species like the brown pelican (Pelecanus occidentalis) thought to be considered year-round 'residents' (Lamb et al. 2017a, Lamb et al. 2020b). For a general overview of Gulf migratory birds, their habitats and ecology, as well as threats, refer to Burger (2018).

From a seabird perspective, particularly for the more pelagic species, the northern Gulf has received relatively limited attention from seabirding enthusiasts (but see Texas Pelagics), seabird researchers, and from the broader seabird conservation community. Seabirds have been studied sporadically in the northern Gulf, and most of the research is restricted spatially or temporally and focused on breeding colonies in the northern Gulf. Relatively few studies (e.g., Fritts and Reynolds 1981, Fritts et al. 1983, Ribic et al. 1997, Davis et al. 2000, Hess and Ribic 2000) have focused on at-sea distribution and abundance of seabirds in this region (but refer to Haney 2011). This disparity in interest, seabird monitoring effort and available data are particularly stark in comparison to both the eastern north Pacific and western north Atlantic (i.e., the regions of each ocean basin adjacent to the coasts of North America). These differences are presumably partly owing to lack of funding to conduct broadscale seabird surveys, lack of funding to conduct long- term monitoring more broadly (Caughlan and Oakley 2001), and the general lack of seabird expertise and/or researchers available to conduct seabird research in the Gulf. The northern Gulf is host to several seabird species whose colonies are of regional, continental, and global importance. Many of the seabird species using the northern Gulf are included in the recently released Birds of Conservation Concern (USFWS 2021), representing priorities for conservation action. Colonies of brown pelican (all scientific names are provided in Appendix A), sandwich tern, royal tern, Forster's

¹ Following President Trump's <u>Executive Order 14172</u>, "Restoring Names That Honor American Greatness," Secretary of the Interior Doug Burgum signed <u>Secretary's Order 3423</u>, "The Gulf of America," which directed the Board of Geographic Names (BGN) to immediately rename the Gulf of Mexico to the Gulf of America. On Feb. 10, 2025, the US Geological Survey updated the <u>Geographic Names Information System (GNIS</u>) to reflect the renaming of the Gulf of Mexico to the Gulf of America. GNIS is the official federal repository for all U.S. domestic geographic names for federal use.

tern, the coastal breeding population of least tern, and black skimmer in Louisiana rise to the level of continental and global importance, based on breeding population estimates (Remsen et al. 2019:table 2). Each of the respective five northern Gulf State Wildlife Action Plans identify some seabird species, primarily nearshore representatives (i.e., species that use habitats and shallower waters influenced by a combination of riverine, estuarine, or coastal processes; Jodice et al. 2019) that breed along the northern Gulf coast, as meeting the definition of Species of Greatest Conservation Need (e.g., FWCC 2019). The Gulf of Mexico Avian Monitoring Network (GOMAMN) clearly understood the conservation need for this taxonomic group. As such, there was consensus to include 14 seabird representatives (~20% of the 68 total bird species) in the GOMAMN Birds of Conservation Concern list (Wilson et al. 2019b:appendix 1, see also Jodice et al. 2019:table 6.1). Finally, Hunter et al. (2006) evaluated threats, provided state and Bird Conservation Region population estimates, and identified conservation priorities and management actions for ~45 seabird species that breed, winter, or use the northern Gulf. Thus, seabirds are an important taxonomic group within the broader avifaunal community of the northern Gulf.

Life-history traits and behaviors of seabirds (northern Gulf Orders include Procellariiformes, Pelecaniformes, Charadriiformes) make them unique among the seven taxonomic groups of birds in the Gulf (Wilson et al. 2019a, Jodice et al. 2019), but also make them particularly vulnerable to perturbations and stressors in the marine system (Furness and Camphuysen 1997, Dias et al. 2019). In general, seabirds are long-lived, have delayed sexual maturity, low reproductive potential owing to small clutch sizes and low within breeding-season renesting probability, high parental investment in eggs and young, semicolonial to colonial nesting strategy, central-place foragers during nesting, and exhibit long-distance and/or transboundary movements within- and among-years (Furness and Monaghan 1987, Schreiber and Burger 2001, Gaston 2004, Jodice and Suryan 2010). Foraging ranges during the breeding season vary among species (and among colonies and individuals within a given species; refer to Lamb 2016, Lamb et al. 2020b) and can range from 10s-100s km. Seabird migration strategies are varied from partial migration to trans- ocean basin migration. Within a given species, migration decisions may vary by sex, age, body condition, colony size (i.e., density-dependence; Lamb et al. 2017a), and functionally due to availability and density of forage fish (Lamb et al. 2017b, Lamb et al. 2020b). During the non-breeding season, foraging ranges tend to be more dynamic/flexible and generally lack the central tendency present during the breeding season. In general, at-sea movements and foraging patterns of seabirds are spatially and temporally dynamic in response to the 3-dimensional nature of at- sea habitat (Tremblay et al. 2009, Ainley et al. 2012). For a more thorough review of seabirds in the northern Gulf, refer to Jodice et al. (2019).

Seabirds are generally considered as reasonable indicators of or proxies for the marine environment (Cairns 1987, Parsons et al. 2008). Given that seabirds are considered upper trophic-level predators in marine systems, they have been important early warning signs of fishery collapses across the world (Piatt et al. 2007a). In addition, major annual declines in breeding effort and productivity, colony collapses, and even seabird die-offs have been cited in regime shifts or trophic cascades (Österblom et al. 2006, Grémillet and Boulinier 2009, MacDonald et al. 2015), whereby changes in the marine environment (e.g., sea surface temperature) in a given region has resulted in major effects to the food chain, food-web dynamics, prey availability and/or density, and resultant responses from higher trophic-level organisms like seabirds, predatory fishes, and marine mammals (Trites and Donnelly 2003, Jodice et al. 2006, Suryan et al. 2006). Finally, seabirds have also been shown to be reliable indicators of contaminants (Mallory and Braun 2012, Gilmour et al. 2019) and marine plastics (Wilcox et al. 2015, Provencher et al. 2020), due to ingestion of contaminated prey and resultant bioaccumulation or by direct ingestion. For a general overview of seabirds as indicators, refer to Piatt et al. (2007b).

The Gulf is one of the top five oceans in terms of biodiversity (Ellis et al. 2011 *sensu* Brenner et al. 2016); this biodiversity is subject to a myriad of threats. Concurrently, the habitats and waters comprising the northern Gulf represent one of the most socio-economically (Sumaila et al. 2012) and ecologically

(Burger 2018, Gallardo et al. 2004) important ecosystems in the world (Fournier et al. 2019). It is estimated that the natural resources of the northern Gulf account for $\sim 30\%$ of the U.S. gross domestic product (GCERTF 2011), including for example, offshore oil and gas production, commercial and recreational fishing (Sumaila et al. 2012), and tourism. The Gulf, including the northern Gulf coast, is increasingly affected by a variety of anthropogenic stressors (e.g., altered hydrological processes, land development, energy development, point-source and non-point source pollution, hypoxia, oil spills, shipping traffic, sea-level rise, sea surface temperature increases, etc.; Halpern et al. 2008) and natural events (e.g., tropical storms, hurricanes, and floods) that may directly or indirectly negatively affect seabirds and their use of habitats in the region. Burger (2018:168-216) provides a detailed review of stressors and threats facing birds in the northern Gulf. The Bureau of Ocean Energy Management (BOEM 2012) provided an extensive list and detailed review of factors potentially affecting birds in the northern Gulf specifically as they relate to oil and gas development (O&G). Gleason et al. (2016; in northern Gulf et al. 2019) further refined this list to the five most important factors potentially resulting in negative consequences to migratory birds related to O&G development, including seabirds (refer also to Ronconi et al. 2015). For seabirds in the northern Gulf specifically, oil spills (both chronic small, as well as large catastrophic spills) and generation of produced waters from drilling activities are considered the most pertinent (Wiese et al. 2001, Fraser et al. 2006, O'Hara and Morandin 2010). Seabirds are extremely vulnerable to spilled oil (e.g., Seip et al. 1991, Begg et al. 1997, O'Hanlon et al. 2020). For example, 36 of the 93 (39%) injured bird species identified from the Deepwater Horizon oil spill were seabirds (DHNRDAT 2016a:table 4.7-3). Estimates from the Deepwater Horizon oil spill indicate that seabird species represented 15 of the top 20 injured species accounting for ~89% of the cumulative total bird injury (DHNRDAT 2016a).

For the purposes of articulating broad habitats potentially used by seabirds in the Gulf, we include herein both nearshore and pelagic systems. Across the northern Gulf, the nearshore zone includes, but is not limited to, habitat features such as beaches, coastal wetlands, coastal or barrier islands, bays and estuaries, and other nearshore waters (landward of the Outer Continental Shelf; OCS) that are influenced by a combination of riverine, estuarine, or coastal processes (Jodice et al. 2019). Pelicans, gulls, and terns tend, on average, to be more common and abundant in these coastal habitats compared to the offshore pelagic waters. Individuals of these species also typically forage within the nearshore system during both the breeding and non-breeding seasons. By comparison, the pelagic zone includes waters influenced by complex oceanographic processes, the Loop Current, and bottom features (e.g., Desoto Canyon) that create upwellings and mixing zones. More details specific to oceanographic features in the Gulf are provided in Section 2.1 below. For this study, the pelagic zone extends from the nearshore zone (roughly the state/OCS boundary) out to the Exclusive Economic Zone (EEZ). Shearwaters, petrels, storm-petrels, pelagic terns, tropicbirds, and boobies are more common and abundant in pelagic zones compared to shallower nearshore waters, foraging over open water; typically occurring in coastal habitats only during nesting. In the Gulf, both nearshore and pelagic systems also may include species that breed in freshwater inland systems, but that occur within marine waters of the northern Gulf during both migration (e.g., black tern) and the nonbreeding period (e.g., common loon, northern gannet). Although the marine habitat categories presented here provide some ambiguity, the use of these zone designations is generally consistent with those used to describe marine systems elsewhere (Spalding et al. 2007); clear linkage to habitat association and ecological processes (Jodice and Survan 2010, Jodice et al. 2013). Refer to Jodice et al. (2019), for associated uncertainties related to management actions and ecological processes for seabirds in the Gulf.

1.1 Regulatory Nexus and Project Goals

The U.S. Fish and Wildlife Service (USFWS), as part of the agency's mission, seeks to minimize, reduce, and mitigate effects to migratory birds (USFWS has Trust Resource responsibility) while simultaneously acquiring data to better inform energy development planning and decisions in the northern Gulf.

Executive Order (EO) and the USFWS-MMS Memorandum of Understanding (MOU) provide additional regulatory guidance per the Migratory Bird Treaty Act (MBTA; 16 U.S.C. 703 et seq). In comparison to the other BOEM OCS regions, the number of studies specifically targeting migratory bird resources in the Gulf has been limited [but see Russell (1995), Lamb et al. (2020b)]. At the same time, there currently are no mitigations, stipulations, or policies in place specifically to reduce, minimize, mitigate, or eliminate take of migratory birds related to offshore energy development, including oil and gas (O&G) development (refer to BOEM 2012, 2013). This seems contrary to information needs (refer to Michael et al. 2022) given the long history of O&G activity in the Gulf and the fact that O&G activity (exclusive to the OCS) in the northern Gulf exceeds all other BOEM Administrative regions combined. The lack of available baseline data, particularly for seabird species composition and at-sea distribution and abundance is particularly salient as it relates to offshore energy development (both O&G and offshore wind-energy development [OWED]) in this region.

The goal of this study was to collect broad-scale data on the distribution and abundance of seabirds in the northern Gulf to inform seasonally- and spatially explicit density estimates for priority seabird species. Seabird data collected and analyzed in this report should provide information at regional, planning area, and project- or site-level spatial scales (e.g., Schneider and Duffy 1985, Schneider and Piatt 1986, Fauchald and Erikstad 2002). Though there is some spatial overlap in aerial and vessel survey coverage, in general, aerial surveys were limited (out to 50 nm) to nearshore, shallower waters (\leq 200 m) on the Continental Shelf, whereas vessel surveys included deeper waters on and off the Continental Shelf out to the EEZ. As it relates to current and future offshore O&G planning, results from this study should be valuable to BOEM for informing National Environmental Policy Act (NEPA) analyses (e.g., Environmental Impact Statements, Environmental Assessments), Exploration Plans (EP), Development Operations Coordination Document (DOCD), oil spill risk assessment (OSRA) models, as well as for formal and informal Endangered Species Act (ESA) Section 7 consultations. Lastly, results from this study should greatly reduce uncertainty (refer to Jodice et al. 2019:tables 6.2–6.3) related to seabird distribution and abundance as it relates to future renewable energy planning and development in the OCS of the northern Gulf (e.g., Musial et al. 2020).

2 Study Area

2.1 Gulf Habitats, Physical Oceanography, and Planning Areas

A detailed overview of the bathymetric and mesoscale oceanographic features in the northern Gulf by BOEM planning area is provided here (refer to Figure 2.1) as it is thought that these features play a major role in determining at-sea distribution and abundance of seabirds (e.g., Haney and McGillivary 1985, Ribic et al. 1997, Poli et al. 2017). As such, we have included a short description of physical and oceanographic features considered unique to each of the three respective planning areas.

Excepting hurricanes, tropical storms, and other severe weather events, the Gulf has a distinctively lowenergy coastline, with non-storm wave heights on the order of only 0.3 m (NASEM 2018). Compared to the North Atlantic Ocean, tidal fluctuations in the Gulf are weak across the low-gradient environments of all three BOEM planning areas. The northern Gulf is generally considered a low wave-energy, micro-tidal region having an average wave height and tidal range on the order of 0.5 m and less than 1 m, respectively (Passeri et al. 2016). Coastlines between Apalachicola Bay, Florida and Louisiana have principally diurnal tides, with one high tide and one low tide per day. Along the Texas coast, tides are mixed diurnalsemidiurnal, with two high and two low tides per day. Semidiurnal tides prevail from Apalachicola Bay southward down the west Florida coast (Kantha 2005).

The Western Planning Area (WPA) has a moderately wide continental shelf that narrows as it first curves to the southwest and then bends south. The continental shelf of the WPA lacks any deeply incised subterranean canyons. This planning area is notable for having a coastal, inner- shelf current regime that runs strongly upcoast (Rio Grande toward Mississippi River) during the summer, and downcoast during other seasons (Morey et al. 2005). Consequently, upcoast- favorable Eckman transport leads to higher salinities and coastal upwelling on the WPA's inner shelf during warmer months. Currents at and near the shelf break are more variable by season, but still predominantly upcoast throughout the year, likely being reinforced by anticyclonic eddies (or warm-core rings, WCRs) that intermittently reach and collide with the shelf edge (Vidal et al. 1992, Nowlin et al. 2005). Temporally stochastic propagation of Loop Current (LC) WCRs into the WPA from further east (Schmitz 2005) tends to follow one of three characteristic paths across the Gulf (Vukovich and Crissman 1986). WCRs move through the WPA most often using the central path (i.e., a trajectory between 24° and 26°N latitude), after decreasing to about 55% of their initial shedding size by the time they reach the Gulf's western shelf break. Average periodicity for WCR separation from the LC is on the order of 11 months, with a range from 5 to 19 months (Vukovich 2007). The WPA is notable for serving as the "eddy graveyard" for WCRs that originate from this LC shedding (Biggs et al. 1996).

The Mississippi River is the dominant force controlling most aspects of the oceanography in the Central Planning Area (CPA). Draining 42% of the continental area of the United States, the river has an annual discharge of ~19,000 m³ s⁻¹ (Wiseman et al. 1997). Nutrients and sediments from this discharge enhance primary productivity, and consequently elevate the abundance of zooplankton and larval fish (Govoni 1997, Grimes and Finucane 1991, Grimes 2001, Dagg and Breed 2003). Inter-annual variability in the discharge of the Mississippi also drives the demographic recruitment of adult fish (e.g., Vaughan et al. 2011). The continental shelf in the CPA is moderately wide and relatively straight. But near the Mississippi Delta, the shelf is quite narrow, with the rather large and incised Mississippi Canyon also located just to the west of the delta. Outer shelf and deepwater areas are usually only moderately affected in direct fashion by frontal dynamics of the main LC, especially in the more western sections of this planning area. At times, however, clear, and warm LC-influenced waters may come very near the coastline in the vicinity of the delta. Every two years or so, the LC penetrates much further into the Gulf to reach a maximum northward location (Leben 2005). On such occasions, substantial amounts of low-salinity, high-chlorophyll Mississippi River water becomes entrained into the LC's frontal regions, and

then transported clockwise and off the continental shelf margin toward the east and south (Walker et al. 1994). On a more consistent temporal basis, eddies shed by the LC can strongly influence this planning area's outer shelf/upper slope current regime. Along with freshwater discharge and a wind regime that is dynamic on both synoptic and seasonal time scales, the along-shore currents in the CPA are complex. Nevertheless, coastal currents in the CPA are influenced by a combination of inputs from low-salinity river discharge, eddy shedding, and synoptic winds. The CPA's LA-TX Coastal Current (LTCC) is responsible for distributing freshwater, sediment, and nutrients along the continental shelf mostly towards the west of the delta (Jarosz and Murray 2005). This current typically flows downcoast, i.e., westward in fall, winter and spring, but it reverses and moves upcoast toward the east during summer. At a narrower spatial scale, the LTCC circulation pattern on the inner shelf (<50 m in depth) is driven predominantly by winds in the weather band (5-10 days), whereas on the outer shelf circulation is more influenced by meso-scale processes (Nowlin et al. 2005).

The Eastern Planning Area (EPA) possesses a relatively simple sea floor geometry with a very wide continental shelf having a gentle slope, especially off peninsular Florida (Weisberg et al. 2005). Outer shelf and deeper waters in this portion of the Gulf are strongly dominated by frontal and temporal dynamics of the LC. The EPA is under especially strong influence of frontal eddies as well as the cyclonic and anti-cyclonic rings that separate from the main current (e.g., Oey et al. 2005). In considerable contrast to the WPA, cyclonic eddies (cold-core rings, CCRs) are most often found in this lease planning area, with their frequency of occurrence here surpassing that of WCRs anywhere else in the Gulf (Vukovich 2007). In deeper portions of the EPA, anomalous northward penetrations of the LC into the Gulf occur when the eastern side of LC is positioned west from the southwest corner of the west Florida shelf, whereas a more direct inflow (from the Yucatan Channel) to outflow route (via the Florida Straits) occurs when the eastern side of the LC comes in contact with the southwest corner of the west Florida shelf (Weisberg and Liu 2017). Inner shelf circulation in the EPA is predominantly upwellingfavorable from fall to spring months (October-April), but down-welling conducive during the summer months (June- September) (Liu and Weisberg 2012). At any time of year and depending on prevailing surface currents/or synoptic winds (including hurricane passage: Liu et al. 2018), the west Florida shelf may experience intrusion-type upwelling as subsurface, nutrient-rich waters are pumped up onto the shelf after surface waters are displaced offshore. Strong freshwater inputs into the EPA originate from the Mississippi River outflow during spring, and from south Florida and the Everglades during summer. Thus, a low-salinity tongue of surface water can regularly extend southeast from DeSoto Canyon along the eastern edge of the LC during the summer months (Morey et al. 2005). More locally within the EPA, an extensive region north of the Keys and southwest of Tampa Bay is notable for its productive outer shelf and upper slope waters that consistently harbor large schools of pelagic schooling tuna. Part of these "tuna grounds" feature quasi-stationary cyclonic eddies at the northern edge of the Florida Current near the Dry Tortugas (Fratantoni et al. 1998). Another feature within the EPA, the DeSoto Canyon off the Florida panhandle, has some of the Gulf's most complex bathymetry. Here eddies with diameters ranging from 50 to 130 km interact with buoyant freshwater plumes and effectively entrain riverine discharge to mix with more oceanic waters (Schiller et al. 2011). The highly varied currents that are observed at DeSoto Canyon, along with warm filaments, LC eddies, and sometimes the outer frontal boundary of the LC itself, all serve to enhance marine productivity and facilitate conditions that elevate or localize pelagic marine life. An eastward jet and anticyclonic currents also promote upwelling at the head of this canyon and the nearby shelf break such that surface waters in the vicinity of the canyon are 2°C colder on average (Hamilton and Lee 2005).



Figure 2.1. Study area map of the northern Gulf including Texas, Louisiana, Mississippi, Alabama, and Florida.

This map shows state boundaries with major coastal cities in each state, BOEM planning area boundaries, oil and gas platforms (represented by black + symbols), and the EEZ boundary with 200-m and 2000-m isobaths. Please refer to text for more details.

2.2 Historical Seabird Surveys

2.2.1 Gulf of America Seabird Surveys (1979 – 1989)

One of the earliest efforts to conduct coordinated surveys for seabirds, marine mammals, and sea turtles was that by Fritts and Reynolds (1981), covering portions of the OCS along the northern Gulf coast. Aerial surveys were conducted from August to December in 1979. Surveys were flown along 111-km and 222-km survey segments extending perpendicular to the coast at 2 sites each in Texas (Brownsville and Corpus Christi) and Florida (Tampa and Naples). Only 14 species of birds were identified, with royal tern being the most abundant; more birds were counted near- as compared to farther offshore.

This effort was followed-up by a more extensive aerial survey effort by Fritts et al. (1983). Their methodology generally appeared to mirror that of Fritts and Reynolds (1981) except that in the follow-up monitoring they surveyed out from Brownsville, Texas, Marsh Island, Louisiana, Naples, Florida, and Merritt Island, Florida. Surveys were conducted from May 1980 to April 1981. These surveys resulted in identification of 68 species representing ~16,800 individual birds. Species diversity was relatively similar among sites, but the number of total birds was highest for transects off the coast of Louisiana (n = 6,698), as compared to either Texas (n = 2,246) or the 2 sites (Naples; n = 5,170; Merritt Island; Florida n = 2,708) in Florida (refer to Burger 2017:table 12.13). The most abundant species were royal tern, laughing gull, and herring gull. Until more recently (Section 2.2.3 below), this early survey represents one of the most comprehensive data sources for pelagic seabird distribution, abundance, and seasonality for the northern Gulf (but refer also to Clapp et al. 1982a, 1982b, 1983).

2.2.2 Gulf of America Seabird Surveys (1990 – 2009)

As part of GulfCet I program (Davis and Fargion 1996), surveys were conducted from several NOAA vessels (Hansen et al. 1996:table 3.5) from 15 April 1992 to 10 June 1994. Survey coverage was bounded on the east by the Alabama-Florida line and on the west by the Texas-Mexico border, encompassing waters between the 100-m (northern boundary) and 2000-m (southern boundary) isobaths. In total, GulfCet I completed 21,350 km of transects during the 30-month study period. Survey effort differed by season: spring = 13,507 km, summer = 2,085 km, fall = 1,275 km, and winter = 4,483 km. Seabird observers only participated in 9 of the 11 cruises (R/V *Oregon II* and R/V *Pelican*) resulting in roughly 160 days-at-sea (DAS) and 20,413 km of transects (Peake 1996). Seabird surveys resulted in \sim 3,000 birds observed representing 32 estuarine, coastal, offshore, and pelagic bird species with 14 of the species accounting for \sim 99% of the total individual birds observed (Peake 1996). For more detailed analyses of seabird data from GulfCet I cruises, refer to Ribic et al. (1997).

As part of the GulfCet II program (Davis et al. 2000), three seabird surveys were conducted during cruises in the northern Gulf from April 1996 to August 1997 (Hess and Ribic 2000). These surveys occurred aboard two NOAA vessels (R/V *Gyre* and R/V *Oregon II*) and encompassed spring, mid-summer, and late summer periods. Spatial coverage included waters of the northern slope and oceanic Gulf, northeast Gulf shelf and slope waters, and the central pelagic and northeastern continental shelf and slope. Seabird survey effort resulted in 77 DAS representing in 10,916 km of transects (Hess and Ribic 2000). The spring survey resulted in ~5,900 birds observed representing 22 species (Hess and Ribic 2000:table 8.2) and the mid-and late-summer surveys resulted in a combined ~2,500 birds observed representing roughly 27 species (Hess and Ribic 2000:table 8.4).

2.2.3 Gulf of America Seabird Surveys (2010 – 2011)

As part of the *Deepwater Horizon* post-spill injury assessment, seabird observers logged 285 DAS from July 2010 to July 2010 (*Deepwater Horizon Bird Study* #6; Haney 2011). Vessel-based surveys were

conducted throughout the year, except January, with the greatest effort in late summer to early fall.

Coverage was extensive and included survey effort in both continental shelf waters and deeper waters off the continental shelf. Survey coverage included continental shelf waters from central Texas, Louisiana, Mississippi, Alabama, and west Florida resulting in >5,000 transects totaling >15,000 transect km. An additional 386 'point counts' representing >340 hr of survey effort also occurred (Haney 2011). Overall, surveys resulted in ~23,000 individual birds observed representing 45 estuarine, coastal, offshore, and pelagic bird species (Haney et al. 2019:table 2). For more details regarding post-spill vessel-based seabird surveys, refer to Haney et al. (2019) and associated tables (e.g., Tables 1 and 2) and figures (e.g., Figure 1) therein. The *Deepwater Horizon Bird Study* #6 is one of the most extensive seabird vessel survey efforts (i.e., 285 DAS, ~950hr on transect) ever conducted in the northern Gulf (Haney et al. 2019:table 1 and fig. 1), and the total # of birds encountered exceed the combined totals of all previous standardized, formal seabird studies ever conducted. For comparative purposes between *Deepwater Horizon Bird Study* #6 (May 2011) and GOMMAPPS (May 2017), refer to Haney et al. (2019:table 3). Refer to Section 5.1.3 (refer also to Table 5.10) below for more comparative results between the *Deepwater Horizon Bird Study* #6 and GOMMAPPS.

As part of the Deepwater Horizon post-spill injury assessment, aerial seabird observers logged 75 survey days from 4 May 2010 to 26 February 2011 (Deepwater Horizon Bird Study #2; Ford 2011). Aerial surveys initially focused on the area between Galveston, Texas to the Florida panhandle, then was expanded to include entire Florida Gulf coast down to and including the Dry Tortugas. However, the focal area was later contracted to focus survey effort in the core area of the spill. Surveys were performed primarily from a fixed-wing Partenavia P68, except in one instance where a Quest Kodiak equipped with amphibious floats was used. Surveys were typically flown at an altitude of ~200' asl (above sea- level) at a speed of 90 to 100 knots. The flight crew consisted of the pilot, a navigator/data recorder, and two observers. Aerial surveys consisted of a combination of random and stratified zigzag pattern of transects between the shoreline and barrier islands (out to ~ 8 km, in the absence of barrier islands), as well as longer offshore linear transects extending out to ~161 km. Aerial surveys covered a total of 96,199 km and observers counted roughly 1 million individual birds (refer to Table 3 in Ford 2011). The 5 most numerous taxonomic groups or species of birds were, in order: terns, gulls, Brown Pelicans, shorebirds, and cormorants. Seasonal and species-specific information, as well as additional level of details per relative abundance can be found in Ford et al. (2014). Though there were numerous Deepwater Horizon post-spill injury assessment studies for birds, those specifically cited here are the most germane to GOMMAPPS.

The seabird surveys included herein are not meant to be an exhaustive list of all such efforts ever conducted in the northern Gulf, and it does not include survey efforts in the southern Gulf (Tunnell and Chapman 2000). What is clear from this review of seabird surveys in the Gulf is that seabirds are an important natural resource in the region, that seabirds remain understudied, and that our understanding of their distribution and abundance (and the physical and biological variables driving distribution and abundance, e.g., Ainley et al. 2005) is limited. In addition, some clear spatial and temporal patterns specific to vessel-based seabird surveys tend to be indicative of spatio-temporal gaps in survey effort (but refer also to Haney et al. 2019:fig. 1). In general, the October - March period remains poorly sampled overall, and the June through September timeframe is only modestly represented among and across all vessel surveys (even including GOMMAPPS; refer to Section 4.0 below). Using information on seabird survey effort/mo from these existing surveys overlain on BOEM's planning areas, and the following quarterly breakouts: March - May, June - August, September - November, and December - February, the following patterns emerge. For the December – February there is no effort in the northern portions of either the WPA or EPA and there is no survey effort in the northern portion of the WPA in March – May. Survey effort is considered low in the northern portion of the EPA in March – May, low in the northern portion of the EPA and WPA in June – August, low in the southern portion of all three planning areas in September – November, and low in the northern portion of the CPA and in the southern portion of the

EPA in December – February. Until the more contemporary seabird surveys like *Deepwater Horizon Bird Study #6* (Haney 2011) and GOMMAPPS, survey effort has not provided adequate coverage through space and time. Even after the *Deepwater Horizon Bird Study #6* (Haney 2011) and GOMMAPPS (2017 – 2020) seabird surveys, spatial and temporal coverage gaps remain. Before these more recent seabird surveys, the largest temporal gaps included the fall and winter seasons and spatial gaps, particularly in the fall/winter, included deeper waters off the continental shelf from the shelf break out to the EEZ. Potential options for filling the remaining spatial and temporal data gaps are provided in Sections 6.3 and 6.4 below.

3 Aerial Seabird Surveys

3.1 Data Collection Schedule

GOMMAPPS seabird aerial surveys were initiated in summer of 2017 with a pilot field season to

compare traditional transect survey design versus the use of Environmental Protection Agency 40 km² hexagon, plot- based survey design (refer to Sections 3.1.1 and 3.2.1 for additional information). The USFWS and the seabird aerial survey science team decided there was a greater need for data during the winter period due to: (1) far less seabird data exist for this seasonal period compared to the spring/summer period; (2) USFWS aircraft, pilot-biologists, and observer availability would be limited due to potential conflicts during the spring/summer period due to the annual Waterfowl Breeding Population and Habitat Survey; and (3) most species of seabirds are at nesting colonies along the northern Gulf coastline during the spring/summer period, thus increasing potential for zero-inflated data, particularly as distance away from a given colony increases. Beginning in 2018, the 3 aerial surveys completed were all conducted during winter: 31 Jan – 27 Feb 2018, 24 Feb – 9 Mar 2019, and 1 – 12 Feb 2020 (Table 3.1).

Table 3.1.Summary of aerial seabird survey effort by year and season including number of hexagonssampled, proportion (%) of hexagons sampled, number of transects within hexagons sampled, and distance(km) flown while on transect within hexagons as part of the GOMMAPPS, 2018 – 2020.

When	Target # of hexagons	# of actual hexagons surveyed	Proportion target hexagons surveyed	# of transects surveyed	Kilometers surveyed (~60.35km/hex)
Summer 2018	180	180	100%	540	10,863
Winter 2018	180	179	99.4%	537	10,802.7
Winter 2019	180	111	61.7%	333	6,698.9
Winter 2020	180	130	72.2%	390	7,845.5
All seasons	720	600	83.3%	1,800	36,210.1

3.1.1 Aerial Survey Spatial Coverage

3.1.1.1 2017 Pilot Field Season: Transects versus 40 km² hexagons

Aerial survey coverage for 2017 was restricted or limited to near-and offshore waters out to 50 nm. In general, aerial survey coverage primarily included shallower waters of the continental shelf roughly approximating the 200-m isobath. Staff from USFWS completed seabird surveys off the coast of Louisiana (based in Houma) to test two survey designs and sampling protocols (refer to Section 3.1.2 below). Surveys were conducted using two USFWS Kodiak amphibious aircraft, with surveys spanning the Louisiana coast from Texas to the Alabama state line and offshore to circa 50 nautical miles. Over the course of seven days, 55 of 60 transects and 48 of 60 hexagons were surveyed (Figure 3.1a).

Beginning with the summer 2018 aerial survey, a hexagon-based study design (n = 180 hexagons) was adopted for all USFWS GOMMAPPS seabird aerial surveys (Figure 3.1b). Two survey crews (Eastern and Western) flew surveys via two USFWS Kodiak amphibious aircraft (except winter 2020 surveys). Prior to conducting aerial surveys, pilots and seabird observers conducted pre-flight meetings, conducted safety briefings, reviewed training materials for identification of seabirds, sea turtles, and marine mammals, tested all the aerial survey-related equipment, and got assigned crew-specific survey block maps and replacement hexagons (if needed). The study area roughly spanned from Brownsville, Texas E-SE down to the Florida Keys. Starting points for each of the respective crews differed depending on survey year, as did the number of target hexagons sampled. It should be noted that the USFWS-USGS-MSU aerial survey science team had complete autonomy and flexibility related to study design, i.e., transects vs. hexagons, timing of surveys, testing and employing double-observer survey protocols, etc. (Section 3.1.2 below).

3.1.1.2 2017 Aerial Surveys (Pilot Study)

Aerial surveys are typically flown along transect lines with birds counted on either side of the aircraft (e.g., USFWS 2015). However, observed individuals are typically associated with the entire transect length, even if the transect intersects multiple habitats, thereby making analysis with finer-scale habitat parameters difficult. The solution often includes a subjective, post-hoc delineation of transects into shorter distance transect segments to facilitate modeling at finer spatial resolutions (Svancara et al. 2002). This approach may result in potential analytical issues such as: (1) unequal sample sizes of segments by habitat(s), (2) the proliferation of zero counts due to breaking long transects into shorter transect segments, and/or (3) if transect segments are not defined by habitat boundaries, birds that are found in different habitats may be assigned to the same sample unit, thereby confounding statistical analyses (Wiens 1989, Karl and Maurer 2010).

Although the USFWS pilot-biologists have a long-history of flying low-level (~60 m above the water) aerial bird surveys over land and the nearshore environment (<10 nm from shore), these same pilot-biologists have limited experience with the deployment of low-level aerial surveys in offshore waters (>10 nm offshore) in the northern Gulf. Given the height of some oil and gas platforms (~120 m above the water) and the density of platforms (2,000 active leases and ~1,600 O&G platforms; OCS only, BOEM 2023) in the northern Gulf, there are several perceived limitations to flying standard transects (i.e., need to deviate off-transect to navigate around platforms in a safe manner and/or to accommodate low-level oil and gas support helicopter traffic).



Figure 3.1. Sampling design used for the USFWS aerial surveys (2018 – 2020) using Environmental Protection Agency 40 km² hexagons including Texas, Louisiana, Mississippi, Alabama, and Florida state boundaries.

BOEM planning area boundaries are identified by thick white lines with 200-m isobath shown as black dotted line and 2000-m isobath shown as black dashed line. Plate a on the left represents the planned survey area between ~10 nm and 50 nm (identified by salmon-colored area). Plate b on the right depicts the random selection of 180 survey plots (hexagon clusters) within the ~10 nm and 50 nm survey area. Please refer to text for more details.

To evaluate different survey methodologies, we tested linear transects (20 nm) arranged perpendicular to the shoreline versus a hexagonal shaped transect (20 nm) during the summer of 2017 (July 5-July 15) off the Louisiana coast (based out of Houma, Louisiana). We chose hexagons because of their low perimeter-to-area ratio which reduces sampling bias related to edge effects (Birch et al. 2007). Further, any point inside of a hexagon is closer to the centroid of the hexagon than any given point inside an equal-area square or triangle. The latter is important because covariate data is often collected or summarized for the centroid of the sampling unit (Birch et al. 2007).

Additionally, there is a need to better understand the most appropriate means of accounting for detection probability issues and observer bias associated with conducting aerial seabird surveys, thus, we also incorporated a double observer protocol. Hence our objectives were to: (1) compare hexagon plot-based sampling vs. transect sampling; (2) explore feasibility of using a double-observer protocol to account for both observer bias and estimate species-specific detection probabilities; and (3) ensure all Standard Operating Procedures and Protocols are functioning properly (e.g., data recording, data management, data storage, aviation training, etc.).

Hexagon-based Design: The Environmental Protection Agency 40 km² hexagons were overlaid across the entirety of northern Gulf and clipped to the study area (coastal Louisiana). Using the centroid of each hexagon, we used ArcMap to select the six nearest neighbors to create a cluster of hexagons and assigned the density of active platforms to each cluster of hexagons (Figure 3.2a). Using a Generalized Random Tessellation Stratified (GRTS) sampling scheme (Stevens and Olsen 2003), 60 hexagons were selected using platform density and distance to shore as sampling strata. A "transect" was flown along a line that passed through the centroid of the respective hexagons that encompass the selected area (Figure 3.2b). Each "transect" was ~11.5 nm in length. Flight direction of hexagons was alternated between clockwise and counterclockwise direction to ensure observers on both sides of the aircraft were subjected to the same observational conditions. This approach allows for a "plot-based" survey, which allows for continuous counting if the aircraft needs to deviate from transect due to interactions with platforms or other air traffic (i.e., bird density will be calculated for the plot area).

Transect Design: Forty nm transects starting at the state-federal water interface (~10 nm from shore) were generated every 1 km for the entirety of the northern Gulf and clipped to the study area (coastal Louisiana). Transects were then divided into two, 20-nm segments. Each transect was buffered 500 m on either side and assigned a density of active platforms within the buffered area. Using a Generalized Random Tessellation Stratified (GRTS) sampling scheme, 60 transects were selected using platform density and distance to shore as sampling strata. (Figure 3.3).



Figure 3.2. Sampling design employed for the USFWS aerial surveys using Environmental Protection Agency 40 km² hexagons during the 2017 pilot field season off the Louisiana coast.

Plate A (top plate) depicts attribution of individual hexagons based upon the density (warmer colors = more platforms) of active oil and gas platforms for individual hexagons within the survey area (~10 nm from shore to 50 nm survey area boundary identified by red lines). Plate B (bottom plate) depicts a close-up view of selected "plots" to be surveyed based upon nearest neighbor algorithm (selection of six nearest neighboring hexagons in teal); red hexagon depicts approximate flight path within each "plot". See text for more details.



Figure 3.3. Planned USFWS aerial transect surveys during the 2017 pilot field season off the Louisiana coast near the Mississippi River mouth.

Turquoise transects represent those lines selected and the gold lines represent the northern and southern boundary of the study area (\sim 10 nm – 50 nm from shore). In 2017, all aerial surveys were flown off the Louisiana coast to evaluate plot-based survey design versus traditional transect-based survey design in a high-density platform area with high oil and gas support activity, i.e., relatively high number of daily helicopter flights.

Double Observer Protocol: An unreconciled double observer protocol was used, whereby each observer recorded birds seen independently from each other and no attempt is made to reconcile between specific individual observations. With three observers in addition to the pilot-biologist who also served as an observer, there were six seat combinations (Figure 3.4). Because the pilot does not rotate, we have an unbalanced panel-design. Thus, observers switched seats mid-day and again at the beginning of next day to ensure adequate samples from each seat assignment (right- front; right-rear; and left-rear).

P 1	P 1	P 2	P 2	P 3	P 3
32	23	13	31	21	12

Figure 3.4. Six boxes representing the seat rotation as part of the double observer protocol used during USFWS aerial surveys.

In each of the respective boxes, P represents the pilot (does not rotate); and numbers 1 through 3 represent each of the observers that rotate seat positions.

Survey Design: All surveys were flown using two USFWS Kodiak Quest amphibious aircraft at an altitude of 61 m (200 ft) and airspeed of 110 kt (~126 mph) (Figure 3.5). Observers were ranked based upon experience (1-2-3-4-5-6) and divided into two crews: crew #1included observer ranks of 1, 4, and 5; crew #2 included observer ranks of 2, 3, and 6. Observers recorded detections from the observable portion of the plane up to 200 m out, on either side of the aircraft. The wings of the plane were marked such that observers could denote the edge of the transect (Figure 3.5). Crews alternated flying transects and hexagons (Day 1: crew #1 flew transects and crew #2 flew hexagons; Day 2: crew #1 flew hexagons and crew #2 flew transects; and so forth).



Figure 3.5. Depiction of USFWS aircraft flying at ~61 m (200') showing the visible strip width of 200 m out the left-hand side of the aircraft (as the aircraft approaches).

Figure adapted from Certain and Bretagnolle (2008).

3.1.1 2017 Aerial Survey Results

During the 2017 pilot season to compare the two survey designs, 56 of the 60 transect lines were flown, but only 49 of the 60 hexagons were completed. Uncompleted surveys were the result of weather conditions and unforeseen logistical issues (e.g., there is no jet fuel available in Venice, Louisiana (mouth of the Mississippi River) thereby forcing crews to travel several miles inland to refuel). This, coupled with budgetary constraints, forced us to make tough decisions (i.e., is it worth flying 50 nm offshore to survey one, 40 km² hexagon?). Nevertheless, sufficient data were collected to evaluate the two methodological approaches. Overall, the proportion of hexagons with birds (0.78) was greater than transects (0.64) (Table 3.2), as well as yielding more overall bird detections by species or species group (Table 3.3).

In the 2017 GOMMAPPS pilot survey, approximately 46% of observations recorded by one of the double observers were missed by the other (Table 3.4: No Match). Of the missed observations, most were single birds (88%; n = 68 of 77 total No Match records). Frequency of missed observations decreased with increasing flock size. Eight of the 77 No Match records were for flock sizes of 2-5 birds, and only one of the No Match records was for flock sizes >5 birds.

Table 3.2. Summary comparison of two aerial survey designs: 3-hexagon cluster versus standard line transects during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana Coast.

	Hexagons	Transects
Number completed	49	56
Proportion with birds	0.78	0.64
Number of bird 'species'	7	7
Proportion with birds: LR	0.75	0.54
Proportion with birds: RR	0.55	0.37

All surveys were flown out of Houma, Louisiana from 5 to 15 July.

Table 3.3. Summary comparison (based on species counts) of two aerial survey designs: 3-hexagon cluster versus standard line transects during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana Coast.

All surveys were flown out of Houma, Louisiana from 5 to 15 July. Species acronyms are defined in Table 5.6a.

Species	Hexagons	Transects
TERN	282	102
ROYT	43	17
GULL	147	21
LAGU	40	12
BRPE	60	61
MAFR	33	20
NOGA	1	0
STRM	0	2

Frequency of missed observations also differed between the two flight crews with 59% of records classified as No Match for one crew and 26% of records classified as No Match for the other. These results suggest that detection likely varies by individual observer and their seating location. Our "No Match" results include instances when a bird record was available to be counted for one observer and not the other. In some cases, the movement of the plane resulted in birds flushing from the flight transect which could have resulted in them having been recorded by one observer (likely front observer) but missed by the other (likely rear observer). Thus, our results represent a "worst-case scenario" for potentially missed observations between front and rear-seat observers.

Table 3.4. Summary of data matches between two observers recording data on the same side of the aircraft during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana Coast.

Match Category ¹	Count of 2017 Double-Observer Records
Species + Count Match	46
Generic + Count Match	10
Species + Bin Match	10
Generic + Bin Match	4
Species-Only Match	0
Generic-Only Match	0
Mismatch	21
No Match	77
Total	168

All surveys were flown out of Houma, Louisiana, from 5 to 15 July.

1 Match Category: (1) Species + Count Match: count and species identification matched between observer ^{records}. (2) Generic + Count Match: count and taxonomic family matched between observer records, (3) Species + Bin Match: log10 count bin (i.e., 0, 1-10, 11-100, 101-1000, and 1000+) and species identification matched between observer records (after count matches accounted for), (4) Generic + Bin Match: log10 count bin (i.e., 0, 1-10, 11- 100, 101-1000, and 1000+) and taxonomic family matched between observer records (after count matches accounted for), (5) Species-Only Match: species identification matched but neither count nor count bin matched between observer records, (6) Generic-Only Match: species taxonomic family matched but neither count nor count bin matched between observer records, (7) Mismatch: species did not match between observer records, and (8) No Match: there was no observation from the other observer recorded within 10 seconds. For the purposes of this study, the identifications of "gull" and "tern" were included in the species-level identifications described here, and these identifications were pooled under the family Laridae for higher-level generic identifications.

Flock counts varied between double observers, with the magnitude of differences increasing with flock size (Figure 3.6) suggesting that counting errors at large group sizes contribute to differences in count records between double observers. Approximately one-third (33%) of double-observer counts matched exactly (Table 3.4: Species + Count Match and Generic + Count Match categories), and an additional 8% of double-observer counts matched for log10 binned counts (Table 3.4: Species + Bin Match and Generic + Bin Match categories). We compared average double-observer records (number of observations recorded by each observer per hexagon/transect) and counts (count recorded for each observers recorded more observations (and higher counts) than rear observers (Table 3.5). These results suggest that the greater visibility in the front seat position allows front observers. Although differences in detection (missed observations) likely contribute to differences in counts per sampling unit between front and rear observers, counting errors at large group sizes also are likely a factor contributing to the differences in front and rear observer counts.

Although GOMMAPPS survey observers were trained in waterbird species identification, our doubleobserver data indicated that only ~33% of the observations recorded by both observers contained matching species identifications (Table 3.4: Species + Count Match, Species + Bin Match, and Species Only Match categories). In addition, GOMMAPPS observers had difficulty discerning individual gull and tern species due to their small body sizes, speed of the aircraft, and often indiscernible features (e.g., similar plumage characteristics, body-size, or bill shape); thus, higher-level gull and tern identifications (e.g., gull, tern, or larid spp.) were used when definitive species identifications could not be made.

Generic identifications, including individuals identified by double-observers as different species within the same taxonomic family (e.g., white-winged scoter [*Melanitta deglandi*] versus black scoter [*Melanitta americana*]) or individuals that were not identified to species-level (except for gulls and terns),
comprised~8% of the total records (Table 3.4: Generic + Count Match, Generic + Bin Match, and Generic Only Match categories). Mismatched records, including individuals identified as different species by the two observers (where taxonomic family also did not match between double observer records), comprised12.5% of the total records (Table 3.4). It is possible that some of these records are likely to be detection errors rather than misidentification errors, as we could not parse-out these two distinct observation error types.



Figure 3.6. Linear regression plot of waterbird counts from front and rear same-side observers during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana coast.

The plot shows that front and rear same-side observers had reasonable agreement when flock sizes were small, but that front and rear same-side observer counts tended to diverge once flock sizes was >20 birds. Please refer to text for more details.

Table 3.5. Mean and standard deviation (SD) for double-observer (same-side front and rear seat positions) number of records and counts of waterbird observations for both hexagons and transects during the 2017 GOMMAPPS summer aerial pilot surveys off the Louisiana Coast.

All surveys were flown out of Houma, LA from 5 – 15 July. NOTE: in all cases, SD is ~2x greater than the mean.

Seat Position	Mean Records	SD of Records	Mean Counts	SD of Counts
Front	3.1	5.3	4.5	9.8
Rear	2.9	5.6	3.9	7.9

Hexagon v. Line Transect Designs: From a logistical perspective, hexagons were more difficult to fly than the traditional straight line transects. Due to the circular nature of the flights, the pilot was continuously making slight turns, which: (1) forced the pilot to pay more attention to flight instruments and the surrounding airspace, thereby reducing their ability to be an observer, and (2) each turn resulted in the aircraft being banked at ~30-45° thereby changing the observational viewshed for all observers. We initially attempted to make the turns at 40-45° degrees to minimize the amount of time observers were "offline", however, some observers suggested these turns were too abrupt, resulting in airsickness. Thus, we settled on a more gradual and gentle turn with slightly reduced turn angle (~30-35°). Nevertheless, observers on the inside of the banked turn were looking straight down, whereas observers on the outside of the banked turn were looking straight up. This scenario likely resulted in potentially available birds that were missed by observers. Even given these unique challenges, hexagons yielded more detections than transects. Hexagon-based surveys detected more individuals and had fewer overall zero counts (i.e., sample units with zero detections) compared to line transects. This is likely the result of birds not being uniformly distributed across the study area. Birds often occur in small to large foraging flocks in open water, as well as flocking during loafing/resting on or near offshore anthropogenic structures (e.g., O&G platforms). While each sampling method covered the same spatial distance (~ 20 nm), the hexagon-based sampling approach covered a smaller, more discrete spatial footprint due to the circular nature, whereas transects had a greater overall spatial footprint due to the straight- line nature. As such, hexagon-based sampling approach appeared to provide an advantage when modeling bird detections against both habitat features and environmental variables (e.g., sea- surface salinity, sea-surface temperature, etc.); more closely approximating the spatial resolution required for modeling.

Based on our 2017 pilot field season, future aerial seabird survey projects might wish to consider using hexagons as a base sampling framework with transects overlain (Figure 3.7). The use of hexagons as a sampling base, facilitates stratification across the entire survey area, as well as allowing researchers to systematically randomize the direction and orientation of the three hexagon transects. In addition, this design should yield the greatest number of detections while also occurring at a spatial resolution that more easily facilitates development of bird-habitat models.

Double-Observer Approach: The double-observer surveys revealed differences in the data collected by same-side front and rear seat observers. Non-detection errors, or missed observations, were most likely to occur when flock sizes were very small or for single birds. Single-bird observations are more likely during the summer months when target species of waterbirds are breeding (the period when our pilot survey occurred). Additional double-observer surveys are needed during the winter months, when waterbirds are more likely to aggregate in large flocks at-sea, to determine if the magnitude of non-detection errors varies as a function of seasonal differences in bird behavior. Although non-detection likely contributed to the differences between double-observer counts recorded per sampling unit, our results indicate that counting errors, particularly for group sizes >30 birds may also contribute to observer surveys that includes variable, but generally larger flock sizes would be useful to assess whether potential

counting errors continue to increase as a function of flock size or whether such errors reach an asymptote at a given number of birds.



Figure 3.7. Depiction of USFWS aircraft flying 3, ~11.5 km transect segments (red lines) within a 'cluster' of 3, 40 km² hexagons (blue outline) with arrows on each end representing turns to go back on transect within the hexagon 'cluster'. Please refer to text for more details.

Species identification, particularly for small-bodied and species with similar plumage color, proved extremely difficult for our observers. Gulls and terns, which were the most difficult to identify, made up most of the pilot survey data. The northern Gulf is an overwintering destination for a diverse suite of waterbird species (refer to Appendix A; Michael et al. 2023), and although gulls and terns are still prevalent during the winter months, there tended to be a greater diversity of waterbird species available to aerial seabird observers during the fall-winter period. In addition, many of these species have gone through molt, and most individuals of a given species are present in their non-breeding plumage, making species identification for wintering gulls and terns much more challenging. Additional double-observer data collected during winter surveys could elucidate whether there are seasonal patterns in misidentification errors that change because of species composition in the Northern Gulf. Gaining a better understanding of the potential sources of bias (refer to Davis et al. 2022) that we found in our pilot survey data is not only useful for our analyses of the GOMMAPPS aerial survey data but would also elucidate potential issues with future aerial surveys.

The double-observer data from our pilot survey season allowed us to reveal potential sources of bias in aerial survey data. We identified issues of non-detection [(for single birds) and counting errors (for groups >30 individuals)] and species misidentification errors (for small and similarly colored species). Although we cannot discern the true extent to which these errors may bias inferences from aerial survey data (because we do not know the true values for presence, species identification, and number of birds), the double-observer method is a useful tool to evaluate potential sources of bias (and detection rate, e.g., Koneff et al. 2008). Through continued use of the double-observer method during 2018 - 2020 GOMMAPPS aerial surveys, we were able to assess the sources of error we identified in our 2017 pilot study in much greater detail (more robust and representative sample) over a large range of conditions (e.g., cross-seasonal effects, larger range of available flock sizes, different species composition). Refer to Davis et al. (2022) for additional details regarding analyses of the 2018 - 2020 GOMMAPPS double-observer methodology used here.

3.1.2 2018 - 2020 Aerial Surveys

Using information learned in the 2017 GOMMAPPS pilot aerial surveys (Section 3.1.3), we randomly selected survey units from the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (U.S. Environmental Protection Agency; EMAP) 40 km² hexagon grid dataset (White et al. 1992) using a generalized random tessellation stratified (GRTS) design (Stevens and Olsen 2003) that covered the nearshore environment (coastline to 50 nm offshore) between the Texas-Mexico border and the Florida Keys (Figure 3.8). Surveys of each hexagon occurred along three parallel ~11.5 km transects spanning the length of the selected hexagonal survey unit and two neighboring units. We also randomized orientation (approach direction) of each of the chosen units. Observers surveyed the same 180, 40 km² hexagonal units (or a subset of these) in each season (2018 – 2020) after the pilot survey (2017). In-flight observers counted and identified (to the lowest taxonomic level) all birds within a 400- m strip transect (200 m on either side of the transect) (Certain and Bretagnolle 2008) (Figure 3.8). Surveys were flown at an altitude of 61 m and a ground speed of 110 knots.

To examine detection errors, data were collected with an unreconciled double-observer protocol where same-side front- and rear-seat observers independently recorded count and species identification records of all marine birds in the observation strip (flight transect out to 200 m) (Certain and Bretagnolle 2008). Two observers (pilot and a crew member) were always stationed in the front seats of the plane, and the second observer for the double-observer protocol sat in a rear seat either behind the pilot or behind a crew member. Crew members other than the pilot (two per plane) rotated their seat positions throughout the survey so crew member detection could be evaluated independently of seat position. All observers (pilot and crew members) marked each observation with a GPS unit and recorded count and species identification records. During post hoc data processing, we grouped double-observer records that were recorded within 10 s of each other. This 10 s window limited double-observer records to those most likely to contain matching records. These grouped double observer records were then classified as: Perfect Match - count and species identification matched between observer records, Perfect Generic Match count and taxonomic group matched between observer records, Species Match - species identification matched but count did not match between observer records, Generic Match - species taxonomic group matched but count did not match between observer records, Mismatch - species and/or species taxonomic group did not match between observer records, and No Match - there was no observation from the other observer recorded within 10 seconds. This double-observer protocol and data processing procedure allowed us to identify potential errors, including non-detection, counting error, and misidentification that would not have been possible to assess without a second observer.

