Density estimates of common bottlenose dolphin (*Tursiops truncatus*) for the U.S. east coast and Gulf of Mexico estuaries:

Supplementary Report

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November 27, 2023

Acknowledgments

We would like to thank all of the marine mammal experts (named and unnamed in this report) and the Duke University Marine Geospatial Ecology Lab members that have shared their time, advice, data, and feedback on this project. Additionally, we thank all of the scientists that have collected and analyzed data that made it possible to provide estimated marine mammal densities. Funding for this project was provided by United States Fleet Forces Command and was managed on their behalf by Naval Facilities Engineering Systems Command, Atlantic.

Introduction

Purpose and background

All populations of common bottlenose dolphins (*Tursiops truncatus*) are protected under the United States [US] Marine Mammal Protection Act (MMPA), where the conservation of these animals requires minimizing any potential interaction or disturbance. Common bottlenose dolphins are distributed within estuaries, nearby coastal areas, and the open ocean, and the best available data are needed to estimate their density, in order to understand potential risks of proposed activities to marine mammals in these areas. To date, 35 strata (distinct areas of interest defined by the US Navy) have been identified within estuarine waters: 22 strata within 6 regions along the US east coast (EC), Atlantic Ocean and 13 strata within 9 regions along the US Gulf of Mexico (GOM) coast. Several populations of common bottlenose dolphins are known to be present within all 35 strata (Fig. 1).

Roberts (2015) provided density and associated uncertainty estimates to the US Navy for each of the 35 estuarine strata identified as an area of interest during the Phase III modeling cycle. For Phase IV, we evaluated current and past research for the same set of estuarine strata, noted the common bottlenose dolphin population stock in the area, compiled potential sources of information, determined the data source that was the best available to estimate density and uncertainty, included the methods for calculations, and summarized the results with a brief discussion. We provided updates if new information was available or noted where updates were not necessary because a better data source was not currently available.

Final results and geospatial data products for all estuarine strata were delivered to the US Navy within the Marine Species Density Database (NMSDD), as part of the Phase IV marine mammal density modeling updates for the US Navy's Atlantic Fleet Training and Testing (AFTT) study area. This document is a stand-alone final report that supplements the associated common bottlenose dolphin geospatial data products and the separate final report containing the model information for all other marine mammal species included for the US Navy Phase IV NMSDD.

As with Phase III, our objective was to provide density and uncertainty estimates for estuarine strata monthly, seasonally, or year-round, depending on the availability of the data. Seasons were defined as winter (December, January, February), spring (March, April, May), summer (June, July, August), or fall (September, October, November). Densities were reported as dolphins/km^2 and uncertainties were reported as the coefficient of variation (CV).

Our approach for reporting densities and uncertainties differs from how the National Oceanic and Atmospheric Administration National Marine Fisheries (NMFS) assesses marine mammals within their stock assessment reports (SARs), as required under the MMPA. Under the MMPA, stocks are defined as a "group of marine mammals of the same species or smaller taxa in a common spatial arrangement, that interbreed when mature" (16 U.S. Code 1361 § 3). SARs are required to be reviewed by NMFS and US Fish and Wildlife Service (USFWS) every year for all "strategic" stocks and every three years for "non-strategic" stocks. All common bottlenose dolphin stocks that we identified as having geographic extents overlapping with the US Navy NMSDD strata were considered "strategic" except for two stocks within two strata: Sabine Lake and St. Andrew Bay (Hayes et al. 2022). Many stocks had geographic extents that ranged outside of the US Navy strata and some of the US Navy strata were also known to contain more than one stock. In cases where it was reported that multiple stocks mixed, such as the edges of an estuary where a resident estuarine stock mixed with a coastal stock that makes incursions into the estuary, we did not differentiate among stocks and provided estimated densities for all common bottlenose dolphins for that geographic area, based on the best available data.