Though the target number of sites was established as 180 sampling units across the northern Gulf, the ability to survey all these units was constrained by weather (i.e., fog), distance between and among units, and budget limitations (Table 3.6). Over one summer and three consecutive winters, aerial surveys were completed on 111 - 180 sample units representing 333 to 540 transects within units, ~6,700 - 10,800 transect kilometers covering between 6.6 - 9.2% of the aerial survey study area (Table 3.6). For all aerial surveys, two USFWS pilot-biologists were used (J. Wortham, S. Earsom) (Table 3.7). In all but one aerial survey, USFWS Kodiak amphibious aircraft were used. A USFWS Partenavia aircraft was used in one instance because Kodiak (n736) was not available (Table 3.7). The Partenavia aircraft was used extensively for aerial seabird surveys as part of the Atlantic Marine Assessment Program for Protected Species (AMAPPS). Based on aerial seabird surveys for AMAPPS, it was estimated that front-seat observers had a ~15% increase in detections in the Partenavia as compared to the Kodiak, but that there should be no difference in detections between the two aircraft for back-seat observers. Though we did not explicitly test for between-aircraft differences in detection *per se*, we did include a survey year effect, which should capture any differences.



Figure 3.8. Planned aerial survey plots (n = 180) as part of the GOMMAPPS summer 2018 and winter 2018 – 2020 surveys with map of the US Gulf of America coastline of Texas, Louisiana, Mississippi, Alabama, and Florida.

The inset map (Plate B) shows a close-up view of the 3, ~11.5 km transect segments spaced ~1 nm apart within a 'cluster' of 3, 40 km2 hexagons.

3.2 Characterizing Marine Birds

Seabird observers for aerial surveys recorded all birds, marine mammals, sea turtles, and fishes detected during surveys and identified each to the lowest taxonomic level possible (Appendix A). We classified all identifiable birds as seabirds, raptors (i.e., hawks, falcons, owls, vultures), shorebirds (i.e., plovers, sandpipers, etc.), wading birds (i.e., herons, egrets, etc.), or waterfowl (i.e., ducks) following categories used in Wilson et al. (2019a). For the purposes of this report, seabirds include select species from the Orders Charadriiformes (terns, gulls, skuas, jaegers, and phalaropes) and Pelecaniformes that forage in marine systems during all or part of the year and any members of the orders Phaethontiformes (tropicbirds), Gaviiformes (loons), Procellariiformes (tube-noses), and Suliformes (frigatebirds, cormorants, boobies)². For additional information related to aerial survey species composition, refer to Section 3.5 and Appendix A.

² See <u>https://www.worldbirdnames.org/new/classification/orders-of-birds-draft/</u>

Table 3.6. Seasonal summary of survey effort for GOMMAPPS aerial seabird surveys, 2018 – 2020*.

When	# of Sites Surveyed ¹	Target # of Sites ²	% of Target # of Sites Surveyed ³	# of Transects Surveyed ⁴	Appr. Distance (km) Surveyed ⁵	Total Area (km ²) Surveyed ⁶	% of Study Area Surveyed 7
Summer (2018)	180	180	100.00	540	10,863.07	21,600	9.21
Winter (2018) ^a	179	180	99.44	537	10,802.72	21,480	9.15
Winter (2019) ^a	111	180	61.67	333	6,698.89	13,320	5.68
Winter (2020) ^a	130	180	72.22	390	7845.55	15,600	6.65
Total	600	720	83.33	1,800	36,210	72,000	7.67

* Refer to Table 3.7 for more detailed information related to survey dates, aircraft, pilot, and observers for each of the seasonal surveys. Typically, 2 U.S. Fish and Wildlife Service (USFWS) aircraft with a pilot-biologist and 2 seabird observers were used for each aerial survey.

^a The decision was made to focus aerial surveys in the northern Gulf during the winter period only for several reasons: (1) funding constraints, (2) availability of aircraft and pilots, (3) from a data needs perspective, the USFWS considered the winter period more critical compared to the summer period, and (4) summer survey data collected in summer 2017 indicated clusters of birds in proximity to known breeding colonies along the northern Gulf coast, and thus summer surveys provided relatively limited value of information.

¹ # of Sites (40 km² clusters) Surveyed: varied annually due to budget constraints, distance between completed and remaining sites, as well as weather-related issues, i.e., low-lying fog on- and offshore, Beaufort sea state >5.

² Target # of Sites (40 km² clusters): was established as 180. Refer to Section 3.1.2 for more information.

³ % of Target # of Sites Surveyed = # of sites surveyed/# of target sites; varied annually.

⁴ Number of Transects Surveyed (40 km² clusters): represents 3 transect per site (40 km² clusters), and thus, the total represents the # of sites surveyed x 3. As such, if all 180 sites were flown during a given survey interval, the total # of transects flown would be 540. The # of transects surveyed varied annually.

⁵ Approximate Distance (km) Surveyed: We randomly selected survey units (n = 180 of 5,866 units) from the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (U.S. EPA EMAP) 40km² hexagon grid dataset (White et al. 1992) using a generalized random tessellation stratified (GRTS) design (Stevens and Olsen 2003) that covered the nearshore environment (coastline to 50 nm offshore) from the Texas-Mexico border to the Florida Keys (link <u>here</u>). Surveys of each hexagon occurred along three transects that were parallel to each other, with each ~11.5 km spanning the length of the selected hexagonal survey unit and two neighboring units. Observers surveyed the same 180 40-km² hexagonal units (or a subset of these due to weather constraints or logistical constraints: winter 2018, n = 179; winter 2019, n = 111; and winter 2020, n = 130) in each survey event (single survey season, e.g., winter 2018).

⁶ Total Area (km²) Surveyed: approximate miles surveyed x transect width (400 m). Refer to superscript 5 above for additional details.

⁷ % of Study Area Surveyed: represents the total area of the 180 sites (40 km² clusters) as a proportion of the total study area that extended West to East from near Brownsville, TX to the Florida Keys, and from the coastline seaward out to 50 nm. As such, the # of sites surveyed represented a relatively small, but representative proportion of the overall study area.

	Aircraft Type	Aircraft #	Pilot	Observer 1	Observer 2	Hexagons Surveyed	Transects Surveyed	# Bird Species Observed ¹	Total # Birds Counted ²
Summer 2018	Kodiak	N736	J. Wortham	R. Wilson	R. Wheat	90	270	32	13,361
(11 – 20 Suly)	Kodiak	N708	S. Earsom	A. Sussman	W. Harrell	90	270	25	3,262
Total						180	540	34	16,623
Winter 2018 (31 Jan	Kodiak	N736	J. Wortham	D. Demarest	N. Wirwa	90	270	42	13,019
– 27 Feb)	Kodiak	N708	S. Earsom	R. Wilson	P. Stinson	89	267	27	7,592
Total						179	537	49	20,611
Winter 2019 (24 Feb – 9 Mar)	Kodiak	N736	J. Wortham	D. Demarest	N. Wirwa	57	171	20	2,938
	Kodiak	N723	S. Earsom	R. Wilson	P. Stinson	54	162	25	15,216
Total						111	333	31	18,154
Winter 2020 (1 – 12	Partenavia*	N701	J. Wortham	A. Sussman	N. Wirwa	65	195	34	3,552
Feb)	Kodiak	N723	S. Earsom	R. Wilson	P. Stinson	65	195	27	12,758
Total						130	390	35	16,310

Table 3.7. Aircraft, pilot, and crew information for the GOMMAPPS aerial seabird surveys, 2018 – 2020.

* Kodiak (N736) aircraft was unavailable for an undetermined period due to mechanical issues. To avoid surveying over a longer time period (i.e., increase survey costs) or conduct surveys during two separate non-overlapping survey windows (i.e., temporal gap between surveys), a decision was made to utilize the available Partenavia (N701) aircraft. The Partenavia (N701) aircraft was used extensively for aerial seabird surveys as part of the Atlantic Marine Assessment Program for Protected Species (AMAPPS).

1 # of Bird Species Observed: Total represents unique species or species codes used. For aerial surveys, a list of four- letter species and species group codes were developed in 2017 – 2018 for birds (>100, four-letter codes available), marine mammals, sea turtles, and sharks and rays as part of the GOMMAPPS aerial survey Standard Operating Procedures and Protocols. For all observations, trained aerial seabird observers identified individuals to the lowest taxonomic level. For a variety of reasons, in some to many cases, observers were not able to classify individual birds observed down to the species-level. As a result, the number of bird species observed includes both species-level and higher-level taxonomic groups, as well as unknown or unidentified birds, e.g., UNID gulls and UNID terns. In total, aerial seabird observers identified 52 species of birds from five taxonomic groups (refer to Wilson et al. 2019a).

2 Total # of Birds Counted: represents the total count of all birds observed during a given year x season aerial survey independent of it was classified down to species-level, at a higher taxonomic level, or with an associated UNID code. The counts here represent total counts from all three in-flight observers (2 front-seat observers and 1 back-seat observer; double-observer), as such there is likely to be some number of 'duplicate' records included in the total presented here (and in Table 3.8). Refer to Table 3.9 and Appendix A for additional bird species-specific information.

Aerial seabird observers detected and recorded a diversity of birds, marine mammals, sea turtles, sharks, and rays during surveys in summer 2018 and winters 2018, 2019, and 2020 (Table 3.8). Specifically, aerial seabird observers detected and recorded a total of 52 species of birds with representatives from five taxonomic groups (Wilson et al. 2019a) during aerial surveys: 23 seabird species, 15 waterfowl species, 10 wading bird species, three raptor species, and one shorebird species (Table 3.9, Appendix A). Though species composition and the number of birds counted varied between summer and winter aerial surveys, of the seabird species detected and classified to species, the most abundant were (in order): brown pelican, double-crested cormorant, black skimmer, royal tern, black terns (2018-only, summer) and double-crested cormorant, northern gannet, brown pelican, common loon, and laughing gull (2018 – 2020, winter). Refer to Sections 3.5 and 3.5.1 below for additional details. Seabird species accounts for the 23 species detected via aerial surveys (except black skimmer and lesser black-backed gull) can be found in Section 5.4 below.

3.3 Covariate Data Collection

To model marine bird abundance, we used environmental variables that are known or thought to be correlated with seabird abundance and distribution (Wakefield et al. 2009). The environmental covariate data were collected for each survey unit and consisted of hourly sea- surface temperature (SST; Figures 3.9a-c and Figure 3.10), sea-surface height (SSH; Figures 3.9d-f and Figure 3.11), and sea-surface salinity (SSS; Figure 3.9g through Figure 3.9i and Figure 3.12) averaged over each day for survey periods in both summer and winter, and distance to shoreline from the midpoint of each survey unit (Distance). Seabird distribution is often uncoupled from current oceanic conditions measured by remotely sensed environmental variables due to time lags between the variables being measured and the factors that attract seabirds (e.g., prey availability; Wakefield et al. 2009). Therefore, for the winter survey periods, we also measured the 15-year averages (2003 - 2017) in each unit for SST, SSH, and SSS during our winter survey window (January 15 – March 15) in addition to the values from the time of the survey because we hypothesized that the long-term averages of environmental variables may also be predictive of seabird abundance. The 15-year timeframe overlaps the most recent period of Hybrid Coordinate Ocean Model (HYCOM³) data availability. We did not include the 15-year average covariate data in our summer model due to limited data from a single summer survey. Distance to shoreline data were calculated from the midpoint of each survey unit to the nearest point on the shoreline, as measure by Euclidean distance in

³ See HYCOM at: <u>https://www.hycom.org/data/gomu0pt04/expt-90pt1m000</u>

QGIS software. The SST, SSH, and SAL data were available at $1/25^{\circ}$ resolution from the HYCOM; 2003 – 2009 data are from experiment 20.1, 2010 – 2014 data are from experiment 31.0, and 2015 – 2019 data are from experiment 32.5 (refer also to Table 4.2 below). We standardized all continuous variables by subtracting the mean and dividing by the standard deviation of each variable. We also assessed correlations among variables, and there were no correlation coefficients greater than 0.7; thus, we used all variables described above in our analyses.

Season	Dates	Faunal Class	# Species ²	Total #
				Observed ³
Summer (2018)	11 – 20 July	Birds ^a	39	16,623
Summer (2018)		Marine Mammals ^b	4	426
Summer (2018)		Sea Turtles ^c	6	398
Summer (2018)		Sharks ^d	3	15
Summer (2018)		Rays ^e	2	184
Winter (2018)	31 Jan – 27 Feb	Birds ^a	50	20,611
Winter (2018)		Marine Mammals ^b	3	331
Winter (2018)		Sea Turtles ^c	5	941
Winter (2018)		Sharks ^d	0	0
Winter (2018)		Rays ^e	2	39
Winter (2019)	24 Feb – 9 Mar	Birds ^a	32	18,154
Winter (2019)		Marine Mammals ^b	4	207
Winter (2019)		Sea Turtles ^c	4	176
Winter (2019)		Sharks ^d	2	38
Winter (2019)		Rays ^e	0	0
Winter (2020)	1 – 12 Feb	Birds ^a	42	16,310
Winter (2020)		Marine Mammals ^b	4	233
Winter (2020)		Sea Turtles ^c	4	161
Winter (2020)		Sharks ^d	2	10
Winter (2020)		Rays ^e	1	1

Table 3.8. Faunal cla	asses of vertebrates	observed during the	GOMMAPP) aer	rial seabird surveys.	2018 - 2020
		observed during the		nui scubiru sui veys	2010 - 2020.

a Birds: includes five taxonomic groups of birds: seabirds, waterfowl, wading birds, shorebirds, and raptors. Refer to Section 3.3 and Appendix A for additional information.

b Marine Mammals: this could include various species of dolphins (most frequently identified species = bottlenose dolphin) and unidentified (UNID) dolphin, West Indian manatee, and various species of whales (most frequently identified species = sperm whale), as well as unidentified (UNID) codes for both dolphins and whales.

c Sea Turtles: this could include all five species of sea turtles (leatherback, green, Kemp's ridley, loggerhead, and hawksbill) that occur in the northern Gulf, as well as a unidentified (UNID) code.

d Sharks: this could include various species of sharks that occur in the northern Gulf if identified to the species level, as well as unidentified (UNID) code.

e Rays: this could include various species of shallow water rays, as well as the larger manta ray that occur in the northern Gulf if identified to the species level, as well as unidentified (UNID) code.

1 Faunal Class: broad classification of vertebrates used by aerial seabird observers.

2 # of Species: For birds, this includes all 4-letter American Ornithologists Union (AOU) codes (link here) for individuals identified to species or species groups, higher-level taxonomic codes like unidentified (UNID GULL and UNID TERN), as well as codes like BIRD. In total, aerial seabird observers identified 52 birds to the species level including: 23 seabird species, 15 waterfowl species, 10 wading bird species, 3 raptor species, and 1 shorebird species. Refer to Appendix A for additional information. For other faunal classes of vertebrates, please refer to appropriate superscript letter above.

3 Total # of Birds Counted: represents the total count of all birds observed during a given year x season aerial survey irrespective of whether it was classified down to species-level, at a higher taxonomic level, or associated unidentified (UNID) code. The counts here represent total counts from all three in-flight observers (2 front-seat observers and 1 back-seat observer; double-observer), as such there is likely to be some number of 'duplicate' records included here (and in Table 3.7). Refer to Table 3.9 and Appendix A for more additional bird species-specific information.

3.3 Aerial Survey Analytical Methods

The GOMMAPPS aerial survey produced marine bird counts (from front observers only) that we analyzed in a generalized linear model (GLM) framework. Poisson GLMs are often used for avian count data, but the Poisson distribution can be restrictive for seabird counts because the mean and variance must be equal, which is often violated in seabird count data.

This high variance-to-mean ratio likely results from a tendency for marine birds to aggregate at-sea, particularly in the winter months (Zipkin et al. 2010, Zipkin et al. 2014). Because of the overdispersion present in our data from both winter (Figure 3.13) and summer aerial surveys (Figure 3.14), we modeled counts using a negative binomial distribution for all seasons, which allows for a higher variance compared to the mean and has previously been shown (Zipkin et al. 2014) to provide a better fit to models of marine bird survey data.

We define y_i as the total count of all marine bird species in a survey unit *i*. We assumed that the count in survey unit *i* had a negative binomial distribution, $y_i \sim \text{NegBinom}(p_i, r)$ with a mean:

$$p_i = r/(r+\lambda_i)$$

and variance:

$$\sigma_i^2 = r \left(1 - p_i \right) / (p_i^2)$$

We modeled variation in λ using a log-linear function.

Winter Data:

$$\log(\lambda_i) = \beta_0 + \beta_1 * (2019i) + \beta_2 * (2020i) + \beta_3 * (SSTi) + \beta_4 * (AvgSSTi) + \beta_5 * (SSHi) + \beta_6 * (SSHi) +$$

 $(AvgSSH_i) + \beta_7 * (SSS_i) + \beta_8 * (AvgSSS_i) + \beta_9 * (Distance_i)$

Where β_0 was modeled as the intercept and β_1 through β_9 were the effects of each of the covariates for each survey unit *i* on count: survey season effects of 2019 (2019) and 2020 (2020), daily sea-surface temperature (SST), the 2003-2017 average of sea-surface temperature during Jan. 15-Mar. 15 (Avg SST), daily sea-surface height (SSH), the 2003-2017 average of sea- surface height during Jan. 15-Mar. 15 (Avg SSH), daily sea-surface salinity (SSS), the 2003- 2017 average of sea-surface salinity (SSS) during Jan. 15-Mar. 15 (Avg SSS), and distance from the midpoint of the survey unit to shoreline (Distance).

Table 3.9. Species composition of birds observed during the GOMMAPPS aerial seabird surveys, 2018 – 2020.

Aerial survey dates for the respective surveys were: 11 - 20 July 2018 (summer), 31 Jan - 27 Feb 2018 (winter), 24 Feb - 9 Mar 2019 (winter), and 1 - 12 Feb 2020 (winter).

Season	Species ¹	Taxa Group ²	Count ³	% of Total
				count
Summer (2018)	Black skimmer	Seabirds	337	2.85
Summer (2018)	Black tern	Seabirds	169	1.43
Summer (2018)	Brown booby	Seabirds	5	0.04
Summer (2018)	Brown pelican	Seabirds	3,509	29.66
Summer (2018)	Cory's shearwater	Seabirds	1	0.01
Summer (2018)	Double-crested cormorant ^a	Seabirds	419	3.54
Summer (2018)	Laughing gull	Seabirds	346	2.92
Summer (2018)	Least tern	Seabirds	127	1.07
Summer (2018)	Magnificent frigatebird	Seabirds	165	1.39
Summer (2018)	Northern gannet	Seabirds	7	0.06
Summer (2018)	Royal tern	Seabirds	295	2.49
Summer (2018)	UNID gull	Seabirds	2,798	23.65
Summer (2018)	UNID shearwater	Seabirds	5	0.04
Summer (2018)	UNID storm-petrel	Seabirds	72	0.61
Summer (2018)	UNID tern	Seabirds	3,291	27.82
Summer (2018)	Osprey	Raptors	3	0.03
Summer (2018)	Turkey vulture	Raptors	2	0.02
Summer (2018)	White-tailed hawk	Raptors	2	0.02
Summer (2018)	UNID shorebird	Shorebirds	125	1.06
Summer (2018)	Great egret	Wadingbirds	37	0.31
Summer (2018)	White ibis	Wadingbirds	75	0.63
Summer (2018)	Roseate spoonbill	Wadingbirds	37	0.31
Summer (2018)	UNID bird		4	0.03
Total			11,831	
Winter (2018)	American white pelican	Seabirds	97	0.77
Winter (2018)	Brown booby	Seabirds	30	0.24
Winter (2018)	Brown pelican	Seabirds	306	2.43
Winter (2018)	Brown noddy	Seabirds	21	0.17
Winter (2018)	Common loon	Seabirds	94	0.75
Winter (2018)	Double-crested cormorant ^a	Seabirds	1,126	8.95
Winter (2018)	Herring gull	Seabirds	138	1.10

Season	Species ¹	Taxa Group ²	Count ³	% of Total Count ⁴
Winter (2018)	Laughing gull	Seabirds	344	2.73
Winter (2018)	Least tern	Seabirds	7	0.06
Winter (2018)	Northern gannet	Seabirds	1,456	11.57
Winter (2018)	Royal tern	Seabirds	35	0.28
Winter (2018)	UNID gull	Seabirds	2,923	23.22
Winter (2018)	UNID jaeger	Seabirds	1	0.01
Winter (2018)	UNID loon	Seabirds	62	0.49
Winter (2018)	UNID phalarope	Seabirds	248	1.97
Winter (2018)	UNID storm-petrel	Seabirds	1	0.01
Winter (2018)	UNID tern	Seabirds	642	5.10
Winter (2018)	UNID grebe	Marshbirds	10	0.08
Winter (2018)	Osprey	Raptors	4	0.03
Winter (2018)	UNID vulture	Raptors	1	0.01
Winter (2018)	Cattle egret	Wadingbirds	57	0.45
Winter (2018)	Great blue heron	Wadingbirds	28	0.22
Winter (2018)	Great egret	Wadingbirds	42	0.33
Winter (2018)	White ibis	Wadingbirds	7	0.06
Winter (2018)	UNID heron/egret	Wadingbirds	160	1.27
Winter (2018)	Bufflehead	Waterfowl	269	2.14
Winter (2018)	Common merganser	Waterfowl	28	0.22
Winter (2018)	Gadwall	Waterfowl	72	0.57
Winter (2018)	Mottled duck	Waterfowl	3	0.02
Winter (2018)	Northern pintail	Waterfowl	29	0.23
Winter (2018)	Red-breasted merganser	Waterfowl	417	3.31
Winter (2018)	Redhead	Waterfowl	1,109	8.81
Winter (2018)	Scaup ^b	Waterfowl	2,358	18.74
Winter (2018)	UNID seaduck	Waterfowl	213	1.69
Winter (2018)	UNID duck	Waterfowl	121	0.96
Winter (2018)	UNID bird		127	1.01
Total			12,586	
Winter (2019)	American white pelican	Seabirds	5	0.04
Winter (2019)	Bonaparte's gull	Seabirds	12	0.10
Winter (2019)	Brown pelican	Seabirds	487	3.88
Winter (2019)	Common loon	Seabirds	157	1.25
Winter (2019)	Double-crested cormorant ^a	Seabirds	238	1.90

Season	Species ¹	Taxa Group ²	Count ³	% of Total Count ⁴
Winter (2019)	Herring gull	Seabirds	75	0.60
Winter (2019)	Laughing gull	Seabirds	25	0.20
Winter (2019)	Magnificent frigatebird	Seabirds	2	0.02
Winter (2019)	Northern gannet	Seabirds	366	2.92
Winter (2019)	Royal tern	Seabirds	37	0.30
Winter (2019)	UNID gull	Seabirds	112	0.89
Winter (2019)	UNID phalarope	Seabirds	132	1.05
Winter (2019)	UNID shearwater	Seabirds	1	0.01
Winter (2019)	UNID tern	Seabirds	702	5.60
Winter (2019)	Black scoter	Waterfowl	13	0.10
Winter (2019)	Bufflehead	Waterfowl	72	0.57
Winter (2019)	Red-breasted merganser	Waterfowl	94	0.75
Winter (2019)	Redhead	Waterfowl	8,867	70.73
Winter (2019)	Scaup⁵	Waterfowl	996	7.94
Winter (2019)	Surf scoter	Waterfowl	78	0.62
Winter (2019)	White-winged scoter	Waterfowl	25	0.20
Winter (2019)	UNID scoter	Waterfowl	31	0.25
Winter (2019)	UNID bird		10	0.08
Total			12,537	
Winter (2020)	American white pelican	Seabirds	38	0.32
Winter (2020)	Brown pelican	Seabirds	404	3.42
Winter (2020)	Common loon	Seabirds	183	1.55
Winter (2020)	Double-crested cormorant ^a	Seabirds	388	3.28
Winter (2020)	Laughing gull	Seabirds	228	1.93
Winter (2020)	Magnificent frigatebird	Seabirds	3	0.03
Winter (2020)	Northern gannet	Seabirds	512	4.33
Winter (2020)	Royal tern	Seabirds	93	0.79
Winter (2020)	UNID gull	Seabirds	3,571	30.20
Winter (2020)	UNID loon	Seabirds	198	1.67
Winter (2020)	UNID phalarope	Seabirds	61	0.52
Winter (2020)	UNID shearwater	Seabirds	4	0.03
Winter (2020)	UNID tern	Seabirds	941	7.96
Winter (2020)	Great egret	Wadingbirds	5	0.04
Winter (2020)	Green heron	Wadingbirds	9	0.08
Winter (2020)	Little blue heron	Wadingbirds	5	0.04

Season	Species ¹	Taxa Group ²	Count ³	% of Total Count ⁴
Winter (2020)	Snowy egret	Wadingbirds	9	0.08
Winter (2020)	Black-bellied whistling duck	Waterfowl	35	0.30
Winter (2020)	Bufflehead	Waterfowl	37	0.31
Winter (2020)	Common merganser	Waterfowl	4	0.03
Winter (2020)	Gadwall	Waterfowl	35	0.30
Winter (2020)	Lesser scaup	Waterfowl	93	0.79
Winter (2020)	Mottled duck	Waterfowl	6	0.05
Winter (2020)	Red-breasted merganser	Waterfowl	136	1.15
Winter (2020)	Redhead	Waterfowl	2,848	24.08
Winter (2020)	Ring-necked duck	Waterfowl	47	0.40
Winter (2020)	Scaup ^b	Waterfowl	1,681	14.21
Winter (2020)	UNID merganser	Waterfowl	164	1.39
Winter (2020)	UNID seaduck	Waterfowl	70	0.59
Winter (2020)	UNID teal	Waterfowl	5	0.04
Winter (2020)	UNID ird		13	0.11
Total			11,826	

a Double-crested Cormorants: an assumption was made to classify all "cormorants" as double-crested cormorants (*Nannopterum auritum*) even though neotropic cormorants (*N. brasilianum*) are known to occur in the northern Gulf, particularly in coastal habitats West of the Mississippi River to the Texas-Mexico border. Double-crested cormorants tend to be more broadly distributed and more abundant compared to the neotropic cormorant in the northern Gulf. Refer to eBird here for double-crested cormorant (you need a CornellLab account)

https://ebird.org/map/doccor?neg=true&env.minX=&env.minY=&env.maxX=&env.maxY=&zh=false&ep=false&ev=Z&mr =1-12&bmo=1&emo=12&yr=all&byr=1900&eyr=2022 and https://science.ebird.org/en/status-and-

trends/species/doccor/abundance-map. Refer to eBird here for neotropic cormorant (you need a CornellLab account) https://ebird.org/map/neocor?neg=true&env.minX=&env.minY=&env.maxX=&env.maxY=&zh=false&gp=false&ev=Z& mr=1- 12&bmo=1&emo=12&yr=all&byr=1900&eyr=2022 and https://science.ebird.org/en/status-andtrends/species/neocor/abundance-map

b Scaup: includes both lesser (*Aythya affinis*) and greater (*A. marila*) scaup. These species are extremely difficult to differentiate via aerial surveys, and as such, these 2 species are and have been included as a single 'species group' during annual programmatic Waterfowl Breeding Population and Habitat Survey (<u>USFWS 2019b</u>, refer also to Smith 1995).

1 Species: for aerial surveys a list of 4-letter species and species group codes were developed in 2017 – 2018 for birds (>100, 4-letter codes available), marine mammals, sea turtles, and sharks and rays as part of the GOMMAPPS aerial survey Standard Operating Procedures and Protocols. For all observations, trained aerial seabird observers identified to the lowest taxonomic level possible, and in some to many cases, observers were not able to classify individual bird observations down to the species-level; unidentified (UNID) codes in Table above. As a result, UNID gulls and UNID terns represented a disproportionately large component of both Counts and % of Total. 2 Taxa Group: generally, follows the taxonomic groups used by the Gulf of Mexico Avian Monitoring Network (GOMAMN) for their Birds of Conservation Concern, link here.

3 Count: sum of species records from front-seat aerial observers only. Thus, the count included here has removed 'duplicate' records from front-seat and back-seat observers employing the double-observer approach. 4 % of Total: count "cell" for a given species divided by Σ Total Count for a given period aerial survey. Reflects the relative contribution of a given species or species group to the total of birds counted/enumerated during a given aerial survey period. Counts included here represent sum of species records from front-seat aerial observers only. Decimal values should but may not Σ to 100% due to small rounding errors.

Summer Data:

 $\log(\lambda_i) = \beta_0 + \beta_1 * (SST_i) + \beta_2 * (SSH_i) + \beta_3 * (SSS_i) + \beta_4 * (Distance_i)$

Where β_0 was modeled as the intercept and β_1 through β_4 were the effects of each of the covariates for each survey unit *i* on count: daily sea-surface temperature (SST), sea-surface height (SSH), sea-surface salinity (SSS), and distance from the midpoint of the survey unit to shoreline (Distance). We analyzed the negative binomial model for all species together in both survey seasons (winter and summer) and estimated parameters in a Bayesian framework with programs R (RStudio Team 2018) and NIMBLE (NIMBLE Development Team 2019). We specified code in R to estimate parameters by Markov Chain Monte Carlo (MCMC) using NIMBLE (NIMBLE Development Team 2019). To run our analysis, we used uninformative priors for all parameters. We ran three chains for 5,000 iterations after a burn-in period of 5,000 iterations and estimated posterior distributions after thinning the chains by 5; thus, we had a total of 3,000 sampled iterations across the three chains (1,000 per chain).

Focal Species Analyses

We selected two species (Eastern brown pelican and northern gannet) and one family (gulls and terns; Laridae) for which we had sufficient data for further analysis. We used summer Eastern brown pelican, summer gull and tern, winter northern gannet, and winter gull and tern count data fit to four separate models for individual species or family.

The Eastern brown pelican is a large-bodied seabird that inhabits nearshore environments of tropical and subtropical North American waters, and they forage in nearshore waters (within 20 km of shore) by plunge-diving for fish. Brown pelicans are a species of conservation concern in many northern Gulf states (Burger 2017); therefore, accurate estimates of their habitat use, distribution, and abundance throughout the annual cycle is important. Northern gannets also are a large- bodied seabird that forages in near- and offshore waters by plunge-diving. Northern gannets migrate during the non-breeding season and use areas along the east coast of the U.S. and the northern Gulf during this period (Mowbray 2020). The tern species of the northern Gulf include royal tern, least tern, sandwich tern, Forster's tern, and gull-billed tern. These species breed in nearshore colonies in the northern Gulf and like brown pelicans and gannets, they forage in the nearshore waters by plunge-diving for fish. Least terns and royal terns are facultatively migratory in the northern Gulf. Sandwich, Forster's, and gull-billed terns are considered as year-round 'residents' in the northern Gulf. Several species of gulls utilize the northern Gulf during some portion of their annual cycle: laughing gull (breeding, year-round), ring-billed gull (non- breeding, fall-winter), herring gull (non-breeding, fall-winter), Bonaparte's gull (non- breeding, fall-winter), Franklin's gull (non-breeding, migration; Burger and Gochfeld 2020), and great and lesser black-backed gulls (nonbreeding, transient; Burger et al. 2020). In the Gulf, gulls have been observed foraging in pelagic waters. tidal creeks, bays, and estuaries, and in proximity to commercial fishing vessels (e.g., Burger 2017).

A list of species common and scientific names and GOMMAPPS survey platform(s) detected is provided in Appendix A. Refer to Section 5.4 for more details (except Franklin's and lesser black-backed gull).

3.4 Aerial Survey Results

In general, species composition and total bird counts varied annually and depending on the timing of aerials surveys, i.e., summer versus winter (Table 3.9). For summer 2018, brown pelican (n = 3,509 individuals, 29.66%), UNID Tern (n = 3,291 individuals, 27.82%), and UNID gull (n = 2,798 individuals, 23.65%) accounted for >80% of all individuals observed (Table 3.9). Double-crested cormorant (n = 419 individuals, 3.54%), laughing gull (n = 346 individuals, 2.92%), black skimmer (n = 337 individuals, 2.85%), and royal tern (n = 295 individuals, 2.49%) each accounted for <5% of the total. For winter 2018,

UNID Gull (n = 2,923 individuals, 23.22%), scaup (n = 2,358 individuals, 18.74%), northern gannet (n = 1,456 individuals, 11.57%), double-crested cormorant (n = 1,126 individuals, 8.95%), and redhead (n = 1,109 individuals, 8.81%) accounted for >70% of all individuals observed (Table 3.9).







Figure 3.9. Triad of graphs for hourly sea-surface temperature (SST; °C, top set of plates) averaged over each day for the winter survey periods for 2018 (a), 2019 (b), and 2020 (c), respectively; hourly sea-surface height (SSH; in m, middle set of plates) averaged over each day for the winter survey periods for 2018 (d), 2019 (e), and 2020 (f), respectively; and hourly sea-surface salinity (SSS, bottom set of plates) averaged over each day for the winter survey periods for 2018 (g), 2019 (h), and 2020 (i), respectively.

In all graphs, the X-axis represents longitude (Easting) and the Y-axis represents latitude (Northing). We obtained dynamic variables at an hourly resolution from the Hybrid Coordinate Ocean Model (HYCOM; Chassignet et al. 2009, Metzger et al. 2017). Please refer to text for more details.



Figure 3.10. Graphic depicting hourly sea-surface temperature (SST; °C) averaged over each day for the summer 2018 survey period (2018 July 11-20) as measured by the Hybrid Coordinate Ocean Model (HYCOM) in the northern Gulf.

The x-axis represents longitude (Easting), the y-axis represents latitude (Northing), and the z-axis represents seasurface temperature (SST). Herein darker colors (green) represent warmer temperature, whereas lighter colors, in this case, yellow and pink, represent intermediate and cooler temperatures. During the period sampled (11 – 20 July 2018) cooler waters occurred in the western Gulf and warmer waters occurred primarily in the eastern and southeastern Gulf.



Figure 3.11. Graphic depicting hourly sea-surface height (SSH; in m) averaged over each day for the summer 2018 survey period (2018 July 11-20) as measured by the Hybrid Coordinate Ocean Model (HYCOM) in the northern Gulf.

The x-axis represents longitude (Easting), the y-axis represents latitude (Northing), and the z-axis represents seasurface height (in meters). Herein darker colors (green) represent greater height, whereas lighter colors, in this case, yellow and pink, represent intermediate and lower (or negative) heights. During the period sampled (11 - 20 July 2018), SSH varied spatially but was typically within the range of +0.1m to -0.1m; greater SSH (green) in deeper waters in the central Gulf off the mouth of the Mississippi River.



Figure 3.12. Graphic depicting hourly sea-surface salinity (SSS) averaged over each day for the summer 2018 survey period (2018 July 11–20) as measured by the Hybrid Coordinate Ocean Model (HYCOM).

The x-axis represents longitude (Easting), the y-axis represents latitude (Northing), and the z-axis represents seasurface salinity (in practical salinity units). Herein darker colors (green) represent greater salinity, whereas lighter colors, in this case, yellow and pink, represent intermediate and lower salinities. During the period sampled (11 - 20July 2018), SSS varied spatially but typically showed much lower salinity in the shallower bays, estuaries, and river mouths, whereas the deeper shelf and shelf-slope waters of the northern Gulf indicated higher salinity.



Figure 3.13. Histograms (a) of all species combined flock sizes per aerial survey unit (40-square km hexagons) and of all species combined flock sizes (>0) aerial survey unit (40 km2 hexagons) for 2018, 2019, and 2020 winter surveys (b).

For both histograms, x-axis represents the number of birds counted and y-axis represents frequency. Most hexagons (196/417; 47%) contained small counts (<10 birds), and ~94% of counts were <200 birds.



Figure 3.14. Histograms (a) of all species combined flock sizes per aerial survey unit (40-square km hexagons) and of all species combined flock sizes (>0) per aerial survey unit (40 km² hexagons) for 2018 summer survey (b).

For both histograms, x-axis represents the number of birds counted and y-axis represents frequency. Most hexagons (125/180; 69%) contained small counts (<10 birds), and ~91% of counts were <100 birds.

Unidentified tern (n = 642 individuals, 5.10%), red-breasted merganser (n = 417 individuals, 3.31%), laughing gull (n = 348 individuals, 2.73%), brown pelican (n = 306 individuals, 2.43%), bufflehead (n = 269 individuals, 2.14%), and herring gull (n = 138 individuals, 1.10%) each accounted for 1-5% of the total. In winter 2019, redhead (n = 8,867 individuals, 70.73%) accounted for a disproportionate number of birds observed (Table 3.9). Scaup (n = 996 individuals, 7.94%), UNID tern (n = 702 individuals, 5.60%), brown pelican (n = 487 individuals, 3.88%), northern gannet (n = 366 individuals, 2.92%), double-crested cormorant (n = 238 individuals, 1.90%), and common loon (n = 157 individuals, 3.20%), redhead (n = 2,848 individuals, 24.08%), scaup (n = 1,681 individuals, 14.21%), and UNID tern (n = 941 individuals, 7.96%) accounted for >75% of all individuals, 3.42%), double-crested cormorant (n = 388 individuals, 3.42%), double-crested cormorant (n = 388 individuals, 1.55%) and red-breasted merganser (n = 136 individuals, 1.15%) each accounted for ≥ 1 to $\sim4\%$ of the total.

Overall, migratory species that overwinter in the Gulf, including various species of diving (e.g., redhead, lesser and greater scaup) and sea ducks (e.g., red-breasted merganser, bufflehead) and seabirds (e.g., northern gannet, common loon, herring gull) were primary species observed during winter aerial surveys (Table 3.9). Northern Gulf breeding seabird species (e.g., brown pelican, laughing gull, royal tern) were important species observed during both summer and winter aerial surveys (Table 3.9). In general, UNID gull and UNID tern combined represented $\sim 28-50\%$ of species composition totals, except in winter of 2019.

Additional details regarding analyses and modeling for both summer 2018 and winter 2018 - 2020 aerial surveys can be found in Section 3.6.2 below.

3.4.1 2018 – 2020 Aerial Survey Results

Winter

All species

There were 6,935 flocks recorded by front-seat observers across all winter survey seasons (2018: n = 3,154; 2019: n = 1,802; 2020: n = 1,979). Recorded flock sizes varied from one individual to thousands across surveys (Winter 2018: 1-2,000; Winter 2019: 1-3,200; Winter 2020: 1-500). However, most observations were of single individuals (Winter 2018: $\sim 71\%$; Winter 2019: $\sim 76\%$; Winter 2020: $\sim 74\%$). The median recorded flock size was one individual across all winter surveys while the mean recorded flock size ranged between $\sim 4-8$ individuals across surveys. Front-seat observers recorded 30-45 unique species (or species groups) during surveys (Winter 2018: n = 45 spp.; Winter 2019: n = 30 spp.; Winter 2020: n = 35 spp.).

The winter model showed a negative relationship of both distance to shore (Figure 3.15) and SST with marine bird count (Figure 3.16). These predictors were the only covariates estimated as significant (95% credible intervals did not overlap zero) in the winter model (Figure 3.17). The winter model results also showed positive effects of the 2019 survey season and the 15- year average of SST on seabird counts, and the other variables had little correlation with marine bird count (Figure 9). Model predictions showed high predicted abundance of marine birds close to the shore with the highest predicted abundance in coastal Louisiana, near the mouth of the Mississippi River (Figure 3.18).

Northern Gannet

Across all winter survey seasons, front-seat observers recorded 1,796 observations of northern gannet flocks or individuals (2018: n = 1,091; 2019: n = 320; 2020: n = 385). Most records were of single birds (n = 1,478/1,796; 82.29%), and the maximum recorded flock size was 50 birds.

The negative binomial model for northern gannet abundance showed that distance from shore, SSH, and the effects of the 2019 and 2020 survey seasons were important predictors (Figure 3.19). Northern gannet counts were negatively correlated with distance from shore (Figure 3.20) and SSH (Figure 3.21), and there were significantly fewer northern gannets observed in 2019 and 2020 than in 2018 (Figure 3.19). Sea-surface salinity was weakly positively associated with northern gannet counts, but this effect was not significant (Figure 3.22). Model predictions showed high predicted abundance of northern gannets in nearshore areas with the highest abundance predictions occurring in the eastern half of the Gulf (Figure 3.23).

Gulls and Terns

Front-seat observers recorded 3,114 observations of gull and tern flocks or individuals during the three winter survey seasons (2018: n = 1,184; 2019: n = 927; 2020: n = 1,003). Approximately 76% of all gull and tern records were single birds (n = 2,375/3,114; 76.27%), and 14 gull and tern records were flocks \geq 100. The mean recorded flock size was 3.8, and the maximum recorded flock size was 903 birds.

Model results for winter gull and tern abundance showed that distance from shore, sea-surface salinity, sea-surface temperature, and the effects of the 2019 survey season were important predictors (Figure 3.24). Gull and tern counts were negatively correlated with distance to shore (Figure 3.25) and SST (Figure 3.26) but were positively correlated with SSS (Figure 3.27).

More gull and terns were observed in 2019 than in 2018; although, this effect was small (Figure 3.24). Model predictions showed high predicted abundance of gulls and terns close to the shoreline with the highest predicted abundance occurring in coastal LA and coastal area of the FL panhandle (Figure 3.28).

Few variables in the winter model were estimated as important. The lack of a relationship with most modeled predictors may indicate that the variables chosen were poor indicators of seabird abundance during the winter period or that they were measured at inappropriate scales. It can be difficult to relate environmental covariates to seabird abundance because it is unclear at what spatial and temporal scales these variables are important (Wakefield et al. 2009).

Additionally, the relative importance of different environmental and oceanographic variables may change across different spatial and temporal scales (Hunt and Schneider 1987). Nevertheless, we established that distance to shore was an important factor that influenced marine bird abundance in northern Gulf nearshore areas during both winter and summer seasons.

Summer

All species

There were 181 flocks recorded by front-seat observer across transect and hexagon flight patterns during the pilot summer survey season (2017). Recorded flock sizes were 1-40 individuals, and most observations were of single individuals (~87% of records). The median recorded flock size was one individual while the mean recorded flock size was ~1.5 individuals. Front-seat observers recorded six unique species during the pilot summer survey.

There were 2,167 flocks recorded by front-seat observer during the full summer survey event (2018). Recorded flock sizes were 1-800 individuals. Single individuals comprised ~66% of records. The median recorded flock size was one individual while the mean recorded flock size was ~5 individuals. Front-seat observers recorded 32 unique species during the full summer survey event.

We used the data from the full summer season to model marine bird abundance in the northern Gulf for summer. The summer model showed a negative relationship between distance to shore and marine bird count (Figure 3.29) as well as weakly positive correlations with SST (Figure 3.30), SSH (Figure 3.31), and SSS (Figure 3.32). However, distance to shore, SST, and SSH all were significant predictors (Figure 3.33). Model predictions showed high predicted abundance of marine birds close to the shoreline with the highest predicted abundance occurring in the eastern half of the northern Gulf (Figure 3.34).

Eastern Brown Pelican

Front-seat observers recorded 203 observations of Eastern brown pelicans during the 2018 summary survey. Of these 203 observations, 90 were of single individuals, 70 were of flock sizes of 2-10 individuals, the remaining records (n = 43) ranged from 11-800 individuals, and 14 of these 43 records were flock sizes >100. Model results for brown pelican abundance showed that distance to shore was the only important predictor variable (Figure 3.35). Brown pelican counts were negatively correlated with distance to shore (Figure 3.36). Overall, predictions for the brown pelican model had very high standard deviations. However, the highest predicted abundance for this species occurred near barrier islands along the Louisiana coast (Figure 3.37).

Gulls and Terns

Front-seat observers recorded 1,701 observations of gulls and terns during the 2018 summary survey. Approximately 71% of these observations were of single individuals (n = 1,205/1,701), and 415 observations were of flock sizes of 2-10 individuals. The remaining 81 observations ranged from 12-240 individuals, and 15/81 of these records were flock sizes >100. Model results for summer gull and tern abundance showed that distance to shore and sea surface height were important predictor variables (Figure 3.38). Summer gull and tern counts were negatively correlated with distance to shore (Figure 3.39) and positively correlated with sea surface height (Figure 3.40). Model predictions showed high predicted abundance of gulls and terns close to the shoreline with the highest abundance predictions

occurring on the eastern half of the northern Gulf (Figure 3.41).

The winter and summer models showed similar results for the relationships between marine bird count and distance to shore. Although SST showed a negative relationship with marine bird count in the winter model and a positive relationship with bird count in the summer model, these relationships seem to be primarily driven by distance to shoreline. In the winter, SST is lower close to shore, and in the summer, SST is higher close to shore. Model predictions for both winter and summer seasons reflect this pattern, with higher marine bird counts predicted close to shore and low to zero counts predicted further from the shoreline in both winter (Figure 3.18) and summer (Figure 3.34).



Figure 3.15. Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for all marine bird species combined during winter aerial surveys, 2018 – 2020.

The x-axis represents the number of birds counted and y-axis represents distance to shore; gray circles indicate observed data. There was a decline in number of birds observed with increasing distance from shore.





The x-axis represents the number of birds counted and y-axis represents sea-surface temperature (SST); gray circles indicate observed data. The number of birds observed declined with increasing values of SST (\geq 22 °C).



Figure 3.17. Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on all marine bird species combined for winter aerial surveys, 2018 – 2020.

Parameters modeled were distance from the midpoint of the survey unit to shoreline (Distance), 2003 – 2017 average of sea-surface salinity during Jan 15-Mar 15 (Avg SSS), sea-surface salinity (SSS), 2003 – 2017 average of sea-surface height during Jan 15-Mar 15 (Avg SSH), sea-surface height (SSH), 2003 – 2017 average of sea-surface temperature during Jan 15-Mar 15 (Avg SST), sea-surface temperature (SST), year (2019, 2020), and the intercept (2018). Parameters to the left of the vertical dashed line indicate negative effects, parameters to the right of the vertical dashed line indicate positive effects, and 95% credible intervals overlapping the dashed line (0) indicates no effect. Please refer to text for more details.



Figure 3.18. Winter predicted abundance model (a) and associated standard deviation of predictions (b) for all marine bird species combined winter aerial surveys, 2018 – 2020.

The survey area includes all 40 km² hexagons representing the entirety of the study area from the coastline out to roughly 50 nm line. The northern boundary approximates a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. Predictor variables in the model included distance to shore, SSS, SSH, SST, and 15-year averages (2003 – 2017) for these same three environmental covariates. Please refer to text for more details.



Figure 3.19. Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on northern gannet (NOGA; *Morus bassanus*) counts for winter aerial surveys, 2018 – 2020.

Parameters modeled were distance from the midpoint of the survey unit to shoreline (Distance), surface salinity (SSS), sea-surface height (SSH), sea-surface temperature (SST), year (2019, 2020), and the intercept (2018). Parameters to the left of the vertical dashed line indicate negative effects, parameters to the right of the vertical dashed line indicate positive effects, and 95% credible intervals overlapping the dashed line (0) indicates no effect. Please refer to text for more details.



Figure 3.20. Marginal effects model plot of distance to shore (dark blue line) on northern gannet (NOGA; *Morus bassanus*) counts (2018 = blue line, 2019 = green line; light bands represent 95% credible intervals) during winter aerial surveys, 2018 – 2020.

The x-axis represents the number of birds counted and y-axis represents distance to shore; gray circles indicate observed data. There was a steep decline in the number of northern gannets observed as distance from shore increased, particularly between 25,000 m and 50,000 m.





The x-axis represents the number of birds counted and y-axis represents sea-surface height (SSH; in meters); gray circles indicate observed data. There was a steady decline in the number of northern gannets counted over the observed range (-0.4 m to -0.2 m) of SSH.





The x-axis represents the number of birds counted and y-axis represents sea-surface salinity (SSS) (in parts per thousand); gray circles indicate observed data. There was a slight increase in number of northern gannets counted over the observed range (30 ppt – 40 ppt) of SSS.



Figure 3.23. Winter predicted abundance model (a) and associated standard deviation of predictions (b) for northern gannets from winter aerial surveys, 2018 – 2020. The survey area includes all 40 km² hexagons representing the entirety of the study area from the coastline out to roughly 50 nm line.

The northern boundary approximates a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. Predictor variables in the model included distance to shore, and average of hourly SSS, SSH, and SST. Please refer to text for more details.



Figure 3.24. Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on gull and tern counts for winter aerial surveys, 2018 – 2020.

Parameters modeled were distance from the midpoint of the survey unit to shoreline (Distance), sea-surface salinity (SSS), sea-surface height (SSH), sea-surface temperature (SST), year (2019, 2020), and the intercept (2018). Parameters to the left of the vertical dashed line indicate negative effects, parameters to the right of the vertical

dashed line indicate positive effects, and 95% credible intervals overlapping the dashed line (0) indicates no effect. Please refer to text for more details.



Figure 3.25. Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for gulls and terns during winter aerial surveys, 2018 – 2020.

The x-axis represents the number of birds counted and y-axis represents distance to shore; gray circles indicate observed data. There was a decline in number of gulls and terns observed with increasing distance from shore.



Figure 3.26. Marginal effects model plot of sea-surface temperature (SST) (dark blue line) and associated 95% credible intervals (light blue band) for gulls and terns during winter aerial surveys, 2018 – 2020.

The x-axis represents the number of gulls and terns counted and y-axis represents SST (C°); gray circles indicate observed data. There was a decline in number of gulls and terns observed with increasing distance from shore. The number of birds observed declined with increasing values of SST (\geq 22 °C).



Figure 3.27. Marginal effects model plot of sea-surface salinity (SSS) on gull and tern counts (blue line) with associated 95% credible intervals (light blue band) during winter aerial surveys, 2018 – 2020.

The x-axis represents the number of gulls and terns counted and y-axis represents sea-surface salinity (SSS) (in parts per thousand); gray circles indicate observed data. There was a slight increase in number of gulls and terns over the observed range (25 ppt – 40 ppt) of SSS.



Figure 3.28. Winter predicted abundance model (a) and associated standard deviation of predictions (b) for gulls and terns from winter aerial surveys, 2018 – 2020.

The survey area includes all 40 km² hexagons representing the entirety of the study area from the coastline out to roughly 50 nm line. The northern boundary approximates a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. Predictor variables in the model included distance to shore, and average of hourly SSS, SSH, and SST. Please refer to text for more details.

4 Vessel-based Seabird Surveys: Methods

The spatial extent of vessel-based surveys included primarily federal waters within the northern Gulf out to the U.S. EEZ (Figure 2.1). We conducted surveys within and across the three BOEM planning areas within the Gulf (west, central, and east), and slightly south of the southeastern corner of the EPA. In general, this area encompassed waters from $\sim 2-500$ km ($\sim 1-300$ mi) offshore and included shelf, slope, and pelagic waters that ranged in depth from $\sim 10-3,500$ m ($\sim 30-11,500$ ft). In area, the BOEM planning areas represent $\sim 116,000$ km² (WPA), $\sim 269,000$ km² (CPA), and $\sim 260,000$ km² (EPA), respectively, roughly encompassing a total area of $\sim 645,000$ km². Proportionally, the planning areas comprise $\sim 18\%$ (WPA), $\sim 42\%$ (CPA), and $\sim 40\%$ (EPA), respectively, of the study area. Because each planning area has an extensive north- south footprint, the type of ocean habitat surveyed can differ greatly within a planning area (e.g., from shelf to pelagic waters).

We conducted seabird surveys from National Oceanic and Atmospheric Administration (NOAA) vessels of opportunity (VOO). Survey departure and arrival ports, timing, and routes were designed specifically for conducting NOAA GOMMAPPS marine mammal surveys (Rappucci et al. 2023) or for NOAA programmatic surveys to collect fisheries and/or plankton data. As a result, the vessel seabird survey team had no ability to change or otherwise influence survey design, per se, unlike the aerial survey team (refer to Section 3.1 above). Nonetheless, the footprint from all seabird vessel surveys provided substantial coverage within each planning area and even some coverage of waters southeast of the southeast portion of the EPA (Figure 4.1). We participated in 14 individual NOAA cruises (Table 4.1, Appendix B). The survey schedule, tracklines surveyed, and movements of vessels between tracklines (or points) were predetermined (by NOAA) depending on the survey impetus and thus were not influenced by seabird observers. These NOAA focal surveys were marine mammal surveys, icthyoplankton surveys (Southeast Area Monitoring and Assessment Program: <u>SEAMAP</u>), and a single trawl- based fishery survey.

GOMMAPPS seabird vessel surveys were initiated in spring of 2017 (Table 4.1). Multiple surveys aboard NOAA VOOs were completed annually in 2017, 2018, and 2019. In 2017, we did not have seabird observers aboard Leg 1 of the R/V Gordon Gunter marine mammal cruise due to: (1) funding that had not yet made its way through the system and thus, we did not have sufficient funding in place to compensate contracted seabird observers, (2) limited availability of qualified seabird observers, (3) insufficient time to get required NOAA paperwork submitted and processed, (4) concern over the departure port and potential commuting time from the departure port before entering the Gulf and (5) potential spatial overlap of Leg 1 R/V Gordon Gunter with that of the recently completed seabird surveys aboard the R/V Pisces. By late 2017, we had compiled a pool of committed, experienced seabird observers, the funding had made its way through the system, and most importantly, we had experienced personnel (J. Chris Haney) in place to coordinate seabird vessel survey personnel, NOAA required documentation for observers, scheduling, observer travel, and other associated logistics. The number of seabird vessel surveys varied by year: 2017 (n = 5), 2018 (n = 7), and 2019 (n = 2), as did the geographic coverage of individual cruises (Figure 4.1, Appendix B). Our decision to limit the number of seabird vessel surveys in 2019 was due partly to funding constraints, but also a function of our decision to maximize seabird data collection opportunities on NOAA vessels specifically dedicated for GOMMAPPS marine mammal surveys in 2017 and 2018. The dedicated GOMMAPPS marine mammal surveys resulted in more survey effort allocated to deeper offshore waters with greater overall survey effort on longer transects.

Seabird observers recorded all birds, marine mammals, sea turtles, and fishes detected during surveys and identified each to the lowest taxonomic order possible (Appendix A). We classified all identifiable birds as either seabirds or other birds (i.e., non-marine avifauna). We followed taxonomic categories used by Wilson et al. (2019a) and grouped all bird non-seabird species (non-marine avifauna) as landbirds (e.g., passerines, swifts and swallows, pigeons and doves, etc.), marshbirds (i.e., American coot), raptors (i.e., osprey, falcons, owls), shorebirds (e.g., plovers, sandpipers, etc.), wading birds (e.g., herons, egrets, etc.),

or waterfowl (e.g., ducks). Refer to Section 3.2 above and Section 5.2 below for additional information.



Figure 3.29. Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for all marine bird species combined 2018 summer aerial surveys.

The x-axis represents the number of birds counted and y-axis represents distance to shore; gray circles indicate observed data. There was a steep decline in number of birds counted as distance from shore increased >25,000 m.





The x-axis represents the number of marine birds counted and y-axis represents SST (C°); gray circles indicate observed data. There was a decline in number of gulls and terns observed with increasing distance from shore. The number of birds observed increased with increasing values of SST, particularly between 30 - 31 °C.



Figure 3.31. Marginal effects model plot of sea-surface height (SSH) (dark blue line) and associated 95% credible intervals (light blue band) for all marine bird species combined counts 2018 summer aerial surveys.

The x-axis represents the number of marine birds counted and y-axis represents SSH (in meters); gray circles indicate observed data. There was a steady increase in the number of marine birds counted over the observed range (-0.4 m to +0.05 m) of SSH.


Figure. 3.32. Marginal effects model plot of sea-surface salinity (SSS) on gull and tern counts (blue line) with associated 95% credible intervals (light blue band) for all marine bird species combined counts 2018 summer aerial surveys.

The x-axis represents the number of marine birds counted and y-axis represents sea-surface salinity (SSS) (in parts per thousand); gray circles indicate observed data. There was a steep increase in number of marine birds counted once SSS exceeded ~25 ppt.



Figure 3.33. Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on all marine bird species combined counts for 2018 summer aerial surveys.

Parameters modeled were distance from the midpoint of the survey unit to shoreline (Distance), sea-surface salinity (SSS), sea-surface height (SSH), sea-surface temperature (SST), and the intercept (mean expected count on log-scale of all marine birds at the mean values of the other modeled variables). Parameters to the left of the vertical dashed line indicate negative effects, parameters to the right of the vertical dashed line indicate positive effects, and 95% credible intervals overlapping the dashed line (0) indicates no effect. Please refer to text for more details.



Figure 3.34. Summer predicted abundance model (a) and associated standard deviation of predictions (b) for all marine bird species combined 2018 aerial surveys.

The survey area includes all 40 km² hexagons representing the entirety of the study area from the coastline out to roughly 50 nm line. The northern boundary approximates a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. Predictor variables in the model included distance to shore, and average of hourly SSS, SSH, and SST. Please refer to text for more details.



Figure 3.35. Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on all marine bird species combined counts for 2018 summer aerial surveys.

Parameters modeled were distance from the midpoint of the survey unit to shoreline (Distance), sea-surface salinity (SSS), sea-surface height (SSH), sea-surface temperature (SST), and the intercept (mean expected count on log-scale of brown pelicans at the mean values of the other modeled variables). Parameters to the left of the vertical dashed line indicate negative effects, parameters to the right of the vertical dashed line indicate positive effects, and 95% credible intervals overlapping the dashed line (0) indicates no effect. Please refer to text for more details.



Figure 3.36. Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for brown pelican (BRPE; *Pelecanus occidentalis*) counts in 2018 summer aerial surveys.

The x-axis represents the number of brown pelicans counted and y-axis represents distance to shore; gray circles indicate observed data. There was a steep decline in number of brown pelicans counted as distance from shore \geq 20,000 m.



Figure 3.37. Summer predicted abundance model (a) and associated standard deviation of predictions (b) for brown pelican (BRPE; *Pelecanus occidentalis*) 2018 aerial surveys.

The survey area includes all 40 km² hexagons representing the entirety of the study area from the coastline out to roughly 50 nm line. The northern boundary approximates a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. Predictor variables in the model included distance to shore, and average of hourly SSS, SSH, and SST. Please refer to text for more details.



Figure 3.38. Parameter estimates (open circles) with associated 95% credible intervals (dark lines) from the negative binomial (log-scale) generalized linear model examining the effects of environmental variables (x-axis) on gull and tern counts for 2018 summer aerial surveys.

Parameters modeled were distance from the midpoint of the survey unit to shoreline (Distance), sea-surface salinity (SSS), sea-surface height (SSH), sea-surface temperature (SST), and the intercept (mean expected count log-scale of gulls and terns at the mean values of the other modeled variables). Parameters to the left of the vertical dashed line indicate negative effects, parameters to the right of the vertical dashed line indicate positive effects, and 95% credible intervals overlapping the dashed line (0) indicates no effect. Please refer to text for more details.



Figure 3.39. Marginal effects model plot of distance to shore (dark blue line) and associated 95% credible intervals (light blue band) for gull and terns counts in 2018 summer aerial surveys.

The x-axis represents the number of gulls and terns counted and y-axis represents distance to shore; gray circles indicate observed data. There was a steep decline in number of brown pelicans counted as distance from shore \geq 25,000 m.



Figure 3.40. Marginal effects model plot of sea-surface height (SSH) (dark blue line) and associated 95% credible intervals (light blue band) for gull and tern counts in 2018 summer aerial surveys.

The x-axis represents the number of gulls and terns counted and y-axis represents SSH (in meters); gray circles indicate observed data. There was a slight increase in the number of gulls and terns counted over the observed range (-0.1 m to +0.1 m) of SSH.



Figure 3.41. Summer predicted abundance model (a) and associated standard deviation of predictions (b) for gulls and terns from 2018 aerial surveys.

The survey area includes all 40 km2 hexagons representing the entirety of the study area from the coastline out to roughly 50 nm line. The northern boundary approximates a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. Predictor variables in the model included distance to shore, and average of hourly SSS, SSH, and SST. Please refer to text for more details.



Figure 4.1. Tracklines (solid black lines) for GOMMAPPS seabird vessel surveys (2017 – 2019).

Map of the US Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida with the seabird vessel survey tracklines following a sawtooth design for NOAA marine mammal surveys (refer to Rappucci et al. 2023;fig. 3), as well as tracklines between survey points for NOAA programmatic ichthyoplankton surveys, and tracklines to and from the port at Pascagoula, MS. The 200-m and 2000-m isobaths are also shown. BOEM Planning Area boundaries are identified by solid yellow lines and the EEZ is identified by dashed red line. Please refer to text for more details.

Order ¹	Cruise	Start Date	End Date	Days At Sea	# Transec ts	Surve y Effort (hrs)	Area Survey ed (km²)	% Classified as Focal Species ²	# Planning Areas ³	EPA	СРА	WPA	Outside ⁴
1	R21702	4/28/2017	5/30/2017	28	164	178.1	3,410.2	0.57	3	х	х	х	Х
2	PI1706	6/4/2017	6/16/2017	13	136	37.9	545.6	0.36	3	х			Х
3	GG1707	7/21/2017	8/5/2017	16	63	161.7	2,995.5	0.52	2	х	х		
4	GG1708	8/9/2017	8/25/2017	17	48	169.6	3,064.8	0.50	2		х	х	Х
5	GG1709	9/17/2017	9/29/2017	13	38	106.2	1,895.3	0.43	2		х	х	х
6	GG1801	1/14/2018	2/8/2018	19	44	160.6	2,689.3	0.43	3	Х	х	х	х
7	GG1802	2/12/2018	2/26/2018	15	44	149.7	2,473.6	0.34	2		х	х	х
8	GG1803	3/1/2018	3/16/2018	16	37	140.8	2,190.5	0.57	2	х	х		Х
9	O21804	4/27/2018	5/11/2018	15	47	125.5	2,253.5	0.50	2	х	х		Х
10	O21805	5/16/2018	5/25/2018	10	56	45.8	779.4	0.23	2		х	х	х
11	PC1805	8/11/2018	10/6/2018	52	440	439.7	8,086.3	0.73	3	Х	х	х	х
12	GG1804	9/11/2018	9/30/2018	20	77	162.4	2,819.1	0.57	3	Х	х	х	х
13	O21901	4/26/2019	5/24/2019	26	86	205.5	3,828.4	0.55	3	Х	х	х	х
14	PC1905	8/21/2019	9/25/2019	33	122	253.7	4,703.5	0.61	3	Х	х	х	х
2017 total				87	449	653.5	11,911. 3						
2018 total				147	745	1224.5	21,291. 7						
2019 total				59	208	459.2	8,531.9						-
Total				293	1,402	2,337. 2	41,734. 9						

 Table 4.1. Summary of seabird vessel survey effort as a part of the GOMMAPPS, 2017 – 2019.

Cruise: codes refer to the survey vessels R/V Gordan Gunter (GG), R/V Oregon II (O2, R2), and R/V Pisces (PI, PC). These codes are entered in Program SEEBIRD at the start of each seabird vessel survey.

Summaries include some records that were later excluded from analysis related to model-specific assumptions such as a constant rate of travel or missing predictor data.

1 Order presented here is based on cruise dates.

2 % Classified as Focal Species: only seabirds; the proportion of focal seabird species observed for a given cruise. Refer to Table 5.6c for more information.

3 # of planning areas: represents the # of planning areas surveyed during a given cruise. More than 1 planning area may be surveyed on a given cruise.

4 Outside: indicates effort occurring outside the defined geographical boundaries of the Eastern, Central, and Western Bureau of Ocean Energy Management (BOEM) planning areas.

4.1 Vessel Survey Protocols, Data Collection, and Data Screening

Data collection during the cruises followed a standardized protocol for collection of marine fauna at sea (e.g., Tasker et al. 1984, Ballance 2007). Because data were entered directly into the SEEBIRD (Vers. 4.3.7) software system (Ballance and Force 2016) installed on Panasonic Toughbook[™] laptops, certain aspects of data recording were constrained by both software features and software limitations (e.g., distance limited to four categories). Because Ballance and Force (2016) provide a thorough review of the software and its application for vessel-based surveys, we refer the reader to that document for operational details. Briefly, an observer on the flying bridge of the vessel identified birds to the lowest taxonomic level and counted all birds within view. Observations were made from the side of the vessel with the least glare (i.e., focal side; 1 = port, 2 = starboard), and the bird's angle of flight direction and distance from the ship were estimated from 0-100 m, 101-200 m, and 201-300 m (Heinemann 1981), corresponding to subsequently defined distance codes 1, 2, and 3 identified in Program SEEBIRD, respectively. Distance code 4 is used when a bird is detected: (1) at distance >300 m within the survey strip or (2) on the opposite side of the vessel from that selected. This distance code is included to record 'rare' birds even when they do not enter the 300 m strip. Relatively low densities of birds coupled with good observation conditions in the Gulf (e.g., calm seas, high visibility) generally allowed species-specific identification and accurate counts to \sim 500 m (but refer also to Bolduc and Fifield 2017) on both sides of the vessel. Such opportunities are not common in areas with higher densities of seabirds, greater abundances of seabirds sitting on the water, greater abundances of pursuit- diving seabirds, or poorer overall observation conditions (e.g., due to high sea state; Chapman 1977) such as those frequently encountered in the north Atlantic, north Pacific, or central Pacific (e.g., Haney and McGillivary 1985, Ainley et al. 2005, Pittman and Huettmann 2006). Poor observation conditions (i.e., sea fog, sea state > Beaufort 4) did occur at times within the Gulf (refer also to Spear et al. 2001). Therefore, we classified observations >300 m on the focal side of the vessel and occurring at any distance on the non-focal side as distance zone '4' (i.e., a constraint of the software as referenced above; see below for more details). These steps and modifications to the survey protocol allowed us to maximize the data return per unit survey effort without sacrificing the probability of detecting birds within survey strip in distance zones 1-3 (on the specified side of the vessel) given the unique observation conditions encountered during seabird vessel surveys in the Gulf.

We used observations of birds collected from all distance zones for documenting occurrence (i.e., mapping locations) and for modeling the probability of occurrence throughout the Gulf based on habitat attributes (i.e., models developed with Program MaxEnt; Section 4.4 below). We graphically compared the suite of seabirds observed in distance zones 1 - 3 on the focal side of the ship with the suite of seabirds observed elsewhere (i.e., >300 m on the focal side, any distance on the non-focal side). Our results indicated that the community of seabirds described in focal distance zones 1 - 3 included a slightly smaller proportion of black and sooty terns and a slightly greater proportion of laughing gulls compared to the community of seabirds described outside of focal distance zones 1 - 3 (Figure 4.2). Therefore, by including observations outside of focal distance zones 1 - 3 we were able to enhance the opportunity to detect black and sooty terns, two species of ecological interest in the region (Jodice et al. 2019). Given the primary objective of mapping species occurrence, the lack of an apparent or ecologically relevant difference in species composition in distance zone 4 on the focal and non-focal side of the ship, and compared to distance zones 1-3, we opted to include seabird observations from all distance zones for

mapping occurrence and modeling the probability of occurrence.



Figure 4.2. Histogram of the seabird community as a proportion of individuals of a given species in the four different distances zones (Zone 1 = 0 - 100 m, Zone 2 = 100 - 200 m, Zone 3 = 200 - 300 m, Zone 4 = >300 m as well as birds observed off or outside the transect boundary) from Program SEEBIRD (Vers. 4.3.7; Ballance and Force 2016) used for seabird vessel surveys (2017 – 2019).

The x-axis represents percent difference by distance zone and y-axis represents 43 species of seabirds observed identified by their respective 4-letter American Ornithologists Union codes. Red bars indicate a given species composed a greater percentage of all individuals observed in distance zones 1 - 3 compared to distance zone 4, whereas blue bars indicate that a given species composed a lesser percentage of all individuals observed in distance zones 1 - 3 than all individuals observed in distance zone 4. Please refer to text for more details. A list of the 4-letter AOU codes can be found on the Institute for Bird Populations website.

4.2 Seabird Response Metrics and Habitat Variables

We defined a detection of marine birds as all individuals observed in an instance, irrespective of the rate of movement of the ship. Observed abundance (i.e., count) is the number of birds seen for a given observation record entered in Program SEEBIRD, irrespective of movement of the ship. We report 'detection data' in summary tables and appendices. All data presentations herein assume that observations made were made without error and are representative of the target species given their availability/presence to be detected in the survey area (and transect) on a given survey date. Further, we assume that: (1) species identification is correct (i.e., no species ID error; but refer also to Conn et al. 2013), (2) perpendicular distances are measured correctly and/or assigned to the correct distance category (Buckland et al. 2001, Thomas et al. 2010), (3) the number of individuals counted (i.e., no bias in enumerating flocks irrespective of flock size; Ryan and Cooper 1989) is correct, and (4) all data collected in real-time were correctly entered in Program SEEBIRD (i.e., no data entry error). Herein, we did not attempt to account for potential detection-related issues, and we assumed p*i* = 1 within the survey for all distance categories (Buckland et al. 2001, 2008) and within the strip (Barbraud and Thiebot 2009) (refer to Figure 4.2; refer also to Michael et al. 2022, 2023).

Environmental variables used in subsequent analyses to represent aspects of the marine habitat potentially relevant to seabirds included dynamic and static features (described below), as well as anthropogenic structures. We included variables recommended by Kinlan et al. (2016) when practicable. All

environmental variables and their origins are further described in Table 4.2. We selected environmental variables based on previously identified seabird-habitat relationships with similar species in the Gulf and western north Atlantic (e.g., Poli et al. 2017, Kinlan et al. 2016, Winship et al. 2018).

We obtained dynamic variables at a daily resolution from the Hybrid Coordinate Ocean Model (HYCOM; Chassignet et al. 2009, Metzger et al. 2017). This suite of variables included sea- surface temperature, sea-surface salinity, sea-surface height, and surface current velocity (eastward (*u*) and northward(*v*)). Surface current velocity was also used to calculate absolute current strength and current direction. We also included chlorophyll-a as a dynamic variable which we obtained at monthly intervals (fewer gaps compared to daily intervals), from Modis Aqua 4 km L3 SMI (OBPG 2014). The coarser temporal resolution used for chlorophyll-a was required to reduce data loss due to cloud cover (i.e., daily data would have resulted in a substantial loss of seabird observations due to missing chlorophyll-a data). We included depth from the SMRT30+ version 6.0 30 arc second dataset (Becker et al. 2009) as a static feature. Positive values were excluded, and NA values were replaced with 0s. To investigate the potential association of seabirds with active oil and gas (O&G) platforms, active platform location data were retrieved from the BOEM Data Center ⁴.

4.3 Modeling Distribution and Abundance of Seabirds

We mapped the locations of all non-marine avifauna (defined above in 2.4.1). For seabirds, we either mapped their occurrence (i.e., species with $n \le 19$ detections) or modeled their probability of occurrence using Program MaxEnt⁵ (Vers. 3.4.2; Phillips et al. 2006). The model detection threshold (n = 20) used is based on simulation results that suggest that ≥ 20 detections results in good performance of MaxEnt models for species that are prevalent and widespread (van Proosdij et al. 2016). Briefly, MaxEnt is a machine learning technique that uses the maximum entropy approach to estimate the probability of occurrence of a species across a specified area based on occurrence (presence only) observations and a set of covariates (i.e., predictor variables that represent habitat conditions). Presence only observations do not weight observations by the number of individuals detected. MaxEnt performs well at relatively low sample sizes (i.e., n < 100 observations) by utilizing a presence-background algorithm that is less sensitive to sample size compared to other approaches used to model species distributions (Phillips et al. 2006, Wisz et al. 2008). The predicted surface should not be interpreted as relative abundance, but rather as the probability of occurrence. By extension, the predicted surface may also be interpreted generally as habitat suitability, although this is a derivative of probability of occurrence.

We modeled the probability of occurrence with 10,000 random background pixels that covered the entire Gulf. Data were modelled at a spatial resolution of 4.67 km x 4.67 km based on the coarsest native spatial resolution available across the selected environmental data (Table 4.2; Michael et al. 2022). As observations occurred in only a portion of the Gulf, we applied "clamping" which, in MaxEnt, assumes that covariates from background pixels with values outside of the range of those from the training data can occur, but at low probabilities (i.e., at the tail end of the distribution; Phillips et al. 2006). Clamping thus reduces the potential for predicting a high probability of occurrence in areas with covariate values well outside of those in the training data. We applied the model to the test data and used the area under the receiver operating characteristics curve (AUC) to quantify the predictive power of the model, where an AUC of 0.5 - 0.6 indicates poor model performance, 0.6 - 0.7 fair model performance, 0.7 - 0.8 good model performance, 0.8 - 0.9 very good model performance, 0.9 - 0.99 excellent model performance, and an AUC of 1 indicates perfect discrimination (Bradley 1997, Duan et al. 2014). We characterized the permutation importance of each covariate (the sensitivity of the model to a given covariate, holding all other covariates constant) using a jackknife procedure, a resampling approach to estimate variance and bias (Efron 1992).

For species with 20 to 27 detections, all observations were included in the MaxEnt model. For species

⁴ See <u>www.data.boem.gov</u>; accessed 03 February 2021.

⁵ See <u>https://biodiversityinformatics.amnh.org/open_source/maxent/</u>

with \geq 28 detections, we assessed model performance by separating the observations into randomly selected training (70%) and testing (30%) datasets. This distribution leaves a minimum of 20 data points in the training model, aligning with our threshold for model development (e.g., van Proosdij et al. 2016). Two species (Forster's tern and double-crested cormorant) had some detections (n = 5 and n = 16, respectively) which, due to the aggregated resolution of the habitat covariates, did not overlap the habitat variables and therefore were excluded from this analysis (i.e., we only mapped the distribution). Forster's tern and double-crested cormorant for <0.5% of total seabirds observed and the remaining 18 species accounted for <0.1% of total seabirds observed. In general, 20 seabird species accounted for ~90% of total marine avifauna observed.

Before the selection of MaxEnt to model the probability of occurrence and relationships between species of seabirds and habitat covariates, alternative modeling approaches for species with relatively numerous detections were considered (e.g., those identified in Kinlan et al. 2016). Although initial results appeared encouraging (e.g., performance metrics indicated a good fit to the data, the predicted spatial distribution appeared reasonable), maximum abundance estimates tended to be infeasibly low or dubiously high, differing by one to two orders of magnitude from the observed maximum abundance. Underestimation is a pervasive issue across model types (e.g., Zhang et al. 2020), and overestimation can also occur, particularly at the extremes of a covariate's range. Employing a suite of weighting schemes to reduce the influence of large flocks did not improve model performance.

Therefore, we determined that the most appropriate modeling approach given available seabird observational data was to use MaxEnt; model probability of occurrence for the 24 focal seabird species with sufficient detections. The surfaces produced by MaxEnt that predict probability of occurrence provide a comprehensive characterization of the distribution of these 24 species in the northern Gulf. These predicted spatial layers augment the current state of knowledge per distribution for each species across all three BOEM planning areas. Moreover, the performance metrics and covariate associations derived from MaxEnt can be readily compared among all combinations of the modeled species. We did not attempt to produce predictive models or subsequently model proximity to oil platforms for those species (n = 18) that did not meet the minimum detection threshold, i.e., ≥ 20 detections, or for Forster's tern and double-crested cormorant that had sufficient detections but did not overlap the habitat variables, due to the aggregated resolution of the habitat covariates. For these species we instead provide a map of observational data.

4.4 Seabird Community Metrics

To understand how the number of species and individuals of each species are distributed across planning areas and seasons, we assess two community metrics by aggregating observations by planning area, then season within each planning area. The species richness of the community is defined by the number of species occurring with a planning area or season. Therefore, richness increases as the number of species increase. When comparing the species richness of two communities, the same species richness value does not necessarily mean that the exact same species occur in both communities. Further, a difference of one does not necessarily mean that a that a single representative species differs between the two communities. We also compared species richness among historical and contemporary surveys in the northern Gulf. We then characterized species diversity using the Shannon-Wiener diversity index. The Shannon-Wiener diversity index evaluates community diversity using species richness and the number of individuals of each species. The interpretation of the Shannon-Wiener index (e.g., Bibi and Ali 2013) is intuitive, with smaller values indicating lesser diversity and larger values indicating greater diversity.

Specifically,

$$H' = \sum_{i=1}^{s} p_i \log(p_i)$$

H' = Shannon-Wiener diversity index

s = total number of species

 p_i = total number of individuals of the *i*th species in relation to the total number of individuals in the population

The maximum value occurs when all species have the same number of individuals. Describing community diversity with Shannon's diversity index provides greater insight into community structure than species richness alone. The Shannon's diversity index was calculated using the 'vegan' package in R (Oksanen et al. 2020).

Table 4.2. Summary of all habitat covariates used in seabird species-specific MaxEnt models (MaxEnt; Phillips et al. 2006) from data collected by seabird vessel surveys, 2017 – 2019.

All covariates were aggregated to ~4.67 km, the native coarsest temporal resolution of the original data product.

Covariate	Units	Ecological Context	Dataset name or derivation	Native Temporal Resolution*	Native Spatial Resolution	Data source
sea-surface temp	°C	Indicator of water mass	HYCOM: 2017 - 2018 (GOMI0.04/expt_32.5), 2019 (GOMu0.04/expt_90.1m000)	daily	0.0400°	https://www.hycom.org/
sea-surface salinity	standard salinity units	Indicator of water mass	HYCOM: 2017 - 2018 (GOMI0.04/expt_32.5), 2019 (GOMu0.04/expt_90.1m000)	daily	0.0400°	https://www.hycom.org/
sea-surface height	m	Hydrographic features, including convergence/divergenc e	HYCOM: 2017 - 2018 (GOMI0.04/expt_32.5), 2019 (GOMu0.04/expt_90.1m000)	daily	0.0400°	https://www.hycom.org/
eastward (u) sea water velocity	m/s	Surface current strength moving towards the eastern (+ velocity) or western (- velocity) extent of the study area	HYCOM: 2017 - 2018 (GOMI0.04/expt_32.5), 2019 (GOMu0.04/expt_90.1m000)	daily	0.0400°	https://www.hycom.org/
northward (v) seawater velocity	m/s	Surface current strength moving towards the northern (+ velocity) or southern (- velocity) extent of the study area	derived from eastward (u) and westward (v) seawater velocity described above	daily	0.0400°	https://www.hycom.org/
absolute current strength	m/s	Absolute strength of surface currents, irrespective of direction; indicates the overall 'intensity' of water movement	derived from eastward (u) and westward (v) seawater velocity described above	n/a	n/a	n/a
current direction	LAT- LONG	Indicator of current direction given u & v velocities	HYCOM: 2017 - 2018 (GOMI0.04/expt_32.5), 2019 (GOMu0.04/expt_90.1m000)	n/a	n/a	n/a
chlorophyll ^a	mg/m ³	Proxy for marine productivity	MODIS Aqua L3 CHLA Monthly 4km	monthly	0.0416°	https://oceancolor.gsfc.nasa.gov/ l3/

Covariate	Units	Ecological Context	Dataset name or derivation	Native Temporal Resolution*	Native Spatial Resolution	Data source
bathymetry ^a	m (ASL)	Bathymetric domain	SMRT30+ version 6.0 30 arc second	n/a	0.0083°	<u>https://catalog.data.gov/dataset/t</u> <u>opography-srtm30-version-6-0-</u> <u>30-arc-</u> <u>second-global2</u>

* Hourly 2019 data were downloaded at daily intervals

^a Refer to Michael et al. (2023) and Michael et al. (2024) for additional details regarding covariates and data sources

4.5 Macro-scale Exposure of Seabirds to Oil Platforms

We measured spatial overlap of seabird habitat with oil platforms to investigate the potential risk to seabirds from active oil and gas activities (refer to Michael et al. 2022). We included 24 species of seabirds in this risk assessment, focusing on the species for which we modeled predicted occurrence (i.e., habitat suitability; Section 4.4 above). We mapped the location of active platforms in federal waters. Platform location data were retrieved from the BOEM Data Center⁶. We filtered the platform data set by date to include only structures that were present during our study period. We also mapped seabird habitat for the 24 focal seabirds. Instead of using the locations at which seabirds were observed as the overlapping data, which would represent a static snapshot of a single point, we used species-specific predicted habitat suitability layer derived from MaxEnt models. Any habitat (i.e., location) with a suitability score >0.6 was defined as highly suitable and was overlaid with the platform data. We then calculated the proportion of highly suitable habitat for each species within the WPA and CPA that was within 10 km of a platform using ArcGIS Desktop 10.8 (ESRI, Redlands, California). We chose 10 km to represent a moderate scale of interaction and one that would likely fall within the visual field for flying seabirds (e.g., if attraction was occurring; Haney et al. 1992). Therefore, the proportion of highly suitable habitat within a planning area represents the macro-scale exposure of each seabird species to oil and gas activity in federal waters (Michael et al. 2022).

4.6 Review of Previous Surveys and Compilations of Seabird Observations in the Northern Gulf

To complement our understanding of the occurrence of seabirds in the northern Gulf we reviewed reports and published manuscripts from previous seabird surveys and seabird summaries. These sources included literature and reports from seabird surveys conducted during the GulfCet I and II programs (Davis and Fargion 1996, Ribic et al. 1997, Davis et al. 2000) and during the *Deepwater Horizon* Natural Resource Damage Assessment (NRDA) *Bird Study #6* (e.g., Haney et al. 2019). We also reviewed compilations that included seabirds (Duncan and Havard 1980, Clapp et al. 1982a, 1983). For each species that we observed during GOMMAPPS surveys we reviewed these sources and note whether that species was observed, and if so, provide relevant details from the source as appropriate. We refer to these data for a spatio-temporal comparison of survey efforts in the northern Gulf and within individual species accounts (refer to Section 5.3) to provide context for our abundance data (refer to Sections 5.2.1 and 5.2.2). Refer to Sections 2.2.1 -2.2.3 above for a general overview of some historical seabird surveys in the northern Gulf; refer also to Burger (2017).

⁶ See <u>www.data.boem.gov;</u> accessed 03 February 2021

5 Vessel-based Seabird Surveys: Results

5.1 Survey Effort

For summary purposes, we included multiple effort-related metrics: days- at-sea (DAS), number of transects, survey effort (hrs), and area surveyed (km²) (Table 4.1). Days-at-sea, a rough metric of effort, varied across vessel cruises/legs. In most cases, seabird observers reasonably expected individual cruises/legs to span \sim 14–24d. Changes in planned schedules and large deviations from planned survey routes were only made based on local or regional weather, mechanical issues, or when health and safety issues made it advisable to do so. During the 2017 – 2019 period, some planned NOAA cruises were either shortened or delayed due to potential government shutdowns and pending tropical storms and/or hurricanes. Over the course of this study all or parts of 5 days (2017), 14 days (2018), and 3 days (2019) were otherwise lost, i.e., no seabird surveys. For example, in 2018, 10 scheduled survey days were lost due to a pending government shutdown.

GOMMAPPS cruises (n = 14) were conducted within each planning area in the northern Gulf from April 2017 – September 2019 by experienced seabird observers (Figure 5.1). We conducted surveys during 293 days at sea representing ~2,300 hrs of observer effort totaling ~41,700 km of transects (Table 4.1). Totals for survey days, survey hours, and km of transects were greatest in 2018 and least in 2019 (Table 4.1).

5.1.1 Spatial Distribution of Survey Effort

In general, GOMMAPPS seabird vessel surveys (2017 – 2019) covered both shallower waters on the continental shelf, as well as deeper waters off the Shelf Break out to the EEZ (Figure 4.1, Appendix B). Whereas the GOMMAPPS aerial surveys were limited in distance from coastline out to 50 nm (refer to Section 3.2.2 above), vessel-based seabird surveys were not limited or constrained by distance from the coast. Though cumulative effort for GOMMAPPS seabird vessel surveys provided relatively complete survey coverage over the entire study area, the spatial coverage varied both spatially and temporally within and among years and across BOEM planning areas (Figure 4.1; refer also to Figure 5.1, Appendix B). As mentioned previously, seabird vessel observers had no flexibility related to study design. Seabird observers utilized NOAA vessels that were either specifically dedicated for GOMMAPPS marine mammal surveys and/or NOAA VOOs conducting annual icthyoplankton and trawl surveys, as part of SEAMAP (Southeast Area Monitoring and Assessment Program). Most of the GOMMAPPS seabird vessel surveys departed and returned to the NOAA Southeast Fisheries Science Center office in Pascagoula, Mississippi. As such, there was a fair amount of seabird survey effort in and around the Pascagoula Bay and Pascagoula Sound area and the area off the mouth of the Mississippi River (Figure 4.1). GOMMAPPS surveys occurred in all three of the BOEM planning areas (Figure 4.1) and occasionally beyond the borders of the planning areas (Table 5.1, Appendix B). We conducted 12,372 km of surveys during 99 days in the EPA, 19,647 km of surveys during 155 days in the CPA, 8,733 km of surveys during 62 days in the WPA, and 983 km outside of planning area boundaries during 42 days of surveys (Table 5.1). It should be noted here, that because surveys may occur in >1 planning area in the same day, the sum of days of effort across planning areas does not equal the total days of effort (Table 5.1).



Figure 5.1. Cumulative trackline maps of survey effort (transect km surveyed) across the four calendar seasons (spring = March-May, summer = June-August, fall = September-November, winter =December-February) and three BOEM planning areas (Western, Central, and Eastern) for GOMMAPPS seabird vessel surveys (2017 – 2019).

Map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida with the seabird vessel survey tracklines and BOEM planning area boundaries (black lines) by season. Spring map in upper left, summer map in upper right, fall map in lower left, and winter map in lower right. Inset of survey effort scale (in km) is shown with teal color representing lesser/limited survey effort and magenta color representing greater/maximum survey effort.

The CPA, which covers ~42% of the northern Gulf, received the greatest vessel-based survey effort across the three study years, accounting for ~45% of survey days and km (Table 5.1, Figure 5.2). The CPA supports the highest level of oil and gas activity and supports ~100 colonies of seabirds and wading birds along its northern edge (e.g., Fontenot et al. 2012, Remsen et al. 2019). Most of these colonies occur along and northeast of the Louisiana delta in a relatively dense concentration, an area that also supports brown pelicans from all three planning areas during the post-breeding period (Lamb et al. 2020a). The largest pelican colony in the northern Gulf (i.e., Gaillard Island in Mobile Bay, Alabama) also occurs on the eastern edge of the central planning area.

The EPA, which covers ~40% of the northern Gulf, received ~30% of survey effort for both survey days and km (Table 5.1, Figure 5.2). The EPA represents the area of least oil and gas activity. Seabird colonies are sparsely located along the Florida panhandle, and then somewhat regularly from Tampa Bay south through the Florida Keys (Gore et al. 2007). The southeastern edge of eastern planning area is also proximal to colonies of sooty terns, brown noddies, magnificent frigatebirds, and masked boobies all located in the Dry Tortugas. The EPA is also the nearest of the three planning areas to colonies of seabirds in the Caribbean including substantial colonies of Audubon's shearwater in the Cay Sal Bank archipelago (Bradley and Norton 2009, Mackin et al. 2015).

The WPA, which covers ~18% of the northern Gulf, received ~20% of our survey effort for both survey days and km (Table 5.1, Figure 5.2). Before GOMMAPPS, the WPA was the least surveyed of the three planning areas for seabirds (Section 5.1.3 below). The WPA is characterized by intermediate levels of oil and gas activity compared to the central and eastern planning areas, although large ports and heavy shipping traffic (e.g., Galveston, Houston) occur there. Colonies of terns (Caspian, Forster's, royal, and sandwich) occur regularly along the coast of Texas and number ~100 per species. Colonies (<10) of brown pelicans occur on the Texas coast also primarily between Galveston and Corpus Christi (refer to the <u>Texas Waterbird Society Atlas</u>; accessed 20 October 2021).

5.1.2 Temporal Distribution of Survey Effort

Although vessel-based surveys occurred during all four seasons, survey effort was not uniformly allocated among seasons (Figure 5.3). Most data were accumulated during spring and during the transition from summer to fall. Across all three years, the highest number of survey days occurred in May, August, and September (Table 4.1, Figure 5.3, respectively). Surveys were not conducted in the months of November and December, and the months of October and January received limited survey effort (<12 d/mo).

For nearshore seabirds that breed in the northern Gulf (e.g., brown pelicans, royal and sandwich terns), this suggests that our understanding of their occurrence in pelagic waters of the northern Gulf is likely highest during incubation, early chick-rearing, and at the onset of post-breeding migratory behavior. Data gaps may still exist for occurrence of nearshore seabirds in pelagic waters during the mid-winter period, although the use of these waters during this time is likely low. For example, individual tracking data from brown pelicans and black skimmers suggests that birds may cross pelagic Gulf waters during pre- and post-breeding migration periods, but they do not appear to remain in pelagic waters (Lamb et al. 2017b, Lamb et al. 2018, Jodice et al. 2019). However, similar tracking data are generally lacking for other nearshore seabirds that breed in the northern Gulf (Jodice et al. 2019; but refer also to Rolland et al. 2020).

For waterbirds that breed at higher latitudes in either the interior or along the east coast of North America (e.g., north Atlantic seabirds, interior terns and gulls, shorebirds) the temporal distribution of our surveys likely captured both pre- and post-breeding migration, and a portion of winter use. Seabirds breeding in the southern Gulf or Caribbean do not follow the same breeding season schedule as the previously mentioned two groups. For some tropical species, breeding may be asynchronous with individuals breeding during any month. For example, on the seabird colonies of the Campeche Bank (Tunnell and Chapman 2000) masked boobies breed throughout the year (Poli et al. 2017). Other tropical species may time breeding to be completed prior to the onset of hurricane season (e.g., black-capped petrel; Simons et al. 2013), or the breeding season may simply be advanced and may occur sooner in the year (e.g., tropical terns). Therefore, a detailed assessment of potential data gaps based on the temporal distribution of our surveys would likely require a species-by-species review.

5.1.3 Gulf of Mexico Marine Assessment Program for Protected Species (GOMMAPPS) Vessel Survey Effort Compared to Previous Seabird Surveys in the Gulf

Before GOMMAPPS, wide-ranging (spatially and temporally) seabird surveys in the northern Gulf were limited to four efforts: a few aerial surveys (Fritts and Reynolds 1981, Fritts et al. 1983), GulfCet I (Davis and Fargion 1996, Ribic et al. 1997), GulfCet II (Davis et al. 2000), and DWH NRDA *Bird Study #6* (Haney et al. 2011, 2019). GulfCet I (1992 – 1994) occurred during all four seasons in the western and north central planning areas and GulfCet II (1996 – 1997) also occurred in the western and north central planning areas but not during autumn. In contrast, NRDA surveys were relatively wide-ranging (i.e., occurred in all three planning areas of BOEM) and occurred in all months of the year except January (Haney 2011, Haney et al. 2019).

Table 5.1. Summary of seabird vessel survey effort across the three BOEM planning areas (Western, Central, Eastern) and calendar seasons as part of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September- November), and winter (December-February); refer also to Figure 4.1.

	Western Planning Area		Central	Planning Area	Easterr	n Planning Area	Outside of Gulf Planning Areas		
Season^	Days	Distance (km)	Days	Days Distance (km)		Days Distance (km)		Distance (km)	
Winter	9	1,382.1	24	2,877.7	6	877.9	4	25.3	
Spring	15	1,637.5	55	5,808.3	37	4,765.3	13	250.8	
Summer	15	2,514.4	32	4,725.9	32	3,515.5	13	595.7	
Fall	23	3,198.8	44 6,234.9		24	3,213.7	12	111.0	
Total	62	8,732.9	155	19,646.9	99	12,372.3	42	982.8	

[^] Seasons were defined as spring (March-May), summer (June-August), fall (September-November), and winter (December-February) (Winship et al. 2018)

Compared to the GulfCet efforts, GOMMAPPS was more extensive with respect to both transect km and hours surveyed. GOMMAPPS surveys had a broader spatial and temporal footprint compared to these three efforts. The spatial and temporal footprint for NRDA surveys (2010 - 2011) was, however, more like that for GOMMAPPS surveys (refer to Jodice et al. 2021b for comparison map and table). The notable difference was that GOMMAPPS provided enhanced coverage of offshore and pelagic waters compared to NRDA in all seasons, while the coverage of shelf waters in all seasons was greater during NRDA.

In general, both the spatial and temporal coverage from the previous vessel-based seabird surveys has dramatically improved through the inclusion of seabird survey data in the northern Gulf from GOMMAPPS. Coverage was improved within and across all BOEM planning areas, as well as within and across all seasons due to GOMMAPPS seabird surveys. Substantial enhancements occurred in spring in the northwest and southwest regions of the Gulf, and in summer in the southwest and south-central regions of the Gulf. The enhancement of coverage in the southwest and south-central regions of the Gulf in additional coverage of pelagic (compared to historical seabird surveys primarily on the shelf) waters. The enhancement of coverage in spring in the northwest and southwest regions of the Gulf may have led to increased opportunities to observe high latitude North American and Arctic breeding birds during pre- breeding migration, while the enhancement of coverage in summer in the southwest and southwest and south-central regions of the Gulf may have led to increased opportunities to observe high latitude North American and Arctic breeding birds during pre- breeding migration, while the enhancement of coverage in summer in the southwest and south-central regions of the Gulf may have led to increased opportunities to observe tropical seabirds during and after the breeding season.

We also posit that the enhanced coverage of deeper pelagic waters further offshore compared to shelf waters by GOMMAPPS may have had the greatest effect on the detection of pelagic seabirds (e.g., shearwaters, petrels) compared to nearshore or migratory seabirds. This comparison that may be most relevant for GOMMAPPS are data from *Deepwater Horizon* NRDA *Bird Study #6*, which also covered all three of the BOEM planning areas and spanned most months of the year. For example, migratory bird species during migration will exhibit Trans-Gulf migratory behavior and thus have the potential to be observed in both nearshore and pelagic waters.



Figure 5.2. Histogram of allocation of survey effort based on number of survey days (top) and distance surveyed (bottom) by year across the three BOEM planning areas (Western, Central, and Eastern) for GOMMAPPS seabird vessel surveys (2017 – 2019).

Plate A the x-axis represents number of survey days, and the y-axis represents the Western, Central, and Eastern BOEM planning areas, as well as outside. Plate B the x-axis represents distance surveyed (transect km), and the y-axis represents the Western, Central, and Eastern BOEM planning areas, as well as outside. Outside is defined as survey effort occurring outside the defined boundaries of the Eastern, Central, and Western BOEM planning areas, e.g., state waters, Florida Strait.



Figure 5.3. Histogram of allocation of survey effort based on number of survey days (top) and distance surveyed (bottom) by calendar month for GOMMAPPS seabird vessel surveys (2017 – 2019).

Plate A the x-axis represents number of survey days, and the y-axis represents calendar month. Plate B the x-axis represents distance surveyed (transect km) and the y-axis represents calendar month. Irrespective of which survey effort metric is considered, effort tended to be highest in the months of May, August, and September with no survey effort in the months of November or December.

However, pelagic seabird species that are considered "seasonally-resident" will not typically occur in shallower waters on the continental shelf. Many to most colonial-breeding seabird species along the northern Gulf will also infrequently to rarely be found in deeper pelagic waters far offshore (except perhaps during migration; Lamb et al. 2018, Jodice et al. 2019). Consequently, differences in survey coverage between GOMMAPPS, and *Deepwater Horizon* NRDA *Bird Study* #6 surveys may have the least influence on detection of Trans-Gulf migrants (e.g., terns, jaegers) and the most influence on detections of nearshore species (perhaps lacking more from GOMMAPPS surveys) and pelagic species (perhaps lacking more from NRDA). This comparison suggests that GOMMAPPS and *Deepwater Horizon* NRDA *Bird Study* #6 may provide complementary spatial coverage, given the caveat that they were conducted several years apart.

5.2 Fauna Observed in the Northern Gulf

Although our primary focus was the detection of seabirds, we recorded all other species to the lowest taxonomic level possible during seabird vessel surveys. Though we present summary data for fish, marine mammals, and sea turtles here, we defer to taxa specific Final Reports and Chapters therein for detailed treatment of marine mammals (i.e., NOAA) and sea turtles (i.e., USGS). We tallied ~24,000 detections of ~160,000 individual animals (Table 5.2). Of these, 10,692 detections were of 51,109 birds from 112 identified species, and 13,406 detections were of ~108,250 individual non-avian fauna.

We recorded 324 detections of ~2k marine mammals among 14 identified species (Table 5.3a through Table 5.3b). Approximately 80% of individuals were either pantropical spotted dolphin, bottlenose dolphin, or Atlantic spotted dolphin (relatively evenly distributed among these three species; Table 5.3b). We recorded 64 detections of 65 sea turtles among four species (Table 5.3a through Table5.3b). Approximately 42% were loggerheads and 40% were unidentified (Table 5.3b). We also recorded ~13k detections of ~107k fish (Table 5.3a). Of these, 99% of individual fish observed were flying fish (Family *Exocoetidae*; not identified to species) (Table 5.3b).

5.2.1 Non-marine Avifauna

We had 1,345 detections of 6,980 birds classified as non-marine avifauna representing 77 species (Table 5.4a through Table5.4c). Detections classified as non-marine avifauna accounted for 12.6% of all avifauna detections, 13.7% of all individual birds, and 63.6% of all avifauna species that were identified.

Landbirds were the most frequently detected non-marine avifauna (Table 5.4a) based on species richness (~64%), number of detections (~61%), and number of individuals (~53%). Passerines comprised the vast majority of landbirds observed although aerial insectivores (i.e., swallows, swifts, nightjars) also occurred regularly (Table 5.4b through Table5.4c). Warblers and passerines occurred in each planning area in both nearshore waters and beyond the 2,000-m isobath (Appendix C).

Aerial insectivores were primarily observed in the CPA and EPA in both nearshore waters and beyond the 2,000-m isobath (Appendix C). Landbirds were observed in all three planning areas and in all four seasons although observations of individuals were more common in the CPA and during the fall (Table 5.5).

Wading birds were the next most abundant group of non-marine avifauna with respect to species richness (~13%), number of detections (~23%), and number of individuals (~24%) (Table 5.4a). Cattle egrets were the most common wading bird observed, making up ~30% of all waders (Table 5.4b through Table5.4c). Wading birds were observed in all three planning areas and in all four seasons although observations of individuals were more common in the CPA and during the fall (Table 5.5). Wading birds were observed in both nearshore waters and beyond the 2,000-m isobath (Appendix C).

Faunal Class	# Detections	# Individuals	Species Richness [*]		
Marine avifauna	9,347	44,029	44		
Nonmarine avifauna	1,345	6,980	68		
Marine mammals	324	2,025	14		
Sea turtles	64	65	4		
Fish ¹	13,017	106,059	<u>></u> 5		
Total	24,097	159,158	<u>></u> 135		

 Table 5.2.
 Summary of various faunal classes based on number of detections, number of individuals, and species richness from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

* Species Richness is simply the # of individual ID to the species-level within a given faunal class. 1 Within the faunal class "Fish", most detections and individuals are represented by the various species of flying fish (Family Exocoetidae). Within Program SEEBIRD (Vers. 4.3.7; Ballance and Force 2016) there is a routine for entering "flying fish" with separate output files generated at the end of each survey day if "flying fish" were observed. For flying fish, though one can enter different species in Program SEEBIRD, most records were coded as unidentified (UNID) Flying Fish (refer to Tables 5.3a-5.4b).

Although we only observed two species of identifiable waterfowl, these species accounted for ~7% of detections and 17% of individuals of non-marine avifauna (Table 5.4a). Of those records identified to species, blue-winged teal was the most common (Table 5.5b through Table 5.4c). Waterfowl were observed in all three planning areas and in all four seasons although observations of individuals were more common in the CPA and during the fall (Table 5.5). Blue-winged teal were observed in both nearshore waters and beyond the 2,000-m isobath (Appendix C). We had a single detection of a greater scaup in the western reaches of the CPA between the 200-m and 2,000-m isobath.

Shorebirds made up ~13% of the species richness for non-marine avifauna, also accounting for ~5% of detections and individuals observed (Table 5.4a). We were unable to identify most (~78%) shorebirds (Tables 5.4b-5.4c). Shorebirds were not observed in winter and were not observed in the WPA (Table 5.5). Shorebirds were observed in both nearshore waters and beyond the 2,000-m isobath (Appendix C). We observed five species of raptors accounting for ~3% of detections of non-marine avifauna and <1% of individuals (Table 5.4a through Table5.4c). Raptors were primarily observed in fall and spring, but not in winter. Raptors were observed within all three planning areas in both nearshore waters and beyond the 2,000-m isobath (Appendix C, Table 5.5).

Marshbirds were represented by two detections of a single species, American coots (Tables 5.4a- 5.4c). Both detections occurred in the spring, and both occurred in the EPA beyond the 2,000-m isobath (Appendix C, Table 5.5). It is plausible these 2 individuals represented Trans-Gulf migrants returning north from wintering grounds in the southern Gulf or Caribbean (Brisbin and Mowbray 2020). Of the 34 American coots observed by Russell (2005:table 6.12), 21 (~62%) of the birds observed occurred in the spring.

Table 5.3a. Summary of number of detections of non-avifauna by season and Bureau of Ocean Energy Management (BOEM) planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September- November), and winter (December-February). Scientific names for all birds identified to species (UNID = unidentified to species) are included in Appendix A.

Species	# Detections	Spring	Summer	Fall	Winter	Eastern Planning Area	Central Planning Area	Western Planning Area	Outside of BOEM planning area
Hammerhead shark	1	0	0	1	0	1	0	0	0
Mahi mahi	5	2	3	0	0	1	3	1	0
Mola mola	1	0	0	0	1	0	0	1	0
Unid. Exocoetus	19	6	7	6	0	6	6	6	1
Unid. fish	6	0	5	0	1	1	1	2	2
Unid. flying fish	12,974	2,624	3,355	6,686	309	3,927	6,393	2,553	101
Unid. shark	1	1	0	0	0	1	0	0	0
Unid. tuna	10	1	3	1	5	1	6	3	0
Total	13,017								
Atlantic spotted dolphin	46	8	5	32	1	33	6	7	0
Bottlenose dolphin	147	38	30	64	15	28	76	34	9
Bryde's whale	1	0	0	1	0	0	0	1	0
Clymene dolphin	1	0	0	0	1	0	1	0	0
Cuvier's Beaked whale	2	1	0	0	1	1	1	0	0
False killer whale	2	2	0	0	0	1	1	0	0
Pantropical spotted dolphin	34	22	1	9	2	17	15	2	0
Risso's dolphin	3	2	0	0	1	0	2	1	0
Rough-toothed dolphin	3	3	0	0	0	1	1	1	0

Species	# Detections	Spring	Summer	Fall	Winter	Eastern Planning Area	Central Planning Area	Western Planning Area	Outside of BOEM planning area
Short-finned pilot whale	1	1	0	0	0	0	0	1	0
Sperm whale	7	4	0	1	2	0	6	1	0
Spinner dolphin	3	3	0	0	0	0	3	0	0
Striped dolphin	5	4	0	0	1	2	3	0	0
Unid. cetacean	3	2	1	0	0	0	2	1	0
Unid. dolphin	53	28	10	14	1	19	23	7	4
Unid. Kogia	2	1	0	0	1	2	0	0	0
Unid. Odontocete	1	1	0	0	0	0	1	0	0
Unid. Stenella	5	0	3	2	0	3	2	0	0
Unid. whale	4	4	0	0	0	0	4	0	0
West Indian manatee	1	0	1	0	0	1	0	0	0
Total	324								
Green turtle	2	1	0	1	0	1	1	0	0
Kemp's ridley turtle	5	1	0	4	0	0	4	1	0
Leatherback turtle	5	2	0	3	0	3	2	0	0
Loggerhead turtle	27	9	1	14	3	15	10	2	0
Unid. sea turtle	25	6	12	6	1	11	4	3	7
Total	64								
Unid. squid	1	0	0	1	0	0	0	1	0

Table 5.3b. Summary of number of individuals of non-avifauna by season and Bureau of Ocean Energy Management (BOEM) planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September- November), and winter (December-February). Scientific names for all birds identified to species (UNID = unidentified to species) are included in Appendix A.

Species	# Individuals	Spring	Summer	Fall	Winter	Eastern	Central	Western	Outside of BOEM planning area
Hammerhead shark	1	0	0	1	0	1	0	0	0
Mahi mahi	6	3	3	0	0	1	4	1	0
Mola mola	1	0	0	0	1	0	0	1	0
Unid. Exocoetus	229	13	29	187	0	84	117	16	12
Unid. fish	6	0	5	0	1	1	0	2	2
Unid. flying fish	105,805	11,795	27,602	65,369	1,039	36,235	46,029	22,524	1,017
Unid. shark	1	1	0	0	0	1	0	0	0
Unid. tuna	10	1	3	1	5	1	0	0	0
Total	106,059								
Atlantic spotted dolphin	443	74	58	287	24	292	102	49	0
Bottlenose dolphin	582	155	136	236	55	147	261	146	28
Bryde's whale	1	0	0	1	0	0	0	1	0
Clymene dolphin	2	0	0	0	2	0	2	0	0
Cuvier's Beaked whale	6	4	0	0	2	4	2	0	0
False killer whale	12	12	0	0	0	6	6	0	0
Pantropical spotted dolphin	589	370	6	169	44	325	248	16	0
Risso's dolphin	32	18	0	0	14	0	26	6	0
Rough-toothed dolphin	19	19	0	0	0	2	7	10	0
Short-finned pilot whale	5	5	0	0	0	0	0	5	0

Species	# Individuals	Spring	Summer	Fall	Winter	Eastern	Central	Western	Outside of BOEM planning area
Sperm whale	17	13	0	1	3	0	15	2	0
Spinner dolphin	13	13	0	0	0	0	13	0	0
Striped dolphin	40	34	0	0	6	14	26	0	0
Unid. cetacean	8	4	4	0	0	0	4	4	0
Unid. dolphin	200	90	39	70	1	63	96	0	8
Unid. Kogia	2	1	0	0	1	2	0	0	0
Unid. Odontocete	1	1	0	0	0	0	1	0	0
Unid. Stenella	44	0	41	3	0	41	3	0	0
Unid. whale	8	8	0	0	0	0	8	0	0
West Indian manatee	1	0	1	0	0	1	0	0	0
Total	2,025								
Green turtle	2	1	0	1	0	1	1	0	0
Kemp's ridley turtle	5	1	0	4	0	0	4	1	0
Leatherback turtle	5	2	0	3	0	3	2	0	0
Loggerhead turtle	27	9	1	14	3	15	10	2	0
Unid. sea turtle	26	6	13	6	1	11	4	3	8
Total	65								
Unid. squid	1	0	0	1	0	0	0	1	0

 Table 5.4a.
 Summary of bird taxonomic groups based on number of detections, number of individuals, and species richness from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Taxa Group ¹	# Detections	# Individuals	Species Richness [*]
Landbirds	822	3,680	49
Marshbirds	2	2	1
Waterfowl	91	1,193	2
Wadingbirds	312	1,687	10
Raptors	41	42	5
Shorebirds	77	376	10
Total	1345	6,980	77

*Species Richness is the # of individual ID to the species-level within a given taxonomic group. 1Taxonomic Group generally follows the taxonomic groups used by the Gulf of Mexico Avian Monitoring Network (GOMAMN) for their Birds of Conservation Concern, link <u>here</u>.