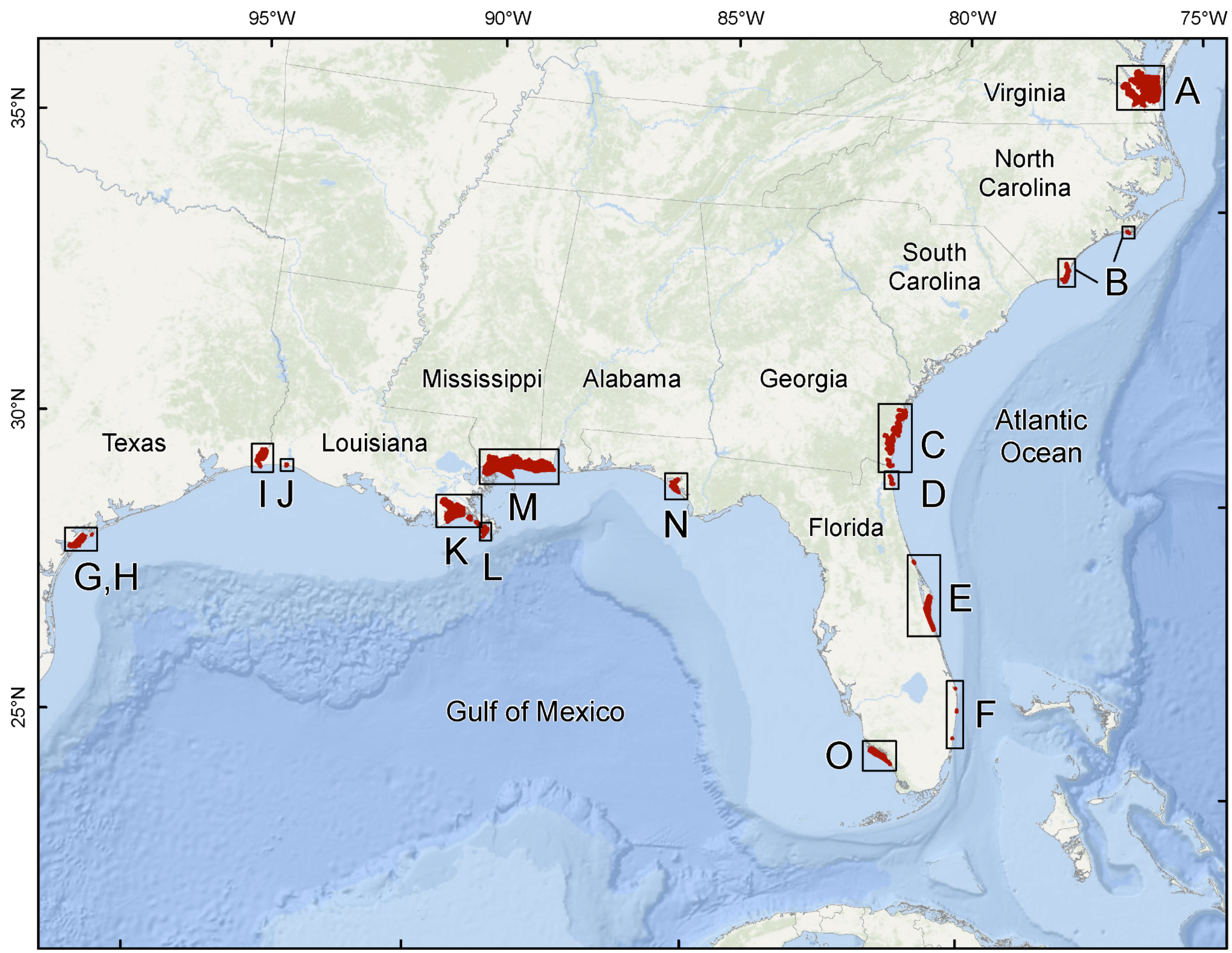

Fig. 1. NMSDD estuarine strata (in red) within the EC (A-F) and GOM coast (G-O). For more details on the strata within labeled regions A-O, see Table 1. US state boundary source: GADM (2018); land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Strategies for identifying the best available data sources

We determined the most relevant, current source of data from the potential list of results within Clarivate's Web of Science citation database, sources reported by the most updated NMFS common bottlenose dolphin stock assessment reports (i.e., Waring et al. 2013, 2016; Hayes et al. 2017, 2018, 2019, 2020), data sources used by Roberts (2015), personal communication with experts (including the US Navy and NMFS), or data from regional models (i.e., Roberts et al. 2022; Southeast Fisheries Science Center 2022). After reviewing potential data sources, we compared our approach with the method used in Phase III for each estuarine stratum and determined if new or improved information was available for estimating common bottlenose dolphin in estuaries within the EC and GOM, or if no changes were necessary from estimates calculated for Phase III. Model versions were updated when density and uncertainty estimates were changed, similar to those detailed within Roberts (2015). The final method used to calculate the density estimate and uncertainty for each stratum was categorized into one of four model types:

1) Model type = External study: Between February and March 2022, we conducted a brief but targeted search for the most current literature with abundance or density estimates within each specific estuary or stratum for common bottlenose dolphins. We searched within the Web of Science (WOS) database and other subscribed collections (BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC) using the search string was for topics = ("dolphin" AND ("density" or "abundance") AND ([estuary name] OR [stock name] OR [US state name]). We replaced the "estuary name" with the names of the strata, the "stock name" with names of the common bottlenose dolphin stocks identified by the NMFS, and the "US state name" with the US state that the estuary was found within.

If available, we used the most relevant source that was published after the most current stock assessment report for the stock, as of March 2022, that occurred with good overlap within the NMSDD strata. For example, if the most current stock assessment report was published in 2017 and we identified relevant data published in 2022, we assessed the methods and results in the most recent source and applied those data to update density estimates within this report. However, if estimates were determined by the study using data that did not overlap sufficiently with the NMSDD strata, or if estimates did not cover all common bottlenose dolphin stocks within the NMSDD strata when more than one stock was present, we expanded our search for any updated literature that would be useful for calculating density estimates and uncertainty since Roberts (2015).

If relevant sources were not identified by our literature search for recent publications, we reviewed the most current stock assessment report to compare the geographic extent of the stock with the US Navy's estuarine strata and applied the best available data identified within the stock assessment report to calculate density estimates. If these data sources were the same as identified by Roberts (2015), we referred to density estimates provided in Phase III. For Phase III, Roberts (2015) used two methods to calculate density estimates (and uncertainty) when data were available from publications (model type = external study) or provided directly (model type = uniform density model). If these data sources were not the same, we updated the density estimates using the more current data (external study), when methods were appropriate and the research overlapped well with the NMSDD strata.

2) Model type = Habitat-based density model: For Phase III, Roberts (2015) used supplemental data, directly provided by scientists, to estimate densities for a subset of NMSDD strata. More details on the data provided for four strata in the Chesapeake Bay, Virginia region (Department of the Navy 2014) and the methods for developing the uniform density model were available in Roberts (2015); we used the same estimates for Phase IV when we determined this as the best approach.

3) Model type = Uniform density model: For Phase III, Roberts (2015) used supplemental data, directly provided by scientists, to estimate densities for a subset of NMSDD strata. More details on the data provided four strata in the regions within the GOM (Blaylock and Hoggard 1994) and the methods for developing the uniform density model were available in Roberts (2015); we used the same estimates for Phase IV when we determined this as the best approach.

4) Model type = Spatial extrapolation: If data were not available from Steps 1-3, we based density estimates (and uncertainty) on the updated regional models from the EC (Roberts et al. 2022) or GOM (Southeast Fisheries Science Center 2022), made available for Phase IV. We applied the value from the raster or hexagon cell directly overlapping the stratum (represented as a polygon) to the stratum whenever possible. When estuarine strata did not directly overlap a raster or hexagon cell with data (values > 0) within the EC or GOM model, we used the adjacent cells with data (values > 0) to extrapolate densities and uncertainties. Estimated density (dolphins/km^2) was calculated by averaging the density of adjacent cells. Estimated uncertainty (CV) was calculated by determining the overall: 1) variance = sum of the mean variance of adjacent cells plus the mean variance between adjacent cells, 2) standard deviation = square root of overall variance, and 3) CV = overall standard deviation/mean density. Similar data extrapolation methods were also used in Roberts (2015) when no post-1994 estimate was available and the estuary was not included in the Blaylock and Hoggard (1994) study (identified as the most relevant data at the time).

Finally, we also contacted marine mammal experts that have studied or were currently studying estuarine common bottlenose dolphin in the regions of interest to ask for advice on recent research or available data for density estimates. Communication with leading experts helped to confirm the most recent references found within the literature, ongoing or upcoming studies, and appropriate application of the available data.

Table 1. Density estimate details for the US east coast, Atlantic Ocean (EC) and Gulf of Mexico (GOM) estuarine strata and substrata. When an estimated density was provided per substrata, the total number of substrata was included in parenthesis. *Updated from Phase III. For an overview map of all strata within regions (A-O), please see Fig. 1.