5.2.2 Marine Avifauna

We tallied 9,347 detections of 44,029 seabirds representing 44 species (Tables 5.6a-5.6c; refer also to Michael et al. 2023). We identified 37,817 birds to species (85.9%). Seabird observations accounted for 87.4% of all avifauna detections, 86.3% of all individual birds, and 39.3% of all birds identified to species. Eleven species comprised 90% of the individual seabirds observed. Two species of terns (black and sooty) comprised 45% of all individual birds observed (Table 5.6a). Black terns accounted for 27% of individuals observed and sooty terns accounted for 18% of individuals observed. No other species accounted for >10% of the observed individuals, while 9 species each accounted for 2 to 7% of the observed individuals (Table 5.6a). This suite of less abundant, but still regularly observed species included three species of gull (laughing, herring, and Bonaparte's), two species of tern (royal and sandwich), two pelecaniforms (magnificent frigatebird and brown pelican), one shearwater (Audubon's), and one sulid (northern gannet) (Table 5.6a).

We grouped all seabirds into 15 taxonomic groups to summarize community composition (Table 5.6a, Table 5.7). The most frequently observed taxonomic group included a mix of coastal and inland terns (~43% of individuals). Pelagic and tropical terns comprised ~21% of individuals and gulls (a mix of coastal and inland breeders) comprised ~18% of individuals. No other taxonomic group comprised >5% of individuals observed.

All taxa groups were observed in all seasons except for gadfly petrels, which were not observed in winter, gannets, which were not observed in summer, common loons, which were not observed in summer or fall, and tropicbirds, which were not observed in winter (Tables 5.6b, 5.6c, 5.8). Gulls from breeding areas in northern latitudes were rare in summer and terns from northern latitudes were absent in winter (Table 5.6b through Table5.6c). Representative species for all the taxonomic groups were observed in both the EPA and CPA (Table 5.8); however, gannets, loons, and phalaropes were not observed in the WPA (Table 5.6b through Table5.6c, and Table 5.8). Other taxonomic groups with low number of observations within a specific planning area included gadfly petrels (n = 1; WPA), cormorants (n = 1; EPA), and tropicbirds (n = 3; WPA).

We also classified species with respect to their primary breeding region (Table 5.6a). For species that breed in more than one region, we classified them based on proximity to the nearest known breeding region. We delineated six breeding regions: (1) the northern Gulf (Texas, Louisiana, Mississippi, Alabama, and the Florida panhandle and peninsula), (2) the southern Gulf and Caribbean (Mexico, the Dry Tortugas, islands of the Caribbean and Bahamas, (3) Atlantic coast of U.S. and Canada (i.e., NW Atlantic), (4) interior U.S. and Canada (i.e., interior north), (5) eastern Atlantic (i.e., islands off Europe and Africa), and (6) south Atlantic (south of the equator).

Table 5.4b. Summary of number of detections for non-marine avifauna by season and BOEM planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September- November), and winter (December-February). Scientific names for all birds identified to species (UNID = unidentified to species) are included in Appendix A.

Species	Таха	# Detections	Spring	Summer	Fall	Winter	Eastern	Central	Western	Outside of BOEM
•	Group									planning area
American redstart	landbird	12	4	0	8	0	2	10	0	0
Baltimore oriole	landbird	1	0	0	1	0	0	1	0	0
Bank swallow	landbird	32	28	0	4	0	15	14	3	0
Barn swallow	landbird	202	72	80	48	2	64	97	31	10
Black-billed cuckoo	landbird	1	1	0	0	0	0	1	0	0
Blackpoll warbler	landbird	1	1	0	0	0	0	1	0	0
Black-throated blue warbler	landbird	2	2	0	0	0	2	0	0	0
Black-throated green warbler	landbird	1	0	0	1	0	0	1	0	0
Blue-winged warbler	landbird	1	0	1	0	0	0	0	1	0
Bobolink	landbird	6	1	5	0	0	3	2	1	0
Brown-headed cowbird	landbird	1	0	0	1	0	0	0	1	0
Cape May warbler	landbird	8	8	0	0	0	6	1	1	0
Chimney swift	landbird	7	4	0	3	0	2	5	0	0
Chipping sparrow	landbird	1	1	0	0	0	0	1	0	0
Chuck-will's-widow	landbird	4	1	0	3	0	1	3	0	0
Cliff swallow	landbird	61	7	28	25	1	21	19	18	3
Common nighthawk	landbird	7	3	0	4	0	1	6	0	0
Common yellowthroat	landbird	4	1	0	3	0	3	1	0	0
Eastern kingbird	landbird	1	0	0	1	0	0	0	1	0
Eastern wood-pewee	landbird	1	1	0	0	0	1	0	0	0
Eurasian collared-dove	landbird	2	0	1	1	0	1	0	1	0
Gray catbird	landbird	2	1	0	1	0	0	2	0	0
Hooded warbler	landbird	3	1	0	2	0	1	2	0	0
Indigo bunting	landbird	1	0	0	1	0	1	0	0	0
Louisiana waterthrush	landbird	1	0	0	1	0	0	1	0	0
Magnolia warbler	landbird	4	3	1	0	0	1	2	1	0
Mourning dove	landbird	2	0	1	1	0	1	1	0	0
Nashville warbler	landbird	1	1	0	0	0	0	0	1	0
Northern rough- winged swallow	landbird	3	0	2	1	0	0	2	1	0
Northern waterthrush	landbird	2	0	0	2	0	0	1	1	0
Orchard oriole	landbird	1	0	0	1	0	0	0	1	0

Species	Taxa	# Detections	Spring	Summer	Fall	Winter	Eastern	Central	Western	Outside of BOEM
	Group	-				-		-		planning area
Ovenbird	landbird	2	2	0	0	0	0	2	0	0
Palm warbler	landbird	6	6	0	0	0	4	1	1	0
Prothonotary warbler	landbird	10	0	9	1	0	0	7	3	0
Purple martin	landbird	12	5	6	0	1	4	8	0	0
Rock pigeon	landbird	4	0	0	0	4	0	4	0	0
Ruby-throated hummingbird	landbird	16	10	0	6	0	1	11	4	0
Scarlet tanager	landbird	1	0	0	1	0	1	0	0	0
Tree swallow	landbird	10	6	0	3	1	8	2	0	0
Tropical kingbird	landbird	1	0	0	1	0	0	0	1	0
Veery	landbird	2	2	0	0	0	1	1	0	0
White-crowned pigeon	landbird	1	0	1	0	0	0	0	0	1
White-winged dove	landbird	4	1	1	2	0	1	1	2	0
Wilson's warbler	landbird	1	0	0	1	0	0	1	0	0
Yellow warbler	landbird	8	3	1	4	0	2	3	3	0
Yellow-billed cuckoo	landbird	1	1	0	0	0	1	0	0	0
Yellow-breasted chat	landbird	1	0	0	1	0	0	1	0	0
Yellow-headed blackbird	landbird	1	0	0	1	0	0	1	0	0
Yellow-rumped warbler	landbird	1	0	0	0	1	0	1	0	0
Unid. bird	bird	56	7	8	25	16	13	27	16	0
Unid. cuckoo	landbird	1	1	0	0	0	0	1	0	0
Unid. passerine	landbird	142	9	5	128	0	20	105	17	0
Unid. passerine	landbird	46	15	6	24	1	2	24	19	1
Unid. swallow	landbird	40	10	14	16	0	11	19	9	1
Unid. warbler	landbird	79	12	19	48	0	28	40	11	0
Total		822								
American coot	marshbird	2	2	0	0	0	2	0	0	0
Total		2								
American kestrel	raptor	2	1	0	1	0	0	1	1	0-
Merlin	raptor	8	3	0	5	0	3	3	2	0
Osprey	raptor	7	0	0	7	0	1	3	1	2
Peregrine falcon	raptor	19	10	1	8	0	8	8	3	0
Short-eared owl	raptor	1	0	1	0	0	1	0	0	0
Unid. falcon	raptor	4	0	0	4	0	0	4	0	0
Total		41								
Black-bellied plover	shorebird	1	0	1	0	0	1	0	0	0
Least sandpiper sh	orebird	5	5	0	0	0	1	4	0	0
Lesser yellowlegs sh	orebird	1	0	1	0	0	0	1	0	0
Species	Taxa Group ¹	# Detections	Spring	Summer	Fall	Winter	Eastern	Central	Western	Outside of BOEM planning area
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Ruddy turnstone	shorebird	3	0	0	3	0	2	1	0	0
Sanderling	shorebird	6	3	1	2	0	4	2	0	0
Semipalmated sandpiper	shorebird	3	3	0	0	0	2	1	0	0
Spotted sandpiper	shorebird	1	1	0	0	0	0	1	0	0
Western sandpiper	shorebird	3	3	0	0	0	1	2	0	0
Whimbrel	shorebird	1	1	0	0	0	0	1	0	0
White-rumped sandpiper	shorebird	1	1	0	0	0	1	0	0	0
Unid. sandpiper	shorebird	2	2	0	0	0	1	1	0	0
Unid. shorebird	shorebird	50	19	23	8	0	18	23	8	1
Total		77		-		-			-	
Black-crowned night- heron	wadingbird	3	0	2	1	0	1	2	0	0
Cattle egret	wadingbird	103	57	10	36	0	38	43	22	0
Great blue heron	wadingbird	21	7	1	8	5	5	16	0	0
Great egret	wadingbird	57	11	1	43	2	21	24	12	0
Green heron	wadingbird	10	4	3	3	0	2	3	5	0
Little blue heron	wadingbird	35	3	7	25	0	11	14	10	0
Snowy egret	wadingbird	11	2	2	7	0	1	7	3	0
Tricolored heron	wadingbird	5	0	1	4	0	0	5	0	0
Yellow-crowned night-heron	wadingbird	3	0	0	3	0	0	1	2	0
White ibis	wadingbird	2	0	1	1	0	0	2	0	0
Unid. Ardeidae	wadingbird	42	2	2	37	1	6	28	8	0
Unid. egret	wadingbird	14	6	0	8	0	6	8	0	0
Unid. heron	wadingbird	6	1	3	2	0	1	5	0	0
Total		312		_					-	
Blue-winged teal	waterfowl	55	13	7	34	1	26	26	3	0
Greater scaup	waterfowl	1	0	0	0	1	0	1	0	0
Unid. duck	waterfowl	35	11	0	23	1	10	20	5	0
Total		91		-		-			-	

Species here includes all birds observed identified to species, as well as UNID codes used in Program SEEBIRD (Vers. 4.3.7; Ballance and Force 2016). The SpeciesCode.txt files associated with Program SEEBIRD was modified to include Gulf seabirds, as well as specific UNID codes for Gulf species, including for non-marine birds. A complete list of species observed, common and scientific names can be found in Appendix A. Species are listed in alphabetical order based on the common name.

1Taxonomic Group generally follows the taxonomic groups used by the Gulf of Mexico Avian Monitoring Network (GOMAMN) for their Birds of Conservation Concern, link here.

Table 5.4c. Summary of number of individuals for non-marine avifauna by season and BOEM planning area (Western, Central, Eastern) from the vessel-based marine bird component of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September- November), and winter (December-February). Scientific names for all birds identified to species (UNID = unidentified to species) are included in Appendix A.

Species	Taxa Group ¹	# Individuals	Spring	Summ er	Fall	Winter	Eastern	Centra I	Wester n	Outside of BOEM planning area
American redstart	landbird	16	4	0	12	0	2	14	0	0
Baltimore oriole	landbird	1	0	0	1	0	0	1	0	0
Bank swallow	landbird	46	35	0	11	0	17	20	9	0
Barn swallow	landbird	348	103	180	63	2	97	158	57	36
Black-billed cuckoo	landbird	1	1	0	0	0	0	1	0	0
Blackpoll warbler	landbird	1	1	0	0	0	0	1	0	0
Black-throated blue warbler	landbird	2	2	0	0	0	2	0	0	0
Black-throated green warbler	landbird	1	0	0	1	0	0	1	0	0
Blue-winged warbler	landbird	1	0	1	0	0	0	0	1	0
Bobolink	landbird	6	1	5	0	0	3	2	1	0
Brown-headed cowbird	landbird	1	0	0	1	0	0	0	1	0
Cape May warbler	landbird	8	8	0	0	0	6	1	1	0
Chimney swift	landbird	11	7	0	4	0	3	8	0	0
Chipping sparrow	landbird	1	1	0	0	0	0	1	0	0
Chuck-will's-widow	landbird	4	1	0	3	0	1	3	0	0
Cliff swallow	landbird	87	7	42	37	1	26	22	26	13
Common nighthawk	landbird	16	3	0	13	0	1	15	0	0
Common yellowthroat	landbird	4	1	0	3	0	3	1	0	0
Eastern kingbird	landbird	5	0	0	5	0	0	0	5	0
Eastern wood-pewee	landbird	1	1	0	0	0	1	0	0	0
Eurasian collared-dove	landbird	2	0	1	1	0	1	0	1	0
Gray catbird	landbird	2	1	0	1	0	0	2	0	0
Hooded warbler	landbird	3	1	0	2	0	1	2	0	0
Indigo bunting	landbird	1	0	0	1	0	1	0	0	0
Louisiana waterthrush	landbird	1	0	0	1	0	0	1	0	0
Magnolia warbler	landbird	5	3	2	0	0	2	2	1	0
Mourning dove	landbird	2	0	1	1	0	1	1	0	0
Nashville warbler	landbird	1	1	0	0	0	0	0	1	0

Species	Taxa Group ¹	# Individuals	Spring	Summ er	Fall	Winter	Eastern	Centra I	Wester n	Outside of BOEM planning area
Northern rough-winged swallow	landbird	4	0	3	1	0	0	3	1	0
Northern waterthrush	landbird	2	0	0	2	0	0	1	1	0
Orchard oriole	landbird	1	0	0	1	0	0	0	1	0
Ovenbird	landbird	2	2	0	0	0	0	2	0	0
Palm warbler	landbird	6	6	0	0	0	4	1	1	0
Prothonotary warbler	landbird	79	0	78	1	0	0	66	13	0
Purple martin	landbird	14	5	8	0	1	4	10	0	0
Rock pigeon	landbird	4	0	0	0	4	0	4	0	0
Ruby-throated hummingbird	landbird	16	10	0	6	0	1	11	4	0
Scarlet tanager	landbird	1	0	0	1	0	1	0	0	0
Tree swallow	landbird	14	9	0	4	1	12	2	0	0
Tropical kingbird	landbird	1	0	0	1	0	0	0	1	0
Veery	landbird	2	2	0	0	0	1	1	0	0
White-crowned pigeon	landbird	1	0	1	0	0	0	0	0	1
White-winged dove	landbird	4	1	1	2	0	1	1	2	0
Wilson's warbler	landbird	1	0	0	1	0	0	1	0	0
Yellow warbler	landbird	11	4	1	6	0	2	4	5	0
Yellow-billed cuckoo	landbird	1	1	0	0	0	1	0	0	0
Yellow-breasted chat	landbird	1	0	0	1	0	0	1	0	0
Yellow-headed blackbird	landbird	1	0	0	1	0	0	1	0	0
Yellow-rumped warbler	landbird	1	0	0	0	1	0	1	0	0
Unid. bird	bird	382	12	26	299	45	146	0	0	0
Unid. cuckoo	landbird	1	1	0	0	0	0	1	0	0
Unid. passerine	landbird	1,451	26	6	1,41 9	0	255	1,155	41	0
Unid. passerine	landbird	156	73	32	50	1	17	101	37	1
Unid. swallow	landbird	104	15	36	53	0	18	49	24	13
Unid. warbler	landbird	841	271	128	442	0	148	643	50	0
Total		3,680								
American coot	marshbird	2	2	0	0	0	2	0	0	0
Total		2								
American kestrel	raptor	2	1	0	1	0	0	1	1	0
Merlin	raptor	8	3	0	5	0	3	3	2	0
Osprey	raptor	7	0	0	7	0	1	3	1	2
Peregrine falcon	raptor	20	10	1	9	0	9	8	3	0

Species	Taxa Group ¹	# Individuals	Spring	Summ er	Fall	Winter	Eastern	Centra I	Wester n	Outside of BOEM planning area
Short-eared owl	raptor	1	0	1	0	0	1	0	0	0
Unid. falcon	raptor	4	0	0	4	0	0	4	0	0
Total		42								
Black-bellied plover	shorebird	1	0	1	0	0	1	0	0	0
Least sandpiper	shorebird	22	22	0	0	0	3	19	0	0
Lesser yellowlegs	shorebird	1	0	1	0	0	0	1	0	0
Ruddy turnstone	shorebird	3	0	0	3	0	2	1	0	0
Sanderling	shorebird	24	19	2	3	0	21	3	0	0
Semipalmated sandpiper	shorebird	6	6	0	0	0	2	4	0	0
Spotted sandpiper	shorebird	1	1	0	0	0	0	1	0	0
Western sandpiper	shorebird	17	17	0	0	0	14	3	0	0
Whimbrel	shorebird	2	2	0	0	0	0	2	0	0
White-rumped sandpiper	shorebird	3	3	0	0	0	3	0	0	0
Unid. sandpiper	shorebird	4	4	0	0	0	1	3	0	0
Unid. shorebird	shorebird	292	90	79	123	0	96	95	99	2
Total		376								-
Black-crowned night- heron	wadingbird	15	0	11	4	0	4	11	0	0
Cattle egret	wadingbird	521	229	13	279	0	141	275	105	0
Great blue heron	wadingbird	73	10	1	34	28	6	67	0	0
Great egret	wadingbird	250	24	1	219	6	52	106	92	0
Green heron	wadingbird	18	4	3	11	0	2	3	13	0
Little blue heron	wadingbird	158	3	13	142	0	89	49	20	0
Snowy egret	wadingbird	33	4	3	26	0	3	23	7	0
Tricolored heron	wadingbird	19	0	11	8	0	0	19	0	0
Yellow-crowned night- heron	wadingbird	7	0	0	7	0	0	4	3	0
White ibis	wadingbird	19	0	6	13	0	0	19	0	0
Unid. Ardeidae	wadingbird	472	12	4	454	2	55	307	0	0
Unid. egret	wadingbird	83	34	0	49	0	42	41	0	0
Unid. heron	wadingbird	19	2	6	11	0	1	18	0	0
Total		1,687								
Blue-winged teal	waterfowl	745	66	55	623	1	342	292	111	0
Greater scaup	waterfowl	1	0	0	0	1	0	1	0	0
Unid. duck	waterfowl	447	65	0	381	1	106	254	87	0

Species	Taxa Group ¹	# Individuals	Spring	Summ er	Fall	Winter	Eastern	Centra I	Wester n	Outside of BOEM planning area
Total		1,193								

Species here includes all birds observed identified to species, as well as UNID codes used in Program SEEBIRD (Vers. 4.3.7; Ballance and Force 2016). The SpeciesCode.txt files associated with Program SEEBIRD was modified to include Gulf seabirds, as well as specific UNID codes for Gulf species, including for non-marine birds. A complete list of species observed, common and scientific names can be found in Appendix A. Species are listed in alphabetical order based on the common name.

1Taxonomic Group generally follows the taxonomic groups used by the Gulf of Mexico Avian Monitoring Network (GOMAMN) for their Birds of Conservation Concern, link here.

Most of the seabirds observed were not local to the northern Gulf (Michael et al. 2023) but were from breeding locations within the northern interior and southern Gulf and Caribbean (Table 5.6a and Table 5.9). These two regions accounted for \sim 75% of individuals observed when combined and each was represented by 12 species. Black terns, the most abundant species observed (Michael et al. 2024), breed at higher latitudes in the interior of the continent (e.g., Prairie Pothole Region) and their presence in the northern Gulf is likely transient as they migrate to South America (Heath et al. 2020). Sooty terns, the second most abundant species observed, breed primarily in the south- central Gulf (i.e., colonies on Campeche Bank: Tunnell and Chapman 2000), southeastern Gulf (i.e., colony on Bird Key in the Dry Tortugas), in high numbers at colonies throughout the Caribbean (Bradley and Norton 2009), and in small numbers along the Texas coast (Tweit 2009). The local seabird community, represented by 10 species that breed in the northern Gulf, comprised ~18% of the individual seabirds observed (Table 5.9). Laughing gulls and royal terns comprised \sim 50% of this group and were observed primarily during winter, suggesting use of surveyed areas during migration/nonbreeding seasons. The remaining seabirds (7% of all individuals) were from NW Atlantic (4%), east Atlantic (2%), and south Atlantic (<1%) locations (Table 5.9). One species from the NW Atlantic group, the northern gannet, represented ~4% of all seabirds observed and commonly inhabits waters of the northern Gulf during the nonbreeding season (Fifield et al. 2014). These three groups were represented by 10 species. Use of the northern Gulf by these species likely occurs during nonbreeding seasons and may also include subadult birds that can range widely prior to reaching breeding age (Jodice and Survan 2010, Fifield et al. 2014).

We detected seabirds from each breeding area in each season (Table 5.9) though relatively small numbers of individuals were documented from the south Atlantic in spring (n = 11) and winter (n = 1), and from the northeast coast of North America in summer (n = 9) and fall (n = 7). We also detected seabirds from each breeding area associated with each of the BOEM planning areas (Table 5.9) though relatively small numbers of individuals were documented in the WPA from the south Atlantic (n = 9) and the northeast coast of North America (n = 12).

5.2.3 Community Metrics for Marine Avifauna

The species richness of marine birds during GOMMAPPS surveys included 44 species. Species richness was highest in the CPA (40 species), intermediate in the EPA (36 species), and lowest in the WPA (27 species) (Figure 5.4). However, caution should be used interpreting species richness values given that survey effort and spatial coverage of individual BOEM planning areas varied widely (refer to Section 5.1.1). Species richness as a stand-alone metric is not all that meaningful, but in combination with abundance (or relative abundance), density (or relative density; Michael et al. 2023), species' conservation status and ecology, this metric can convey important information (e.g., Santora and Sydeman 2015). Nonetheless, these data provide some evidence that most of the seabird species that occur within the northern Gulf tend to occupy the CPA at some point, during the year. Species not detected in the WPA tended to be northern migrants from both interior and coastal locations (e.g., Bonaparte's gull, northern gannet) and species that breed in the southern Gulf and Caribbean (e.g., brown noddy, red-footed booby) (Table 5.9).

Among seasons, species richness was lowest in winter (21 species), with northern Gulf breeding species, as well as species from the southern Gulf and Caribbean generally not present. Spatial coverage during winter was poor overall compared to other seasons and this may very well explain the low species richness. Species richness was similar in spring (34 species), summer (31 species), and fall (34 species) although species composition of the community was not identical across these three seasons (Table 5.1 and Figure 5.3). Within seasons and planning areas, species richness ranged from 9 to 31 species (Figure 5.4a). Species richness was lowest during winter in the EPA (9 species) and WPA (10 species), and highest during spring and fall in the CPA (31 species in each season). Species richness varied the least among seasons in the EPA (Figure 5.4a).

Table 5.5a. Summary of number of detections by taxonomic group for non-marine avifauna by BOEM planning area (Western, Central, Eastern) and season from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September-November), and winter (December-February). Refer to Appendix C for additional details related to spatial distribution of species-specific observations.

Taxa Group ¹	Spring	Summer	Fall	Winter
Landbirds	620	552	2,452	56
Marshbirds	2	0	0	0
Waterfowl	131	55	1,004	3
Waders	322	72	1,257	36
Raptors	14	2	26	0
Shorebirds	38	26	13	0
Total	1,127	707	4,752	95

¹Taxonomic Group generally follows the taxonomic groups used by the Gulf of Mexico Avian Monitoring Network (GOMAMN) for their Birds of Conservation Concern, link here.

Table 5.5b. Summary of number of individuals by taxonomic group for non-marine avifauna by BOEM planning area (Western, Central, Eastern) and season from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September-November), and winter (December-February). Refer to Appendix C for additional details related to spatial distribution of species-specific observations.

East	Central	West	Outside of BOEM planning area
779	2,316	285	64
2	0	0	0
448	547	198	0
395	942	240	0
14	19	7	2
143	132	99	2
1,781	3,956	829	68

¹Taxonomic Group generally follows the taxonomic groups used by the Gulf of Mexico Avian Monitoring Network (GOMAMN) for their Birds of Conservation Concern, link <u>here</u>.

A community with greater species diversity equates to enhanced community complexity typically characterized by greater numbers of species and more even abundances of species. Overall, species diversity (Shannon-Wiener Diversity Index; H') calculated only for marine birds during GOMMAPPS surveys was H' = 2.2. Species diversity was relatively similar across planning areas. Diversity was highest in the WPA (H' = 2.1) and virtually the same in the EPA (H' = 1.9) and CPA (H' = 1.8) (Figure 5.4b). As with species richness, caution should be applied when interpreting values of species diversity given that survey effort and spatial coverage of individual BOEM planning areas varied widely (refer to Sections 5.1.1-5.1.2). Nonetheless, these data indicate that the community observed in the WPA was slightly more diverse compared with other planning areas when data were pooled across seasons and years.

Species diversity varied ~ 2.8-fold among seasons and planning areas. Among seasons, species diversity appeared higher in spring (H' = 2.4) compared to other seasons. During spring, marine species are both migrating through the northern Gulf and breeding within the northern Gulf, potentially leading to greater diversity. Species diversity appeared lowest in fall (H' = 1.4) to be intermediate in winter (H' = 1.9) and summer (H' = 1.7). As noted previously, winter survey effort was by far the least compared to survey effort in other seasons (refer to Section 5.1.1). Within seasons and planning areas, species diversity ranged from H' = 0.9 - 2.4 (Figure 5.4b). Diversity was highest in the CPA in the spring (H' = 2.4) and lowest in the CPA in the fall and EPA in the summer (H' = 0.9 for both).

Comparisons of species diversity measures among studies in the Gulf are challenging due to differences in seasonal coverage, spatial coverage, and survey designs, methodologies, and protocols. Furthermore, the level of detail provided with the "raw" data associated with each of the vessel-based seabird surveys also differ, making it challenging to calculate certain metrics. Therefore, we only compare species richness, noting that both spatial and temporal coverage, as well as methodologies, differed among studies. Any differences provided here should be interpreted with caution (Table 5.10). Notably, the two most recent vessel-based seabird survey projects which were the most similar in survey designs, methodologies and protocols, and spatial coverage, very similar species richness. *Bird Study #6* vessel surveys (e.g., Haney et al. 2019) and the surveys during this study tallied 43 and 44 seabird species, respectively (Note: Bird study #6 observed that GOMMAPPS did not observe included American white pelican, Franklin's gull, and sooty shearwater. Species that GOMMAPPS observed that *Bird Study #6* did not include Fea's petrel, Manx shearwater, red-footed booby, and red-throated loon. The species that differed between these two survey efforts did not occur regularly or in large numbers. Other species observed during other studies, but not during GOMMAPPS include Arctic tern (GulfCet II), black skimmer (GulfCet I), and black-legged kittiwake (Fritts et al. 1983) (Table 5.10). The combined species richness for seabirds across all these studies is 50. Additional details on species distribution in the Gulf is provided below (Appendix D).

5.2.4 Summary of Marine and Nonmarine Avifauna Communities in the Gulf

Broadly, these data demonstrate that the pelagic seabird community in the northern Gulf is diverse in terms of species richness, taxa representation, and the geographic representation (i.e., where these species breed; Table 5.6a). The community of seabirds within offshore and pelagic waters of the northern Gulf (refer to Appendix D) is primarily comprised, with respect to both individuals and species, of migratory species from the continental interior (e.g., black tern, herring gull, Bonaparte's gull) and species that breed in the southern Gulf and Caribbean (sooty tern, Audubon's shearwater, magnificent frigatebird) (Michael et al. 2023). Species that breed locally in the northern Gulf (e.g., royal and sandwich tern, laughing gull, brown pelican) make up a smaller proportion of the overall offshore seabird community, likely because most of these species are nearshore species that may only use offshore waters infrequently (e.g., during migration). These data indicate that ~85% of the seabirds observed in the northern Gulf were gulls and terns, but that they originated from a diverse geographic area reflecting both higher latitudes in coastal and interior regions and the southern Gulf and Caribbean (Michael et al. 2023).

In summary, the avifauna of the northern Gulf comprises both non-marine and marine birds which were represented by 121 species during our surveys (Tables 5.4c, 5.6c, Appendix A). We documented locally- breeding species, but also species that breed from throughout the western hemisphere ranging from high to low latitudes of both the north and south Atlantic. Species that breed within the northern Gulf were not the most abundant in terms of either individuals or species richness, indicating that occupancy of offshore and pelagic waters in the northern Gulf is not driven primarily or exclusively by proximity to breeding colonies. Most seabirds we observed were migrants from outside the northern Gulf proper (refer to Michael et al. 2023). When the large number of landbirds (particularly during spring and fall migrations) we observed are also considered, the data indicate that during our surveys the avifauna community in offshore and pelagic waters of the northern Gulf was primarily comprised of migratory, staging, and wintering bird species.

Table 5.6a. Summary of seabird observations with number of detections, number of individuals, and proportion of total individuals for seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Breeding region is a general descriptor of the most likely breeding location for a given species. Species common names are presented in alphabetic order.

Species	AOU ¹ Code	Seabird Group	Breeding Region	# Detections	#Individuals	% Individuals
Audubon's shearwater	AUSH	Shearwater	sGulf/Caribbean	517	1,766	4.01
Band-rumped storm- petrel	BSTP	Storm Petrel	Eastern Atlantic	334	512	1.16
Black tern	BLTE	Tern	Northern migrant- continental interior or high Arctic	726	12,109	27.50
Black-capped petrel	BCPE	Gadfly Petrel	sGulf/Caribbean	29	31	0.07
Bonaparte's gull	BOGU	Gull	Northern migrant- continental interior or high Arctic	83	1,356	3.08
Bridled tern	BRTE	Pelagic Tern	sGulf/Caribbean	232	489	1.11
Brown booby	BRBO	Booby	sGulf/Caribbean	300	355	0.81
Brown noddy	BRNO	Pelagic Tern	sGulf/Caribbean	117	595	1.35
Brown pelican	BRPE	Pelican	nGulf	240	814	1.85
Caspian tern	CATE	Tern	nGulf	6	7	0.02
Common loon	COLO	Loon	Northern migrant- continental interior or high Arctic	55	67	0.15
Common tern	COTE	Tern	Northern migrant- continental interior or high Arctic	176	488	1.11
Cory's shearwater	COSH	Shearwater	Eastern Atlantic	81	117	0.27
Double-crested cormorant	DCCO	Cormorant	nGulf	33	130	0.30
Fea's petrel	FEPE	Gadfly Petrel	Eastern Atlantic	3	3	0.01
Forster's tern	FOTE	Tern	nGulf	23	86	0.20
Great Black-backed gull	GBBG	Gull	Northern migrant- Atlantic coast	3	3	0.01
Great shearwater	GRSH	Shearwater	Southern Atlantic	49	60	0.14
Gull-billed tern	GBTE	Tern	nGulf	2	2	< 0.01
Herring gull	HERG	Gull	Northern migrant- continental interior or high Arctic	856	1,636	3.72
Laughing gull	LAGU	Gull	nGulf	1,086	2,569	5.83
Leach's storm-petrel	LESP	Storm Petrel	Northern migrant- Atlantic coast	19	24	0.05
Least tern	LETE	Tern	nGulf	10	18	0.04
Long-tailed jaeger	LTJA	Jaeger/Skua	Northern migrant- continental interior or high Arctic	2	2	< 0.01
Magnificent frigatebird	MAFR	Frigatebird	sGulf/Caribbean	478	940	2.13
Manx shearwater	MASH	Shearwater	Northern migrant- Atlantic coast	4	4	0.01
Masked booby	MABO	Booby	sGulf/Caribbean	124	136	0.31
Neotropic cormorant	NECO	Cormorant	nGulf	1	2	< 0.01
Northern gannet	NOGA	Gannet	Northern migrant- Atlantic coast	320	1,658	3.77

Species	AOU ¹ Code	Seabird Group	Breeding Region	# Detections	#Individuals	% Individuals
Parasitic jaeger	PAJA	Jaeger/Skua	Northern migrant- continental interior or high Arctic	43	73	0.17
Pomarine jaeger	POJA	Jaeger/Skua	Northern migrant- continental interior or high Arctic	293	486	1.10
Red phalarope	REPH	Phalarope	Northern migrant- continental interior or high Arctic	2	2	< 0.01
Red-billed tropicbird	RBTR	Tropicbird	sGulf/Caribbean	12	12	0.03
Red-footed booby	RFBO	Booby	sGulf/Caribbean	11	11	0.02
Red-necked phalarope	RNPH	Phalarope	Northern migrant- continental interior or high Arctic	10	16	0.04
Red-throated loon	RTLO	Loon	Northern migrant- continental interior or high Arctic	2	2	< 0.01
Ring-billed gull	RBGU	Gull	Northern migrant- continental interior or high Arctic	8	9	0.02
Roseate tern	ROST	Pelagic Tern	sGulf/Caribbean	5	20	0.05
Royal tern	ROYT	Tern	nGulf	1,104	1,869	4.24
Sandwich tern	SATE	Tern	nGulf	372	1,445	3.28
Sooty tern	SOTE	Pelagic Tern	sGulf/Caribbean	851	7,855	17.84
South Polar skua	SPSK	Jaeger/Skua	Southern Atlantic	1	1	< 0.01
White-tailed tropicbird	WTTR	Tropicbird	sGulf/Caribbean	3	3	0.01
Wilson's storm- petrel	WISP	Storm Petrel	Southern Atlantic	27	34	0.08
Total				8,653	37,817	85.89% ²

Species here includes all birds observed identified to species and entered in Program SEEBIRD (Vers. 4.3.7; Ballance and Force 2016). The original SpeciesCode.txt file associated with Program SEEBIRD was modified to include Gulf seabirds, as well as specific UNID codes for Gulf species, including for non-marine birds. A complete list of species observed, common and scientific names can be found in Appendix A. Species are listed in alphabetical order based on the common name.

1 AOU Code: AOU = American Ornithologists Union. Each species is represented by a unique four-letter code. A list of the four-letter AOU codes provided in alphabetical order can be found on The Institute for Bird Populations website; <u>here</u>.

2 Total % does not sum to 100%. This represents the proportion of all seabirds, including those not identified to species, represented by a given species. Not all seabirds were identified to species, but 85.89% of the individuals observed were identified to species.

Table 5.6b. Summary of number of detections for marine avifauna by season and BOEM planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September- November), and winter (December-February). Scientific names for all birds identified to species (UNID = unidentified to species) are included in Appendix A.

Species *	# Detections	Spring	Summer	Fall	Winter	Eastern Planning Area	Central Planning Area	Western Planning Area	Outside of BOEM planning area
Audubon's shearwater	517	175	235	103	4	258	117	102	40
Band-rumped storm-petrel	334	185	131	18	0	201	85	43	5
Black-capped petrel	29	5	21	3	0	22	6	1	0
Black tern	726	87	278	361	0	31	529	148	18
Bonaparte's gull	83	75	0	0	8	75	8	0	0
Bridled tern	232	45	107	60	20	111	68	32	21
Brown booby	300	64	94	122	20	82	112	91	15
Brown noddy	117	3	108	6	0	11	3	0	103
Brown pelican	240	112	32	58	38	18	131	17	74
Caspian tern	6	1	1	1	3	0	4	2	0
Common loon	55	43	0	0	12	27	23	0	5
Common tern	176	54	8	114	0	109	38	17	12
Cory's shearwater	81	0	36	45	0	11	39	30	1
Double-crested cormorant	33	6	4	7	16	1	8	0	24
Fea's petrel	3	1	2	0	0	2	1	0	0
Forster's tern	23	0	4	19	0	4	9	1	9
Great Black-backed gull	3	2	0	0	1	0	2	0	1
Great shearwater	49	1	13	34	1	18	28	2	1
Gull-billed tern	2	0	1	1	0	0	0	2	0
Herring gull	856	163	5	19	669	145	341	357	13
Laughing gull	1,086	455	140	371	120	106	515	347	118
Leach's storm-petrel	19	9	5	5	0	11	4	4	0
Least tern	10	6	3	1	0	1	6	1	2
Long-tailed jaeger	2	0	1	1	0	1	1	0	0
Magnificent frigatebird	478	92	120	263	3	154	223	72	29
Manx shearwater	4	0	0	0	4	0	0	4	0
Masked booby	124	21	40	63	0	25	27	71	1
Neotropic cormorant	1	0	0	1	0	0	1	0	0
Northern gannet	320	119	0	2	199	73	218	0	29
Parasitic jaeger	43	17	1	6	19	13	9	19	2

Species *	# Detections	Spring	Summer	Fall	Winter	Eastern Planning Area	Central Planning Area	Western Planning Area	Outside of BOEM planning area
Pomarime jaeger	293	80	20	5	188	72	67	154	0
Red-billed tropicbird	12	2	2	8	0	5	7	0	0
Red-footed booby	11	0	7	4	0	6	4	0	1
Red-necked phalarope	10	4	0	5	1	5	4	0	1
Red phalarope	2	2	0	0	0	2	0	0	0
Red-throated loon	2	2	0	0	0	0	1	0	1
Ring-billed gull	8	0	0	3	5	0	3	1	4
Roseate tern	5	0	4	1	0	1	0	0	4
Royal tern	1104	215	182	657	50	135	560	324	85
Sandwich tern	372	116	105	151	0	58	182	41	91
Sooty tern	851	256	521	64	10	522	111	49	169
South Polar skua	1	1	0	0	0	0	1	0	0
White-tailed tropicbird	3	0	3	0	0	2	1	0	0
Wilson's storm-petrel	27	9	16	2	0	9	14	4	0
Sooty/Bridled tern	16	0	16	0	0	11	0	0	5
Unid. booby	7	0	6	1	0	1	4	2	0
Unid. cormorant	1	0	0	1	0	0	0	1	0
Unid. gull	38	8	3	2	25	4	16	18	0
Unid. jaeger	33	10	2	8	13	10	11	11	1
Unid. large gull	17	0	1	2	14	6	9	1	1
Unid. large shearwater	4	0	0	0	4	0	4	0	0
Unid. Laridae	116	73	19	19	5	50	45	16	5
Unid. Onychoprion	59	4	47	8	0	43	10	1	5
Unid. phalarope	3	1	1	0	1	1	2	0	0
Unid. Pterodroma	2	0	1	1	0	1	1	0	0
Unid. shearwater	18	0	5	11	2	4	7	5	2
Unid. small shearwater	3	0	0	0	3	0	1	2	0
Unid. storm-petrel	33	7	22	3	1	15	12	6	0
Unid. Sulidae	10	3	2	3	2	4	5	1	0
Unid. tern	329	123	44	153	9	161	109	46	13
Unid. tropicbird	5	0	3	2	0	2	0	3	0
Total	9,347		-					-	-

*Species here includes all birds observed identified to species, and unidentified (UNID) codes used in Program SEEBIRD (Vers. 4.3.7; Ballance and Force 2016). The SpeciesCode.txt files associated with Program SEEBIRD was modified to include Gulf seabirds, and specific UNID codes for Gulf species, including for non-marine birds. A complete list of species observed, common and scientific names can be found in Appendix A. Species are listed in alphabetical order based on the common name.

Table 5.6c. Summary of number of individuals for marine avifauna by season and BOEM planning areas (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September- November), and winter (December-February). Scientific names for all birds identified to species (UNID = unidentified to species) are included in Appendix A.

Species*	# Individuals	Spring	Summer	Fall	Winter	Eastern Planning	Central Planning	Western Planning	Outside of BOEM
						Area	Area	Area	planning area
Audubon's shearwater	1,766	1,040	493	225	8	1,046	286	178	256
Band-rumped storm-petrel	512	280	205	27	0	321	124	62	5
Black-capped petrel	31	5	23	3	0	24	6	1	0
Black tern	12,109	379	2,345	9,385	0	105	8,943	2,606	455
Bonaparte's gull	1,356	1,069	0	0	287	1,061	295	0	0
Bridled tern	489	87	281	91	30	226	197	41	25
Brown booby	355	68	129	138	20	84	125	100	46
Brown noddy	595	3	570	22	0	30	3	0	562
Brown pelican	814	280	98	365	71	33	354	132	295
Caspian tern	7	2	1	1	3	0	5	2	0
Common loon	67	50	0	0	17	29	24	0	14
Common tern	488	205	18	265	0	327	83	28	50
Cory's shearwater	117	0	53	64	0	13	62	41	1
Double-crested cormorant	130	25	5	25	75	1	23	0	106
Fea's petrel	3	1	2	0	0	2	1	0	0
Forster's tern	86	0	4	82	0	7	15	11	53
Great Black-backed gull	3	2	0	0	1	0	2	0	1
Great shearwater	60	1	17	41	1	23	34	2	1
Gull-billed tern	2	0	1	1	0	0	0	2	0
Herring gull	1,636	423	5	28	1,180	298	531	775	32
Laughing gull	2,569	885	370	881	433	122	797	1,065	585
Leach's storm-petrel	24	10	9	5	0	12	4	8	0
Least tern	18	14	3	1	0	1	12	1	4
Long-tailed jaeger	2	0	1	1	0	1	1	0	0
Magnificent frigatebird	940	147	256	534	3	260	380	251	49
Manx shearwater	4	0	0	0	4	0	0	4	0
Masked booby	136	21	41	74	0	26	27	82	1
Neotropic cormorant	2	0	0	2	0	0	2	0	0
Northern gannet	1,658	841	0	2	815	93	531	0	1,034
Parasitic jaeger	73	25	1	8	39	17	11	40	5

Species*	# Individuals	Spring	Summer	Fall	Winter	Eastern Planning Area	Central Planning Area	Western Planning Area	Outside of BOEM planning area
Pomarine jaeger	486	117	30	5	334	111	79	296	0
Red-billed tropicbird	12	2	2	8	0	5	7	0	0
Red-footed booby	11	0	7	4	0	6	4	0	1
Red-necked phalarope	16	9	0	5	2	10	5	0	1
Red phalarope	2	2	0	0	0	2	0	0	0
Red-throated loon	2	2	0	0	0	0	1	0	1
Ring-billed gull	9	0	0	3	6	0	4	1	4
Roseate tern	20	0	19	1	0	1	0	0	19
Royal tern	1,869	312	297	1,200	60	224	832	666	147
Sandwich tern	1,445	574	254	617	0	139	601	66	639
Sooty tern	7,855	2,455	4,744	497	159	5,216	1,311	703	625
South Polar skua	1	1	0	0	0	0	1	0	0
White-tailed tropicbird	3	0	3	0	0	2	1	0	0
Wilson's storm-petrel	34	9	23	2	0	11	16	7	0
Sooty/Bridled tern	44	0	44	0	0	34	0	0	10
Unid. booby	11	0	10	1	0	1	5	5	0
Unid. cormorant	40	0	0	40	0	0	0	40	0
Unid. gull	265	9	42	5	209	4	157	104	0
Unid. jaeger	43	11	2	8	22	11	11	20	1
Unid. large gull	33	0	1	18	14	6	9	17	1
Unid. large shearwater	4	0	0	0	4	0	4	0	0
Unid. Laridae	2,087	1,238	703	135	11	1,112	296	545	134
Unid. Onychoprion	443	9	362	72	0	283	112	20	28
Unid. phalarope	5	1	3	0	1	1	4	0	0
Unid. Pterodroma	2	0	1	1	0	1	1	0	0
Unid. shearwater	32	0	6	23	3	12	9	9	2
Unid. small shearwater	3	0	0	0	3	0	1	2	0
Unid. storm-petrel	40	10	25	4	1	20	13	7	0
Unid. Sulidae	18	3	4	9	2	9	8	1	0
Unid. tern	3,137	1,066	200	1,785	86	958	780	938	461
Unid. tropicbird	5	0	3	2	0	2	0	3	0
Total	44,029								

*Species here includes all birds observed identified to species, as well as unidentified (UNID) codes used in Program SEEBIRD (Vers. 4.3.7; Ballance and Force 2016). The SpeciesCode.txt files associated with Program SEEBIRD was modified to include Gulf seabirds, as well as specific UNID codes for Gulf species, including for non-marine birds. A complete list of species observed, common and scientific names can be found in Appendix A. Species are listed in alphabetical order based on the common name.

5.3 Species Accounts: Abundance, Distribution, and Predicted Occurrence

For each species of seabird observed during GOMMAPPS surveys we begin with a brief summary of the ecology of the species with an emphasis on breeding location, range, and diet as described in species accounts from Birds of the World⁷, the International Ornithological Congress World Bird List⁸, and the inventory of Caribbean seabirds (Bradley and Norton 2009). We reference the global status for each species as classified by the Global IUCN Red List Category, accessed from BirdLife International ⁹. For each species we also provide the Continental Combined Score from Partners in Flight (PIF 2021, Panjabi et al. 2021) and the designation from the Partners in Flight Continental Watch List¹⁰. For the Continental Combined Score higher values indicate higher conservation concern. The categories for designation from the watch list are: Red (highly vulnerable), Yellow-D (steep declines & major threats), Yellow-R (range restricted), CBSD (common birds in steep decline). For species that appear on the Birds of Conservation Concern List (USFWS 2021) we note the designation, whether the species is listed for concern within Bird Conservation Region 37 (BCR 37- Gulf Coastal Prairie), at the continental scale, or within Marine Bird Conservation Region 20 (MBCR 20- Gulf of Mexico). For species that breed in the Caribbean, we reference their local status as defined by Bradley and Norton (2009).

Table 5.7. Summary of seabird taxonomic groups based on number of detections, number of individuals, and proportion of individuals from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Seabird Group	# Detections	# Individuals	% Individuals
Tern	2,748	19,161	43.52
Pelagic tern	1,280	9,446	21.45
Gull	2,207	7,958	18.07
Shearwater	676	1,986	4.51
Gannet	320	1,658	3.77
Frigate	478	940	2.13
Pelican	240	814	1.85
Storm petrel	413	610	1.39
Jaeger/Skua	372	605	1.37
Booby	452	531	1.21
Cormorant	35	172	0.39
Loon	57	69	0.16
Gadfly petrel	34	36	0.08
Phalarope	15	23	0.05
Tropicbird	20	20	0.05
Total	9,347	44,029	

Proportion (%) of individuals is calculated as the number of individuals observed of a given species divided by the total number of seabirds identified to species.

⁹ See the Global IUCN Red List Category, accessed from BirdLife International at <u>https://datazone.birdlife.org/species/results?thrlev1=&thrlev2=&kw=&fam=0&gen=0&spc=&c</u> <u>mn=®=0&cty=0&stsea=Y</u>; accessed 15 March 2021

⁷ See Birds of the World at <u>https://birdsoftheworld.org/bow/home</u>.

⁸ International Ornithological Congress World Bird List:

https://www.worldbirdnames.org/new/classification/family-index-2/

¹⁰ Partners in Flight Continental Watch List: <u>https://partnersinflight.org/wp- content/uploads/2017/03/SPECIES-OF-CONT-CONCERN-from-pif-continental-plan-final- spread-2.pdf</u>; accessed on 24 March 2021

Each species account includes an overview of the relevant observation data including but not limited to number of detections, number of individuals, flock size (refer to Figure 5.5; frequency distributions of flock size for all species with a maximum flock size of at least 15 birds), and abundance and distribution among planning areas and seasons. A map of all observed detections is included for each species and qualitative descriptions of areas used within the Gulf are provided. For all species that met our modeling threshold (\geq 20 detections), we review results from predictive models for occurrence and habitat suitability (refer to Section 4.4). These overviews include identification and discussion of influential predictor variables (Section 5.4 below) and a map detailing predicted occurrence (i.e., habitat suitability) based on model results (Appendix D). For all species that met our modeling threshold (\geq 20 detections), we raitable habitat (from MaxEnt Vers. 3.4.2; Phillips et al. 2006) that occurs within 10 km of an oil platform as an example of macro-scale exposure to the risk from oil and gas activities (Table 5.11; refer also to Section 4.6) and provide a map to depict the relationship (Appendix D.).

Table 5.8. Summary of number of individuals for respective seabird taxonomic groups by season and BOEM planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Seasons were defined as follows: spring (March- May), summer (June-August), fall (September-November), and winter (December-February).

seabird Group	Spring	Summer	Fall	Winter	Eastern Planning Area	Central Planning Area	Western Planning Area
Booby	92	191	226	22	126	169	188
Cormorant	25	5	67	75	1	25	40
Frigatebird	147	256	534	3	260	380	251
Gadfly petrel	6	26	4	0	27	8	1
Gannet	841	0	2	815	93	531	0
Gull	3,626	1,121	1,070	2,141	2,603	2,091	2,507
Jaeger/Skua	154	34	22	395	140	103	356
Loon	52	0	0	17	29	25	0
Pelagic tern	2,554	6,020	683	189	5,790	1,623	764
Pelican	280	98	365	71	33	354	132
Phalarope	12	3	5	3	13	9	0
Shearwater	1,041	569	353	23	1,094	396	236
Storm-petrel	309	262	38	1	364	157	84
Tern	2,552	3,123	13,337	149	1,761	11,271	4,320
Tropicbird	2	8	10	0	9	8	3
Total	11,693	11,716	16,716	3,904	12,343	17,150	8,882

* Seabird Group: seabird groups used here are the same as in Table 5.7.

Table 5.9. Summary of number and proportion of individuals (%) for all seabirds identified to species assigned to a breeding region, by season, and by BOEM planning area (Western, Central, Eastern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Breeding Region	Species ¹	# Individuals	%	% Spring	% Summer	% Fall	% Winter	% WPA	% CPA	% EPA
	operiod		Individuals ²							
Northern migrant- continental interior or high Arctic	12	16,246	43.0	24.5	22.5	65.8	52.8	51.9	62.9	19.4
southern Gulf or Caribbean	12	12,213	32.3	41.0	65.0	11.4	6.2	19.1	15.6	70.8
northern Gulf	10	6,942	18.4	22.3	9.7	21.8	18.0	27.3	16.6	5.2
Northern migrant- Atlantic coast	4	1,689	4.5	9.1	0.1	0.0	22.9	0.2	3.4	1.0
Eastern Atlantic	3	632	1.7	3.0	2.4	0.6	0.0	1.4	1.2	3.3
Southern Atlantic	3	95	0.3	0.1	0.4	0.3	0.0	0.1	0.3	0.3
Total	44	37,817								

Seasons were defined as follows: spring (March-May), summer (June-August), fall (September-November), and winter (December-February).

1Species: the number of unique seabird species from a given breeding region.

2% Individuals: the proportion (%) of individuals from a given breeding region relative to all seabirds identified to species. All other proportions (%) are based on the total number of individuals from a given breeding region.

Each species account (Section 5.4 below) concludes with a reference to abundance and/or distribution in the Gulf as noted in previous surveys or summaries (Table 5.10; refer also to Appendix D), and a brief conclusion that includes ecological and/or conservation context. Species are presented in taxonomic order following the current classification of the International Ornithological Congress¹¹.



Figure 5.4. Histograms of seabird species richness (top figure) and species diversity (bottom figure) for GOMMAPPS seabird vessel surveys (2017 – 2019).

Top figure: the x-axis represents species richness scaled from 0 to 35 species and the y-axis represents each of the three BOEM planning areas (Western, Central, and Eastern) by season (spring = March-May, summer = June-August, fall = September-November, winter =December-February). Bottom figure: the x-axis represents species diversity (Shannon-Wiener diversity index H' value) scaled from 0 to 3 and the y-axis represents each of the three BOEM planning areas (Western, Central, and Eastern) by season (spring = March-May, summer = June-August, fall = September-November, central, and Eastern) by season (spring = March-May, summer = June-August, fall = September-November, winter =December-February). Species richness tended to reflect a spatial pattern (Central > Eastern > Western) with lowest species richness in winter. Species diversity tended to be relatively similar across the three Planning Areas but tended to follow a seasonal pattern (Spring > Summer > Fall > Winter). Please refer to text for more details.

5.3.1 Overview of Predictor Variables

Before reviewing the data for each species, we provide a brief overview of the nine predictor variables used in our modeling efforts. The purpose of this overview is to provide ecological context associated

¹¹ International Ornithological Congress: https://www.worldbirdnames.org/new/ ; accessed 28 March 2021

with each predictor variable, to aid in ease of interpretation, and reduce potential redundancies across the individual species accounts (Section 5.3.2 below). We also refer the reader to Section 2.1 which provides an overview of the physical oceanographic features for each of the BOEM planning areas.

To predict habitat suitability (Thuiller and Münkemüller 2010), we assessed nine variables: eight dynamic, oceanographic variables and one static, bathymetric variable that are often assessed when modeling habitat use of seabirds (Table 4.2). Before reviewing the output for each species for which habitat suitability was modeled, we briefly review each of the habitat variables and provide oceanographic and ecological context for interpreting their appearance in habitat models. Details on data sources and units of measure appear in Section 4.3.

Chlorophyll-a is indicative of biological productivity, which we aggregated to a monthly scale. Specifically, chlorophyll-a is considered a reasonable index to the density of phytoplankton, which forms the base of a food web that subsequently includes zooplankton and larger predators such as fish, marine mammals, and seabirds (Péron et al. 2010, Suryan et al. 2012). While low to moderate values of chlorophyll-a can occupy a broad spatial footprint within the Gulf, high values are spatially restricted to coastal areas and extreme values to a few coastal locations along the north coast of the Gulf (e.g., Apalachee Bay, Mississippi River Delta; Figure 5.6a). Within tropical and sub-tropical systems seabird occurrence can be associated with areas of high productivity (Ballance et al. 1997, Jaquemet et al. 2005), but also may be associated with areas of lower productivity if other environmental attributes (e.g., currents and winds) concentrate prey or otherwise reduce overall energetic costs (Ballance et al. 1997, Pinet et al. 2011).

Sea-surface salinity (SSS) describes the salt concentration in seawater and indicates the relative contribution of freshwater, such as river-runoff, to the marine environment. This balance between 'fresh' and 'salt' water can influence the distribution of flora (e.g., *Sargassum*) and fauna that in turn, can influence habitat use by seabirds. Within the Gulf, salinity is lower near the coast, with the lowest values near freshwater input(s): Mississippi River Delta, Atchafalaya River Delta, and at the mouth of Mobile Bay (Figure 5.6b). The salinity of the shelf, slope, and pelagic environments is relatively high within the Gulf. Salinity in combination with other environmental variables (e.g., SST) can often indicate water mass boundaries that can attract seabirds particularly in tropical and subtropical systems (Ribic et al. 1997) and different species may be associated with low, intermediate, or high levels of salinity (e.g., Ribic and Ainley 1997, Vilchis et al. 2006, Spear et al. 2001).

Sea-surface height (SSH) is the relative elevation of the ocean at a given point to a reference height at the ocean surface (mean geoid). Globally influenced by the Earth's rotation, season, and lunar-cycle, daily mesoscale variation in sea-surface height is the product of currents, bathymetry, and unique water masses. These water masses indicate different dynamic ocean features and processes such as eddies or upwellings which can aggregate prey and subsequently marine predators (Hyrenbach et al. 2006). High sea-surface height indicates convergence and warm, nutrient-poor water, potentially within a warm-core eddy, such as 'inside' the Loop Current Gyre (Figure 5.6c). Low sea-surface height reflects divergence, the upwelling of cool, nutrient-rich waters, and possibly cold-core eddies. Within the Gulf, sea-surface height tends to be lowest near the shelf-slope; water depths 200 m - 2,000 m. Both eddies and fronts can aggregate seabird prey. Within the Gulf, intermediate values of SSH are broadly distributed in the pelagic waters and along a sharp boundary associated with the Loop Current (Figure 5.6c). In the WPA, SSH may be indicative of upwelling areas and eddies that occur there (refer to Section 2.1). Seabirds may respond to low, high, or intermediate values of SSH, but the response can vary even within a species (Yoda et al. 2014, Poli et al. 2017).

Table 5.10. Number of seabird species observed and identified to species from seabird vessel surveys as part of the GOMMAPPS and six historical seabird studies in the northern Gulf.

A "+" indicates a species was detected/observed/recorded and identified to species, a "-" indicates a species was not detected/observed/recorded, and year ranges indicate the specific year(s) that observations were made for a given study. Species that were common across all seven seabird studies (*n* = 13) are identified in bold italics.

Species	Fritts and Reynolds	Fritts et al. 1980–1981	Ribic et al. 1992–1993	GulfCet I 1992–1994	GulfCet II 1996–1997	NRDA 2010–2011	GOMMAPPS 2017–2019
	1979						
American white pelican	-	+	-	-	-	+	-
Arctic tern	-	-	-	-	+	-	-
Audubon's shearwater	+	+	+	+	+	+	+
Band-rumped storm- petrel	-	-	+	+	+	+	+
Black skimmer	-	+	-	+	-	-	-
Black tern	+	+	+	+	+	+	+
Black-capped petrel	-	+	-	-	-	+	+
Black-legged kittiwake	-	+	-	-	-	-	-
Bonaparte's gull	-	+	+	+	-	+	+
Bridled tern	+	+	+	+	+	+	+
Brown booby	+	+	-	-	-	+	+
Brown noddy	-	+	+	+	+	+	+
Brown pelican	+	+	-	+	-	+	+
Caspian tern	-	-	-	-	-	+	+
Common loon	+	+	-	-	-	+	+
Common tern	-	+	+	+	+	+	+
Cory's shearwater	+	+	+	+	+	+	+
Double-crested cormorant	-	+	-	-	-	+	+
Fea's petrel	-	-	-	-	-	-	+
Forster's tern	-	-	-	+	-	+	+
Franklin's gull	-	+	-	+	-	+	-
Great black-backed gull	-	+	-	-	-	+	+
Great shearwater	-	+	-	-	+	+	+
Gull-billed tern	-	+	-	+	-	+	+
Herring gull	+	+	+	+	+	+	+
Laughing gull	+	+	+	+	+	+	+

Species	Fritts and	Fritts et al.	Ribic et al.	GulfCet I	GulfCet II	NRDA	GOMMAPPS
	Reynolds	1980–1981	1992–1993	1992–1994	1996–1997	2010–2011	2017–2019
	1979						
Leach's storm-petrel	-	-	-	+	+	+	+
Least tern	+	+	+	+	+	+	+
Long-tailed jaeger	-	-	-	-	+	+	+
Magnificent frigatebird	+	+	+	+	+	+	+
Manx shearwater	-	-	-	-	+	-	+
Masked booby	+	+	+	+	+	+	+
Neotropic cormorant	-	-	-	-	-	+	+
Northern gannet	+	+	+	+	+	+	+
Parasitic jaeger	-	-	-	+	+	+	+
Pomarine jaeger	-	-	+	+	+	+	+
Red-billed tropicbird	-	-	-	+	+	+	+
Red-footed booby	-	-	-	-	-	-	+
Red-necked phalarope	-	-	-	-	-	+	+
Red phalarope	-	-	-	+	-	+	+
Red-throated loon	-	-	-	-	-	-	+
Ring-billed gull	-	+	-	+	-	+	+
Roseate tern	-	-	-	-	-	+	+
Royal tern	+	+	+	+	+	+	+
Sandwich tern	+	+	+	+	+	+	+
Sooty Shearwater	-	-	-	-	+	+	-
Sooty tern	+	+	+	+	+	+	+
South Polar skua	-	-	-	-	-	+	+
White-tailed tropicbird	-	+	+	+	+	+	+
Wilson's storm-petrel	-	-	-	+	+	+	+
Total	16	30	19	30	27	43	44

Sea-surface temperature (SST) describes the thermal conditions at the sea-surface which can indicate water mass boundaries and influence the distribution and abundance of prey (e.g., Ribic et al. 1997). Within the Gulf, sea-surface temperature is lower onshore and increases relatively rapidly between the 200-m - 2,000-m isobaths, then increases more gradually within the pelagic environment (Figure 5.6d). The waters occur within the interior of the Loop Current. In mid- and higher latitude systems, seabirds are often associated with cooler SSTs that also tend to be more productive (Frederiksen et al. 2007). In tropical or sub-tropical systems, seabirds may differ in their response to SSTs depending, in part, on their foraging mode or other environmental characteristics that may serve to concentrate prey (Jacquemet et al. 2004, Spear et al. 2001, Weeks et al. 2013, Precheur et al. 2016, Lamb et al. 2020b).

In combination, sea-surface salinity, sea-surface height, and sea-surface temperature, as well as chlorophyll-a, can be used to identify unique water masses (Ribic et al. 1997, Spear et al. 2001). Different water masses can provide favorable foraging habitats for different species due to the unique chemical components and biological communities within a water mass, as well as unique attributes of the foraging ecology and energetic constraints of a given seabird species.

Surface current is the directional flow or movement of surface water in degrees (-180, 180), interpreted as cardinal directions; north (-46° to 45°), east (46° to 75°), south (-76° to 75°), west (-75° to -45°) (Figure 5.6e). Surface current direction is derived from eastward (u) and northward (v) surface current vectors; described below. Surface current direction does not have a broad- scale gradient of increasing or decreasing from onshore to offshore, but rather is highly variable. Difficult to interpret on its own, surface current direction can provide valuable insight on spatial and dynamic associations of seabirds when interpreted with another covariate providing a spatial context. For example, an association with primarily south-eastward current direction, which is highest in the pelagic waters of the EPA, and with low levels of chlorophyll-a are indictive of pelagic habitats of the EPA (Jodice et al. 2021b).

Surface current velocity (m/s) vectors (eastward (u) and northward (v); Figure 5.6f through Figure 5.6g) indicate the current strength in that direction. The absolute current speed (Figure 5.6h) is derived from eastward and northward vectors. These covariates associate with small-scale physical processes (Schwemmer et al. 2009). As with current direction, the additional context of other important covariates and the spatial distribution of observations would aid the interpretation of a relationship to eastward, northward, or absolute surface current velocity. These covariates were not strongly associated with the potential occurrence of the species evaluated. The Eulerian data collection and the broad spatial scale of our analysis may have prevented or constrained our ability to identify strong associations with velocity vectors and direction (Schwemmer et al. 2009).

Bathymetry, the only static covariate we included, defines marine domains based on their depth. Bathymetry is strongly associated with water circulation and vertical mixing, which subsequently influences the distribution and abundance of prey (Yen et al. 2004, Kappes et al. 2011). Within the Gulf water depths ≤ 200 m are strongly influenced by freshwater with a shallow slope to the seabed. Waters between 200 m and 2,000 m (i.e., the shelf-slope) are characterized by a steep slope and by highly dynamic currents interacting with the slope. In the pelagic domain (waters >2,000 m), eddies and jets play important roles in shaping the distribution and abundance of fauna. The broadest shelf areas occur in the EPA (Florida Shelf) and the northwest and northeast corners of the CPA and WPA, respectively (Louisiana-Texas Shelf), while deep pelagic waters occur primarily in the southern extent of the CPA and the western extent of the EPA (Figure2.1). Refer to Section 2.1 for a broad overview regarding the oceanographic features (including bathymetry) for the three BOEM planning areas.

The relative contribution of each predictor variable for each species appears in Table 5.12. To ease comparisons of the relationships between these predictor variables and predicted occurrence (i.e., habitat suitability), we provide plots (i.e., results from Maxent models) for any relationship where the predictor

variables sum to contribute \geq 50% to the final model for any species (Figures 5.7a - 5.7f). These plots are grouped by predictor variables (e.g., SSS grouped together for all species, SSH grouped together for all species).



Figure 5.5. Histograms of flock sizes by species for seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

The top panel represents those seabird species with observed flock sizes ≥80 birds; the bottom panel represents those species with observed flock sizes between 15 and 79 birds. For all species in both panels, the x-axis represents flock size, and the y-axis represents number of detections. In general, for all species there was a dramatic drop-off in number of detections of large flock sizes at the upper end of observed flock sizes by species. A list of the four-letter AOU codes can be found on the Institute for Bird Populations website. Please refer to text for more details.

Table 5.11. Characterization of species-specific overlap with oil and gas platforms for the western and central BOEM planning areas, individually and combined.

Species	WPA	WPA	WPA	СРА	СРА	СРА	Combined	Combined	Combine
	Top 1/3 suitable	% Top 1/3 habitat within 10	Rank	Top 1/3 suitable habitat (km ²)	% Top 1/3 habitat within	Rank	Top 1/3 suitable habitat	% Top 1/3 habitat within 10 km of	d Rank
	habitat	km of platform ²			10 km of		(km²)	platform ²	
	(km ²) ¹				platform ²			P	
AUSH ^a	38,778.1	4.9	16	40,761.2	12.5	18	79,539.3	0.1	20
BCPE ^a	5,773.7	27.1	9	22,240.8	9.0	21	28,014.5	0.1	17
BLTE ^a	8,913.7	32.2	7	22,898.7	71.2	4	31,812.5	0.6	8
BOGU ^a	48.3	0.0	21	360.9	6.1	23	409.2	0.1	22
BRBO ^a	62,854.6	15.7	12	11,3245.2	30.6	12	176,099.8	0.3	12
BRNO ^a	0.0	-	-	0.0	-	-	0.0	0.0	24
BRPE ^a	5,892.5	59.2	2	35,236.0	79.9	2	4,1128.5	0.8	2
BRTE ^a	29,377.0	16.8	11	61,656.8	28.5	14	91,033.7	0.2	13
BSTP ^a	21,562.5	4.3	17	32,512.6	12.2	19	5,4075.1	0.1	19
COLO ^a	0.0	-	-	2,076.8	66.3	8	2,076.8	0.7	5
COSH ^a	27,625.0	13.1	13	49,545.7	30.4	13	77,170.7	0.2	14
COTE ^a	1,807.5	56.7	4	12,356.1	67.8	7	14,163.6	0.7	4
GRSH ^a	3,540.9	25.5	10	38,168.5	47.1	10	41,709.4	0.5	10
HERG ^a	38,187.1	12.6	14	47,624.7	44.2	11	85,811.8	0.3	11
LAGU ^a	23,279.2	30.7	8	32,747.8	69.1	6	56,026.9	0.5	9
MABO ^a	60,568.0	12.0	15	68,124.3	19.5	16	128,692.3	0.2	15
MAFR ^a	7,916.8	53.9	5	45,058.7	63.9	9	52,975.5	0.6	7
NOGAª	11.5	100.0	1	21,825.5	83.3	1	21,837.1	0.8	1
PAJA ^a	30,746.1	3.6	19	46,368.1	22.9	15	77,114.2	0.2	16
POJA ^a	54,199.4	3.8	18	68,566.8	9.8	20	122,766.2	0.1	21
ROYT ^a	14,364.4	41.7	6	39,073.7	71.1	5	53,438.1	0.6	6
SATE ^a	3,914.6	57.1	3	22,795.7	73.2	3	26,710.3	0.7	3
SOTE ^a	5,701.4	0.0	22	3,926.1	6.3	22	9,627.5	0.0	23
WISP ^a	12,221.5	2.5	20	53,209.6	14.5	17	65,431.1	0.1	18

See Appendix A for definitions of species four-letter American Ornithologists Union (AOU) codes. <u>NOTE</u>: the eastern planning area is excluded due to the general absence of offshore O&G development on the Outer Continental Shelf (OCS) in this planning area.

1 Top third suitable habitat (km²): represents the area of the upper one-third of suitable habitat for a given species with a given area based on combination of individual MaxEnt (Phillips et al. 2006) models for 24 seabird species. Refer to section 4.4 for additional details; refer also to Michael et al. (2022). 2 Percent (%) top third habitat within 10 km of a platform: represents the proportion of the upper one-third of suitable habitat within 10 km of an oil platform within a given area based on combination of individual MaxEnt (Phillips et al. 2006) models for 24 seabird species. Refer to section 4.4 for additional details; refer also to Michael et al. (2022).

3 Rank: represents the relative order by species from the highest (lowest value) to lowest (largest value) proportional values of the upper one-third of suitable habitat within 10 km of an oil platform.

a See Table 5.6a for the four-letter American Ornithologists Union (AOU) codes used to identify seabird species in this Table. Michael et al. (2022) developed an oil spill vulnerability index for seabirds in the northern Gulf.

5.4 Individual Species Accounts

Species identified here with <u>an underline only</u> did not meet or exceed the minimum detection threshold ($n \ge 20$ detections) for modeling whereas species identified with both <u>italics and underlined</u> met this threshold for modeling. Refer to Section 5.3 for additional details. For each of the species below, in text we refer to both relevant Tables and Figures, as well as Appendix D and the associated Figure number and letter parenthetically. Appendix D contains spatial distribution maps of seabird detections (A), predicted occurrence (B) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat with O&G platforms (C) from seabird vessel survey data collected as part of the GOMMAPPS for all 24 species of seabirds that met the minimum detection threshold (Section 4.3). For those species that did not meet the minimum detection threshold only spatial distribution maps of seabird detections are included. For ease of interpretation, species profiles below are presented in alphabetical order by common name.

5.4.1 Audubon's shearwater

The Audubon's shearwater is a wing-propelled, pursuit-diving shearwater. Within the western north Atlantic, this species breeds throughout the Caribbean and Bahamas, with extensive colonies on Cay Sal Bank, the closest known breeding sites to the Gulf. The breeding schedule is somewhat variable throughout the Caribbean, though breeding is typically initiated in January – March. Globally the species is considered of least concern. The species has a PIF score of 14 and a watch list classification of Yellow-D (steep declines and major threats). The Caribbean subspecies is endemic to the region and is listed as a Caribbean at-risk species (Bradley and Norton 2009:chapt. 1). Audubon's shearwater is listed as a Bird of Conservation Concern (USFWS 2021) at the continental level and occurs throughout much of the year within the northern Gulf (MBCR 20) although it does not breed in this MBCR. Their diet is comprised primarily of small fish and squid although data are limited. The species often forages over patches of *Sargassum* but also will practice facilitated foraging.

We tallied 517 detections of 1,766 individuals (Table 5.6a through Table c). Group size ranged from 1 - 180 with a median of 3.4 birds, and Audubon's shearwater accounted for 4.7% of the total number of identified seabirds observed (Figure 5.5a, Table 5.6a through Table c). Audubon's shearwaters were observed in each of the three planning areas (Table 5.11, Appendix D; 1a). Most observations of Audubon's shearwater occurred in summer and spring (n = 988 in March) while winter observations (i.e., initiation of breeding season) were rare (although survey effort was low in winter) (Table 5.6a through Table b).



Figure 5.6a. Map of chlorophyll-a (mg/m³) in the Gulf of America.

Chlorophyll-a is represented in various shades of green with areas in dark green indicative of higher chlorophyll-a, and thus, greater potential primary productivity. The three BOEM planning areas (Western, Central, and Eastern) are identified with thick white lines, 200-m isobath is identified as black dotted line and the 2000-m isobath is identified as black dashed line, overlain on a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. In general, chlorophyll-a tended to be highest close to the coastline but extended seaward approximately to the 200-m isobath off Louisiana, Mississippi, and Alabama coasts. See text for more details.





Sea-surface salinity is represented in shades of dark blue (high SSS), light green (moderate SSS), and yellow (low SSS). The three BOEM planning areas (Western, Central, and Eastern) are identified with thick white lines, 200-m isobath is identified as white dotted line and the 2000-m isobath is identified as white dashed line, overlain on a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. In general, SSS tended to be lowest (a function of large freshwater inputs) close to the coastlines for Texas, Louisiana, Mississippi, and Alabama and near outflows of major rivers along the Florida coast. See text for more details.





Sea-surface height is represented in shades of light green (high SSH), light blue (moderate SSH), and dark blue (low SSH). The three BOEM planning areas (Western, Central, and Eastern) are identified with thick white lines, 200-m isobath is identified as white dotted line and the 2000-m isobath is identified as white dashed line, overlain on a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. In general, SSH tended to be highest in the southeastern Gulf (via the Florida Straits) extending into the Central and Eastern Planning Area boundary near the intersection with the Exclusive Economic Zone (EEZ), light blue extensions into the Central Planning Area, and areas to the south and west beyond the southern boundary of the EEZ. Please refer to text for more details.



Figure 5.6d. Map of sea-surface temperature (SST; °C) in the Gulf of America.

Sea-surface temperature is represented in shades of dark orange (high SST), light yellow (moderate SST), and blue (low SST). The three BOEM planning areas (Western, Central, and Eastern) are identified with thick white lines, 200m isobath is identified as black dotted line and the 2000-m isobath is identified as black dashed line, overlain on a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. In general, SST tended to be highest in the southeastern Gulf (via the Florida Straits) and to the south and west beyond the southern boundary of the EEZ. See text for more details.



Figure 5.6e. Map of sea-surface currents (in degrees) in the Gulf of America.

Sea-surface current flow is provided as colored arrows indicative of current direct at a given point. Blue arrow = North (NE or NW), orange arrow = South (SE or SW), green arrow = East (NE or SE), and purple arrow = West (NW or SW). The three BOEM planning areas (Western, Central, and Eastern) are identified with thick white lines overlain on a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. Though there was spatial variation in current direction within and among the three BOEM planning areas, in general, the Western planning area is dominated by westerly currents (purple arrows), the Eastern planning area is dominated by easterly currents (green arrows), and the Central planning area is best described as mixed current flows. Please refer to text for more details.





Eastward surface velocity is represented in shades of dark green (high velocity), light yellow (moderate velocity), and purple (low velocity). The three BOEM planning areas (Western, Central, and Eastern) are identified with thick white lines, 200-m isobath is identified as black dotted line and the 2000-m isobath is identified as black dashed line, overlain on a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. In general, eastward surface velocity tended to be highest (green) in the southeastern Gulf (via the Florida Straits) with a bifurcation extending north and westward roughly between the 200-m and 2000-m isobaths into the Western planning area, as well west along the southern boundary of the EEZ. See text for more details.



Figure 5.6g. Map of northward surface current velocity (m/s) in the Gulf of America.

Northward surface velocity is represented in shades of dark green (high velocity), light yellow (moderate velocity), and purple (low velocity). The three BOEM planning areas (Western, Central, and Eastern) are identified with thick white lines, 200-m isobath is identified as black dotted line and the 2000-m isobath is identified as black dashed line, overlain on a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. In general, northward surface velocity tended to be highest (green) via influx of Caribbean waters between the east side of the Yucatan Peninsula and western tip of Cuba extending into the southeastern quadrant of the Central planning area, as an outflow from the Gulf through the Florida Straits, and far southwest corner of the Western planning area between the 200-m and 200-m isobaths (and extending further south). See text for more details.





Absolute surface current velocity is represented in shades of dark green (high velocity), light yellow (moderate velocity), and purple (low velocity). The three BOEM planning areas (Western, Central, and Eastern) are identified with thick white lines, 200-m isobath is identified as white dotted line and the 2000-m isobath is identified as white dashed line, overlain on a map of the U.S. Gulf coastline of Texas, Louisiana, Mississippi, Alabama, and Florida. Here, absolute surface velocity was highest indicative of a northerly loop into the Eastern and Central planning areas via water movements between the east side of the Yucatan Peninsula and western tip of Cuba and down through the Florida Straits, as well as far southwest corner of the Western planning area between the 200-m and 200-m isobaths (and extending further south). See text for more details.

Most observations of Audubon's shearwaters occurred in the eastern northern Gulf, east of De Soto Canyon and over the Florida Escarpment (Appendix D; 1a). We also observed a cluster of observations within the TX-LA Shelf east of Corpus Christi and near the western edge of the Florida Keys. This species was observed, however, over most of the east-west and north-south footprint of the survey area except for the TX-LA Shelf. The predictive model generated an AUC value of 0.917 for the training data set and 0.897 for the testing data set indicating very good to excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for Audubon's shearwaters (Appendix D; 1b) included waters (1) over the Florida Escarpment and along the north-south length of the Florida peninsula, an area that can experience substantial upwelling, (2) within a narrow east-west band paralleling much of the Texas and Louisiana continental slope, and (3) within the Straits of Florida. This latter area is proximate to breeding colonies at Cay Sal Bank. Areas of lower habitat suitability were predicted to include pelagic waters in the CPA which are likely associated with oligotrophic waters of the interior Loop Current.

Habitat suitability for Audubon's shearwaters was best predicted by SSH and bathymetry, although neither was a particularly strong predictor (% contribution ~24% for each; Table 5.12). Habitat suitability declined as depth increased (e.g., avoidance of deep oligotrophic waters in the south CPA) and peaked at mid-ranges of SSH, the latter suggesting an association with edges of water masses that concentrate prey such as the eastern edge of the Loop Current and dynamic waters in the WPA between the 200-m and 2,000-m isobath (Figure 5.7c through Figure 5.7d). Habitat suitability in the western north Atlantic for Audubon's shearwaters tagged in the Bahamas was higher for shelf breaks and warmer waters (Ramos et al. 2021). Among a suite of small shearwaters, Ramos et al. (2021) found substantial variability in environmental variables that best predicted habitat suitability suggesting that shearwaters can adapt their
plastic foraging behavior to different environmental conditions.

Among species for which we modeled habitat suitability (n = 24), Audubon's shearwater ranked 20th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (9%; Table 5.11, Appendix D; 1c). Within the WPA ~5% of highly suitable habitat was proximal to a platform and within the CPA ~12% was proximal to a platform (Appendix D; 1c).

Our data suggest that Audubon' shearwaters occur regularly throughout much of the northern Gulf particularly in the spring and summer, likely representing post-breeding individuals based on the breeding phenology of the species in the Caribbean. Previous seabird surveys in the northern Gulf also reported the species regularly (Table 5.10). The origin of Audubon's shearwaters in the northern Gulf is not clear. Shearwaters tracked from breeding colonies in the northern Bahamas, Martinique, and Tobago did not enter Gulf waters during breeding or nonbreeding (Ramos et al. 2021, W. Mackin, pers. comm., Durham, North Carolina). One recovered global location sensor deployed on a breeding shearwater at Cay Sal Bank did, however, demonstrated regular and long-term use of Gulf waters during two consecutive nonbreeding periods (late summer and fall; W. Mackin, pers. comm., Durham, North Carolina). Of documented breeding sites for this species, Cay Sal Bank (~5,000 pairs; Mackin et al. 2015) is the closest to the Gulf.

Band-rumped storm-petrel

The band-rumped storm-petrel is a small, surface-feeding seabird that often hugs the surface of the water. Band-rumped storm-petrels breed in the eastern north Atlantic in Macronesia (as well as the Pacific Ocean) during winter and occur in the western north Atlantic, including the Gulf during its nonbreeding season (Woolfenden et al. 2001). The species is considered of least concern globally with a PIF score of 17 and a watch list classification of Red (highly vulnerable). Band-rumped storm-petrel is listed as a Bird of Conservation Concern at the continental level and occurs within the northern Gulf (MBCR 20) primarily during its nonbreeding season (USFWS 2021). The diet is comprised primarily of small fish and zooplankton and foraging can be nocturnal (Lee 1984). Storm-petrels often occur in mixed-species foraging flocks and forage nocturnally on myctophids, fish with particularly high energy density that are typically concentrated by current features.

Table 5.12. Percent contribution for each of nine predictor variables to final predictive models of species occurrence for 24 species of seabirds in the Gulf (seabird vessel survey data-only), 2017 – 2019.

Predictor variables are: bathymetry, chlorophyll-a, current direction, absolute current strength, sea-surface height, sea-surface salinity, sea-surface temperature, surface current velocity: eastward, and surface current velocity: northward (MaxEnt; Phillips et al. 2006). See Sections 4.3 and 4.4 for detailed description of the modeling approach and predictor variables (see also Table 4.2).

Species	Bathymetry	Chlorophyll-a	Current Direction	Current Strength	Sea-surface Height	Sea- surface	Sea-surface Temperature	Velocity: eastward	Velocity: northward
				(absolute)		Salinity		(<i>u</i>)	(<i>v</i>)
Audubon's shearwater ^a	23.7	9.5	12.0	0.8	24.4	15.8	7.6	3.3	2.9
Band-rumped storm- petrel ^a	26.6	10.8	14.5	1.4	19.0	25.7	0.2	0.0	1.9
Black tern ^a	13.5	45.4	0.8	1.5	0.9	36.3	1.2	0.0	0.4
Black-capped petrel ^{a,b}	13.1	14.4	59.4	0.4	4.1	0.7	7.3	0.1	0.5
Bonaparte's gull ^a	9.4	54.6	1.7	3.0	13.3	9.7	8.3	0.0	0.0
Bridled tern ^a	26.9	10.0	26.9	0.9	23.1	7.0	1.1	1.7	2.3
Brown booby ^a	10.6	8.5	4.2	1.4	13.1	38.7	21.2	0.1	2.2
Brown noddy ^a	15.3	7.5	2.3	2.5	48.5	0.0	21.4	0.8	1.6
Brown pelican ^a	10.0	39.1	1.2	1.9	5.3	40.7	0.2	1.3	0.3
Common loon ^a	6.9	49.7	7.2	1.3	9.6	7.5	17.7	0.0	0.0
Common tern ^a	22.2	1.7	7.4	2.8	7.0	13.4	42.2	3.4	0.0
Cory's shearwater ^a	22.4	1.1	1.2	0.2	12.0	56.0	4.2	0.0	2.9
Great shearwater ^a	6.7	31.6	12.0	0.1	4.4	44.6	0.1	0.4	0.1
Herring gull ^a	10.9	1.2	0.8	1.4	7.7	56.8	21.1	0.0	0.1
Laughing gull ^a	10.4	23.4	0.5	0.5	2.6	54.3	4.2	3.2	0.9
Magnificent frigatebird ^a	14.4	42.6	0.9	2.1	14.7	2.5	18.2	3.9	0.7
Masked booby ^a	20.4	6.5	0.7	3.4	13.9	53.3	0.7	0.5	0.7
Northern gannet ^a	9.2	47.0	1.2	0.2	10.8	22.3	8.9	0.4	0.0
Parasitic jaeger ^a	26.1	0.1	1.3	8.2	35.9	12.6	10.4	1.4	4.1
Pomarine jaeger ^a	30.1	1.0	4.0	0.8	21.8	40.4	0.0	0.2	1.7
Royal tern ^a	12.5	52.1	0.2	2.0	0.3	5.6	26.0	1.0	0.3
Sandwich tern ^a	10.9	59.1	2.5	7.2	1.5	2.4	14.0	2.3	0.1
Sooty tern ^a	14.3	1.1	34.9	0.6	27.3	5.7	6.2	3.9	6.0
Wilson's storm-petrel ^a	27.9	20.0	11.7	1.5	14.8	23.4	0.0	0.1	0.5
# species covariate ranked highest ¹	3	7	3	0	3	8	1	0	0
# species covariate >25% ²	6	9	3	0	4	10	1	0	0
# species covariate >40% ³	0	7	1	0	1	7	1	0	0

1 Number (#) of species for which the respective covariate ranked the highest.

2 Number (#) of species for which % contribution of the respective covariate contributed or explained >25% in the final predictive model.

3 Number (#) of species for which % contribution of the respective covariate contributed or explained >40% in the final predictive model.

a Refer to Michael et al. (2023) for additional details regarding the relationship between seabird relative density and environmental covariates.

b For additional information regarding the relationship between environmental covariates for this species, refer to Jodice et al. (2021b).

We tallied 334 detections totaling 512 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 11 with a mean group size of 1.5, and band-rumped storm-petrels accounted for 1.3% of the total number of identified seabirds observed (Table 5.6a). Band-rumped storm-petrels were widespread and observed in each of the three planning areas, as well as in the Straits of Florida (Appendix D; 2a). Individuals were primarily observed in spring and summer (~95%; the nonbreeding season for this species) (Tables 5.6a-b).

Most observations of band-rumped storm-petrels occurred beyond the 200-m isobath particularly in the northwest reaches of the EPA and in the CPA south of the Mississippi Delta (Appendix D; 2a). The predictive model generated an AUC value of 0.934 for the training data set and 0.922 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for band-rumped storm-petrels (Appendix D; 2b) included waters throughout each of the planning areas within the 200-m – 2,000-m isobath, with suitable habitat in deeper pelagic waters of each planning area.

Habitat suitability for band-rumped storm-petrels was best predicted by bathymetry and SSS (~26% each; similar to the model for Wilson's storm-petrel; Table 5.12, Figures 5.7a and 5.7e), indicating a greater use of pelagic waters (Appendix D; 2c, Figure 5.6a through Figure 5.6b). Highly suitable habitat appears to occur in regions that support upwelling (e.g., south coast of Texas, and the northeast and northwest edges of the Loop Current where frontally induced upwelling occurs; Appendix D; 2b). The habitat characteristics of the northeastern Gulf are similar to that described for the species off Cape Hatteras and in the South Atlantic Bight where this species showed an affinity for areas with upwelling such as within cold core eddies (Paluszkiewicz et al. 1983, Lee 1984, Haney 1985).

Among species for which we modeled habitat suitability (n = 24), band-rumped storm-petrel ranked 19th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (9%; Table 5.11). Within the WPA ~4% of highly suitable habitat was proximal to a platform and within the CPA ~12% was proximal to a platform (Appendix D; 2c).

Our data suggest the species occurs regularly in deeper waters of the Gulf, and that it appears to be the most abundant storm-petrel in the northern Gulf. This species has been regarded as a casual visitor (e.g., Duncan and Havard 1980) in the northern Gulf but perhaps its occurrence has been under-estimated due to difficulties distinguishing it from other storm-petrels (Table 5.10).



Figure 5.7a. Plots of coefficient response curves for the predictor variable bathymetry (A) derived from MaxEnt models (Phillips et al. 2006) for seven species (Audubon's shearwater, band-rumped storm-petrel, bridled tern, common tern, parasitic jaeger, pomarine jaeger, Wilson's storm-petrel) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Plots are only provided for the least parameterized model (9 potential predictor variables) for a given species that sum to >50% of contribution to the final model. For this plate, the x-axis represents log contribution to raw prediction and the y-axis represents bathymetry (in meters). Though the shape of the curves differed by species, in all cases log contribution to raw prediction tended to increase quickly then dropped-off at bathymetry values between -2000 m and -4000 m. Please refer to text for more details.



Figure 5.7b. Plots of coefficient response curves for the predictor variable chlorophyll-a (B) derived from MaxEnt models (Phillips et al. 2006) for nine species (black tern, Bonaparte's gull, brown pelican, common loon, great shearwater, magnificent frigatebird, northern gannet, royal tern, and sandwich tern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Plots are only provided for the least parameterized model (nine potential predictor variables) for a given species that sum to >50% of contribution to the final model. For this plate, the x-axis represents log contribution to raw prediction and the y-axis represents chlorophyll-a (mg/m^3). Though the shape of the curves differed by species, in all cases log contribution to raw prediction tended to increase abruptly for observed values then tended to decline for chlorophyll-a values between 5 mg/m³ and 10 mg/m³. See text for more details.



Figure 5.7c. Plots of coefficient response curves for the predictor variable current direction (C) derived from MaxEnt models (Phillips et al. 2006) for three species (black-capped petrel, bridled tern, and sooty tern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Plots are only provided for the least parameterized model (nine potential predictor variables) for a given species that sum to >50% of contribution to the final model. For this plate, the x-axis represents log contribution to raw prediction and the y-axis represents current direction (in degrees). Though the shape of the curves differed by species, in all cases log contribution to raw prediction tended to exhibit a bimodal curve with rather steep declines between -200 and 0 and subsequent steep increases between 0 and 200. See text for more details.



Figure 5.7d. Plots of coefficient response curves for the predictor variable sea-surface height (D) derived from MaxEnt models (Phillips et al. 2006) for four species (Audubon's shearwater, brown noddy, parasitic jaeger, and sooty tern) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Plots are only provided for the least parameterized model (nine potential predictor variables) for a given species that sum to >50% of contribution to the final model. For this plate, the x-axis represents log contribution to raw prediction and the y-axis represents sea-surface height (in meters). Though the shape of the curves differed by species, in all cases log contribution to raw prediction tended to exhibit a bell curve with rather steep increases between -0.25 m and 0 with steep declines between 0 and 0.25 m. See text for more details.





Figure 5.7e. Plots of coefficient response curves for the predictor variable sea-surface salinity (E) derived from MaxEnt models (Phillips et al. 2006) for twelve species (band-rumped stormpetrel, black tern, brown booby, brown pelican, Cory's shearwater, great shearwater, herring gull, laughing gull, masked booby, northern gannet, pomarine jaeger, and Wilson's storm-petrel) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Plots are only provided for the least parameterized model (nine potential predictor variables) for a given species that sum to >50% of contribution to the final model. For this plate, the x-axis represents log contribution to raw prediction and the y-axis represents sea-surface salinity (typically in parts per thousand). Though the shape of the curves differed by species, in all cases log contribution to raw prediction tended to drop-off dramatically at values between 27 to 30.See text for more details.



Figure 5.7f. Plots of coefficient response curves for the predictor variable sea-surface temperature (F) derived from MaxEnt models (Phillips et al. 2006) for four species (brown booby, brown noddy, common tern, and magnificent frigatebird) from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Plots are only provided for the least parameterized model (nine potential predictor variables) for a given species that sum to >50% of contribution to the final model. For this plate, the x-axis represents log contribution to raw prediction and the y-axis represents sea-surface temperature (°C). Response curves for brown booby, common tern, and magnificent frigatebirds exhibited declines between 22 °C and 24 °C, whereas brown noddy exhibited a peak at 22 °C. See text for more details.

Black-capped petrel

The black-capped petrel is one of five gadfly petrels that breed in the north Atlantic. Black- capped petrels are endemic to the western north Atlantic and nest at only five sites on Hispaniola. The species is considered globally endangered with a PIF score of 20 (highest PIF score of any seabird we detected) and a watch list classification of Red (highly vulnerable). Black-capped Petrel is listed as a Bird of Conservation Concern (USFWS 2021) at the continental level and occurs throughout the year within MBCR 20 although it does not breed in this BCR. This species was originally proposed for listing (USFWS 2019a, 83 FR 50560) as threatened with 4(d)) under the Endangered Species Act. However, in May 2023 the Service reopened the public comment period on the proposed listing (88 FR 27427) due to significant new information (USFWS 2023). In December 2023, the Service listed the species as endangered; effective 29 January 2024 (89 FR 89611). During the breeding season, black- capped petrels can undertake provisioning trips that last 1-3 weeks and that may range to 1,500 km from the nesting area while during the nonbreeding season they range widely through the western north Atlantic (Jodice et al. 2015). The status and breeding stage of black-capped petrels in the Gulf is unknown. The species also occurs in both a light and dark color morph (Howell and Patteson 2008). It is unclear, however, if the ranges of these two morphs are similar or disparate either spatially or temporally (Satgé et al. 2023). The diet appears to be comprised primarily of squid and small fish, but data are sparse (Simons et al. 2013).

(F)

We tallied 29 detections of black-capped petrels totaling 31 individuals (Tables 5.6a-c). Three of the petrels observed were classified as light-morph individuals (March 2018, August 2018 in the eastern Gulf; Jodice et al. 2021a). Group size ranged from one to two and Black-capped petrels accounted for <1% of the total number of identified seabirds observed (Table 5.6a). Black- capped petrels were observed in each of the three planning areas (Appendix D; 3a). Most observations of black-capped petrels occurred in late summer (Table 5.6a through Table 5.6b). We observed petrels in March - May and July - September. We did not observe birds on cruises in January through February (although survey effort was low then), June, or October.

Most observations of black-capped petrels occurred in the EPA, east of De Soto Canyon and over the Florida Escarpment, although birds were observed as far west as ~-96 longitude along the 200-m isobath (Appendix D; 3a). The predictive model generated an AUC of 0.950 for the training data set and 0.880 for the testing data set indicating very good to excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for black-capped petrels (Appendix D; 3b) included waters (1) west of the FL shelf beyond the 200-m isobath and extending along the north-south length of the FL peninsula, (2) south of the Mississippi River delta along the 2,000-m isobath, and (3) within a narrow east-west band paralleling much of the Texas and Louisiana continental slope. Areas of lower habitat suitability were predicted to include shelf/slope waters in each planning area and pelagic waters in the CPA which are likely associated with oligotrophic waters of the interior Loop Current. Habitat suitability was predicted to peak as currents were more eastward to southward (Figure 5.7c). These results are likely indicative of dynamic waters associated with the Loop Current interacting with the edge of the Florida Shelf. (Figure 5.6e).

Among species for which we modeled habitat suitability (n = 24), black-capped petrel ranked 17th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (13%; Table 5.11) with substantial disparity between the two planning areas. Within the WPA ~27% of highly suitable habitat was proximal to a platform and within the CPA ~9% was proximal to a platform (Appendix D; 3c).

Before GOMMAPPS, there was little evidence that black-capped petrels regularly occupied the northern Gulf. Ramos et al. (2017) does not indicate regular use of the Gulf by any of the eight gadfly petrels that breed in the Atlantic (north or south Atlantic). Although seabird surveys conducted following the *Deepwater Horizon* blowout did note the presence of black-capped petrels (Haney et al. 2019), no other previous research efforts did (e.g., Ribic et al. 1997, Davis et al. 2000) and records from other sources were scarce (Simons et al. 2013) (Table 5.10). Our data, along with the *Bird Study #6* vessel survey data, demonstrate that black-capped petrels occur throughout much of the northern Gulf and in most seasons of the year, and therefore, this region warrants consideration as being included within the marine range of the species (Jodice et al. 2021b).

Black tern

Black terns are small terns that breed primarily in freshwater emergent wetlands within the interior of North America and Canada (e.g., Prairie Pothole Region; Shuford 1999, Naugle et al. 2000, Steen and Powell 2012) and migrate through the Gulf to wintering areas in South America (Heath et al. 2020). Black terns are considered of least concern globally with a PIF score of 12 and a watch list classification of CBSD (common birds in steep decline). Black terns are surface feeders that primarily forage on small fish and insects and are often seen in mid- to large-sized, multi-species foraging flocks.

We tallied 726 detections of black terns totaling 12,109 individuals (Table 5.6a-c). Group size ranged from 1 to 760 with a mean of 16.7 birds, and black terns accounted for 32.0 % of the total number of identified seabirds observed (Figure 5.5a, Table 5.6a). Black terns were observed in all planning areas

(Appendix D; 4a). Approximately 78% of black terns were observed in the fall, 19% in summer, 3% in spring, and none in winter (although surveys during winter were infrequent; Table 5.6a and Table 5.6b).

We observed black terns primarily within the 200-m isobath near the Mississippi River Delta and along the coast of Texas from Galveston Bay south through Corpus Christi. The largest flocks also occurred in these locations. Individuals and smaller flocks were occasionally observed between the 200-m and 2,000-m isobaths but rarely in deeper, pelagic waters. The predictive model generated an AUC value of 0.952 for the training data set and 0.934 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for black terns (Appendix D; 4b) included coastal waters throughout both the CPA and WPA, with highest suitability predicted to occur in the Mississippi River Delta and central Texas coast.

Habitat suitability for black terns was best predicted by chlorophyll-a, and SSS which contributed 45% and 36% to the final model, respectively (Table 5.12). Habitat suitability showed a peaked relationship with chlorophyll-a, which was associated with productive, nearshore waters (Figures 5.6a and 5.7b). Habitat suitability also declined at higher levels of SSS also suggesting higher use of coastal waters (Figures 5.6b and 5.7e).

Among species for which we modeled habitat suitability (n = 24), black tern ranked 8th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (60%; Table 5.11). Within the WPA ~32% of highly suitable habitat was proximal to a platform and within the CPA ~71% was proximal to a platform (Appendix D; 4c).

Our data indicate that black terns are common in nearshore waters (i.e., within the 200-m isobath) during their nonbreeding period (Michael et al. 2024). Occasional extremely large flocks occur near the Mississippi River Delta and secondarily near Corpus Christi, Texas. Previous survey efforts showed a range of detections from none to abundant, likely based on the location and timing of surveys (Table 5.10). Black terns were the most abundant species we observed and the coastal regions of the northern Gulf, particularly in the CPA and WPA, appear to provide important migratory habitat for this species (Michael et al. 2024).

Bonaparte's gull

Bonaparte's gulls breed in the interior of Canada and the high Arctic and overwinter in the Gulf. Bonaparte's gulls are considered of least concern globally with a PIF score of 9 and no watch list classification. Bonaparte's gulls are surface feeders that forage primarily on small fish or large invertebrates in bays, estuaries, and coastal areas, often in small to mid-sized flocks. We tallied 83 detections of Bonaparte's gulls totaling 1,356 individuals (Tables 5.6a-c). Group size ranged from 1 - 265 with a mean of 16.3 birds, and Bonaparte's gulls accounted for 3.6% of the total number of identified seabirds observed (Figure 5.5a, Tables 5.6a). Bonaparte's gulls were observed in the EPA and CPA, but not within the WPA (although range maps for this species do include the western Gulf; Appendix D; 5a). Bonaparte's gulls were seen in winter (21% of individuals) and spring (79% of individuals; Tables 5.6ab).

Bonaparte's gulls were observed in three locations: (1) between Cape San Blas and Alligator Point, Florida, (2) slightly offshore of Pensacola, Florida, and (3) near the port of Pascagoula, Mississippi (Appendix D; 5a). Bonaparte's gulls were observed almost exclusively within the 200-m isobath. The predictive model generated an AUC of 0.986 for the training data set and 0.970 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well in the EPA. We did not, however, observe birds throughout extensive portions of habitat predicted to be suitable in the CPA and WPA perhaps due to a lack of surveys in inshore waters. Areas predicted as likely to contain suitable habitat for Bonaparte's gulls (Appendix D; 5b) included waters of the northwestern corner of the EPA and Apalachee Bay.

Habitat suitability for Bonaparte's gull was best predicted by primary productivity that contributed 55% to the final model (Table 5.12). Habitat suitability showed a peaked relationship with chlorophyll-a (Figure 5.7b). Habitat suitability was highest in the northern reaches of Apalachee Bay where some of the higher values of chlorophyll-a occurred although higher and lower values occur elsewhere, we did not observe the species (e.g., Mississippi River Delta and pelagic waters, respectively; Figure 5.6a). Bonaparte's gulls appear to forage near currents or contours where plankton may be locally concentrated (Braune and Gaskin 1982).

Among species for which we modeled habitat suitability (n = 24), Bonaparte's gull ranked 22nd in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (5%; Table 5.11). Within the WPA, 0% of highly suitable habitat was proximal to a platform and within the CPA ~ 6% was proximal to a platform (Appendix D; 5c).

Our data suggest that while this species was relatively abundant it was localized to just a few areas in the northern reaches of the CPA and EPA. Previous survey efforts showed a range of detections from none to locally common, likely based on the location and timing of surveys (Table 5.10).

Bridled tern

Bridled terns are small, pelagic terns that breed throughout the Caribbean, Bahamas, and the southern Gulf. The species is pantropical and considered of least concern globally with a PIF score of 11 and a no watch list classification. The endemic Caribbean subspecies is considered of no immediate conservation concern (~9,000 pairs; Bradley and Norton 2009). Bridled terns are surface feeders that primarily forage in *Sargassum* patches on small forage fish (Haney 1986, Moser and Lee 2012), usually singly but occasionally in larger flocks. Bridled terns often use facilitated foraging (i.e., associated with predatory fish; Dunlop and Surman 2012).

We tallied 232 detections totaling 489 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 53 with a median of 2.1 birds, and bridled terns accounted for ~1.3% of the total number of identified seabirds observed (Figure 5.5b, Table 5.6a). Bridled terns were widespread, occurring in each of the three planning areas although at relatively low densities (Appendix D; 6a). Most observations occurred during the transition from late summer to fall (68%), although individuals were observed throughout the year (Table 5.6a through Table 5.6b).

Most observations of bridled terns occurred in the EPA west of the central and south peninsula of Florida between the 200-m and 2,000-m isobath. Individuals were observed regularly, however, over most of the east-west and north-south footprint of the survey area (Appendix D; 6a). The predictive model generated an AUC value of 0.884 for the training data set and 0.851 for the testing data set indicating very good but not excellent model performance. These AUC values were some of the lower values generated among seabirds we modeled. The occurrence records on which the model was trained matched model projections relatively well. Areas predicted as likely to contain suitable habitat for bridled terns (Appendix D; 6b) included waters (1) west of the Florida Shelf and along the north-south length of the Florida peninsula, including the Florida Keys and the Straits of Florida, (2) within a narrow east-west band paralleling much of the Texas and Louisiana continental slope, and (3) near the head of De Soto Canyon, an area prone to frequent eddy activity and upwelling. Areas of lower habitat suitability were predicted to include much of the TX-LA Shelf (often areas of high turbidity) and pelagic waters in the southern extent of the CPA associated with oligotrophic waters of the interior Loop Current. In Western Australia, the species is also known to regularly forage over shelf waters (Dunlop and Surman 2012).

Habitat suitability for bridled terns was best predicted by current direction, bathymetry, and SSH. Each contributed ~23–27% to the final model (Table 5.12). Bridled terns responded positively to southerly currents, intermediate levels of SSH, and slope waters (Figure 5.7a and Figure 5.7c). The combination of these appears to be indicative of features in the eastern Gulf such as eddies, jets, and rings that are likely to aggregate *Sargassum* and therefore provide suitable foraging habitat (e.g., Figure 5.6c and Figure 5.6h).

Among species for which we modeled habitat suitability (n = 24), bridled tern ranked 13th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (25%; Table 5.11). Within the WPA ~17% of highly suitable habitat was proximal to a platform and within the CPA ~28% was proximal to a platform (Appendix D; 6c).

Our data suggest the species occurs regularly throughout the Gulf, particularly during post- breeding periods (late summer into fall). Surman et al. (2018) measured migration distances of ~3,500 km for bridled terns tracked from breeding sites in Western Australia and therefore the Gulf would appear to be well within reach of colonies throughout the Caribbean. Although the species occurs throughout our study area, it appears to be most common along the western edge of the Florida Shelf and in the Straits of Florida, perhaps due to the proximity to colony sites on Cay Sal Bank (~1,100 pairs). Bridled terns have not been recorded nesting on Areciffe Alacranes in the southern Gulf (Morales-Vera et al. 2017). Bridled terns were not recorded frequently during previous seabird surveys in the Gulf, perhaps due to the lack of extensive survey effort over the Florida Shelf in the southeastern reaches of the EPA (Table 5.10).

Brown booby

Brown boobies are pantropical sulids that breed throughout the Caribbean, Bahamas, and the southern Gulf. The species is considered of least concern globally with a PIF score of 12 and no watch list classification. The Caribbean population is, however, considered to be at risk (Bradley and Norton 2009). Brown boobies are plunge-divers that primarily forage on flying fish and squid, not uncommonly in mixed-species flocks and/or foraging over schools of predatory fish. Brown boobies breed asynchronously throughout the year and therefore birds may be found at any stage of breeding at a colony during most months of the year.

We tallied 300 detections of brown boobies totaling 355 individuals (Tables 5.6a-c). Group size ranged from 1 to 18 with a median of 1.2 birds, and brown boobies accounted for \sim 1% of the total number of identified seabirds observed (Figure 5.5b, Table 5.6a). Brown boobies were observed in each of the three planning areas (Appendix D; 7a). Most observations occurred in fall and summer although individuals were observed during each month surveys were conducted (Table 5.6a through Table 5.6b).

We observed brown boobies regularly over most of the east-west and north-south footprint of the survey area (Appendix D; 7a). The predictive model generated an AUC value of 0.872 for the training data set and 0.877 for the testing data set, being one of the lowest AUC values among modeled seabirds but still performing very well. The wide spatial and temporal distribution we observed may have contributed to the slightly reduced performance of the predictive model for this species and the lack of specific areas with relatively higher levels of habitat suitability. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for brown boobies (Appendix D; 7b) were extensive, but one area of particularly high suitability included waters inshore of the 200-m isobath on the TX-LA Shelf west of Corpus Christi, TX. This area experiences wind-driven upwelling that may serve to concentrate prey. Areas of lower habitat suitability included pelagic waters in the CPA which are likely associated with oligotrophic waters of the interior Loop Current.

Habitat suitability for brown boobies was best predicted by SSS and SST which contributed 38.7% and 21.2% to the predictive model, respectively (Table 5.12). Habitat suitability showed a peaked relationship with both variables which is indicative of foraging at the edges of water mass boundaries where prey is

often concentrated and with waters between the 200-m and 2,000-m isobaths (Figures 5.6b and d; Figure 5.7e through Figure 5.7f).

Among species for which we modeled habitat suitability (n = 24), brown booby ranked 12th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (25%; Table 5.11). Within the WPA ~16% of highly suitable habitat was proximal to a platform and within the CPA ~31% was proximal to a platform (Appendix D; 7c).

Our data suggest the species is more common throughout the Gulf than previously considered (Table 5.10), particularly off the south Texas coast and beyond coastal waters. Brown boobies breed in the southern Gulf on Arrecife Alacranes (~50 - 100 nests; Tunnel and Chapman 2000, Vera- Morales et al. 2017) and throughout the Caribbean (~7,000 pairs) with the closest colonies to the Gulf occurring at Cay Sal Bank (0 - 50 pairs), the Cayman Islands (~100 pairs) and possibly Cuba (Bradley and Norton 2009, Mackin et al. 2015). Given that the species is found in the northern Gulf year-round, and that the species breeding or non-breeding birds. Tracking data for the species demonstrate, however, that individuals do not forage at great distances from the colony during breeding (Soanes et al. 2016), but they may range as far as 500 to 5,000 km from colonies during nonbreeding periods (Kohno et al. 2019). This suggests that brown boobies observed in the northern Gulf were more likely to be nonbreeding birds.

Brown noddy

Brown noddies are small, pelagic terns that breed throughout the Caribbean, Bahamas, and the southern Gulf. The species is pantropical and considered of least concern globally with a PIF score of 10 and no watch list classification. Within the Caribbean, the species is considered as having no immediate conservation concern (~42,000 pairs; Bradley and Norton 2009). Brown noddies are surface feeders that primarily forage on small forage fish and squid, often in mixed-species flocks and often using facilitated foraging (i.e., associated with predatory fish).

We tallied 117 detections totaling 595 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 140 with a mean of 5.1 birds (5th largest mean group size of all seabirds observed), and brown noddies accounted for ~1.6% of the total number of identified seabirds observed (Figure 5.5a, Table 5.6a). Brown noddies were primarily observed in the EPA (Appendix D; 8a), and south of the southern and eastern border of the EPA. Almost all observations (96%) of brown noddies occurred in summer (Table 5.6a through Table 5.6b).

Most observations of brown noddies occurred at the southern extent of the EPA near the western extent of the Florida Keys, and north of the Florida Keys within the south Florida Shelf. The predictive model generated an AUC value of 0.976 for the training data set and 0.883 for the testing data set indicating very good to excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for brown noddies (Appendix D; 8b) included waters within the 200-m isobath along the southern end of the Florida Shelf and extending east along the Florida Keys and the Straits of Florida. The former area is characterized by frequent eddies that concentrate prey (i.e., tuna grounds; refer to Section 2.1) and high benthic productivity that subsequently supports a diverse fish community (Halley et al. 2005). The latter area is proximate to substantial-size colonies in the Florida Keys and Caribbean. Modeled habitat suitability also was higher within a narrow east-west band paralleling the Yucatan Peninsula (an area that also supports a breeding colony) and in a small patch in the southwestern extent of Campeche Bay that supports seasonal upwellings (Zavala-Hidalgo et al. 2006). Much of the remainder of the Gulf was predicted to offer lower habitat suitability (Appendix D; 8b).

Habitat suitability for brown noddies was best predicted by SSH which contributed 48.5% to the predictive model and SST which contributed 21.4% to the final model (Table 5.12). Habitat suitability showed a peaked relationship with SSH, which is often indicative of foraging at the edges of water mass boundaries which tend to concentrate prey, and a peaked relationship with SST (Figures 5.7d and f). Observations of brown noddies were strongly clustered around the Dry Tortugas and the Straits of Florida (Appendix D; 8a), both areas that are characterized by moderate levels of SSH and SST as the Loop Current exits the Gulf (Figures 5.6c-d). Maxwell et al. (2016) found that brown noddies nesting on the Dry Tortugas foraged predominantly within 40 km of the colony in habitats with intermediate measures of SST compared to areas with lower residence times (both higher and lower SST), and that these former areas were associated with the shelf break and the edge of loop current (i.e., same area where we also observed most brown noddies during our surveys). Among species for which we modeled habitat suitability (n = 24), brown noddy ranked 24th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (0%; Table 5.12) because we estimated there to be no highly suitable habitat in these two planning areas (Appendix D; 8c).

Our data confirm the species is common in the southeastern Gulf, likely due to the proximity to colonies on the Dry Tortugas National Park (~2,000 pairs). Colonies also occur near the entrance to the Gulf on Cay Sal Bank (~4,500 pairs; Mackin et al. 2015) and in the southern Gulf on Arrecife Alacranes (~5,000 pairs; Morales-Vera et al. 2017). Previous seabird surveys in the Gulf did not report the species regularly (Table 5.10), likely due to survey coverage that did not extend into the southeastern area of the Gulf.

Brown pelican

The brown pelican is a coastal seabird that breeds throughout the northern Gulf (~25,000 pairs) and along the mid- and southern coasts of the U.S. Atlantic. It is a resident in the northern Gulf throughout the year. The species also breeds in the Caribbean (smaller colonies than in the Gulf) and southern Gulf. Brown pelicans are considered of least concern globally with a PIF score of 10 and no watch list classification. Brown pelicans are plunge-divers that primarily forage on schooling fish such as Gulf menhaden in the northern Gulf (Lamb et al. 2017b) in bays, estuaries, and coastal areas, often in small to mid-sized flocks. Brown pelicans also will forage on discarded bycatch from commercial fishing vessels (Jodice et al. 2011).

We tallied 240 detections of brown pelicans totaling 814 individuals (Tables 5.6a-c). Group size ranged from 1 to 78 with a mean of 3.4 birds and brown pelicans accounted for 2.1% of the total number of identified seabirds observed (Figure 5.5b, Table 5.6a). Brown pelicans were observed in each of the three planning areas (Appendix D; 9a). Individuals were observed in all four seasons, with ~65% of birds observed in spring and fall (Tables 5.6a-b).

Most observations of brown pelicans occurred in the CPA with concentrations occurring along and north of the Louisiana Delta, in and/or near Mississippi Sound and Mobile Bay, along the central and south coast of Texas, and along the south coast of FL (Appendix D; 9a). The predictive model generated an AUC value of 0.929 for the training data set and 0.883 for the testing data set indicating very good to excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for brown pelicans included waters along most of the northern coast of the Gulf from the Big Bend region of Florida through the Texas coast and including portions of the southern Gulf, as well. Areas of high suitability (Appendix D; 9b) near the Louisiana Delta and Mississippi Sound, near Mobile Bay, and along the coast of Texas are likely due in part to the occurrence of known breeding colonies in these regions. Areas of lower habitat suitability (Appendix D; 9b) included waters beyond the 200-m isobath although brown pelicans were observed at the southern extent of the study area in small numbers in pelagic waters (the species is known to cross the Gulf during migration; Lamb et al. 2020a).

Habitat suitability for brown pelicans was best predicted by SSS and primary productivity (as represented by measures of chlorophyll-a) which each contributed ~40% to the final model (Table 5.12). Habitat suitability was higher in areas with lower levels of SSS and showed a peaked relationship with chlorophyll-a. These two features are associated with productive, nearshore waters influenced by major river runoff (Figure 5.6a through Figure 5.6b, Figure 5.7b and Figure 5.7e). Lamb et al. (2020a) also found that primary productivity and salinity were good predictors of habitat suitability for brown pelicans in the northern Gulf.

Among species for which we modeled habitat suitability (n = 24), brown pelican ranked 2nd in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (77%; Table 5.11). Within the WPA ~59% of highly suitable habitat was proximal to a platform and within the CPA ~80% was proximal to a platform (Appendix D; 9c).

Our data suggest that brown pelicans occur primarily within the 200-m isobath but also can occur throughout the northern Gulf in small numbers. Given that our surveys occurred offshore, and brown pelicans tend to forage primarily in nearshore waters in relative proximity to colonies during the breeding season (Lamb et al. 2020a), fewer detections of birds offshore (i.e., farther from colonies), particularly during spring and summer, is not surprising. During winter, birds also are likely to be nearshore and/or beyond the bounds of the study area in the southern Gulf or the western Caribbean (Lamb et al. 2020a). Pelicans that breed in each of the three planning areas also occur within the Mississippi Delta at some phase of their annual cycle (e.g., pelicans from Texas, Florida, and Louisiana stage there) making that area a hotspot for the species (Lamb et al. 2020a).

Aerial surveys are likely to better capture the distribution of brown pelicans in coastal waters, but the species appears to occur regularly enough in offshore waters to continue to warrant survey attention (Haney et al. 2019).

Caspian tern

Caspian tern is a large tern that breeds along the Great Lakes, the interior of Canada, and also regularly along the northern Gulf coast (Cuthbert and Wires 2000, 32–34,000 pairs in North America; Hunter et al. 2006, ~2,000 pairs in the southeast U.S.). The species is considered of least concern with a PIF score of 10 and no watch list classification. We recorded six detections totaling seven individuals and observed birds in each season (Table 5.6a through Table 5.6c). Caspian terns were not observed in the EPA, but we did observe birds in nearshore waters and between the 200-m and 2,000-m isobaths in the WPA and CPA (Appendix D; 10). Previous surveys within the Gulf recorded it rarely or not at all (Table 5.10), although eBird records occur regularly in the coastal zone of all three planning areas¹².

Common loon

Common loons are one of two species of loon that occurs in the Gulf, the other being red- throated loons. Common loons breed on large lakes in the northern tier of the United States and throughout Canada and migrate into the Gulf during the nonbreeding period (Kenow et al. 2002, Paruk et al. 2014). The species is considered of least concern globally and is relatively common throughout much of its breeding range, with a PIF score of 10 and no watch list classification. Common loons are foot-propelled pursuit-divers that forage on small fish.

Common loons forage individually but also in mixed-species foraging flocks in the northern Gulf with plunge-divers (e.g., northern gannets and brown pelicans) and subsurface predators (Jodice 1992). During the nonbreeding period the species undergoes a simultaneous wing molt and thus, experiencing a flightless

¹² See <u>https://ebird.org/species/caster1</u>

period, during which time they are vulnerable to various stressors. The species is known to experience periodic die-offs during the overwinter period in the eastern Gulf (Forrester et al. 1997).

We tallied 55 detections totaling 67 individuals (Table 5.6a through Table5.6c). Group size ranged from 1 to 6 with a mean of 1.2 birds, and common loons accounted for <1% of the total number of identified seabirds observed (Table 5.6a). Common loons were not observed in the WPA, and rarely observed west of the Louisiana Delta (Appendix D; 11a). Most observations (75%) occurred in winter; this species was not observed in summer or fall (Table 5.6a through Table 5.6b).

Most observations of common loons occurred in the CPA and EPA, in/near the Mississippi Sound and Apalachee Bay (Appendix D; 11a). The predictive model generated an AUC value of 0.996 for the training data set and 0.975 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for common loons (Appendix D; 11b) included an extensive area within the 200-m isobath which included the Florida Big Bend, Mississippi Sound, and the LA-TX Shelf in the northwest portion of the CPA. Waters beyond the 200-m isobath were predicted to offer lower habitat suitability (Appendix D; 11b).

Habitat suitability for common loons in the Gulf was best predicted by primary productivity (as represented by measures of chlorophyll-a) which contributed 49.7% to the final model (Table 5.12). Habitat suitability showed a peaked relationship with chlorophyll-a which was associated with productive, nearshore waters influenced by major river runoff and/or extensive seagrass beds in the Florida Big Bend (Figure 5.6a, Figure 5.7b) which has been documented to regularly support wintering loons (Jodice 1992).

Among species for which we modeled habitat suitability (n = 24), common loon ranked 5th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (66%; Table 5.11) with substantial disparity between the two planning areas. Within the CPA, ~66% of highly suitable habitat was proximal to a platform (Appendix D; 11c). No suitable habitat occurred for common loons in the WPA (Appendix D; 11b).

Our data suggest that common loons are common in coastal waters of the northern Gulf during winter particularly between the Mississippi Delta and Florida Big Bend. Vessel surveys were, however, not frequent in areas predicted to provide suitable habitat for the species and previous vessel- based surveys also recorded loons infrequently (Table 5.10). In contrast, aerial surveys provide a useful platform for detecting loons (Section 3.0; refer also to Jodice 1992) and therefore, are likely to better determine the distribution of common loons in the Gulf. The species appears to be susceptible to oil spills (Haney et al. 2019) and other localized stressors due in part to the proportion of time they spend on and beneath the surface of the water, as well as to their high fidelity to wintering areas (Paruk et al. 2015).

Common tern

Common terns are mid-sized terns that breed throughout inland Canada, along the upper tier of the interior and northeastern U.S. and along the Atlantic coast from the Maritime Provinces through the Mid-Atlantic States. Common tern winter throughout the Gulf, Central America, and the Caribbean. Common terns are considered of least concern globally with a PIF score of 12 and a watch list classification of CBSD (common birds in steep decline). Common terns are surface feeders that primarily forage on small forage fish such as sciaenids, clupeids, and anchovies often over predatory fish schools (Mauco et al. 2001, Bugoni and Vooren 2004). Common terns also will forage on discards from trawlers (Bugoni and Vooren 2004, Wickliffe and Jodice 2010).

We tallied 176 detections of common terns totaling 488 individuals (Table 5.6a-c). Group size ranged from 1 to 18 with a mean of 2.8 birds, and common terns accounted for 1.3% of the total number of

identified seabirds observed (Figure 5.5b, Table 5.6a). Common terns were observed in each of the three planning areas (Appendix D; 12a). Individuals were observed in similar proportions in spring and fall (~95%) and not in winter (Table 5.6a through Table 5.6b; surveys were infrequent in winter).

Most observations of common terns occurred over the Florida Shelf, just north of the Mississippi River Delta, and in/near Mississippi Sound (Appendix D; 12a). The predictive model generated an AUC value of 0.932 for the training data set and 0.924 for the testing data set indicating very good to excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for common terns (Appendix D; 12b) included waters within the 200-m isobath from the Mississippi River Delta east through Apalachee Bay, and south over the Florida Shelf to midway along the peninsula. Areas of lower habitat suitability (Appendix D; 12a) were predicted to include waters beyond the 200-m isobath and west of the Mississippi River Delta, although we did observe a cluster of common terns off the central Texas coast in a region that is associated with seasonal upwelling.

Habitat suitability for common terns was best predicted by SST, which contributed 42% to the final model, and bathymetry which contributed 22% to the final model (Table 5.12). Habitat suitability showed a peaked relationship with SST and a negative relationship with bathymetry which was likely associated with productive, nearshore waters in the northeastern reaches of the EPA (Figures 5.6d and 5.7a and f).

Among species for which we modeled habitat suitability (n = 24), common tern ranked 4th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (66%; Table 5.11). Within the WPA, ~57% of highly suitable habitat was proximal to a platform and within the CPA ~ 68% was proximal to a platform (Appendix D; 12c).

Our data suggest the species occurs regularly in the northeastern Gulf over the mid-outer Florida Shelf, but also may be observed in lesser numbers in the western section of the WPA. Previous survey efforts showed a range of detections from none to abundant, likely based on the location and timing of surveys (Table 5.10). The distribution of common terns may be influenced to some extent by the occurrence and activity of predatory fish (Bugoni and Vooren 2004).

Cory's shearwater

Cory's shearwater is a large shearwater in the genus *Calonectris*, a group of long-distance migrants that transit entire ocean basins. The species is considered of least concern globally with a PIF score of 14 and a watch list classification of Yellow-R (restricted range). Cory's shearwater is listed as a Bird of Conservation Concern (USFWS 2021) at the continental level and occurs within MBCR 20 primarily during its nonbreeding season. Cory's shearwater breed in the eastern north Atlantic and return to colonies typically during mid-winter (e.g., February). To date, satellite -tagged birds from the eastern Atlantic have not been tracked to the Gulf, and Monteiro et al. (1996) suggested that birds in the Gulf may be non-breeders. The species occurs in the western north Atlantic during its nonbreeding season and pre-breeders may range widely as well. The species is primarily a surface feeder on fish (e.g., mackerel) and squid (Granadeiro et al. 1998, Xavier et al. 2011).

We tallied 81 detections of Cory's shearwater totaling 117 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 8 with a mean group size of 1.4, and Cory's shearwater accounted <for 1% of the total number of identified seabirds observed (Table 5.6a). Cory's shearwaters were observed in each of the three planning areas, as well as in the Straits of Florida (Appendix D; 13a). The species was observed primarily in summer and fall (relatively similar counts each season), but not during winter or spring (i.e., the start of their breeding season; Tables 5.6a-b).

Most observations of Cory's shearwaters occurred west of the Mississippi River Delta between the 200-m

and 2,000-m isobaths (Appendix D; 13a). There was a concentration of observations in the WPA between these isobaths. Pulich (1982) noted this species as commonly occurring in this region. Further, this area appears to concentrate predatory fish such as tuna and mackerel (Hoffman et al. 1981). The predictive model generated an AUC value of 0.937 for the training data set and 0.961 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for Cory's shearwaters (Appendix D; 13b) included waters throughout each planning area within the 200-m - 2,000-m isobath.

Habitat suitability for Cory's shearwaters was best predicted by SSS and bathymetry, which contributed 56% and 22% to the final model, respectively (Table 5.12). Habitat suitability showed a peaked relationship with SSS likely indicating foraging at the edges of water mass boundaries which tend to concentrate prey (Figures 5.6b and 5.7e) (e.g., Pulich 1982). Habitat suitability (Appendix D; 13b) was predicted to decline beyond the 2,000-m isobath.

Among species for which we modeled habitat suitability (n = 24), Cory's shearwater ranked 14th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform with substantial disparity between the two planning areas (24%; Table 5.11). Within the WPA, ~13% of highly suitable habitat was proximal to a platform and within the CPA ~30% was proximal to a platform (Appendix D; 13c).

Our data suggest the species occurs regularly over the shelf break across each of the three planning areas, with slightly higher concentrations along the shelf/slope edge in the CPA and WPA, as also noted by Pulich (1982). These areas may contain fronts which serve to concentrate prey (Haney and McGillivary 1985). Previous survey efforts showed a range of detections from none to abundant, likely based on the location and timing of surveys (Table 5.10).

Fea's petrel

Fea's petrel is a gadfly petrel that breeds on just four islands in the eastern Atlantic on the Cape Verde and Madeira islands. It is considered near threatened globally with a PIF score of 18 and a watch list classification of Red (highly vulnerable). We recorded three detections totaling three individuals (one in spring, two in summer; Table 5.6b through Table 5.6c). Two individuals were observed near the western border of the EPA at and beyond the 2,000-m isobath and one individual near the 200-m isobath south of the Mississippi River (Appendix D; 14). These observations occurred near observations of black-capped petrels (Appendix D; 3a). We also recorded two unidentified *Pterodroma*, likely either Fea's or black-capped petrel (one in summer, one in fall). Although one of these detections was near other observations of gadfly petrels, one was uniquely located (i.e., no other petrel observations nearby) over the Florida Shelf offshore of Charlotte Harbor.

Previous surveys within the Gulf did not observe this species (Table 5.10), and there are no records for this species in eBird from within the Gulf, although one record is reported offshore of Miami¹³.

Forster's tern

Forster's tern is a large, marsh-nesting tern that breeds along the TX-LA Coast and in the U.S. upper Midwest region. The species has declined in some areas with loss or degradation of freshwater marsh habitat. The species is considered of least concern globally with a PIF score of 13 and no watch list classification. Forster's tern is listed as a Bird of Conservation Concern (USFWS 2021) within BCR 37, and BCR 37 is an important breeding region for this species (e.g., ~71% of northern Gulf breeding pairs occur in Louisiana; Remsen et al. 2019). We recorded 23 detections totaling 86 individuals, with 82

¹³ See eBird: <u>https://ebird.org/species/feapet1</u>

observed in fall (Table 5.6b through Table 5.6c). We observed birds in each of the three planning areas: in nearshore waters along the central Texas coast, near the Mississippi River, and in the Mississippi Sound (Appendix D; 15). Haney et al. (2019) reported 31 individuals, although other previous seabird surveys in the Gulf failed to observe this species (Table 5.10). Records for the species on eBird occur throughout the coastal zones of the WPA, CPA, and EPA and throughout the coastal zones of the southern Gulf¹⁴.

Great black-backed gull

Great black-backed gulls are large gulls that breed along the Atlantic coast from the Maritime Provinces through the Mid-Atlantic States, with an apparently increasing southward expansion of their breeding range. The species is considered of least concern globally with a PIF score of 14 and a watch list classification of Yellow-D (steep declines and major threats). We recorded three detections totaling three individuals with two birds observed in spring and one in winter (Table 5.6b through Table 5.6c). All three birds were observed in the CPA in nearshore waters in the Mississippi Sound (Appendix D; 16). Previous surveys within the Gulf failed to observe this species or recorded it only rarely (possibly due to limited surveys in winter; Table 5.10), although eBird records occur regularly in the coastal zone of all three planning areas¹⁵.

Great shearwater

Great shearwater is a large shearwater in the genus *Ardenna*, a group of long-distance migrants that can transit entire ocean basins. The species is considered of least concern globally with a PIF score of 13 and no watch list classification. Great shearwaters breed in the south Atlantic. Great shearwaters migrate north from breeding sites along the western Atlantic and then cross to the east and migrate south to breeding sites within the eastern end of the Atlantic. The species is a surface feeder that forages on squid and fish (Petry et al. 2008) and will follow commercial fishing vessels and forage on discarded bycatch as well (Wickliffe and Jodice 2010).

We tallied 49 detections of great shearwaters totaling 60 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 3 with a mean group size of 1.2, and great shearwaters accounted for <1% of the total number of identified seabirds observed (Table 5.6a). Great shearwaters were observed in each of the three planning areas, as well as in the Straits of Florida (Appendix D; 17a). The species was observed primarily in fall (~ 65%) and summer (~30%) with a single individual recorded during winter and during spring (Tables 5.6a-b).

Observations of great shearwaters were mostly dispersed, but we did observe small clusters of birds within the 200-m isobath in Mississippi Sound, near the head of DeSoto Canyon, and south of Panama City off the Florida Panhandle (Appendix D; 17a). The predictive model generated an AUC value of 0.931 for the training data set and 0.938 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for great shearwaters (Appendix D; 17b) included waters in the northeastern CPA and the northwestern EPA, both within the 200-m isobath and between the 200-m and 2,000-m isobath (e.g., the head of De Soto Canyon).

Habitat suitability for great shearwaters was best predicted by SSS and chlorophyll-a, which contributed 45% and 32% to the final model, respectively (Table 5.12). The strong positive relationship with moderate levels of chlorophyll-a may be related to commonly observing birds in Mississippi Sound, an area with moderate but not extreme values (e.g., Mississippi River Delta) of chlorophyll-a (Figures 5.6a and 5.7b). These waters appear to be similar in color to colder waters of the western north Atlantic that

¹⁴ See eBird: <u>https://ebird.org/species/forter</u>

¹⁵ See eBird: (<u>https://ebird.org/species/gbbgul</u>

this species also frequents during the nonbreeding season. The peaked relationship with SSS likely indicates foraging at the edges of water mass boundaries which tend to concentrate prey (e.g., as with Cory's shearwater; Pulich 1982).

Among species for which we modeled habitat suitability (n = 24), great shearwater ranked 10th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (45%; Table 5.11) with substantial disparity between the two planning areas. Within the WPA, ~25% of highly suitable habitat was proximal to a platform and within the CPA ~47% was proximal to a platform (Appendix D; 17c).

Our data suggest the species occurs primarily in the northern reaches of the Gulf near the Mississippi River Delta and in Mississippi Sound. Previous survey efforts showed a range of detections from none to abundant, likely based on the location and timing of surveys (Table 5.10).

Gull-billed tern

Gull-billed tern is a northern Gulf breeding species that nests on barrier islands, primarily in Texas and Louisiana (Molina and Erwin 2006, Molina et al. 2010). The species is considered of least concern globally with a PIF score of 13 and no watch list classification. However, it is considered a species of high concern in the North American Waterbird Conservation Plan (Kushlan et al. 2002). Gull-billed terns are, however, of increasing conservation concern within the southeastern United States (e.g., Hunter et al. 2006). Gull-billed tern is listed as a Bird of Conservation Concern (USFWS 2021) at the continental level and is known to breed within BCR 37. We observed two gull-billed terns (Appendix D; 10), one in summer and one in fall, both over the Texas shelf (Table 5.6c). Although other earlier surveys within the Gulf failed to observe this species (Table 5.10), Haney et al. (2019) reported 18 individuals, and eBird records occur regularly in the coastal zone of all three planning areas¹⁶.

Herring gull

Herring gulls are large gulls that breed inland in the northern tier of North America and along the north and middle coasts of the Atlantic, although their range is expanding south along the Atlantic coast. Herring gulls are considered of least concern globally with a PIF score of 11 and a watch list classification of CBSD (common birds in steep decline). Herring gulls are surface feeders that primarily forage on small forage fish in bays, estuaries, and coastal areas, as well as foraging opportunistically in terrestrial and anthropogenic habitats. Anderson et al. (2019) tracked herring gulls that breed in the eastern Arctic to wintering grounds in the Gulf; primarily in the WPA and CPA.

We tallied 856 detections of herring gulls totaling 1,636 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 87 with a mean of 1.9 birds, and herring gulls accounted for 4.3% of the total number of identified seabirds observed (Figure 5.5a, Table 5.6a). Herring gulls were observed in each of the three planning areas (Appendix D; 18a). Individuals were observed in all four seasons, with ~75% of birds observed in winter (Tables 5.6a-b), likely reflecting their appearance in the northern Gulf as wintering birds.

We regularly observed herring gulls in and/or near Mississippi Sound, but also regularly between the 200m and 2000 m isobaths in each of the three planning areas (Appendix D; 18a). The predictive model generated an AUC value of 0.926 for the training data set and 0.932 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for herring gulls included waters throughout most of the northern Gulf between the 200-m and 2,000-m isobaths (Appendix D; 18b). Anderson et al. (2019) found that herring gulls marked with PTTs would use habitats as far as ~300 km

¹⁶ See eBird: <u>https://ebird.org/species/gubter1</u>

offshore. Lower habitat suitability was predicted to occur over the Florida Shelf and in the southern extent of the CPA and EPA (i.e., oligotrophic waters of the interior Loop Current).

Habitat suitability for herring gulls was best predicted by SSS and SST which combined relatively evenly to contribute 75% to the final model (Table 5.12). Habitat suitability was predicted to be relatively consistent across a wide range of each variable, but to decline steeply at the most saline and warmest temperatures (e.g., deepest and warmest waters of the northern Gulf) and to be lower in nearshore waters with lower levels of SSS (Figure 5.6b and Figure 5.6d, Figure 5.7e).

Among species for which we modeled habitat suitability (n = 24), herring gull ranked 11th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (30%; Table 5.11) with substantial disparity between the two planning areas. Within the WPA ~13% of highly suitable habitat was proximal to a platform and within the CPA ~44% was proximal to a platform (Appendix D; 18c).

Our data suggest the species occurs primarily between the 200-m and 2,000-m isobath throughout much of the northern Gulf, primarily during its nonbreeding period (Table 5.6b through Table 5.6c); though birds were observed year-round. Along with laughing gull and Bonaparte's gull, herring gulls accounted for $\sim 15\%$ of the seabird community in the northern Gulf. Previous survey efforts showed a range of detections from few to abundant, likely based on the location and timing of surveys (Table 5.10).

Laughing gull

Laughing gulls are small gulls that breed throughout the northern Gulf and along the mid- and southern coasts of the U.S. Atlantic and is considered a year-round resident in the northern. The species also breeds in the Caribbean (smaller colonies than Gulf) and in the southern Gulf. Laughing gulls are considered of least concern globally with a PIF score of 12 and no watch list classification. Laughing gulls are surface feeders that primarily forage on small forage fish in bays, estuaries, and coastal areas, often in small to mid-sized flocks. Laughing gulls also will forage on discarded bycatch from commercial fishing vessels (Jodice et al. 2011).

We tallied 1,086 detections of laughing gulls totaling 2,569 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 170 with a mean of 2.4 birds, and laughing gulls accounted for 6.8% of the total number of identified seabirds observed (3rd most abundant seabird observed; Figure 5.5a, Table 5.6a). Laughing gulls were observed in each of the three planning areas (Appendix D; 19a). Individuals were observed in all four seasons, with ~60% of birds observed in spring and fall (Table 5.6a through Table 5.6b).

We observed concentrations of laughing gulls along and north of the Mississippi River Delta, in and/or near Mississippi Sound and Mobile Bay, and along the central and south coast of Texas. There also was a concentration of observations in the 200-m isobath offshore of Corpus Christi, Texas in the WPA (Appendix D; 19a). The predictive model generated an AUC value of 0.908 for the training data set and 0.903 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for laughing gulls (Appendix D; 19b) included waters along most of the central and western coasts of the northern Gulf except for the northern extent of the TX-LA Shelf. Areas of highest suitability (Appendix D; 19b) from the Mississippi River Delta and Mobile Bay, and along the coast of Texas are likely due in part to the occurrence of breeding colonies in these regions. Areas of lower habitat suitability were predicted to occur in waters beyond the 200-m isobath, although laughing gulls were observed at the southern extent of the study area in small numbers in pelagic waters. Habitat suitability for laughing gulls was best predicted by SSS which contributed 54% to the final model, and primary productivity (as represented by measures of chlorophyll-a) which contributed 23% to the final model (Table 5.12). Habitat suitability was higher in areas with lower levels of SSS and showed a peaked relationship with chlorophyll-a, both often associated with productive, nearshore waters (Figures 5.6a-b, Figure 5.7e).

Among species for which we modeled habitat suitability (n = 24), laughing gull ranked 9th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (53%; Table 5.11) with substantial disparity between the two planning areas. Within the WPA ~31% of highly suitable habitat was proximal to a platform and within the CPA ~69% was proximal to a platform (Appendix D; 19c).

Our data suggest the species occurs primarily within the 200-m isobath, but also occurs throughout the northern Gulf in small numbers. Aerial surveys are likely to better capture the distribution of laughing gulls in coastal waters, but the species appears to occur regularly enough in offshore waters to continue to warrant survey attention. Previous survey efforts showed a range of detections from few to abundant, likely based on the location and timing of surveys (Table 5.10).

Leach's storm-petrel

The Leach's storm-petrel is a small storm-petrel that breeds along the northern coast of the Atlantic (Maritime Provinces and slightly into Maine) and in the eastern north Atlantic in colonies that can number in the millions of pairs. Globally it is considered vulnerable with a PIF score of 9 and no watch list classification. We recorded 19 detections of 24 individuals with ~80% observed in spring and summer (Tables 5.6b-c). Leach's storm petrels were observed in all three planning areas primarily between the 200-m and 2000-m isobaths (Appendix D 20). Other surveys within the Gulf rarely reported this species (Table 5.10) although records from eBird also suggest it occurs in each of the three planning areas¹⁷. We also recorded 33 detections of unidentified storm-petrels totaling 40 individuals with ~88% observed in spring and summer (Appendix D; 20). The distribution of Leach's storm-petrel and of unidentified storm-petrels was relatively similar to that of the band-rumped (Appendix D; 2a) and Wilson's storm-petrel (Appendix D; 33a).

Least tern

The least tern is a small tern that breeds along major rivers (e.g., Mississippi and Missouri rivers and tributaries) in the interior of the U.S. within the Great Plains, along the Gulf and Atlantic coasts, and in the Caribbean (e.g., ~20 pairs nearby the Gulf on Cay Sal Bank; Mackin et al. 2015). Globally it is considered of least concern, with a PIF score of 15 and a watch list classification of Yellow-D (steep declines and major threats). Within the U.S., the interior population, which was federally listed as endangered in May 1985 was recently (January 2021) delisted due to recovery (<u>86 FR 2564 2581</u>). Least tern is listed as a Bird of Conservation Concern (USFWS 2021) at the continental level (with interior breeding populations from the continental interior and from BCR 37). We recorded 10 detections of 18 individuals with ~75% observed in spring (Table 5.6c). Least terns were observed in all three planning areas but primarily in nearshore waters in Mississippi Sound and off the Texas coast (Appendix D; 10). We also observed least terns beyond the 200-m and 2,000-m isobaths in the WPA and EPA, respectively. Other surveys within the Gulf recorded it rarely to infrequently (Table 5.10) although eBird records occur regularly in the coastal zone of all three planning areas¹⁸.

¹⁷ See eBird: (<u>https://ebird.org/species/lcspet</u>

¹⁸ See eBird: <u>https://ebird.org/species/leater1</u>

Long-tailed jaeger

The long-tailed jaeger breeds in the high Arctic. The species is considered of least concern globally with a PIF score of 9 and no watch list classification. We recorded two detections totaling two individuals, one each in summer (August) and fall (Table 5.6c). One individual occurred along the 200-m isobath southwest of the Mississippi Delta and the other in deep pelagic waters near the eastern edge of the EPA (Appendix D; 21). Other surveys within the Gulf recorded this species only rarely (Table 5.10) and eBird records also occur rarely but within each of the planning area¹⁹.

Magnificent frigatebird

The magnificent frigatebird is a large pelecaniform that breeds in the Caribbean and southern Gulf. Frigatebirds have a protracted breeding season that may last ~8 months although fledged birds may remain near the nest site for ~1 year for additional feeding by parents. The exact timing of breeding can vary among colonies resulting in the nonbreeding season being difficult to predict regionally. Magnificent frigatebirds are considered of least concern globally with a PIF score of 16 and a watch list classification of Yellow-R (range restricted). Within the Caribbean the species is considered at risk (~6,100 pairs; Bradley and Norton 2009). Magnificent frigatebird is listed as a Bird of Conservation Concern (USFWS 2021) at the continental level and occurs throughout much of the year within MBCR 20, although it breeds only in the southeastern extent of this MBCR (i.e., Dry Tortugas). Magnificent frigatebirds will kleptoparasitize other seabirds and scavenge at offshore commercial fishing vessels (Wickliffe and Jodice 2010). Birds also forage on flying fish and squid, often using facilitated foraging. The species often occurs in flocks at sea and may also form large roosting groups in mangroves and other coastal trees/shrubs in protected bays (e.g., Seahorse Key just offshore from Cedar Key, Florida).

We tallied 478 detections totaling 940 individuals (Table 5.6b through Table 5.6c). Group size ranged from 1 to 39 with a mean of 2.0 birds, and magnificent frigatebirds accounted for 2.5% of the total number of identified seabirds observed (Figure 5.5b, Table 5.6a). Magnificent frigatebirds were observed in all three planning areas (Appendix D; 22a). Approximately 50% of magnificent frigatebirds were observed in fall and 50% in spring and summer (Table 5.6c).

Magnificent frigatebirds occurred across the entire east-west and north-south footprint of the study area although concentrations occurred along the north coast of Texas, east and west of the Louisiana Delta, in/near the Mississippi Sound, and over the Florida Shelf in the southeastern reaches of the EPA (Appendix D; 22a). The predictive model generated an AUC value of 0.911 for the training data set and 0.885 for the testing data set indicating very good to excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for magnificent frigatebirds (Appendix D; 22b) included waters throughout most of the study area within the 200-m isobath. Within each planning area, suitable habitat and clusters of observations occurred nearby known roosting areas. Areas of lower habitat suitability (Appendix D; 22b) were predicted to include the southern extent of the CPA over deep pelagic waters (i.e., oligotrophic waters of the interior Loop Current).

Habitat suitability for magnificent frigatebirds was best predicted by primary productivity (as represented by measures of chlorophyll-a) which contributed 43% to the final model (Table 5.12). Habitat suitability showed a peaked relationship with chlorophyll-a, which was associated with productive, nearshore waters (Figure 5.7b). Frigatebirds appear to be able to forage successfully in waters with moderate to low levels of chlorophyll-a (Figure 5.6a) due in part to their efficient flight energetics (Balance et al. 1997, Weimerskirch et al. 2004).

¹⁹ See eBird: <u>https://ebird.org/species/lotjae</u>

Among species for which we modeled habitat suitability (n = 24), magnificent frigatebird ranked 7th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (62%; Table 5.11). Within the WPA ~54% of highly suitable habitat was proximal to a platform and within the CPA ~64% was proximal to a platform (Appendix D; 22c).

Our data suggest that this species occurs regularly within the 200-m isobath throughout much of the northern Gulf with concentrations occurring relatively proximal to large roosting areas. During the breeding season, magnificent frigatebirds tended to forage within 300 km of colonies but did forage up to ~1,000 km from colonies (Soanes et al. 2016, Zaluski et al. 2019). These distances are not within the range of known colonies in Areciffe Alacranes (~200 pairs) or the Dry Tortugas (~ 100 pairs). However, post-breeding magnificent frigatebirds may travel at least 1,400 km from colonies (Weimerskirch et al. 2006) placing much of the northern Gulf within reach of known colonies in the southern Gulf and western Caribbean. Previous seabird surveys in the Gulf reported a range of values for magnificent frigatebirds varying from rare to regular (Table 5.10).

Manx shearwater

The Manx shearwater is a large shearwater that breeds along the northern coast of the western Atlantic and in the eastern north Atlantic. The species is considered of least concern globally with a PIF score of 15 and a watch list classification of Yellow-D (steep declines and major threats). We recorded four detections totaling four individuals (symbols overlapped on map) all in winter and all between the 200-m and 2000-m isobath off the south Texas coast in the WPA (Table 5.6c, Appendix D; 14). We observed unidentified shearwaters in this same general area, and unidentified large shearwaters in the CPA as well (Appendix D; 14). None of the other previous seabird surveys in the Gulf observed this species (Table 5.10), although records from eBird suggests it does occur (rarely) in each of the three planning areas²⁰.

Masked booby

Masked boobies are pantropical sulids that breed throughout the Caribbean, Bahamas, and the southern Gulf. The species is considered of least concern globally with a PIF score of 12 and no watch list classification. The Caribbean population, however, is considered at-risk (~750 pairs; Bradley and Norton 2009). Masked boobies are plunge-divers that primarily forage on flying fish and squid, not uncommonly in mixed-species flocks and/or over predatory fish. Masked boobies breed asynchronously throughout the year, and therefore, birds may be found at any stage of breeding at a colony during most months of the year.

We tallied 124 detections of masked boobies totaling 136 individuals (Table 5.6b through Table 5.6c). Group size ranged from 1 to 5 with a median of 1.1 birds, and masked boobies accounted for <1% of the total number of identified seabirds observed (Table 5.6a). Masked boobies were observed in each of the three planning areas (Appendix D; 23a). Most observations occurred in September (53%) (Table 5.6c).

Although we observed individuals over most of the east-west and north-south footprint of the survey area, a concentration of masked boobies occurred along the 200-m isobath in the western reaches of the WPA (Appendix D; 23a), a region prone to upwelling. The predictive model generated an AUC value of 0.917 for the training data set and 0.871 for the testing data set indicating very good to excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for masked boobies (Appendix D; 23b) included waters between the 200-m and 2000-m isobaths along the breaks of the Florida Shelf and the southern TX-LA Shelf, both areas that appear to include upwelling features. Areas of lower habitat suitability (Appendix D; 23b) were not common and restricted to the southeastern corner of the CPA (i.e.,

²⁰ See eBird: <u>https://ebird.org/species/manshe</u>

oligotrophic waters of the interior Loop Current) and turbid waters to the east of the Mississippi Delta.

Habitat suitability for masked boobies was best predicted by SSS which contributed 53% to the final model (Table 5.12). Habitat suitability showed a peaked relationship with SSS, likely indicating foraging at the edges of water mass boundaries which tend to concentrate prey (Figures 5.6b and 5.7e). Poli et al. (2017) found that masked boobies breeding on Arrecife Alacranes tended to forage at edges of water masses, as best indicated by intermediate values of SSH (e.g., Figure 5.6c).

Among species for which we modeled habitat suitability (n = 24), masked booby ranked 15th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (16%; Table 5.11). Within the WPA ~12% of highly suitable habitat was proximal to a platform and within the CPA ~19% was proximal to a platform (Appendix D; 23c).

Our data suggest the species is common throughout the northern Gulf particularly in fall, with individuals appearing most concentrated in the WPA. Tracking data for the species suggests that individuals breeding in the southern Gulf do not forage in the northern Gulf while incubating or provisioning chicks (maximum foraging distance 230 km; Poli et al. 2017) and tracking data from the Caribbean also suggest that foraging appears to be relatively local to the colony during breeding (<50 km; Soanes et al 2016, Wilkinson et al. 2020). Migratory routes are not clear, but Jodice et al. (2014) found that while individuals breeding on Pedro Bank in the Caribbean often remained within 200 km of the colony, at least one individual banded there did migrate or disperse to Arrecife Alacranes (~1,300 km). Therefore, the western reaches of the WPA appear to be well within reach of migratory masked boobies from Arrecife Alacranes (~900 km) where ~2,000 pairs nest (Morales-Vera et al. 2017). The Dry Tortugas also supports a small colony (<50 pairs); the species does not nest on Cay Sal Bank. Previous seabird surveys in the Gulf did not record the species regularly (Table 5.10), although Clapp et al. (1982a) noted the species was likely underestimated.

Neotropic and Double-crested cormorant

The neotropic cormorant breeds along the upper coast of Texas and at sites more inland, as well as south into Mexico and Central America. The species is considered of least concern globally with a PIF score of 6 and no watch list classification. We recorded 1 detection totaling 2 individuals in fall just south of the Mississippi Delta near the 200-m isobath (Table 5.6b through Table 5.6c, Appendix D; 24). Haney et al. (2019) reported 6 individuals. Other surveys within the Gulf failed to observe this species (Table 5.10), although records from eBird suggests it does occur regularly in each of the three planning areas in nearshore waters, as well as throughout the southern Gulf²¹.

Double-crested cormorant nests in coastal waters of the Great Lakes region and Atlantic coastal states, as well as at inland large freshwater lakes, wetlands, and river systems in the north-central and western U.S. into Canada; often in large colonies. The species is a foot-propelled pursuit diver that often occurs in large flocks in marine waters and estuaries. The species is considered of least concern with a PIF score of 8 and no watch list classification. We recorded 33 detections totaling 130 individuals (Table 5.6b through Table 5.6c). We observed very few (n = 5) during summer (i.e., breeding season) and the remainder throughout spring, fall, and winter (Table 5.6c, Appendix D; 24). The species was observed in the CPA and EPA (Appendix D; 24). Most birds were observed within the 200-m isobath nearby the Mississippi Delta, in the Mississippi Sound, and near the Dry Tortugas, although we did observe two different individuals at or beyond the 2,000-m isobath. Haney et al. (2019) reported 100 individuals. Other surveys within the Gulf either failed to observe or did not report this species (Table 5.10), although records from eBird suggests it occurs regularly in each of the three planning areas in nearshore waters, as well as

²¹ See eBird: <u>https://ebird.org/species/neocor</u>

throughout the southern Gulf²².

Northern gannet

Northern gannets are sulids that breed in the Canadian Maritime Provinces and in the eastern north Atlantic. Northern gannets from at least four colonies in Labrador and Newfoundland migrate into the Gulf during the nonbreeding period, arriving between November and February and departing between February and April (Montevecchi et al. 2012, Fifield et al. 2014). Northern gannets are considered of least concern globally with a PIF score of 10 and no watch list classification. Northern gannets are plunge divers that primarily forage on schooling pelagic fish, often in mid- to large-sized flocks, and in the Gulf during winter, in mixed-species foraging flocks with common loons and other subsurface predators (Jodice 1992).

We tallied 320 detections of northern gannets totaling 1,658 individuals (Table 5.6b through Table 5.6c). Group size ranged from 1 to 441 with a mean of 5.2 birds, and northern gannets accounted for 4.4% of the total number of identified seabirds observed (Figure 5.5a, Table 5.6a). Northern gannets were observed in the EPA and CPA, but not in the WPA (although the species does occur in the WPA; Montevecchi et al. 2012). Approximately 50% of gannets were observed in spring and 50% in winter with few (n = 2) to no birds observed in fall and summer, respectively (Table 5.6b through Table 5.6c).

Northern gannets were regularly observed east and west of the Louisiana Delta, in/near the Mississippi Sound, and in the northern reaches of Apalachee Bay (Appendix D; 25a). The predictive model generated an AUC value of 0.972 for the training data set and 0.929 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for northern gannets (Appendix D; 25b) included waters throughout most of the northern portion of the CPA and EPA within the 200-m isobath. This region is within the core area that supports Gulf menhaden (Lamb et al. 2017b) and was also predicted to be highly suitable for brown pelicans (see brown pelican species account), another Gulf menhaden specialist (Lamb et al. 2017b). Areas of lower habitat suitability (Appendix D; 25b) were predicted to include pelagic waters beyond the 200-m isobath. Northern gannets appear to enter the Gulf from the south (Fifield et al. 2014), and therefore, these birds may have been migrating north to areas of higher habitat suitability.

Habitat suitability for northern gannets in the northern Gulf was best predicted by primary productivity (as represented by measures of chlorophyll-a) which contributed 47% to the final model (Table 5.12). Habitat suitability showed a peaked relationship with chlorophyll-a, which was associated with productive, nearshore waters influenced by major river runoff and/or seagrass beds in the Florida Big Bend (Figure 5.6a and Figure 5.7b). Habitat suitability also declined at higher levels of SSS (contribution = 22%) also suggesting an avoidance of pelagic marine waters.

Among species for which we modeled habitat suitability (n = 24), northern gannet ranked 1st in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (83%; Table 5.11). Within the WPA, 100% of highly suitable habitat was proximal to a platform and within the CPA ~83% was proximal to a platform, although we only estimated there to be 11.5km² of suitable habitat in the WPA (Appendix D; 25c).

Our data suggest northern gannets occur primarily within the 200-m isobath throughout much of the northern Gulf, particularly between the Mississippi Delta and Florida Big Bend, primarily during the species' nonbreeding period. Although our vessel surveys did detect northern gannets regularly, others which have not included nearshore waters have recorded this species less frequently (Table 5.10). The

²² See eBird: <u>https://ebird.org/species/doccor</u>

greater use of nearshore waters by northern gannets suggests that vessel surveys may not be the optimal survey platform to monitor this species. In contrast, aerial surveys provide a useful platform for detecting northern gannets (Section 3.0 above; Jodice 1992) and therefore, are likely to offer a valid complement to vessel-based surveys.

Parasitic jaeger

Parasitic jaegers are medium sized predatory birds that breed in the Arctic tundra and winter at-sea. Parasitic jaegers are considered of least concern globally with a PIF score of 9 and no watch list classification. Only recently has tracking data begun to reveal the connectivity between breeding and over-wintering locations. For example, Harrison et al. (2021) tracked a bird tagged in the Canadian Arctic to the Gulf where it spent the entirety of its overwinter period within the EPA. Parasitic jaegers are primarily kleptoparasites that will also scavenge bycatch at offshore commercial fishing vessels (Wickliffe and Jodice 2010).

We tallied 43 detections of parasitic jaegers totaling 73 individuals (Table 5.6b through Table 5.6c). Group size ranged from 1 to 14 with a mean of 1.7 birds, and parasitic jaegers accounted for <1% of the total number of identified seabirds observed (Tables 5.6a). Parasitic jaegers were observed in all three planning areas and occurred from shallow through deep pelagic waters (Appendix D; 26a). Approximately 90% of parasitic jaegers were observed in winter and spring (Table 5.6b and Table 5.6c).

We only observed two areas with any concentration of parasitic jaegers (Appendix D; 26a). We observed a small cluster of individuals in the western end of the WPA, where they may be associated with a localized upwelling zone or the occurrence of shrimp trawlers, and a cluster of individuals off the Florida Keys where they were associated with concentrations of pelagic terns (i.e., targets of kleptoparasitism). The predictive model generated an AUC value of 0.944 for the training data set and 0.815 for the testing data set indicating very good to excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for parasitic jaegers (Appendix D; 26b) included waters throughout most of the study area between the 200-m and 2,000-m isobaths. Areas of lower habitat suitability (Appendix D; 26b) were predicted to include the southern extent of the CPA which are likely associated with oligotrophic waters of the interior Loop Current.

Habitat suitability for parasitic jaegers was best predicted by SSH and bathymetry which contributed 36% and 26% to the final model, respectively (Table 5.12). Habitat suitability showed a peaked relationship with SSH, which suggests an affinity for edges of water masses (e.g., eastern edge of Loop Current, western reaches of WPA; Figure 5.6c and Figure 5.7d) and a curvilinear negative relationship with depth (e.g., primary use between the 200-m and 2000-m isobaths; Figure 5.7a).

Among species for which we modeled habitat suitability (n = 24), parasitic jaeger ranked 16th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (15%; Table 5.11) with substantial disparity between the two planning areas. Within the WPA, ~4% of highly suitable habitat was proximal to a platform and within the CPA ~23% was proximal to a platform (Appendix D; 26c).

Our data suggest that the species occurs regularly but in relatively low numbers during its nonbreeding season throughout the breadth of the northern Gulf. Previous survey efforts recorded the species infrequently as well during winter (Table 5.10). Relatively low contributions of environmental variables to the final model suggest that the species may not have an affinity for specific habitat types but rather may be tracking the occurrence of other seabird species like various species of terns from which it parasitizes prey. Although sample sizes were small (n = 4), at least some individuals tagged on Canadian Arctic breeding areas wintered in the Gulf (Harrison et al. 2021).

Pomarine jaeger

Pomarine jaegers are large predatory birds that breed in the high Arctic tundra and winter at-sea, with concentrations in the Caribbean. Pomarine jaegers are considered of low concern globally with a PIF score of 10 and no watch list classification. Pomarine jaegers are primarily kleptoparasites that will also scavenge bycatch at offshore commercial fishing vessels (Wickliffe and Jodice 2010).

We tallied 293 detections of pomarine jaegers totaling 486 individuals (Table 5.6b through Table 5.6c). Group size ranged from 1 to 38 with a mean of 1.7 birds, and pomarine jaegers accounted for 1.3% of the total number of identified seabirds observed (Figure 5.5b, Table 5.6a). Pomarine jaegers were observed in all three planning areas (Appendix D; 27a). Approximately 90% of pomarine jaegers were observed in spring and winter (Table 5.6b through Table 5.6c).

We observed pomarine jaegers primarily beyond the 200-m isobath but also beyond the 2,000-m isobath (Appendix D; 27a). We observed a small cluster of individuals in the western end of the WPA where they may be associated with a localized upwelling zone or the occurrence of shrimp trawlers. The predictive model generated an AUC value of 0.914 for the training data set and 0.893 for the testing data set indicating very good to excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for pomarine jaegers (Appendix D; 27b) included waters throughout most of the study area between the 200-m and 2,000-m isobath except for waters south of the Mississippi River Delta. Areas of lower habitat suitability (Appendix D; 27b) were predicted to include the southern extent of the CPA which are likely associated with oligotrophic waters of the interior Loop Current.

Habitat suitability for pomarine jaegers was best predicted by SSS and bathymetry, which contributed 40% and 30% to the final model, respectively (Table 5.12). Habitat suitability showed a peaked relationship with SSS, which suggests an affinity for edges of water masses, and a curvilinear negative relationship with depth (Figures 5.7a and 5.7e).

Among species for which we modeled habitat suitability (n = 24), pomarine jaeger ranked 21st in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (7%; Table 5.11). Within the WPA, ~ 4% of highly suitable habitat was proximal to a platform and within the CPA ~10% was proximal to a platform (Appendix D; 27c).

Our data suggest that this species occurs regularly but in relatively low numbers during its nonbreeding season throughout the breadth of the northern Gulf with concentrations on the slope of the WPA and the slope of the EPA. Previous survey efforts recorded the species infrequently as well during winter (Table 5.10). The breeding origin of pomarine jaegers in the Gulf is still uncertain. Individuals tagged in the Canadian Arctic wintered in the Pacific, despite being tagged nearby to parasitic jaegers that wintered in the Gulf (small sample size for this species; n = 1, Harrison et al. 2021).

Red-billed and White-tailed tropicbird

Red-billed tropicbirds breed throughout the Caribbean. The species is considered of least concern globally, but within the Caribbean it is considered of conservation concern (Bradley and Norton 2009). The breeding season begins in winter and extends into late spring/early summer.

We recorded 12 detections totaling 12 individual red-billed tropicbirds with 75% observed in fall, and the remainder in spring and summer (Tables 5.6a-c). We suspect these are pre- and post- breeding birds based on the breeding phenology for the species and tracking data that indicates they forage within 200 km of the colony during breeding in the Caribbean (Soanes et al. 2016).

Red-billed tropicbirds were observed over shelf waters, as well as beyond the 200-m and 2,000-m isobaths

in the CPA and EPA, closer inshore compared to detections of white-tailed tropicbirds (Appendix D; 28). Other surveys within the Gulf also recorded the species infrequently (Table 5.10). We did detect tropicbirds that we were not able to identify to species in summer and fall in the EPA and WPA (Appendix D; 28).

White-tailed tropicbirds breed throughout the Caribbean. The species is considered of least concern globally, but within the Caribbean is considered of conservation concern (Bradley and Norton 2009). The breeding season begins in winter and extends into late spring/early summer. We recorded three detections totaling three individual white-tailed tropicbirds with all observed in summer (i.e., likely post-breeding; Table 5.6a through Table 5.6c). White-tailed tropicbirds were observed beyond the 2,000-m isobath south of the Mississippi Delta and in the southern reaches of the EPA, further offshore compared to detections of red-billed tropicbirds (Appendix D; 28). Other surveys within the Gulf also recorded the species infrequently (Table 5.10). We did detect tropicbirds that we were not able to identify to species in summer and fall in the EPA and WPA (Appendix D; 28).

Red-footed booby

The red-footed booby is a tropical sulid that breeds in the southern Gulf (e.g., 13 pairs on Arrecife Alacranes; Morales-Vera et al. 2017) and throughout the Caribbean. It is considered of least concern globally with a PIF score of 12 and no watch list classification. The species is of no immediate conservation concern in the Caribbean (Bradley and Norton 2009). We recorded 11 detections totaling 11 individuals (summer n = 7, fall n = 4; Table 5.6a through Table 5.6c). Red-footed boobies were observed over shelf waters, as well as beyond the 200-m and 2,000-m isobaths in the CPA and EPA (Appendix D; 28). Other surveys within the Gulf failed to observe this species (Table 5.10) but those surveys generally covered areas to the west of where GOMMAPPS detected this sulid, and records from eBird suggest it does occur (rarely) in the CPA and EPA²³.

Red-necked and red phalaropes

Red-necked and red phalaropes are small sandpipers that breed in inland habitats (Arctic tundra) and are known to gather in large flocks in marine systems where they forage on plankton and small fish. Both species are considered of least concern globally with PIF scores of 11 and 12, respectively, and no watch list classification. Some conservation concern exists over an apparent decline in concentrations that had been observed within the Bay of Fundy. We recorded 10 detections totaling 16 red-necked phalaropes and two detections totaling two red phalaropes (Table 5.6a through Table 5.6c, Appendix D; 29). Red-necked phalaropes were observed primarily in spring (~50%) and not at all in summer, while both red phalaropes also were observed in spring. Red- necked phalaropes were observed in all three planning areas primarily within the 200-m isobath, but also between the 200-m and 2,000-m isobath (Appendix D; 29). These individuals also appeared clustered in the Mississippi Sound where they may have been associated with productive waters near freshwater outflow, and along the northeastern portion of the Loop Current where dynamic waters can concentrate prey. We observed one red phalarope in nearshore waters off the Florida Panhandle and one near the edge of the Florida Shelf; similar to locations of several of the red-necked phalaropes (Appendix D; 29). A lack of surveys during winter in all three planning areas may have reduced our observations of these two species. Haney et al. (2019) recorded 78 phalaropes (possibly due to greater effort in winter), although other previous surveys within the Gulf failed to observe these two species (Table 5.10). Records from eBird indicate that both species occur within each of the respective planning areas²⁴.

²³ See eBird: <u>https://ebird.org/species/refboo</u>

²⁴ See eBird: <u>https://ebird.org/species/redpha1</u> and <u>https://ebird.org/species/renpha</u>

Red-throated loon

Red-throated loons breed in freshwater lakes in the Arctic Regions of Canada and on the Alaska Coastal Plain. The species is considered of least concern globally with a PIF score of 11 and no watch list classification. We recorded 2 detections totaling 2 individuals both in spring and both in inshore waters of the Mississippi Sound; an area we also observed common loons (Tables 5.6a-c, Appendix D; 24). Other previous surveys within the Gulf failed to observe this species (Table 5.10), although records from eBird suggest it does occur (rarely) in each of the three planning areas in nearshore waters²⁵.

Ring-billed gull

Ring-billed gulls are a common and widespread gull that nests in the Great lakes, northern tier of the U.S., and southern Canada. The species is considered of least concern globally with a PIF score of 6 and no watch list classification. We recorded eight detections totaling nine individuals all in fall and winter (Tables 5.6a-c). Ring-billed gulls were observed only in the CPA and primarily in nearshore waters in Mississippi Sound (Appendix D; 16). Haney et al. (2019) reported 15 individuals, although other previous surveys within the Gulf failed to observe this species (Table 5.10); eBird records occur regularly in the coastal zone of all three planning areas²⁶.

Roseate tern

Roseate tern is a medium-sized tern that breeds along the northern coast of the Atlantic, in the western end of the Florida Keys, and in the Caribbean (e.g., ~ 80 pairs nearby the Gulf on Cay Sal Bank; Mackin et al. 2015). Globally it is considered of least concern but within the United States it is federally listed as endangered at its Atlantic coast breeding sites, whereas it considered as threatened in Florida, Puerto Rico, and the Virgin Islands (75 FR 17153 17154). The PIF score for the species is 15 with a watch list classification of yellow-D (steep declines and major threats). We recorded five detections totaling 20 individuals with ~95% observed in summer (Tables 5.6b-c). Roseate terns were observed primarily in nearshore waters south of the EPA proximal to breeding areas in the Florida Keys and in nearshore waters of the Florida Shelf just south of Tampa Bay (Appendix D; 15). Other previous surveys within the Gulf failed to observe this species or recorded it only rarely (Table 5.10); eBird records for the species indicate it only occurs in the EPA²⁷.

Royal tern

Royal terns are large coastal terns that breed throughout the northern Gulf and along the mid- and southern coasts of the U.S. Atlantic and is considered a year-round resident in the northern Gulf (Buckley et al. 2021). The species also breeds in the Caribbean (smaller colonies than Gulf, ~ 2,500 pairs on Cay Sal Bank; Mackin et al. 2015) and the southern Gulf (~100 pairs on Areciffe Alacranes; Morales-Vera et al. 2017). Royal terns are considered of least concern globally with a PIF score of 11 and no watch list classification. Royal terns are surface feeders that primarily forage on small fish (e.g., Atlantic croaker, bay anchovy) in bays, estuaries, and coastal areas (Rolland et al. 2020) in the northern Gulf (Liechty et al. 2016); often in small to mid-sized flocks. Royal terns also will forage on commercial fisheries bycatch (Jodice et al. 2011, Liechty et al. 2016).

We tallied 1,104 detections of royal terns totaling 1,869 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 55 with a mean of 1.7 birds, and royal terns accounted for 4.9% of the total number of identified seabirds observed (Figure 5.5b, Table 5.6a). Royal terns were observed in each of the

²⁵ See eBird: <u>https://ebird.org/species/retloo</u>

²⁶ See eBird: https://ebird.org/species/ribgul

²⁷ See eBird: <u>https://ebird.org/species/roster</u>

three planning areas (Appendix D; 30a). Individuals were observed in all four seasons, with \sim 50% of birds observed in fall and the fewest birds observed in winter (Table 5.6b through Table 5.6c; although survey effort was limited in winter).

Royal terns occurred throughout most coastal areas of the northern Gulf although they tended to be clumped along and north of the Mississippi River Delta, in or near Mississippi Sound and Mobile Bay, along the central and south coast of Texas, and along the south coast of Florida (Appendix D; 30a). The predictive model generated an AUC value of 0.920 for the training data set and 0.910 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well although we did observe royal terns frequently beyond the 200-m isobath. Areas predicted as likely to contain suitable habitat for royal terns (Appendix D; 30b) included waters (1) along most of the northern coast of the Gulf (except for the Florida Panhandle), particularly near the Mississippi River Delta and along the coasts of Texas and central/south Florida. Suitability of these regions is likely due, in part, to the occurrence of colonies in these areas. Areas of lower habitat suitability (Appendix D; 30b) were predicted to include waters beyond the 200-m isobath, although royal terns were observed in pelagic waters (i.e., in small numbers) at the southern extent of the study area.

Habitat suitability for royal terns was best predicted by primary productivity (as represented by measures of chlorophyll-a) which contributed 52% to the final model (Table 5.12). Habitat suitability showed a peaked relationship with chlorophyll-a, which was associated with productive, nearshore waters (Figure 5.6a and Figure 5.7b). Royal terns tracked from colonies in Louisiana tended to forage within ~30 km of the colony (Rolland et al. 2020), further suggesting the need for quality habitat to be located near colonies.

Among species for which we modeled habitat suitability (n = 24), royal tern ranked 6th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (63%; Table 5.11) with substantial disparity between the two planning areas. Within the WPA, ~42% of highly suitable habitat was proximal to a platform and within the CPA ~71% was proximal to a platform (Appendix D; 30c).

Our data suggest royal terns occur primarily within the 200-m isobath in the northern Gulf but also throughout the northern Gulf in small numbers. Previous survey efforts showed a range of detections from none to abundant, likely based on the location and timing of surveys (Table 5.10). Species- specific studies appear to be lacking in the northern Gulf and therefore regionally specific data on diet and movements are not readily available. Given that our surveys occurred offshore, and those royal terns are likely to forage in relative proximity to colonies during the breeding season, fewer detections of birds offshore (i.e., farther from colonies) are not surprising.

Sandwich tern

Sandwich terns are mid-sized, coastal terns that breed throughout the northern Gulf and along the mid- and southern coasts of the U.S. Atlantic and is considered a year-round resident in the northern Gulf. The species also breeds in the Caribbean (including at least 50 pairs at Cay Sal Bank; Mackin et al. 2015) where it has been expanding its range, as well as in the southern Gulf (~350 pairs on Areciffe Alacranes; Morales-Vera et al. 2017). Sandwich terns typically breed within colonies of royal terns. Sandwich terns are considered of least concern globally with a PIF score of 10 and no watch list classification. Sandwich terns breeds in BCR 37, where it is listed as a Bird of Conservation Concern (USFWS 2021). Sandwich terns are surface feeders that primarily forage on small fish (e.g., Atlantic croaker, bay anchovy) in bays, estuaries, and coastal areas in the northern Gulf (Liechty et al. 2016); often in small to mid-sized flocks (Shealer 1996). Sandwich terns also will forage on commercial fisheries bycatch (Jodice et al. 2011, Liechty et al. 2016).

We tallied 372 detections of sandwich terns totaling 1,445 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 129 with a mean of 3.9 birds, and sandwich terns accounted for 3.8% of the

total number of identified seabirds observed (Figure 5.5a, Table 5.6a). Sandwich terns were observed in each of the three planning areas (Appendix D; 31a). Individuals were observed in similar proportions in spring, summer, and fall, but no sandwich terns were observed during winter surveys (Table 5.6b through Table 5.6c; although survey effort was limited in winter, particularly in shallow, nearshore waters).

Most observations of sandwich terns occurred in the CPA, with concentrations occurring just north of the Mississippi Delta and in or near the Mississippi Sound (Appendix D; 31a). We also observed a cluster of observations along the central Texas and central Florida coasts. The predictive model generated an AUC value of 0.942 for the training data set and 0.961 for the testing data set indicating excellent model performance. The occurrence records on which the model was trained matched model projections well. Areas predicted as likely to contain suitable habitat for sandwich terns (Appendix D; 31b) included waters along most of the northern coast of the Gulf except for the Big Bend region of Florida. Areas of highest suitability (Appendix D; 31b) near the Mississippi Delta, and along the coasts of Texas and central/south Florida are likely due, in part, to the occurrence of colonies in these areas. Areas of lower habitat suitability (Appendix D; 31b) included waters beyond the 200-m isobath, although sandwich terns were observed in small numbers in pelagic waters.

Habitat suitability for sandwich terns was best predicted by primary productivity (as represented by measures of chlorophyll-a), which contributed 59% to the final model (Table 5.12). Habitat suitability showed a peaked relationship with chlorophyll-a, which was associated with productive, nearshore waters (Figure 5.6a and Figure 5.7b). Sandwich terns tracked from colonies in Europe tend to forage within ~50 km of the colony (Perrow et al. 2011, Fijn et al. 2017), further suggesting the need for quality habitat to be located near colonies.

Among species for which we modeled habitat suitability (n = 24), sandwich terns ranked 3rd in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (71%; Table 5.11). Within the WPA ~57% of highly suitable habitat was proximal to a platform and within the CPA ~73% was proximal to a platform (Appendix D; 31c).

Our data suggest the species does not occur regularly outside of coastal waters and species- specific studies appear to be lacking in the northern Gulf. As such, regionally specific data on diet and movements are not readily available. Previous survey efforts showed a range of detections from none to abundant, likely based on the location and timing of surveys (Table 5.10). Given that our surveys occurred offshore, and those royal terns are likely to forage in relative proximity to colonies during the breeding season, fewer detections of birds offshore (i.e., farther from colonies) are not surprising.

Sooty tern

Sooty terns are mid-sized, pelagic terns that breed throughout the Caribbean, Bahamas, and the southern Gulf (Schreiber et al. 2020). The species is pantropical, considered to be of least concern globally with a PIF score of 9 and no watch list classification. Although the species is the most abundant seabird breeding in the tropical Atlantic (~300,000 pairs; Bradley and Norton 2009) it is also considered to be at-risk within the Caribbean (Bradley and Norton 2009). Sooty terns are surface feeders that primarily forage on small forage fish and squid, often in large flocks and in mixed-species flocks, and often using facilitated foraging (i.e., associated with predatory fish).

We tallied 851 detections totaling 7,855 individuals (Table 5.6a through Table 5.6c). Group size ranged from 1 to 483 with a mean of 9.2 birds (3rd largest mean group size of all seabirds observed), and sooty terns accounted for ~21% of the total number of identified seabirds observed (Figure 5.5a, Table 5.6a). Sooty terns were observed in all three planning areas (Appendix D; 32a). Sooty terns were observed regularly in all four seasons (Table 5.6b through Table 5.6c).

Sooty terns were observed throughout the north-south footprint of the study area, although they appeared to be most abundant in the EPA. The predictive model generated an AUC value of 0.897 for the training data set and 0.890 for the testing data set indicating very good but not excellent model performance. The occurrence records on which the model was trained matched model projections relatively well. Areas predicted as likely to contain suitable habitat for sooty terns (Appendix D; 32b) included waters between the 200-m and 2,000-m isobaths in the southern extent of the EPA. High habitat suitability also extended through the Straits of Florida. This latter area is relatively proximal to substantial colonies in the Florida Keys and Caribbean. Huang et al. (2017) found that sooty terns breeding on the Dry Tortugas foraged predominantly north of the colony over the Florida Shelf in this same general area. Areas of lower habitat suitability (Appendix D; 32b) were predicted to include shelf waters and pelagic waters in the CPA which are likely associated with oligotrophic waters of the interior Loop Current.

Habitat suitability for sooty terns was best predicted by current direction (35%) and SSH (28%) which together contributed 53% to the final model (Table 5.12). Habitat suitability was highest with southern currents (Figure 5.6h), which indicates a greater use of the eastern edge of the Loop Current as it flows south towards the Straits of Florida. Further, habitat suitability showed a peaked relationship with SSH which is also indicative of foraging at frontal zones that tend to concentrate prey (e.g., moderate levels of SSH located at the eastern edge of the Loop Current and upwelling zones in the WPA; Figures 5.6c and 5.7d).

Among species for which we modeled habitat suitability (n = 24), sooty tern ranked 23rd in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (3%; Table 5.11) with substantial disparity between the two planning areas. Within the WPA, 0% of highly suitable habitat was proximal to a platform and within the CPA ~6% was proximal to a platform (Appendix D; 32c).

Our data confirm the species is common throughout the Gulf, often nearby to breeding colonies, and is one of the most abundant birds in the Gulf. Sooty terns were recorded regularly during previous surveys (Table 5.10). Although sooty terns tracked from breeding colonies in the Caribbean and Dry Tortugas remained within ~100 km of colonies during the breeding season (Huang et al. 2017, Soanes et al. 2016), sooty terns tagged in the Indian Ocean foraged on average 1,000 km from the colony. During prebreeding and post-breeding, sooty terns may transit entire ocean basins (Huang et al. 2017, Jaeger et al. 2017). With ~24,000 pairs on Cay Sal Bank (Mackin et al. 2015), ~140,000 pairs on Areciffe Alacranes (Morales-Vera et al. 2017), ~400,000 pairs in the greater Caribbean, and ~40,000 pairs in the Dry Tortugas, the northern Gulf appears to represent an important year-round component of their range.

South polar skua

The south polar skua breeds in Antarctica and is considered of least concern globally with a PIF score of 12 and no watch list classification. We recorded one individual in May near the 2000-m isobath south of the Mississippi Delta (Table 5.6c, Appendix D; 21). Haney et al. (2019) reported one individual, while other previous surveys within the Gulf failed to observe this species (Table 5.10). Records from eBird also indicate this species occurs rarely, but in each of the planning areas²⁸.

Wilson's storm-petrel

The Wilson's storm-petrel is a small storm-petrel in the genus *Oceanites*, a group of surface- feeding storm-petrels that often hug the surface of the water. The species is considered of least concern globally with a PIF score of 10, no watch list classification, and is considered one of the most abundant seabirds in the world, if not one of the most abundant of all bird species. Wilson's storm-petrel breed in the southern hemisphere during the austral spring/summer. The species occurs in the northern hemisphere during its

²⁸ See eBird: <u>https://ebird.org/species/sopsku</u>

nonbreeding season. The diet is comprised primarily of small fish and zooplankton and foraging can be nocturnal (Croxall et al. 1988, Quillfeldt 2002). Storm-petrels often occur in mixed-species foraging flocks and forage nocturnally on myctophids, a group of fish with particularly high energy density.

We tallied 27 detections totaling 34 individuals (Table 5.6b through Table 5.6c). Group size ranged from 1 to 3 and Wilson's storm-petrels accounted for <1% of the total number of identified seabirds observed (Table 5.6a). Wilson's storm-petrels were observed in each of the three planning areas, although only at the western edge of the EPA (i.e., not over the Florida Shelf; Appendix D; 33a). Individuals were primarily observed in summer and spring (~93%) during the nonbreeding period for this species (Table 5.6b through Table 5.6c). No Wilson's storm-petrels were observed during winter, although survey effort was limited during these months. Most observations of Wilson's storm-petrels occurred between the 200-m and 2,000-m isobath, although we did observe this species beyond the 2000-m isobath in the CPA and EPA (Appendix D; 33a). The predictive model generated an AUC value of 0.963 for the training data set indicating very good to excellent model performance (sample size was insufficient for a testing data set). The occurrence records matched model projections well. Areas predicted as likely to contain suitable habitat for Wilson's storm-petrels (Appendix D; 33b) included waters throughout each planning area within the 200-m -2,000-m isobath, with moderately suitable habitat in deeper pelagic waters as well.

Habitat suitability for Wilson's storm-petrels was best predicted by bathymetry and SSS, each contributing ~25% to the final model (Table 5.12). Habitat suitability was poorer in shallower waters and positively associated with SSS (Figure 5.7e). Taken together, this suggests a greater use of more pelagic waters and for waters along the edges of fronts and eddies which concentrate plankton and may support prey such as myctophids (Figure 5.6b).

Among species for which we modeled habitat suitability (n = 24), Wilson's storm-petrel ranked 18th in terms of amount of suitable habitat in the WPA and CPA within 10 km of an oil platform (12%; Table 5.11). Within the WPA, ~2% of highly suitable habitat was proximal to a platform and within the CPA ~14% was proximal to a platform (Appendix D; 33c).

Our data suggest the species occurs regularly, but in small numbers during its nonbreeding season in deeper waters of the Gulf. This species is regarded as a regular occupant of the northern Gulf and the most frequent storm-petrel occurring in the Gulf (Table 5.10), although our data also suggest it was not the most abundant storm-petrel (refer to band-rumped storm petrel species account above).

5.5 Conservation Status of Focal Seabirds

Of the 44 seabird species we identified during GOMMAPPS surveys, 41 were classified globally as Least Concern. Leach's storm-petrel was classified globally as Vulnerable, Fea's petrel was classified globally as near threatened, and black-capped petrel was classified globally as endangered. Within Caribbean breeding species, one species was classified as endemic and globally endangered (black-capped petrel), and seven species were classified as at-risk within the region (sooty tern, white-tailed tropicbird, red-billed tropicbird, magnificent frigatebird, Audubon's shearwater, masked booby, and brown booby). Only the black-capped petrel, interior least tern, and roseate tern are federally listed or being considered for listing under the U.S. Endangered Species Act.

PIF Scores ranged from 6 to 20 for seabirds identified during our surveys. The modal PIF score was 12 and 34 species had a PIF Score <15. Those scoring >15 included: least tern, roseate tern, magnificent frigatebird, Manx shearwater, band-rumped storm-petrel, Fea's petrel, and black- capped petrel. Most seabird species (n = 28) received no watch list designation. Five species were classified as Yellow – D (least tern, roseate tern, great black-backed gull, Audubon's shearwater, and Manx shearwater), two species were classified as Yellow – R (Cory's shearwater and magnificent frigatebird), three species were

classified as CBSD (herring gull, common tern, and black tern), and three species were classified as Red (band-rumped storm-petrel, Fea's petrel, and black-capped petrel).

The Gulf of Mexico Avian Monitoring Network designated 14 of the 44 species we identified during our vessel surveys as priorities for monitoring (Jodice et al. 2019). Species that breed in the southern Gulf and Caribbean included sooty tern, Audubon's shearwater, black-capped petrel, magnificent frigatebird, and masked booby. Species that breed in the northern Gulf included least tern, gull-billed tern, royal tern, sandwich tern, and brown pelican. Species that breed outside of the Gulf or Caribbean included common loon, band-rumped storm-petrel, and northern gannet.

5.6 Summary of Habitat Relationships

Across the 24 species for which we modeled habitat suitability; predictive models tended to perform well. The AUC for the training dataset was 0.872 to 0.996 and for the testing dataset was 0.815 to 0.975 (i.e., very good to excellent; Duan et al. 2014). The mean (\pm SD) AUC across all species for the training dataset was 0.934 \pm 0.306 and for the testing dataset was 0.908 \pm 0.396 (i.e., excellent). Models appeared to perform best for species with spatially and/or temporally concentrated distributions (e.g., common loon, Bonaparte's gull, sandwich tern).

Among the environmental variables we assessed (Table 5.12), SSS appeared most frequently as a strong predictor (n = 7 species, $\geq 40\%$) or as the top-ranked predictor (n = 8 species). Within our study area, lower values of SSS generally occurred near freshwater inputs, such as the Mississippi River Delta, the Atchafalaya River Delta, and the mouth of Mobile Bay (Figure 5.6b). In isolation, SSS can be an indicator of nearshore versus pelagic waters (e.g., low versus high values), but it can also indicate water mass boundaries (e.g., intermediate values). Species most strongly associated with SSS (e.g., >40%) either as a sole predictor or in combination with another predictor included: herring gull, Cory's shearwater, laughing gull, masked booby, great shearwater, brown pelican, and pomarine jaeger (Table 5.12). For most of these species, SSS appeared to represent a distinction between use of nearshore versus pelagic waters.

Chlorophyll-a appeared second-most frequently as a strong predictor (n = 6 species; $\geq 40\%$) or as the topranked predictor (n = 6 species; Table 5.12). Within our study area, chlorophyll-a was lowest in pelagic waters, intermediate within the 200-m isobath, and high to extremely high near sources of freshwater input such as the Mississippi River Delta, the Atchafalaya River Delta, and the mouth of Mobile Bay (Figure 5.6a). In isolation, chlorophyll-a can be an indicator of nearshore compared to pelagic waters. Species most strongly associated with chlorophyll-a (e.g., >40%) either as a sole predictor or in combination with another predictor included: sandwich tern, Bonaparte's gull, royal tern, common loon, northern gannet, black tern, and magnificent frigatebird. For most of these species, chlorophyll-a appeared to represent a distinction between use of nearshore versus pelagic waters and was represented by a strongly peaked relationship (e.g., Bonaparte's gull, Figure 5.7b; indicative of use of nearshore waters with moderate levels of chlorophyll-a) or a more gradual peak-to-decline relationship (e.g., royal tern, Figure 5.7b; indicative of a broad tolerance for nearshore or offshore waters where chlorophyll-a shifts from moderate to lower values).

Although SSS and chlorophyll-a occurred regularly as strong predictors (Table 5.12), each typically occurred with another variable. Of the 24 species for which MaxEnt models were run, only three were characterized by a single strong predictor. The predicted occurrence of black- capped petrels was best predicted by current direction (59.4%, likely representing dynamic waters associated with the north and eastern portions of the Loop Current), of common terns by SST (42.2%, likely representing cooler waters of Apalachee Bay and the western reaches of the WPA), and of brown noddies by SSH (48.5%, likely representing the Loop Current as it exits to the Florida Straits). This suggests that most species are instead
responding to environmental conditions that are created from the interaction of oceanographic processes that subsequently benefit foraging or flight behaviors.

For example, the predictive model for four different species (black tern, brown pelican, great shearwater, northern gannet) included chlorophyll-a, and SSS where both variables contributed $\geq 20\%$ to the final model (Table 5.12). For each species except great shearwater, the predictive plots were characterized by a peak in predicted occurrence at moderate levels of chlorophyll-a (Figure 5.7b) and a broad tolerance of low to moderate levels of SSS with a sharp decline at the highest levels of SSS (Figure 5.7e). The distribution of observations for these species (Appendix D) generally overlapped (particularly near the Mississippi River Delta and in Mississippi Sound; and the predicted occurrence among these three species also appeared to be similar. Brown pelican and northern gannet appear to overlap in diet, with a strong reliance on schooling pelagic prey such as Gulf menhaden (Lamb et al. 2017b; refer also to Short et al. 2017). Black terns also appear to forage on small schooling fish such as bay anchovies (*Anchoa mitchilli*) and sardines (*Sardinella aurita*), species that also comprise a portion of the diet for brown pelicans and northern gannets. The relationship between the predicted occurrence of great shearwater and both chlorophyll-a, and SSS was more confined compared to the other three species, as was their distribution (Appendix D; 17a) and map of predicted occurrence (Appendix D; 17b).

The other combination of predictor variables that appeared most frequently in combination was bathymetry with SSH (parasitic jaeger and Audubon's shearwater) and bathymetry with SSS (pomarine jaeger, band-rumped and Wilson's storm-petrels). For Audubon's shearwater, band-rumped storm-petrel, and pomarine jaeger these models appeared to characterize their use of offshore (>200-m isobath) waters associated with the north and eastern edge of the Loop Current (Appendix D; 1a, 2a, 27a). The pattern for parasitic jaeger and Wilson's storm-petrel is less clear, but also appears to indicate use of waters >200-m isobath. The predicted occurrence for band-rumped and Wilson's storm-petrel appeared similar with respect to predictor variables, with each species showing avoidance of waters with lower levels of SSS within the 200-m isobath (Appendix D; 2a, 33a).

Patterns among predictor variables and species also suggest some similarities within taxa, but also indicate some important differences (refer to Michael et al. 2023). For example, the models of predicted occurrence for a suite of nearshore species that nest in the northern Gulf and considered as year-round 'residents' appear quite similar, though not identical. The occurrence of brown pelicans, laughing gulls, and both royal and sandwich terns was predicted in part by levels of chlorophyll-a (Figure 5.7b). Sandwich terns responded most to this variable and showed a more constrained distribution within nearshore waters where chlorophyll-a tends to be higher, as compared to the other species mentioned here (Figure 5.6a, Appendix D; 31a).

5.7 Comparisons of Habitat Relationships among Related Species

We modeled the predicted occurrence of two species of pelagic/tropical terns, both of which breed in the southern Gulf and Caribbean: bridled tern (Appendix D; 6b) and sooty tern (Appendix D; 32b). Models for the two species were similar and the predicted occurrence was similar in spatial extent but differed in detail within the broader distributions. The occurrence of both bridled and sooty terns was influenced in part by current direction and SSH (Table 5.12). Highest habitat suitability for each species was most likely to occur along the edge of south flowing currents (Table 5.6h) that occurred in the EPA and that were characterized by intermediate levels of SSH (i.e., the southward flow of the Loop Current; Figure 5.6c). Both species also had broad distributions over slope waters but avoided shelf waters. Bridled terns (Appendix D; 6a) tended to be more spatially dispersed while sooty terns (Appendix 6; 32a) were more clumped.

Similarly, flock sizes for bridled terns were typically lower compared to sooty terns (Figure 5.5). Based on

observations of each species during cruises, we also noted that bridled terns often were associated with *Sargassum* and were engaged in flight heights within 2-3m of the water's surface, while sooty tern flight heights tended to be at higher elevations, likely to enhance their use of facilitated foraging strategies (i.e., foraging over tuna or other predators). These behaviors may contribute to the difference in their spatial dispersion. Habitat suitability for bridled terns (Appendix D; 6b) also was slightly broader along the 200-m isobath in the CPA compared to sooty terns. Refer to Michael et al. (2023) for additional details regarding seabird assemblages in the northern Gulf.

The predicted occurrence of laughing and herring gulls also was similar, but not identical. Both species responded strongly to SSS (Table 5.12). Habitat suitability for laughing gulls (Appendix D; 19b) was slightly higher at lower levels of SSS (i.e., nearshore waters) compared to herring gulls (Appendix D; 18b) for which habitat suitability peaked in more saline (i.e., deeper) waters (Figure 5.7e). These data suggest that herring gulls (Appendix D; 18a) are likely to be more abundant offshore, while laughing gulls (Appendix D; 19a) tend to be more abundant nearshore, although both species showed a wide tolerance across levels of SSS (Figure 5.7e).

We modeled the predicted occurrence for three species of shearwaters: Audubon's, great, and Cory's. For both Cory's and great shearwaters, SSS was an important predictor variable and the relationship between that variable and predicted occurrence was similar, showing a gradual increase in habitat suitability as SSS increased, peaking at high, but not the highest values (Table 5.12, Figure 5.7e). Their actual and predicted distributions differed, however, with great shearwaters primarily occurring near the head of DeSoto Canyon in the northeast corner of the CPA (Appendix D; 17a) while Cory's shearwaters (Appendix D; 13a) were widely distributed throughout all three planning areas often in association with the 200-m isobath (i.e., bathymetry was also a strong predictor for Cory's shearwater). Bathymetry also was an important predictor for the distribution of Audubon's shearwater (Figure 5.7a), although this species showed a wider tolerance for water depth compared to Cory's shearwater. Habitat suitability was higher beyond the 2000-m isobath for Audubon's shearwaters (Appendix D; 1b) compared to Cory's shearwaters (Appendix D; 13b). Both Audubon's and Cory's shearwaters occurred in the WPA between the 200-m and 2,000-m isobath, although habitat suitability for Audubon's shearwaters did extend farther offshore in this area as well. Habitat suitability for Audubon's shearwaters also peaked at intermediate levels of SSH which appear to be associated with frontal zones such as the eastern boundary of the Loop Current (Figures 5.6c and 5.7d). Therefore, these three species of shearwater showed a rather wide range of distribution and habitat suitability with Audubon's being the most broadly distributed and great shearwaters being the most constrained.

Both masked and brown booby responded to SSS, and this variable contributed ~53% and 39% to the final models for the two species, respectively (Table 5.12). Brown boobies (Appendix D; 7a) showed a broader tolerance for lower SSS (and hence its lower contribution in the final model) compared to masked boobies (Appendix D; 23a), and this relationship is reflected in the actual and predicted occurrence for the two species (Figure 5.7e). The predicted occurrence for brown boobies includes more inshore waters while the predicted occurrence for masked boobies is primarily beyond the 200-m isobath. Masked boobies plunge dive to greater depths than brown boobies can forage in less clear water conditions (Tunnel and Chapman 2000, Shealer 2002). A stronger reliance on flying fish in the diet of masked boobies compared to a broader diet in brown boobies also may contribute to the masked booby use of offshore areas where waters tend to be clearer (Santos et al. 2019).

5.8 Spatial Overlap of Suitable Habitat with Oil Platforms

One conceptual model that is available to assess risk exposure for a species or population considers the extent to which individuals and the hazard overlap and interact in space (e.g., Burger et al. 2011). Briefly, macro-scale exposure occurs when the species or population broadly overlaps with the risk in space. Meso- and micro-scale exposure would occur when the species or population interacts more directly with the hazard, for example via attraction or a lack of avoidance that may result in collision or some other form of contact (e.g., immersion in contaminated waters, ingestion of prey from contaminated waters). Refer to Michael et al. (2022) for additional details regarding seabird oil-spill vulnerability assessment for northern Gulf seabirds.

Our analysis considered the macro-scale risk that seabirds experience in the northern Gulf from oil platforms (Michael et al. 2022). Gleason et al. (2016) noted five specific risk types for seabirds associated with O&G platforms in the northern Gulf: (1) collision-related mortality, (2) contact with produced waters (direct and indirect), (3) oil spills (small and large, acute and chronic), (4) nocturnal circulation events, and (5) disturbance (e.g., personnel-support helicopter and vessel traffic). Each of these risks may be considered in terms of the distance or range at which it may affect seabirds. For example, collision and nocturnal circulation events may be considered relatively local or at site-scale. To collide with a platform or to be attracted to lighting or other visual cues, birds would likely need to be at or near the platform (e.g., within several km). The remaining three risks may be considered local to relatively distant in nature. Seabirds may interact with produced waters directly through contact with sheens (O'Hara and Morandin 2010) or indirectly through consumption of contaminated prey. While the former is likely to be relatively local in nature (i.e., restricted to the spatial footprint of the sheen), the latter could be quite distant in nature (i.e., prey contaminated locally could travel a distance from the source then be consumed by a seabird). Similarly, disturbance could be local or distant, and oil spills could also range from small-scale or local to large-scale and distant. For example, by one estimation, the ultimate spatial footprint of the Deepwater Horizon covered ~150,000 km² (Berenshtein et al. 2020).

Therefore, to accommodate the range in the distance at which these five risks may occur, we performed a spatial overlap of oil platforms with seabird use areas (Michael et al. 2022) at two distances; 10 km which represents local-scale interactions (e.g., collision) and 20 km which represents more distant interactions (e.g., wide-ranging spills). We calculated the overlap between predicted habitat classified as highly suitable (i.e., out from models in maxent) and the occurrence of at least one platform within the 10 km (i.e., a binomial response that does not escalate in risk with additional platforms). This overlap represents a basic macro-scale exposure assessment. Because our data lack the context of behavioral aspects such as flight patterns, residency time in an area, and foraging activity, it is difficult to assess the levels of meso-and micro-scale exposure. Nonetheless, an assessment at the macro-scale can guide future studies and identify species for which interactions with platforms may be more probable based on spatial proximity.

Of the 24 species for which we modeled habitat suitability, 14 had at least 20% of their highly suitable habitat located within 10 km of at least one platform (Table 5.11). Pooled across species, the proportion of highly suitable habitat within 10 km of at least one platform was marginally greater (P = 0.07) in the CPA ($40.8 \pm 0.27.6\%$) compared to the WPA ($26.1 \pm 25.9\%$), suggesting the CPA may present slightly more risk to this suite of species compared to the WPA. All the species for which >50% of their highly suitable habitat was within 10 km of at least one platform (n = 9) may be classified as coastal or nearshore seabird species. Four of these species (brown pelican, laughing gull, royal tern, sandwich tern) breed throughout the northern Gulf and are year-round residents. Of the remaining five species, four migrate to the Gulf from northern breeding areas (common loon, northern gannet, common tern, black tern) and one is a year-round resident in the northern Gulf that breeds in the southern Gulf and Caribbean (magnificent frigatebird). Therefore, both year-round residents and migrants have substantial macro-scale exposure with respect to proximity to oil platforms.

For the remaining species for which <50% of their highly suitable habitat was within 10 km of at least one platform (n = 15), all would be considered pelagic seabirds and not nearshore seabirds. Furthermore, none of these 15 species breeds in the northern Gulf, nor do they appear to be year-round residents. Seven of these species breed in the southern Gulf and Caribbean, four in northern interior or coastal locations, and two each in the south Atlantic and eastern north Atlantic. Risk to these species from oil platforms is not lacking, but our assessment suggests that this suite of species is less likely to occur in locations that are in proximity to oil platforms compared to the former suite of species. Although the degree of macro-scale exposure is less for these non-resident species, the geographic extent of potential effect spans the north-south and east-west footprint of the Atlantic basin. Furthermore, doubling the distance at which we would consider macro- scale exposure to occur has a strong effect on the assignment of risk. For example, if the distance used to define macro-scale exposure is extended from 10 km to 20 km, then for the two species with the least estimated risk (Wilson's storm-petrel and Bonaparte's gull), the proportion of suitable habitat predicted to overlap oil platforms increases from 2.5% to 13.4% and 6.1% to 26.8%, respectively. Additional efforts to examine the distance at which seabirds incur greater risk to the presence of O&G platforms appears warranted.

Risk to seabirds in the northern Gulf is not exclusively related to the location of O&G platforms. For example, Lamb et al. (2020b) assessed risk to brown pelicans from pipelines and vessel traffic, as well as oil platforms. Risk was also assessed by measuring levels of polycyclic aromatic hydrocarbons (PAHs) on feathers of adults and chicks and in blood of breeding adults (Lamb et al. 2020b, Jodice et al. 2022). PAHs in the Gulf can originate from a variety of sources, including oil and gas activity, natural seeps, and terrestrial sources. Lamb et al. (2020b) found that assessing risk was more complex than simply assuming that risk was highest in the CPA because oil and gas activity was highest there. The transboundary nature of both the pelicans and the stressors, along with stressors originating from multiple sources, complicates the assessment beyond associating risk strictly to a given planning area.

6. Conclusions and Future Directions

The most recent assessment of global threat status of seabirds indicated that nearly half of all seabird species (47%) have been declining, and up to 31% of seabird species are considered globally threatened (BirdLife International 2018). The decline of many seabird species can be linked to anthropogenic factors including fisheries bycatch, climate change, and invasive species (Dias et al. 2019). However, despite the clear and present threats to seabird populations regionally and globally, their distribution and abundance, habitat requirements and habitat associations at sea, particularly during the non-breeding season, remain poorly understood.

Results described herein represent one of the most spatially and temporally extensive monitoring efforts conducted on seabird distribution and abundance in the northern Gulf (e.g., Haney et al. 2019). Collectively, vessel and aerial surveys identified 46 species of seabirds during GOMMAPPS (Appendix A), surpassing the number of species observed on previous survey efforts in the northern Gulf (Table 5.10). Seabird species that overlapped GOMMAPPS and the previous surveys included 13 representative species: Audubon's shearwater, black tern, bridled tern, Cory's shearwater, herring gull, laughing gull, least tern, magnificent frigatebird, masked booby, northern gannet, royal tern, sandwich tern, and sooty tern. Though not a primary objective of the surveys, several non-marine bird species were also detected including landbirds (n = 49 species), waterfowl (n = 17 species), wading birds (n = 12 species), shorebirds (n = 10 species), raptors (n = 7 species), and 1 representative of marsh birds (Appendix A).

Our data indicated distinct seasonal seabird assemblages using the northern Gulf (Tables 5.6b-c; Michael et al. 2023). In the nearshore environment, brown pelicans, terns, and gulls accounted for >80% of all species observed during the summer aerial survey (Table 3.9). In comparison, gulls, northern gannet, double-crested cormorants, and waterfowl (e.g., scaup, redheads) accounted for >70% of all species observed during the winter aerial surveys. In the pelagic environment, the spring-summer seabird assemblage tended to be dominated by species that breed in the northern Gulf (e.g., bridled tern, brown pelican, laughing gull, sandwich tern), as well as more transient groups such as shearwaters and stormpetrels. In comparison, the fall-winter seabird assemblage in pelagic waters was dominated by wintering migrants including Bonaparte's gull, common loon, herring gull, jaegers, and northern gannets. While seabird surveys conducted under GOMMAPPS represent the most comprehensive seabird survey to date in the northern Gulf, additional data collection would allow stakeholders to assess the spatial-temporal variability in seabird distribution and abundance more fully. Understanding seasonal variation in species composition and distribution is particularly relevant to better understanding potential effects from future offshore energy development (e.g., oil and gas, wind energy, aquaculture). To that end, seabird data from GOMMAPPS is being used to inform a variety of regulatory and conservation decisions.

6.1 GOMMAPPS Seabird Data: Regulatory Decision-making in the Northern Gulf

Before the *Deepwater Horizon* oil spill, there were few studies of seabird distribution and abundance in the northern Gulf, and available data were limited spatially or temporally (refer to Section 2.2 above). For seabirds, the *Deepwater Horizon* post-spill injury assessment studies (e.g., Ford 2011, Haney 2011, Haney et al. 2019) filled some data gaps since earlier seabird studies conducted in the late 1990s-early 2000s (e.g., Peake 1996, Ribic et al. 1997, Hess and Ribic 2000). Spatial and temporal gaps in seabird data remained, however, prompting the seabird conservation community in the Gulf to prioritize gathering additional data and information (Jodice et al. 2019) to enhance not only general ecological knowledge but also to support regulatory needs (e.g., proposed offshore wind-energy development). These data gaps set the context for the research described herein, with a goal to collect broad-scale information on the distribution and abundance of seabirds in the northern Gulf to inform seasonally- and spatially explicit density estimates for priority species. Although GOMMAPPS data continue to be applied in a regulatory

context and within a marine spatial planning framework, we note that the temporal scope (2017 – 2020), quantity of data available in pelagic waters during fall – winter period (limited NOAA vessel availability), and infrequent spatial replication across the broad footprint of the study area limit the strength of inference (e.g., Cunningham and Lindenmeyer 2017).

Provided below are some contemporary examples of GOMMAPPS seabird data and model outputs being applied to inform specific regulatory processes and proposed actions related to energy development on the northern Gulf OCS.

- <u>USFWS Species Status Assessment</u>: The black-capped petrel was originally proposed for listing (83 FR 50560) on 9 October 2018, as threatened with a rule issued under section 4(d) of the Act to provide for the conservation of this species. Black-capped petrel sighting data from (2017-2018) GOMMAPPS seabird vessel surveys were provided to the USFWS Species Status Assessment Team; these sightings represented new information for the northern Gulf, and thus, were included in the Species Status Assessment (Vers. 1.1; USFWS 2018). Using additional GOMMAPPS data (Apr 2017 Sept 2019) for this species, Jodice et al. (2021a) published a paper recommending consideration for expanding the marine range of the black-capped petrel. Using black-capped petrel seabird vessel sighting data from both GOMMAPPS and *Deepwater Horizon Bird Study #6* (2010 2011; refer to Haney et al. 2019), Jodice et al. (2021b) published a paper revising the marine range for this species, including the northern Gulf. On 1 May 2023, the USFWS re-opened a 30-day comment period for the listing of the black- capped petrel under ESA (<u>88 FR 27427</u>).
- O&G development: recent review of the Bureau of Safety and Environmental Enforcement website indicates there are roughly 1,601 (link here) to 1,862 (link here) platforms on the OCS of the northern Gulf. Interest in further O&G development remains strong, as evidenced from the 29 March 2023 BOEM Gulf of Mexico Lease Sale 259. This lease sale generated \$263,801,783 in high bids for 313 tracts covering 1.6 million acres in federal waters of the northern Gulf (link here). Gulf of Mexico Lease Sales 259 and 261 Supplemental Environmental Impact Statement (SEIS) was completed in January 2023 (link here), and for birds overall, the impact-level was expected to be 'moderate' based on the alternatives for a single lease sale (table ES-1 at link). Minimizing or mitigating potential effects to migratory birds continues to be important to the USFWS and the Gulf bird conservation community as it relates to O&G activities in the northern Gulf. Michael et al. (2022) used data from GOMMAPPS seabird vessel surveys to integrate spatial, temporal, and life-history characteristics into a single index for relative oil vulnerability for 24 species of seabirds. Species in the upper 20% of VSOI (vulnerability of seabirds to oiling index) scores were northern gannet, Audubon's shearwater, brown booby, great shearwater, and herring gull, whereas species in the lower 20% of VSOI scores were parasitic jaeger, Bonaparte's gull, pomarine jaeger, brown noddy, and common tern. The authors noted that much of the overlap of seabird habitat with O&G platforms occurred in water depths of 200 - 500 m, particularly near the 200-m isobath (Michael et al. 2022:fig. 5), an area characterized as having high cumulative seabird vulnerability.
- <u>Oil spill response planning</u>: In August of 2021, the USFWS received a Request for Information (RFI) from Bureau of Safety and Environmental Enforcement (BSEE) to BOEM related to GOMMAPPS seabird data. Once explicit details associated with this request were received, GOMMAPPS products including seasonal model outputs for aerial surveys, 24 species cumulative habitat suitability model output for vessel surveys, additional methodological details, and publications were provided to the BSEE contractor, Research Planning Inc. (RPI). Access was then provided to these geospatial data products via USFWS ArcGIS Online (AGOL). In January 2023, some of the GOMMAPPS seabird science staff met virtually with RPI staff to review RPI's draft products associated with the Environmental Sensitivity Index (ESI). The GOMMAPPS seabird data will be included as part of a Gulf Environmental Sensitivity Index (ESI) Atlas (Sensitive Species Profiles) for use by BSEE, USCG, and other federal and state agencies, as part of the broader Offshore Gulf Area Contingency Plan (here).

<u>Offshore wind-energy development (OWED)</u>: data from GOMMAPPS, along with other bird- specific data sets relevant to the region, were used by BOEM in coordination with NOAA National Centers for Coastal Ocean Science (NCCOS) to evaluate a range of potentially affected stakeholders (and associated available geospatial data layers) through a marine spatial planning process to inform decision-making (figure 5 at link) related to OWED. GOMMAPPS data used in this process included: (1) nearshore species predictive cumulative model for winter aerial surveys (2018 – 2020), (2) nearshore species predictive cumulative model for summer aerial surveys (2018), (3) black-capped petrel seabird vessel survey observations (map; 2017 – 2019), (4) black-capped petrel relative probability of occurrence (i.e., habitat suitability; refer to Jodice et al. 2021b) from seabird vessel survey observations, and (5) 24 species cumulative relative probability of occurrence (i.e., habitat suitability; Michael et al. 2022) from seabird vessel survey observations.

Randall et al. (2022:fig 3.6) represents a depiction of GOMMAPPS (seabird vessel survey data-only) 24 seabird species cumulative relative probability of occurrence (i.e., habitat suitability) model relative to the larger BOEM Wind Energy Call Area. We suggest that the GOMMAPPS seabird data represent a preconstruction baseline that may be useful in evaluating hypotheses related to avoidance and displacement (e.g., Molis et al. 2019, Vanermen and Steinen 2019). The challenge ahead may be evaluating effects of offshore wind farms in the northern Gulf given the large number of O&G platforms present in the area that seabirds and other migratory birds may interact (i.e., perching/loafing, foraging in immediate vicinity; Russell 2005). GOMMAPPS data may represent the only existing and readily available source for estimating species-specific flight heights for seabirds (and several other species). Seabird vessel survey observers utilized Program SEEBIRD (Vers. 4.3.7; I and Force 2016) which allows observers to enter categorical flight height data (seven categories; ranging from 0 to 2 m to >200 m). We accrued >7,500 seabird records of estimated flight height and are developing plans for future analyses of these data that could be used to inform collision-risk models or species vulnerability assessments in the northern Gulf (e.g., Robinson- Wilmott et al. 2013, Adams et al. 2017, Kelsey et al. 2018, Winship et al. 2018).

- Offshore aquaculture development (OAD): leading up to the Gulf of Mexico Aquaculture Opportunity Areas (AOA) Programmatic Environmental Impact Assessment (PEIS) process, NOAA had already produced the AOA Atlas for the Gulf (Riley et al. 2021). An AOA is a 'small', defined geographic area that was defined through a marine spatial planning analysis process and National Environmental Policy Act (NEPA) under Executive Order 13921 (7 May 2020). Given the information available at the time, these 9 AOAs were determined to be environmentally, socially, and economically feasible to support commercial aquaculture operations (Riley et al. 2021). As part of the Gulf AOA PEIS process, NOAA (and NOAA affiliates; NOAA) is not the action agency per the proposed action, but rather they (NOAA Fisheries, NOAA NCCOS) are taking a lead role in the NEPA process tasked with identifying (AOAs) in the Gulf (nine AOAs have been identified) using a science-based planning process. From a USFWS perspective, migratory birds (including seabirds) are the primary concern, and as such NOAA has received information regarding potential effects to migratory birds given the proposed action, draft GOMMAPPS seabird survey 'results,' published papers, and links to the GOMMAPPS seabird data available on NOAA's National Centers for Environmental Information (NCEI) website (refer to Appendix E). For additional information on potential effects of offshore aquaculture, refer to review by Fujita et al. (2023). For a specific multi-taxon (excluding seabirds), marine spatial planning approach for offshore aquaculture in the northern Gulf (see Farmer et al. 2022).
- <u>NOAA Gulf ecosystem status report</u>: though the GOMMAPPS seabird project does not meet most definitions of a long-term monitoring effort (sensu Love et al. 2015, Schulz 2021), it may not be directly applicable to the next revision of the NOAA's *Integrated Ecosystem Assessment Program Gulf of Mexico Ecosystem Status Report* (Karnauskas et al. 2017). However, at a minimum, the GOMMAPPS seabird data contained in this report could be used to select a representative list of breeding and transient or wintering seabird species (i.e., three to five species for each seasonal period) as priority living marine

resources to evaluate the state of the pelagic ecosystem (e.g., Michael et al. 2023). Further, these data could be included as part of a combined taxa-based (i.e., marine mammals, sea turtles, seabirds) seasonal predictive "hotspots" model using all the GOMMAPPS observational data (NOAA aerial and vessel surveys, USFWS aerial and vessel surveys). As an example, such an effort could be used to identify potentially new marine protected areas (Grüss et al. 2019) or expansion of existing areas (Lamont et al. 2023) in the northern Gulf.

6.2 Seabirds: Remaining Data Gaps

Here we address information gaps that seem relevant given the data we collected during GOMMAPPS (refer to Appendix E) and the limited availability of data from previous projects. Although we consider temporal and spatial coverage separately, it is the interaction of these two factors that ultimately may need to be addressed in future seabird surveys. It should be recognized that temporal constraints or limitations associated with collecting seabird survey data are inherent for both aerial and vessel survey platforms. Such issues may represent real constraints (particularly vessel surveys) for future seabird surveys, even if sufficient funding for seabird observational surveys becomes available. We also discuss potential tracking studies that would fill data gaps on individual movement patterns and thus could inform regulatory decision- making from that perspective (e.g., enhancing our understanding of source colonies for seabird species that breed outside of the northern Gulf; Jodice et al. 2019, Michael et al. 2023).

- Aerial surveys: there may be strong rationale for conducting surveys outside of the breeding season (i.e., breeding seabirds are only available during foraging bouts and seabird abundance and distribution largely a function of colony location), particularly given the large number of seabird species that use the northern Gulf that do not breed in the northern Gulf (refer to Table 3.9, Appendix A)
- Aerial surveys: availability of both USFWS aircraft, pilot-biologists, and seabird aerial survey crews have to be taken into consideration early-on during the planning phase related to timing of aerial surveys.
- Aerial surveys: funding availability and associated aircraft and crew costs are a major factor that have to be evaluated early-on during the planning phase related to temporal aspects of aerial surveys, i.e., how frequently will surveys be flown. Frequency of aerial surveys (i.e., 1/yr, 2x/yr, multiple surveys/yr) is also a consideration under the broader context of aerial survey design.
- Vessel surveys: sampling effort was not uniformly distributed spatially or was incomplete during some seasons. During GOMMAPPS, seabird observers used both dedicated GOMMAPPS marine mammal survey vessels, as well as vessels specifically used for conducting annual programmatic icthyoplankton and fisheries surveys. As a result, some months (Nov Dec) did not receive any survey effort while other months (Jun Jul, Oct, Jan) received limited survey effort (refer to Section 5.1.2). Ideally, if NOAA dedicated marine mammal survey vessels were available, a winter summer winter survey schedule would provide additional temporal coverage (i.e., Dec Mar). Given the current state of knowledge, it is unlikely that temporal data gaps can be addressed solely by relying on use of NOAA VOOs out of Pascagoula, Mississippi.
- Vessel surveys: funding availability is an important factor that necessitates consideration early-on during the planning phase related to temporal aspects of vessel surveys, i.e., how many Days at sea/yr. Seabird vessel survey windows, as well as the type of NOAA surveys being conducted are considerations under the broader context of vessel survey design. To be clear, there is little to no flexibility per seabird survey design related to when or where vessel surveys are conducted for those NOAA VOOs based out of Pascagoula, Mississippi.
- Vessel surveys: there is fairly strong rationale for conducting surveys outside of the breeding season (i.e.,

availability of breeding seabirds is limited to time away from colony during foraging bouts and seabird abundance and distribution is largely a function of colony location), particularly given the large number of seabird species that utilize the northern Gulf but that do not breed in the northern Gulf (refer to Table 5.6a; Michael et al. 2023). Decisions regarding study design and spatial resolution to address specific objectives associated with a given regulatory decision process for a specific type of offshore energy development and the most appropriate survey platform is not fully reviewed here. In general, it is probable that GOMMAPPS aerial and vessel survey data (i.e., baseline seabird data) are of sufficient spatial resolution to address large spatial-scale questions at the scale of the northern Gulf (e.g., Jodice et al. 2021b, Michael et al. 2022, 2023) (and possibly at the planning area scale). However, GOMMAPPS seabird data, in isolation, are almost certainly not sufficient in quantity or at a sufficiently fine-enough spatial (or temporal) resolution to address site-scale questions (Maclean et al. 2013, Mercker et al. 2021).

- Aerial surveys: a hexagon-based study design (*n* = 180 hexagons) was used for all GOMMAPPS seabird aerial surveys (Figure 3.1b) or 60 hexagons for each of the three BOEM planning areas. The aerial survey study area roughly spanned from Brownsville, Texas E-SE down to the Florida Keys with aerial survey coverage primarily including shallower continental shelf waters approximating the 200-m isobath (coastline out to ~50 nm).
- Aerial surveys: future study design considerations (i.e., traditional perpendicular transects v. plot-based design) may warrant further evaluation within the context of funding availability, availability of USFWS aircraft and crews as related to the scope of project objectives (and hypotheses). Clearly, as part of the planning phase, spatial sampling intensity (as well as flight altitude) would warrant additional consideration, time, and discussion.
- Aerial surveys: future study design considerations necessitate accounting for local-scale and seasonal weather-related issues, e.g., strong winds, precipitation, and fog during winter surveys. Fog, in particular coastal fog, can be a major challenge during winter aerial surveys, especially in the Central and Western planning areas.
- Vessel surveys: seabird vessel surveys coverage included both shallower waters on the continental shelf, as well as deeper waters off the Shelf Break out to the EEZ. Though cumulative effort for GOMMAPPS seabird vessel surveys provided relatively complete survey coverage over the entire study area (Figure 4.1), survey effort varied spatially across the three planning areas (Table 5.1, Figure 5.1). There remain spatial limitations for seabird surveys aboard NOAA VOOs. It seems unlikely that spatial data gaps can solely be addressed by reliance on NOAA VOOs out of Pascagoula, Mississippi.
- Vessel surveys: future study design considerations (i.e., sawtooth design v. traditional perpendicular transects) ought to be assessed within the context of funding availability, availability of NOAA VOOs (and other vessels) as it relates to the scope of project objectives (and hypotheses). Spatial sampling intensity would clearly warrant additional consideration during the planning phase of future seabird vessel surveys. For example, future surveys could contract with recreational offshore fishing boats, commercial offshore fishing vessels, O&G transport vessels, or other large vessel options out of Louisiana (Venice, Port Fourchon, etc.) and Texas (Freeport, Port Aransas, etc.). For example, in the eastern Gulf, it may be possible to contract or partner with the University of South Florida and conduct seabird surveys from the *R/V Weatherbird II* and *R/V W. T. Hogarth*. Doing so may very well increase temporal and spatial coverage.
- Vessel surveys: there may be opportunity to capitalize on seabird data collection opportunities by private individuals and recreational seabirding groups engaged in periodic seabird cruises or opportunistic shallow water seabird surveys (~10-20 nm from the coast). There is an extremely limited (Texas Pelagics; with a few pelagic trips annually out of Freeport and Port Aransas, Texas) recreational and commercial

seabirding 'industry' in the northern Gulf. As well, there are opportunistic seabird surveys conducted periodically off the Louisiana coast (Louisiana State University, Museum of Natural History staff); these tend to be limited to shallower continental shelf waters. A fair amount of time and coordination would be necessary prior to either of these potential data sources being considered for inclusion as part of a larger northern Gulf seabird survey 'database'.

In general, we have a poor understanding of species-specific breeding colony locations for many of the seabird species observed during GOMMAPPS (refer to Table 3.9, and Table 5.6a through Table 5.6c; refer also to Michael et al. 2023:table 2). In comparison to various other bird taxonomic groups that utilize the diversity of habitats of the Gulf during some portion of their annual life cycle, seabird distribution, abundance, and use (including diets) of the Gulf and migratory connectivity remains poorly understood (Jodice et al. 2019). Clearly, there are some exceptions. The brown pelican, for example, is well understood, at least partly owing to the wealth of data gleaned from recent research (Lamb 2016, Lamb et al. 2020). Seabird vessel survey data indicate that the "local" northern Gulf breeding seabird community, represented by 10 species, comprised only ~18% of the individual seabirds observed. In comparison, just two species of terns (black and sooty) made up 45% of all individual birds observed. Most of the seabirds observed were not "local" to the northern Gulf breeding seabird community, but rather were from breeding locations within the northern interior U.S., southern Gulf, and Caribbean. These vastly different source regions accounted for \sim 75% of all individuals observed (n = 12 species/region). Though we were able to broadly assign breeding region affiliation to seabird species observed during GOMMAPPS, in the absence of a representative sample of marked individuals, there is no way to know with certainty the origin of individual species, particularly with respect to assignment to a specific breeding area or individual colony within a larger breeding region. Understanding breeding region affiliation and more importantly, breeding area or colony-level affiliation for seabirds that use the Gulf has direct conservation implications, particularly in the case of human-caused mortality events, like the DWH oil spill. Restoration and recovery of injured seabird species (DHNRDAT 2016b) may be most effective if restoration strategies and techniques target important breeding areas or known breeding colonies (DHNRDAT 2017). This requires that restoration practitioners know "where" individual injured seabird species breed.

Tracking studies of a representative suite of target seabird species was identified as a priority component in the GOMMAPPS Seabird Science Plan. Although this component did not receive funding, it remains an information gap as it relates to current and future offshore energy development. More specifically, individual tracking data would allow stakeholders to better address questions related to displacement and avoidance of seabirds due to OWED (refer to review by Thaxter and Perrow 2019).

- Individual tracking data: could provide information on flight heights and would provide directional movement data relevant to both offshore wind energy development, as well as offshore oil and gas development.
- Individual tracking data: would provide information about time spent in federal waters of the northern Gulf and specifically relative allocation of time spent within federal vs state waters in the Central and Western BOEM planning areas as a function of colony location and season.
- Individual tracking: would provide information on foraging distances from colonies, breeding season home range and short-distance movements, post-breeding dispersal and movements, etc.; as a function of sex, age, body condition, and colony size (density- dependence). For the suite of seabirds that breed outside the northern Gulf (Michael et al. 2023), individual tracking studies on select known breeding sites and colonies outside the northern Gulf colonies would provide information on both migratory pathways, as well as connectivity to the northern Gulf.

- Individual tracking: would allow for determination of "hot moments" (e.g., seasonal abundance patterns) and "hot spots" (e.g., seasonal distribution patterns) and potential intersections with anthropogenic threats (e.g., Le Corre et al. 2012, Lamb 2016, Lamb et al. 2020).
- Individual tracking: tend to be more spatially expansive "filling-in" spatial gaps that are regularly present (spatially, temporally, or both) when relying solely on aerial and vessel- based observational survey data (e.g., Jodice et al. 2015:fig. 3).

6.3 Additional Information Needs

Included below is a bulleted list of additional information needs related to northern Gulf seabirds. This list is not meant to be exhaustive, but rather included here to elucidate some known information needs or data gaps that have previously been identified by other authors (e.g., Jodice et al. 2019, Ottinger et al. 2019), and in some cases, proposals to address these gaps have been submitted for funding under other Gulf Restoration funding mechanisms, e.g., NOAA RESTORE Act Science Program (NOAA 2015).

- Seabird diets, foraging ecology (e.g., Furness and Monaghan 1987), chick provisioning rates, and energetic values of prey species delivered to nestlings: the relationship of these data to nestling body condition and fledging success as a function of colony location and colony size is poorly understood for most species in the region. The study of brown pelicans sampled at colonies spanning the northern Gulf by Lamb et al. (2020) demonstrated the relationship of diet to body condition and reproductive success for this species. Given the backdrop of climate change and associated increases in sea-surface temperature, an enhanced understanding of seabird-forage fish connections for a representative suite of both breeding and non-breeding seabirds that use the northern Gulf during some portion of their annual life-history period appears warranted.
- Establishing seabird population baselines for contaminants: post-spill, it became apparent that pre-spill, baseline data on contaminant loads for seabirds were limited (DHNRDAT 2016a:chapt. 4). For seabirds in particular, given their trophic position and their ability to transit large expanses of open ocean in a relatively short period of time (e.g., Anderson et al. 2009, Michelutti et al. 2010), establishing species' population "baselines" for various contaminants (e.g., Hg, Se, Cd, As, PAHs, PFAS, PFOS, PCBs, POPs, organochlorines, etc.) via blood, feathers, tissues, or eggs is critical (Ottinger et al. 2019, Ndu et al. 2020, Jodice et al. 2023). Contaminants have the potential for long-term, sub-lethal population- level effects. However, teasing apart residual 'baseline' contaminant burdens versus contaminants acquired while in the northern Gulf for either long-distance migratory or transient seabird species is challenging. Refer to reviews by Burger and Gochfeld (2001) and Albores-Barajas et al. (2023).
 - 1. Currently, there is a general absence of species-level baselines for contaminants thus, hampering interpretation of contaminant results for seabirds collected post- spill in the northern Gulf. Presently in the northern Gulf, seabird contaminant burdens and population baselines are limited, e.g., brown pelican (Jodice et al. 2022, 2023), northern gannet (Champoux et al. 2020).
 - 2. Given the large spatial footprint of O&G infrastructure in the northern Gulf, the large volume of produced water discharges, and the associated chemical constituents (e.g., Veil et al. 2004), there appears to be potential for negative effects to seabirds and their prey assuming spatial-temporal overlap. For example, potential effects may be short-term and acute, long-term and sublethal, or some combination of the two (refer to review by Murawski et al. 2021). Assessing when and where these effects are active, and specific exposure pathways, appears warranted. For seabirds breeding in and using the northern Gulf, a better understanding of potential effects of contaminant burdens on reproductive decisions and reproductive success is a critical information gap, i.e., potential for carry-over effects.

- 3. Given the large spatial footprint of O&G infrastructure in the northern Gulf (and associated chronic, small oil spills; refer to review by Haney et al. 2017), coupled with a large influx of nutrients (e.g., nitrogen and phosphorous; Mitsch et al. 2001, Porter et al. 2015) and other anthropogenic agricultural field inputs including insecticides, pesticides, and herbicides from the Midwest and the upper Mississippi River watershed that eventually end-up as outflow into the northern Gulf via the Mississippi River; seabird contaminant research seems warranted (Ottinger et al. 2019). Additionally, there is a myriad of point- and non-point sources of pollution across the northern Gulf coastline (and just inland) (Lewis et al. 2002, Lewis and Chancy 2008, Romero et al. 2018). As such, the potential exists that breeding and non-breeding seabirds in the northern Gulf are being affected, either through direct exposure (i.e., contact or ingestion) or via indirect pathways (i.e., consuming contaminated prey).
- Long-term, standardized aerial and vessel seabird surveys: given the history of O&G development in the northern Gulf, relatively recent interest in LNG ports (on- and offshore), as well as the recent interest in OWED and offshore aquaculture development (Sections 6.1.1 6.1.3 above) establishing a long-term seabird monitoring program with data (and associated metadata) housed in a 'centralized' data repository (Adams et al. 2019) similar to what is currently available along the Atlantic and Pacific coasts seems warranted. The northern Gulf is one of the most industrialized oceans in the world and represents a major economic driver of the U.S. economy (review by McKinney et al. 2021), and the area supports more O&G infrastructure (i.e., platforms, pipelines, onshore processing facilities) and associated activities (i.e., oil tankers, tugs and barges, helicopters, and crew support vessels, etc.) in OCS waters than all other BOEM Regions combined. Despite that, the northern Gulf lags compared to either the Atlantic or Pacific BOEM Regions in terms of quantity and availability of seabird data to inform regulatory decision-making.
- Trophic connections between seabirds and their prey in the northern Gulf: for some species like the brown pelican, research has described the trophic connection to and reliance on Gulf menhaden (Lamb 2016, Lamb et al. 2020), a very important commercial fish species. Gulf menhaden may also be an important forage fish to migratory seabird species like the northern gannet and common loon. Linkages between seabird species and important forage fishes is needed to better understand potential seasonal and annual availability limitations that may negatively affect fledging success, post-fledging survival, sub-adult survival, and adult survival with the potential for cross-seasonal effects. However, there remains large key uncertainties about interactions among trophic levels within the northern Gulf pelagic system.
 - 1. Is there a functional relationship between the proportion, total amount, or tonnage removed via commercial fisheries, for example Gulf menhaden, and the minimum threshold available (i.e., post-removal) needed to sustain breeding, transient, and wintering populations of seabirds in the northern Gulf (e.g., Sydeman et al. 2017, Koehn et al. 2021)? As estimated by Cury et al. (2011), does the "1/3 Rule" apply to seabirds and forage fish availability in the northern Gulf?
 - 2. It is our understanding that NOAA needs (or requires) empirical estimates of how much tonnage or proportion of a given forage fish (e.g., Gulf menhaden) are 'removed' annually from the northern Gulf system by seabirds (e.g., brown pelican and Gulf menhaden). Such removal estimates could be incorporated into Gulf menhaden biological removal models or population models providing more precise estimates of quantity of target commercial fishes available to commercial fishers.
 - 3. There appears to be some evidence that the 'Junk Food Hypothesis' (Wanless et al. 2005, Romano et al. 2006, Pichegru et al. 2007, Grémillet et al. 2008) may not be as relevant to seabirds in the northern Gulf as it is for apex predators in higher latitudes (Lamb et al. 2017b). However, this hypothesis has only been assessed for brown pelicans and has not been evaluated more broadly

for the suite of other breeding and non-breeding seabirds using this region. For example, discards of live, whole fish from commercial shrimp trawlers may provide high density, readily available, easy to capture prey (i.e., stunned, or dead fish at the ocean surface) for seabirds and other marine predators (e.g., sharks, dolphins) that is predictable in time and space (Wickliffe and Jodice 2010, Jodice et al. 2011). However, some fish species made readily available to seabirds as bycatch may be of lower nutritional value, require more handling and processing time, or ultimately, be of lower energy density compared to their preferred prey (Jodice et al. 2006, Jodice et al. 2011).

4. Seabirds as indicators of environmental change: our ability to identify and prioritize key trophic pathways (and associated seabird-prey interactions) is limited and the availability of key forage fish that may be the bottom-up drivers of these pathways in the northern Gulf is poorly understood.

A better understanding of these trophic relationships would be beneficial from an offshore energy development context, but also from the perspective of post-*Deepwater Horizon* oil spill restoration, particularly for injured seabirds (DHNRDAT 2017). Having the various trophic pathways identified and understanding species interactions within the pathways may allow us to better tease apart annual variability in the system from both directional climate-change driven effects and potential negative effects due to commercial fisheries harvest (e.g., Koehn et al. 2016, 2017).

6.4 Current and Planned Bird-related Monitoring and Research in the Northern Gulf

The projects identified below have been funded (marked as *) or are under consideration for funding (marked as **); for funded projects, each of the individual projects below is at a different stage or phase. Each of the bird-focused projects included have either direct or perceived benefits for regulatory agencies as well as energy development decision-making processes while also providing additional data necessary to evaluate potential effects of future proposed actions on the OCS. Project funding along with associated project budgets and statement(s) of work are publicly available or available upon request.

- Gulfwide Aerial Photographic Colony-Nesting Bird Surveys*:
 - In 2010 and 2011, a combination of Gulfwide traditional aerial transect surveys and aerial photographic colony surveys were completed by G. Ford and Colibri Ecological Consulting as part of the post-*Deepwater Horizon* oil spill injury assessment (see *Bird Study* #2; Ford 2011, Ford et al. 2014).
 - Gulfwide aerial photographic colony surveys were also completed in 2012, 2013, 2015, and 2021, as well as surveying coastal colonies only Louisiana in 2018.
 - Specific details regarding data and geographic extent of aerial photographic surveys can be found at the following links (<u>Project ID 257</u>, <u>Avian Data Monitoring Portal</u>).
- USFWS aerial seabird surveys within the BOEM OWED <u>RFI Area</u>* (DWH NRDAR- MBP/SciApps):
 - From 6 to 17 July 2022, USFWS staff completed low-level aerial seabird observational surveys via Kodiak amphibious aircraft off the coast of Louisiana and Texas. In total, 70 survey plots were completed representing >2,500 mi of transects surveyed over nine days.
 - From 17 Feb to 2 Mar 2023, USFWS staff completed aerial seabird surveys via Kodiak amphibious aircraft off the coast of Louisiana and Texas. In total, 69 survey plots were completed

representing >2,500 mi of transects surveyed over nine days.

- *Gulf of Mexico Colony Atlas* (USFWS-USGS South Carolina Cooperative Fish and Wildlife Research Unit at Clemson Univ.)*:
 - Following on a need identified by the Gulf Coast Joint Venture Bird Nesting Island Cooperative, this project was initiated in Aug 2021; to create a northern Gulf colony atlas and registry like that developed for the South Atlantic Bight (South Carolina, Georgia, and northeast Florida; Ferguson et al. 2018).
 - As part of this project, a group of stakeholders representing a community of practice (~48 individuals), as well as a Technical Advisory Team (eight individuals) were formed. A single inperson meeting and several virtual meetings were held to acquire input on potential data available, identify specific data providers, identify focal species, and define spatial and temporal boundaries.
 - The project will be site-based (i.e., not species driven), such that outputs will include coastal breeding species of seabirds, shorebirds, and wading birds organized by the locations at which surveys were conducted. The temporal frame will be ~2010 2022 and the spatial frame will include roughly the lower Texas coast around to roughly Tampa Bay with the inland boundary determined using NOAA C-CAP.
 - To date, 38 datasets from eight different data providers have been incorporated, representing 46 breeding species and >50,000 bird surveys.
- *NOAA Gulf of Mexico Marine Mammal and Seabird Vessel Surveys* (Open Ocean Trustee Implementation Group; NOAA and USFWS DWH NRDAR)*:
 - Building-off of GOMMAPPS seabird vessel surveys, there was a desire to follow-up that effort via Vessel Surveys for Abundance and Distribution (VSAD) of marine mammals and seabirds with surveys in summers of 2023 and 2024.
 - Leg 1 (22 June 1 July 2023): two seabird observers conducted visual observations of seabirds aboard the *R/V Gorton Gunter*. Observers counted all seabirds inside the 300 m strip for a total of ~121 hours over 9+ calendar days. Seabird observers archived 2,139 total sightings of individual pelagic, offshore, and coastal marine birds into Program SEEBIRD (Vers. 4.3.7); 18 seabird species. This detection rate averaged ~231 birds/d or around 18 birds/hr.²⁹
 - <u>Legs 2/3 combined (20 July 15 August 2023)</u>: two seabird observers conducted visual observations of seabirds aboard the *R/V Gorton Gunter*. Observers counted all seabirds inside the 300 m strip for a total of ~319 hours. Seabird observers archived 2,057 total sightings of individual pelagic, offshore, and coastal marine birds into Program SEEBIRD (Vers. 4.3.7); 18 seabird species. This detection rate averaged ~76 birds/d or around 6 birds/hr.
 - <u>Leg 1 (2-15 June 2024)</u>: two seabird observers conducted visual observations of seabirds aboard the *R/V Gorton Gunter*. Observers counted all seabirds inside the 300 m strip for a total of ~167 hrs over 14 calendar days. Seabird observers archived 1,223 total sightings of individual pelagic, offshore, and coastal marine birds into Program SEEBIRD (Vers. 4.3.7); 21 seabird species. This detection rate averaged ~91 birds/d or around 7 birds/hr.³⁰

²⁹ See the NOAA Fisheries blog at <u>https://www.fisheries.noaa.gov/science-blog/successful-final-leg-gulf-mexico-marine-mammal-and-seabird-vessel-survey</u>

³⁰ See the NOAA Fisheries blog at https://www.fisheries.noaa.gov/science-blog/kicking-2024-marine-mammal-and-

- Leg 2 (1-19 July 2024): two seabird observers conducted visual observations of seabirds aboard the *R/V Gorton Gunter*. Observers counted all seabirds inside the 300 m strip for a total of ~220.5 hrs over 19 calendar days. Seabird observers archived 841 total sightings of individual pelagic, offshore, and coastal marine birds into Program SEEBIRD (Vers. 4.3.7); 22 seabird species. This detection rate averaged ~46 birds/d or around 4 birds/hr.
- Leg 3 (27 July-12 Aug 2024): two seabird observers conducted visual observations of seabirds aboard the *R/V Gorton Gunter*. Observers counted all seabirds inside the 300 m strip for a total of ~181 hrs over 17 calendar days. Seabird observers archived 889 total sightings of individual pelagic, offshore, and coastal marine birds into Program SEEBIRD (Vers. 4.3.7); 21 seabird species. This detection rate averaged ~58 birds/d or around 5 birds/hr. Additional information for this project is available on the Open Ocean TIG website, as well as on NOAA's Vessel Surveys for Abundance and Distribution (VSAD) project blog.
- Gulf of Mexico X-Band Radar Vessel Survey-Pilot Study (USFWS-USGS)*:
 - Pilot project to test functionality and operability of portable x-band radar system aboard NOAA Vessels of Opportunity (VOOs) in late summer-early fall 2023. Motion compensation, sea clutter mitigation, and advanced methods of target discrimination will be integrated into a single radar platform. Radar operation will be varied systematically between rotating and stationary sampling modes to capture data on animal speed, direction, range, and discrimination of targets into broad categories. These base metrics will be used to estimate abundance, geographic distribution, and height stratification. Human observers will supplement and corroborate radar observations with taxon-specific information on distribution and bird behavior.
- Assessing Avian Collision-Risk for Offshore Wind Energy Development in the Gulf of Mexico: A Remote Sensing Approach (BOEM-USGS)³¹ *:
 - This study proposes to use various remote bird monitoring technologies (including portable xband radar units placed on O&G platforms) to better understand spatial and temporal patterns in avian abundance and distribution, as well as flight heights of birds (and bats) the airspace over the open ocean. Access to and instrumentation on a number of O&G platforms in proximity to planned BOEM OWED <u>WEA options</u> identified in the Central and Western planning areas is an important component of this project. Fieldwork is planned to begin in fall 2024 or in spring 2025.
- Decision Support for Avian Risk Assessment of Offshore Wind Energy Development in the Gulf of Mexico (Biodiversity Research Institute-USFWS)**:
 - Given the interest in OWED on the OCS and the importance of this region to the continent's migratory birds during migration, there is a clear need for either or both a vulnerability assessment (e.g., Robinson-Willmott et al. 2013) and collision-risk models (e.g., Adams et al. 2017) for birds in the northern Gulf. Though this proposal was not selected for funding under the most recent NOAA RESTORE Act Science Program FFO-2023, the project idea and/or proposal continues to represent a clear knowledge gap and/or data need.

seabird-survey-year-

^{2#:~:}text=In%20June%202024%2C%20scientists%20from,Marine%20Mammals%20and%20Seabirds%20project. ³¹ See the Study Profile at <u>https://espis.boem.gov/study%20profiles/BOEM-ESP-GM-23-01.pdf</u>

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Appendix A. List of all vertebrates detected and identified to species from both aerial (A) and vessel (V)-based survey platforms as part of the GOMMAPPS, 2017–2020

Common Name ¹	Scientific Name ²	Platform Observed ³
Taxonomic Group		
Seabirds		
American white pelican	Pelecanus erythrorhynchos	A
Audubon's shearwater	Puffinus iherminieri	V
Band-rumped storm-petrel	Oceanodroma castro	V
Black skimmer	Rynchops niger	A
Black-capped petrel	Pterodroma hasitata	V
Black tern	Chlidonias niger	A,V
Bonaparte's gull	Chroicocephalus philadelphia	A,V
Bridled tern	Onychoprion anaethetus	V
Brown booby	Sula leucogaster	A,V
Brown noddy	Anous stolidus	A,V
Brown pelican	Pelecanus occidentalis	A,V
Caspian tern	Hydroprogne caspia	A,V
Common loon	Gavia immer	A,V
Common tern	Sterna hirundo	V
Cory's shearwater	Calonectris diomedea	A,V
Double-crested cormorant	Phalacrocorax auritus	A,V
Fea's petrel	Pterodroma feae	V
Forster's tern	Sterna forsteri	V
Great black-backed gull	Larus marinus	A,V
Great shearwater	Ardenna gravis	V
Gull-billed tern	Gelochelidon nilotica	V
Herring gull	Larus argentatus	A,V
Laughing gull	Leucophaeus atricilla	A,V
Lesser black-backed gull	Larus fuscus	A
Leach's storm-petrel	Oceanodroma leucorhoa	V
Least tern	Sternula antillarum	A,V
Long-tailed jaeger	Stercorarius longicaudus	V
Magnificent frigatebird	Fregata magnificens	A,V
Manx shearwater	Puffinus puffinus	V
Masked booby	Sula dactylatra	A,V
Neotropic cormorant	Phalacrocorax brasilianus	V
Northern gannet	Morus bassanus	A,V
Parasitic jaeger	Stercorarius parasiticus	V
Pomarine jaeger	Stercorarius pomarinus	V

Common Name ¹	Scientific Name ²	Platform Observed ³
Red phalarope	Phalaropus fulicarius	V
Red-billed tropicbird	Phaethon aethereus	V
Red-footed booby	Sula sula	V
Red-necked phalarope	Phalaropus lobatus	V
Red-throated loon	Gavia stellata	V
Ring-billed gull	Larus delawarensis	V
Roseate tern	Sterna dougallii	A,V
Royal tern	Thalasseus maximus	A,V
Sandwich tern	Thalasseus sandvicensis	V
Sooty tern	Onychoprion fuscatus	A,V
South polar skua	Stercorarius maccormicki	V
White-tailed tropicbird	Phaethon lepturus	V
Wilson's storm-petrel	Oceanites oceanicus	A,V
Landbirds		
American redstart	Setophaga ruticilla	V
Baltimore oriole	Icterus galbula	V
Bank swallow	Riparia riparia	V
Barn swallow	Hirundo rustica	V
Black-billed cuckoo	Coccyzus erythropthalmus	V
Blackpoll warbler	Setophaga striata	V
Black-throated blue warbler	Setophaga caerulescens	V
Black-throated green warbler	Setophaga virens	V
Blue-winged warbler	Vermivora cyanoptera	V
Bobolink	Dolichonyx oryzivorus	V
Brown-headed cowbird	Molothrus ater	V
Cape May warbler	Setophaga tigrina	V
Chimney swift	Chaetura pelagica	V
Chipping sparrow	Spizella passerina	V
Chuck-will's-widow	Antrostomus carolinensis	V
Cliff swallow	Petrochelidon pyrrhonota	V
Common nighthawk	Chordeiles minor	V
Common yellowthroat	Geothlypis trichas	V
Eastern kingbird	Tyrannus tyrannus	V
Eastern wood-pewee	Contopus virens	V
Eurasian collared-dove	Streptopelia decaocto	V
Gray catbird	Dumetella carolinensis	V
Hooded warbler	Setophaga citrina	V
Indigo bunting	Passerina cyanea	V
Louisiana waterthrush	Parkesia motacilla	V
Magnolia warbler	Setophaga magnolia	V

Common Name ¹	Scientific Name ²	Platform Observed ³
Mourning dove	Zenaida macroura	V
Nashville warbler	Leiothlypis ruficapilla	V
Northern rough-winged swallow	Stelgidopteryx serripennis	V
Northern waterthrush	Parkesia noveboracensis	V
Orchard oriole	Icterus spurius	V
Ovenbird	Seiurus aurocapilla	V
Palm warbler	Setophaga palmarum	V
Prothonotary warbler	Protonotaria citrea	V
Purple martin	Progne subis	V
Rock pigeon	Columba livia	V
Ruby-throated hummingbird	Archilochus colubris	V
Scarlet tanager	Piranga olivacea	V
Tree swallow	Tachycineta bicolor	V
Tropical kingbird	Tyrannus melancholicus	V
Veery	Catharus fuscescens	V
White-crowned pigeon	Patagioenas leucocephala	V
White-winged dove	Zenaida asiatica	V
Wilson's warbler	Cardellina pusilla	V
Yellow warbler	Dendroica petechia	V
Yellow-billed cuckoo	Coccyzus americanus	V
Yellow-breasted chat	Icteria virens	V
Yellow-headed blackbird	Xanthocephalus xanthocephalus	V
Yellow-rumped warbler	Setophaga coronata	V
Marshbirds		
American coot	Fulica americana	V
Raptors		
American kestrel	Falco sparverius	V
Merlin	Falco columbarius	V
Osprey	Pandion haliaetus	A,V
Peregrine falcon	Falco peregrinus	V
Short-eared owl	Asio flammeus	V
Turkey vulture	Cathartes aura	A
White-tailed hawk	Geranoaetus albicaudatus	A
Shorebirds		
Black-bellied plover	Pluvialis squatarola	A,V
Least sandpiper	Calidris minutilla	V
Lesser yellowlegs	Tringa flavipes	V
Ruddy turnstone	Arenaria interpres	V
Sanderling	Calidris alba	V
Semipalmated sandpiper	Calidris pusilla	V

Common Name ¹	Scientific Name ²	Platform Observed ³
Spotted sandpiper	Actitis macularius	V
Western sandpiper	Calidris mauri	V
Whimbrel	Numenius phaeopus	V
White-rumped sandpiper	Calidris fuscicollis	V
Wadingbirds		
Black-crowned night-heron	Nycticorax nycticorax	V
Cattle egret	Bubulcus ibis	A,V
Great blue heron	Ardea herodias	A,V
Great egret	Ardea alba	A,V
Green heron	Butorides virescens	A,V
Little blue heron	Egretta caerulea	A,V
Roseate spoonbill	Platalea ajaja	A
Snowy egret	Egretta thula	A,V
Tricolored heron	Egretta tricolor	A,V
Yellow-crowned night-heron	Nyctanassa violacea	V
White ibis	Eudocimus albus	A,V
Wood stork	Mycteria americana	A
Waterfowl		
Black-bellied whistling duck	Dendrocygna autumnalis	A
Black scoter	Melanitta americana	A
Blue-winged teal	Spatula discors	V
Bufflehead	Bucephala albeola	A
Canvasback	Aythya valisineria	A
Common merganser	Mergus merganser	A
Greater scaup	Aythya marila	V
Hooded merganser	Lophodytes cucullatus	A
Lesser scaup	Aythya affinis	A
Mottled duck	Anas fulvigula	A
Northern pintail	Anas acuta	A
Northern shoveler	Spatula clypeata	A
Red-breasted merganser	Mergus serrator	A
Redhead	Aythya americana	A
Ring-necked duck	Aythya collaris	A
Surf scoter	Melanitta perspicillata	A
White-winged scoter	Melanitta deglandi	A
Marine Mammals		
Bryde's whale	Balaenoptera edeni	V
Cuvier's beaked whale	Ziphius cavirostris	V
False killer whale	Pseudorca crassidens	V

Common Name ¹	Scientific Name ²	Platform Observed ³
Melon-headed Whale	Peponocephala electra	A
Short-finned pilot whale	Globicephala macrorhynchus	V
Sperm whale	Physeter macrocephalus	A,V
Atlantic spotted dolphin	Stenella frontalis	V
Bottlenose dolphin	Tursiops truncatus	A,V
Clymene dolphin	Stenella clymene	V
Pantropical spotted dolphin	Stenella attenuata	V
Risso's dolphin	Grampus griseus	V
Rough-toothed dolphin	Steno bredanensis	V
Spinner dolphin	Stenella longirostris	V
Striped dolphin	Stenella coeruleoalba	V
West Indian manatee	Trichechus manatus	A,V
Sea Turtles		
Green	Chelonia mydas	A,V
Hawksbill	Eretmochelys imbricata	A
Kemp's ridley	Lepidochelys kempii	A,V
Leatherback	Dermochelys coriacea	A,V
Loggerhead	Caretta caretta	A,V
Sharks, Fish, etc.		
Common dolphinfish (Mahi mahi)	Coryphaena hippurus	V
Ocean sunfish	Mola mola	V
Unid. Exocoetus	Exocoetus sp.	V
Unid. tuna	Thunnus sp.	V
Hammerhead shark	Sphyrna zygaena	A,V
Whale shark	Rhincodon typus	A

¹ Common names for most taxa groups are presented in alphabetical order. For birds, general taxonomic groupings follow those developed by the Gulf of Mexico Avian Monitoring Network <u>https://gomamn.org/</u>

 2 Scientific names for birds obtained from Birds of the World online https://birdsoftheworld.org/bow/home
3 Platform refers to seabird survey platform: A = aerial survey, V = vessel survey, and A, V = observed from both survey platforms

Appendix B. Trackline maps for seabird vessel surveys with associated effort-based metrics as part of the GOMMAPPS, 2017 – 2019.

Surveys here represents NOAA vessel codes used: R/V *Gordan Gunter* (GG), R/V *Oregon II* (O2, R2), and R/V *Pisces* (PI, PC). Vessel surveys are provided below in chronological order beginning in April 2017 and ending in September 2019.

Survey: R21702

Dates: 2017-04-28 to 2017-05-30 Platform: Vessel Number of transect segments analyzed: 164 Total survey area analyzed: 3,410.2 km² 95° W 90° W 85° W 30° N--30° N 25° N-25° N Vessel route U.S. exclusive economic zone BOEM planning areas 125 250 500 Kilometers 95° W 90° W 85° W

Cumulative time on-effort: 178.1 hours

Survey: PI1706

Dates: 2017-06-04 to 2017-06-16 Platform: Vessel Number of transect segments analyzed: 136 **Total survey area analyzed:** 545.6 km² Cumulative time on-effort: 37.9 hours



Dates: 2017-07-21 to 2017-08-05 Platform: Vessel Number of transect segments analyzed: 63 **Total survey area analyzed:** 2,995.5 km² **Cumulative time on-effort:** 161.7 hours



Dates: 2017-08-09 to 2017-08-25 Platform: Vessel Number of transect segments analyzed: 48 Total survey area analyzed: 3,064.8 km² Cumulative time on-effort: 169.6 hours



Dates: 2017-09-17 to 2017-09-29 Platform: Vessel Number of transect segments analyzed: 38 Total survey area analyzed: 1,895.3 km² Cumulative time on-effort: 106.2 hours



Dates: 2018-01-14 to 2018-02-08 Platform: Vessel Number of transect segments analyzed: 44 Total survey area analyzed: 2,689.3 km² Cumulative time on-effort: 160.6 hours



Dates: 2018-02-12 to 2018-02-26 Platform: Vessel Number of transect segments analyzed: 44 Total survey area analyzed: 2,473.6 km² Cumulative time on-effort: 149.7 hours



Dates: 2018-03-01 to 2018-03-16 Platform: Vessel Number of transect segments analyzed: 37 Total survey area analyzed: 2,190.5 km² Cumulative time on-effort: 140.8 hours



Survey: O21804

Dates: 2018-04-27 to 2018-05-11 Platform: Vessel Number of transect segments analyzed: 47 Total survey area analyzed: 2,253.5 km² Cumulative time on-effort: 125.5 hours



Survey: O21805

Dates: 2018-05-16 to 2018-05-25 Platform: Vessel Number of transect segments analyzed: 56 Total survey area analyzed: 779.4 km² Cumulative time on-effort: 45.8 hours



Survey: PC1805

Dates: 2018-08-11 to 2018-10-06 Platform: Vessel Number of transect segments analyzed: 440 Total survey area analyzed: 8,086.3 km² Cumulative time on-effort: 439.7 hours



Dates: 2018-09-11 to 2018-09-30 Platform: Vessel Number of transect segments analyzed: 77 Total survey area analyzed: 2,819.1 km² Cumulative time on-effort: 162.4 hours



Survey: O21901

Dates: 2019-04-26 to 2019-05-24 Platform: Vessel Number of transect segments analyzed: 86 Total survey area analyzed: 3,828.4 km² Cumulative time on-effort: 205.5 hours



Survey: PC1905

Dates: 2019-08-21 to 2019-09-25 Platform: Vessel Number of transect segments analyzed: 122 Total survey area analyzed: 4,703.5 km² Cumulative time on-effort: 253.7 hours



Appendix C. Spatial distribution of non-marine avifauna detections during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019

Landbirds



Figure A-C 1. Spatial distribution map of non-marine avifauna detections for landbirds (nine species of warblers and allies) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (American redstart, black-throated blue warbler, black- throated green warbler, blackpoll warbler, hooded warbler, magnolia warbler, palm warbler, yellow warbler, and yellow-rumped warbler) are identified by different colored circles; see inset in lower righthand corner.



Figure A-C2. Spatial distribution map of non-marine avifauna detections for landbirds (nine species of warblers and allies) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (blue- winged warbler, Cape May warbler, common yellowthroat, Louisiana waterthrush, Nashville warbler, northern waterthrush, ovenbird, prothonotary warbler, and Wilson's warbler) are identified by different colored circles; see inset in lower righthand corner.



Figure A-C3. Spatial distribution map of non-marine avifauna detections for landbirds (five species of blackbirds and allies) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (Baltimore oriole, bobolink, brown-headed cowbird, orchard oriole, and yellow-headed blackbird) are identified by different colored circles; see inset in lower right corner.



Figure A-C4. Spatial distribution map of non-marine avifauna detections for landbirds (six species of aerial insectivores) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (chimney swift, Chuck-will's-widow, common nighthawk, northern rough-winged swallow, purple martin, and tree swallow) are identified by different colored circles; see inset in lower righthand corner.



Figure A-C5. Spatial distribution map of non-marine avifauna detections for landbirds (four species) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (black-billed cuckoo, yellow-billed cuckoo, indigo bunting, and scarlet tanager) are identified by different colored circles; see inset in lower righthand corner.



Figure A-C6. Spatial distribution map of non-marine avifauna detections for landbirds (three species of flycatchers) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (eastern kingbird, eastern wood-pewee, and tropical kingbird) are identified by different colored circles; see inset in lower righthand corner.



Figure A-C7. Spatial distribution map of non-marine avifauna detections for landbirds (five species) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (chipping sparrow, gray catbird, ruby-throated hummingbird, veery, and yellow-breasted chat) are identified by different colored circles; see inset in lower righthand corner.



Figure A-C8. Spatial distribution map of non-marine avifauna detections for landbirds (five species of doves and pigeons) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (Eurasian collared-dove, mourning dove, rock pigeon, white-crowned pigeon, and whitewinged dove) are identified by different colored circles; see inset in lower righthand corner.



Figure A-C9. Spatial distribution map of non-marine avifauna detections for landbirds (unidentified warblers) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Detections are identified by brown circles.





Detections are identified by green circles.

Raptors



Figure A-C11. Spatial distribution map of non-marine avifauna detections for raptors (five species) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (American kestrel, merlin, osprey, peregrine falcon, and short-eared owl) are identified by different colored circles; see inset in lower righthand corner.

Shorebirds



Figure A-C12. Spatial distribution map of non-marine avifauna detections for shorebirds (10 species) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (black- bellied plover, least sandpiper, lesser yellowlegs, ruddy turnstone, sanderling, semipalmated sandpiper, spotted sandpiper, western sandpiper, whimbrel, and white-rumped sandpiper) are identified by different colored circles; see inset in lower righthand corner.
Wading Birds



Figure A-C13. Spatial distribution map of non-marine avifauna detections for wading birds (six species) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (black-crowned night-heron, green heron, snowy egret, tricolored heron, white ibis and yellow-crowned night-heron) are identified by different colored circles; see inset in lower righthand corner.

Waterfowl



Figure A-C14. Spatial distribution map of non-marine avifauna detections for waterfowl (two ducks and American coot) during seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Each of the unique species (American coot, blue-winged teal, and greater scaup) are identified by different colored circles; see inset in lower righthand corner.

Appendix D. Spatial Distribution Map of Seabird Detections

Predicted seabird occurrence map, modeled overlap of highly suitable seabird habitat map within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-1. Spatial distribution of Audubon's shearwater detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-2. Spatial distribution of band-rumped storm-petrel detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.







Figure D-4. Spatial distribution of black tern (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-5. Spatial distribution of Bonaparte's gull detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-6. Spatial distribution of bridled tern detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.















Figure D-10. Spatial distribution of three tern species (Caspian tern, gull-billed tern, least tern) and unidentified tern detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.







Figure D-12. Spatial distribution of common tern detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-13. Spatial distribution of Cory's shearwater detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-14. Spatial distribution of one petrel and one shearwater species (Fea's petrel, Manx shearwater) and unidentified *Pterodroma*, unidentified shearwater, unidentified large shearwater, and unidentified small shearwater detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-15. Spatial distribution of three tern species (Forster's tern, roseate tern, and sooty/bridled tern) and unidentified *Onychoprion* detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-16. Spatial distribution of two gull species (great black-backed gull and ring-billed gull) and unidentified Laridae, unidentified gull, and unidentified large gull detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.











Figure D-19. Spatial distribution of laughing gull detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-20. Spatial distribution of Leach's storm-petrel and identified storm-petrel detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-21. Spatial distribution of long-tailed jaeger and south polar skua and unidentified jaeger detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-22. Spatial distribution of magnificent frigatebird detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.







Figure D-24. Spatial distribution of red-throated loon, two cormorant species (double-crested cormorant and neotropic cormorant) and unidentified cormorant detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-25. Spatial distribution of northern gannet detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.







Figure D-27. Spatial distribution of pomarine jaeger detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.



Figure D-28. Spatial distribution of red-footed booby, red-billed and white-tailed tropic birds, unidentified boobies, unidentified Sulidae, and unidentified tropic bird detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.


Figure D-29. Spatial distribution of two phalarope species (red phalarope, red-necked phalarope) and unidentified phalarope detections using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Spatial distribution map represents locations of individual detections identified by small, filled circles and colors representing different species (see inset). Please refer to text for more details.



Figure D-30. Spatial distribution of royal tern detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Spatial distribution map represents locations of individual detections with circle size and color representing different flock sizes. Predicted habitat suitability is represented by yellow (high suitability), light green (moderate suitability), and dark blue (low suitability). Overlap was determined as the proportion of highly suitable habitat (i.e., habitat suitability \geq 0.6) within 10 km of an oil and gas platform; black circles represent oil and gas platforms with 10 km hollow circle (i.e., buffer). See text for more details.



Figure D-31. Spatial distribution of sandwich tern detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Spatial distribution map represents locations of individual detections with circle size and color representing different flock sizes. Predicted habitat suitability is represented by yellow (high suitability), light green (moderate suitability), and dark blue (low suitability). Overlap was determined as the proportion of highly suitable habitat (i.e., habitat suitability ≥ 0.6) within 10 km of an oil and gas platform; black circles represent oil and gas platforms with 10 km hollow circle (i.e., buffer). Please refer to text for more details.



Figure D-32. Spatial distribution of sooty tern detections (top panel), their predicted occurrence (middle panel) (i.e., habitat suitability; 0 - 1) from MaxEnt (Vers. 3.4.2; Phillips et al. 2006) and overlap of highly suitable habitat (bottom panel) within 10 km of oil and gas platforms using data from seabird vessel surveys as part of the GOMMAPPS, 2017 – 2019.

Spatial distribution map represents locations of individual detections with circle size and color representing different flock sizes. Predicted habitat suitability is represented by yellow (high suitability), light green (moderate suitability), and dark blue (low suitability). Overlap was determined as the proportion of highly suitable habitat (i.e., habitat suitability ≥ 0.6) within 10 km of an oil and gas platform; black circles represent oil and gas platforms with 10 km hollow circle (i.e., buffer). See text for more details.





Spatial distribution map represents locations of individual detections with circle size and color representing different flock sizes. Predicted habitat suitability is represented by yellow (high suitability), light green (moderate suitability), and dark blue (low suitability). Overlap was determined as the proportion of highly suitable habitat (i.e., habitat suitability ≥ 0.6) within 10 km of an oil and gas platform; black circles represent oil and gas platforms with 10 km hollow circle (i.e., buffer). Please refer to text for more details.

Appendix E. Publications, Data Releases, and other Materials Resulting from Data Collected for this Study

E.1 Peer-reviewed publications

- Davis KL, Silverman ED, Sussman AL, Wilson RR, Zipkin EF. 2022. Errors in aerial survey count data: identifying pitfalls and solutions. Ecology and Evolution 12(3): e8733. https://doi.org/10.1002/ece3.8733
- Jodice PGR, Michael PE, Gleason JS, Haney JC, Satgé YG. 2021a. Expanding the marine range of the endangered black-capped petrel *Pterodroma hasitata*: occurrence in the northern Gulf of Mexico and conservation implications. BioRxiv. https://doi.org/10.1101/2021.01.19.427288
- Jodice PGR, Michael PE, Gleason JS, Haney JC, Satgé YG. 2021b. Revising the marine range of the endangered black-capped petrel *Pterodroma hasitata*: occurrence in the northern Gulf of Mexico and exposure to conservation threats. Endangered Species Research. 46:49-65.
- Michael PE, Gleason JS, Haney JC, Hixson KM, Satgé YG, Jodice PGR. 2024. Black Tern *(Chlidonias niger)* beyond the breeding grounds: Occurrence, relative density, and habitat associations in the northern Gulf of Mexico. Wilson Journal of Ornithology 136:220-236.
- Michael PE, Haney JC, Gleason JS, Hixson KM, Satgé YG, Jodice PGR. 2025. Flying fish habitat and co-occurrence with seabirds in the northern Gulf of Mexico. Fisheries Oceanography: e12712. https://doi.org/10.1111/fog.12712
- Michael PE, Hixson KM, Haney JC, Satgé YG, Gleason JS, Jodice PGR. 2022. Seabird vulnerability to oil: exposure potential, sensitivity, and uncertainty in the northern Gulf of Mexico. Frontiers in Marine Science 9: 880750. https://doi.org/10.3389/fmars.2022.880750
- Michael PE, Hixson KM, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2023. Migration, breeding location, and seascape shape seabird assemblages in the northern Gulf of Mexico. PLoS ONE 18(6): e0287316. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0287316

E.2 Peer-reviewed publications in review

- Haney JC, Michael PE, Gleason JS, Wilson RR, Jodice PGR, Satgé YG, Hixson KM. 2025. Relative abundance, seasonal occurrence, and distribution of offshore marine birds in the northern Gulf of Mexico. Accepted. Marine Ornithology.
- Michael PE, Haney JC, Gleason JS, Hixson KM, Satgé YG, Jodice PGR. 2024. Flying fish habitat and cooccurrence with seabirds in the northern Gulf of Mexico. Fisheries Oceanography. 23: 0:e12712 . https://doi.org/10.1111/fog.12712

E.3 Peer-reviewed publications in preparation

E.4 Theses

Davis KL. 2024. From data to dynamics: data collection, modeling considerations, and analyses for

understanding avian population and community dynamics. PhD dissertation. Michigan State University, East Lansing, MI. 100 p. https://doi.org/doi:10.25335/d1cf-h333

E.5 Conference presentations

- Davis KL, Farr MT, Wilson RR, Silverman ED, Sussman AL, Lyons JE, Zipkin EF. 2019. Optimizing aerial survey design: pitfalls and progress. American Ornithological Society Conference, Anchorage, AK.
- Davis KL, Wilson RR, Silverman ED, Sussman AL, Lyons JE, Zipkin EF. 2020. Flock counting error in aerial seabird surveys. International Statistical Ecology Conference (Virtual).
- Davis KL, Wilson RR, Gleason JS, Silverman ED, Sussman AL, Lyons JE, Zipkin EF. 2024. Environmental drivers of waterbird abundance and distribution in the Gulf of Mexico. The Gulf of Mexico Conference, Tampa, FL.
- *Davis KL, Wilson RR, Silverman ED, Zipkin EF. 2021. The way we count counts: using waterbird data to investigate the effects of counting error on abundance estimates. 45th Annual Meeting of the Waterbird Society (2nd Virtual Meeting). *Recipient of Best Student Presentation Award
- Farr M. 2018. Impacts of offshore energy development, oceanographic features, and climate change on seabird distributions. Michigan State University Environmental Science and Policy Program Symposium, East Lansing, MI.
- Gleason J. 2016. Migratory Bird Briefing Part 3: Gulf of Mexico Marine Assessment Program for Protected Species. U.S. Fish and Wildlife Service Leadership Update Meeting, March 2016, Atlanta, GA.
- Gleason JS. 2019. GOMMAPPS: establishing the importance of the Gulf of Mexico to North American seabirds (and beyond). Birds and Oil Spills Meeting, Louisiana Sea Grant, Baton Rouge, LA.
- Gleason JS. 2020. Gulf of Mexico Marine Assessment Program for Protected Species: Seabirds- vessel and aerial surveys. Presented on behalf of the GOMMAPPS Seabird Science Team on 27 Jan. 2020 in Cedar Key, Florida to the Cedar Key Audubon (open to the public). Cedar Key News article: https://cedarkeynews.com/index.php/conservation/5334-cka-enjoys-gleason
- Gleason JS, Adams EM, Schulz JL, Jodice PGR, Wilson RR. 2022. Incorporating seabird monitoring efforts into offshore wind siting and associated mitigation opportunities in the Gulf of Mexico. The Gulf of Mexico Conference, Baton Rouge, LA.
- Gleason JS, Michael PE, Haney JC, Jodice PGR, Davis KL, Sussman AL, Wilson RR, Silverman ED, Zipkin EF, Lyons JE. 2019. Gulf of Mexico Marine Assessment Program for Protected Species: seabirds- vessels and aerial surveys. Gulf of Mexico Alliance (GOMA) Federal Working Group (Virtual).
- Gleason JS, Michael PE, Hixson KM, Haney JC, Satgé YG, Jodice PGR. 2024. Observations of nonmarine avifauna during seabird vessel surveys in the northern Gulf of Mexico (2017-2019). The Gulf of Mexico Conference, Tampa, FL. Poster.
- Gleason JS, Niemuth ND, Forman KJ, Fairbanks TJ, McLeod SJ, Schulz BR. 2024. The black tern: Gulf restoration delivery for a wetland-dependent species on private lands in the eastern Prairie Pothole Region. The Gulf of Mexico Conference, Tampa, FL.

- Gleason JS, Sussman AL, Davis KL, Haney JC, Hixson KM, Jodice PGR, Lyons JE, Michael PE, Satgé YG, Silverman ED, Zipkin EF, Wilson RR. 2022. Gulf of Mexico Marine Assessment Program for Protected Species (GOMMAPPS): Seabird Surveys in the Northern Gulf of Mexico. Bureau of Ocean Energy Management, Information Transfer Meeting, 14 Sept. 2022 (Virtual).
- Gleason JS, Wilson RR. 2017. GOMMAPPS- 2017 Seabird Update. Bureau of Ocean Energy Management, Information Transfer Meeting, New Orleans, LA.
- Gleason JS, Wilson RR. 2017. GOMMAPPS seabird planning update. Gulf of Mexico Oil Spill & Ecosystem Science Conference, Special Session-BOEM Gulf of Mexico Marine Assessment Program for Protected Species, New Orleans, LA.
- Gleason JS, Wilson RR. 2018. GOMMAPPS seabird planning update. Gulf of Mexico Oil Spill & Ecosystem Science Conference, Special Session-BOEM Gulf of Mexico Marine Assessment Program for Protected Species, New Orleans, LA.
- Gleason JS, Wilson RR, Jodice PGR, Lyons JE, Zipkin EF, Silverman ED, Haney JC, Satgé YG, Adams EM, Earsom SD, Koneff MD, Wortham JS. 2018. Gulf of Mexico Marine Assessment Program for Protected Species (GOMMAPPS): a nexus to regulatory decision- making in Symposium entitled, "Setting regional priorities for research and monitoring bird populations in the face of uncertainty" at the 136th American Ornithological Society Conference in Tucson, AZ.
- Gleason JS, Wilson RR, Tirpak JM. 2016. GOMMAPPS seabird perspectives- overview from the U.S. Fish & Wildlife Service. Gulf of Mexico Oil Spill & Ecosystem Science Conference, Special Session-BOEM Gulf of Mexico Marine Assessment Program for Protected Species, Tampa, FL.
- Green RE, Gleason JS, Lamont MM, Mullin KD. 2017. Assessing broad-scale abundance and distribution of marine mammals, sea turtles, and seabirds in the Gulf of Mexico- the new GOMMAPPS field program. Gulf of Mexico Oil Spill & Ecosystem Science Conference, New Orleans, LA.
- Haney JC. 2017. Importance of the eastern Gulf of Mexico to marine birds. Florida Marine Science Symposium, October 25, 2017, Tampa, FL.
- Haney JC, Gleason JS, Jodice PGR, Michael PE, Hixson KM, Satgé YG, Wilson RR, Davis KL, Zipkin EF. 2022. Research applications from GOMMAPPS wildlife surveys to offshore wind energy development in the Gulf of Mexico. Atlantic Marine Bird Cooperative Annual Meeting, 29 Nov-1 Dec (Virtual).
- Haney JC, Gleason JS, Wilson RR, Jodice PGR, Satgé YG, Michael PE, Hixon KM. 2022. What is GOMMAPPS? Meeting with National Audubon Society, 5 July 2022 (Virtual).
- Haney JC, Michael PE, Gleason JE, Hixson KM, Satgé YG. 2023. Flight behaviors in subtropical seabirds exacerbate collision risk for wind energy development in offshore waters. Conference on Wind Energy and Wildlife Impacts, Šibenik, Croatia.
- Haney JC, Michael PE, Gleason JS, Hixson KM, Satgé YG. 2023. Flight behaviors in subtropical seabirds exacerbate collision risk for wind energy development in deep-water environments. 47th Annual Meeting of the Waterbird Society, Ft. Lauderdale, FL.
- Haney JC, Satgé YG, Gleason JS, Jodice PGR, Wilson RR. 2019. When gaps aren't voids: what we (don't) know about marine birds in the Gulf of Mexico. Gulf of Mexico Oil Spill & Ecosystem Science Conference, New Orleans, LA.

- Jodice PGR. 2023. Conservation issues for seabirds in the Gulf of Mexico: physiology and geographic range. Louisiana Tech. University, Spring Seminar Series, 30 January 2023 (Virtual).
- Jodice PGR, Gleason JS, Haney JC, Satgé YG, Michael PE. 2019. The Gulf of Mexico Marine Assessment Program for Protected Species: Development and implementation of largescale, longterm monitoring strategies. Joint Annual Conference of The American Fisheries Society and The Wildlife Society, Reno, NV.
- Jodice PGR, Satgé YG, Gleason JS, Keitt BS, Gaskin CP, Haney JC. 2024. Distribution of a globally endangered seabird in the northern Gulf: a range revision for the Black-capped Petrel. The Gulf of Mexico Conference, Tampa, FL.
- Jodice PGR, Satgé YG, Michael PE, Gleason JS, Haney JC, Keitt BS, Gaskin CP. 2020. Revising the marine range of the endangered Black-capped Petrel. Pacific Seabird Group Annual Meeting, Portland, OR.
- Michael PE, Gleason JS, Haney JC, Hixson KM, Satgé YG, Jodice PGR. 2022. Black terns in the northern Gulf of Mexico: Vessel-based observations and insights from the Gulf of Mexico Marine Assessment Program for Protected Species (GOMMAPPS). 46th Annual Meeting of the Waterbird Society, Corpus Christi, TX. Paper.
- Michael PE, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2019. Black terns in the northern Gulf of Mexico: initial observations from the Gulf of Mexico Marine Assessment Program for Protected Species. 43rd Annual Meeting of the Waterbird Society, Salisbury, MD.
- Michael PE, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2019. Distribution and abundance of marine birds in an industrialized sea: vessel-based surveys in the Gulf of Mexico. Pacific Seabird Group Annual Meeting, Kauai, HI.
- Michael PE, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2019. Novel insights on the distribution and abundance of seabirds from vessel-based surveys in the northern Gulf of Mexico. Gulf of Mexico Oil Spill & Ecosystem Science Conference, New Orleans, LA.
- Michael PE, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2020. Flyingfish and feathers: habitat associations and avifaunal associations of flying-fish in the northern Gulf of Mexico. World Fisheries Congress, Adelaide, Australia.
- Michael PE, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2020. Marine bird distributions in the Gulf of Mexico: informing marine spatial planning. World Seabird Conference 3, Hobart, Australia.
- Michael PE, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2020. Flying without a passport: northern Gulf of Mexico exemplifies multi-national use with uncertain origin of seabirds. 6th Annual World Seabird Twitter Conference, 4-6 May 2020. Available at: https://www.seabirds.net/events/wstc/
- Michael PE, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2020. Diversity and distribution of seabirds in pelagic waters of the northern Gulf of Mexico. Gulf of Mexico Oil Spill & Ecosystem Science Conference, Tampa, FL.
- Michael PE, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2021. Flying without a passport: hosting traveling seabirds in the northern Gulf of Mexico. 7th Annual World Seabird Twitter Conference, 4-6 May 2021. Available at: https://www.seabirds.net/events/wstc/

- Michael PE, Haney JC. 2024. Preliminary profiles for seabird flight heights in the northern Gulf of Mexico. NYSERDA, State of the Science Workshop on Offshore Wind, Wildlife, and Fisheries, Stony Brook, NY. Poster.
- Michael PE, Haney JC, Gleason JS, Hixon KM, Satgé YG, Jodice PGR. 2025. Flying fish habitat and cooccurrence with seabirds in the northern Gulf of Mexico. Waterbird Society/Pacific Seabird Group Joint Meeting, San Jose, Costa Rica, 6-9 January 2025. Paper.
- Michael PE, Hixon KM, Gleason JS, Haney JC, Satgé YG, Jodice PGR. 2021. Exposure, sensitivity, and uncertainty: understanding the vulnerability of seabirds to oil interactions in the northern Gulf of Mexico. American Geophysical Union Fall Meeting, New Orleans, LA.
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DOI Minted: https://doi.org/10.25921/afrq-h385

Citation:

Gleason JS, Wilson RR, Jodice PGR, Satgé YG, Michael PE, Hixson KM, Sussman AL, Haney JC. 2022. Seabird visual surveys using line-transect methods collected from NOAA vessels in the northern Gulf of Mexico for the Gulf of Mexico Marine Assessment Program for Protected Species (GOMMAPPS) project from 2017-07-21 to 2019-09-25 (NCEI Accession 0247206). U.S. Department of the Interior, Bureau of Ocean Energy Management. NOAA National Centers for Environmental Information. Unpublished dataset. https://doi.org/10.25921/afrq-h385





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