Area	Region and stratum	Period	Model type	Model version
EC	A) Chesapeake Bay, Virginia			
	Chesapeake Bay (31)	Year	Habitat-based density model	2015.02.18 Chesapeake Bay v1
	James River (26)	Year	Habitat-based density model	2015.02.18 Chesapeake Bay v1
	Mobjack Bay (16)	Year	Habitat-based density model	2015.02.18 Chesapeake Bay v1
	York River (5)	Year	Habitat-based density model	2015.02.18 Chesapeake Bay v1
EC	B) Southern North Carolina			
	Beaufort Inlet	Year	External study	*Beaufort Inlet v1
	Cape Fear River	Year	External study	*Cape Fear River v1
EC	C) Southern Georgia			
	Sapelo Sound	Season	External study	Southern Georgia v1
	Doboy Sound	Season	External study	Southern Georgia v1
	Altamaha River	Season	External study	Southern Georgia v1
	Hampton River	Season	External study	Southern Georgia v1
	St. Simons Sound	Season	External study	Southern Georgia v1
	St. Andrew Sound	Season	External study	Southern Georgia v1
	Cumberland Sound	Season	External study	Southern Georgia v1
EC	D) Jacksonville, Florida			
	Nassau Sound	Month	Spatial extrapolation	*2022.05.01 AFTTv4 ECv6 GoMMAPPSv2
	St. Johns River	Month	Spatial extrapolation	*2022.05.01 AFTTv4 ECv6 GoMMAPPSv2
EC	E) Indian River Lagoon, Florida			
	Ponce de Leon Inlet	Season	External study	*Indian River v2

Area	Region and stratum	Period	Model type	Model version
	Banana River	Season	External study	*Indian River v2
	Indian River North	Season	External study	*Indian River v2
	Indian River South	Season	External study	*Indian River v2
EC	F) Southeast Florida			
	Loxahatchee River	Month	Habitat-based density model	*2022.05.01 AFTTv4 ECv6 GoMMAPPSv2
	Lake Worth	Month	Spatial extrapolation	*2022.05.01 AFTTv4 ECv6 GoMMAPPSv2
	Lake Mabel	Month	Spatial extrapolation	*2022.05.01 AFTTv4 ECv6 GoMMAPPSv2
GOM	G) Corpus Christi Bay, Texas			
	Corpus Christi Bay	Year	Uniform density model	Corpus Christi Bay v1
GOM	H) Redfish Bay, Aransas Bay, Mesquite Bay, Texas			
	Mesquite Bay	Year	Uniform density model	Redfish, Aransas Bays v1
	Redfish Bay Aransas Bay	Year	Uniform density model	Redfish, Aransas Bays v1
GOM	I) Sabine Lake, Texas and Louisiana			
	Sabine Lake	Year	External study	*Sabine Lake v2
GOM	J) Calcasieu Lake, Louisiana			
	Calcasieu Lake	Year	Uniform density model	Calcasieu Lake v1
GOM	K) Barataria Bay, Louisiana			
	Barataria Bay Caminada Bay	Year	External study	*Barataria Bay Bay v2
	Bastian Bay Shell Island Bay	Year	External study	*Barataria Bay Bay v2

Area	Region and stratum	Period	Model type	Model version
	Bay Coquette	Year	External study	*Barataria Bay Bay v2
GOM	L) Western Mississippi River Delta, Louisiana			
	Scott Bay Dixon Bay	Month	Spatial extrapolation	*2022.05.01 AFTTv4 ECv6 *GoMMAPPSv2
	Southwest Pass	Month	Spatial extrapolation	*2022.05.01 AFTTv4 ECv6 GoMMAPPSv2
GOM	M) Mississippi Sound, Lake Borgne, Mississippi and Alabama			
	Mississippi Sound Lake Borgne	Season	External study	*Mississippi Sound v2
GOM	N) St. Andrew Bay, Florida			
	St. Andrew Bay	Year	External study	*St Andrew Bay v2
	O) Gullivan Bay, Ten Thousand Islands, Florida			
	Gullivan Bay Ten Thousand Islands (18)	Month	Habitat-based density model (12); Spatial extrapolation (6)	*2022.05.01 AFTTv4 ECv6 GoMMAPPSv2

US East Coast Estuaries

Chesapeake Bay, Virginia Region

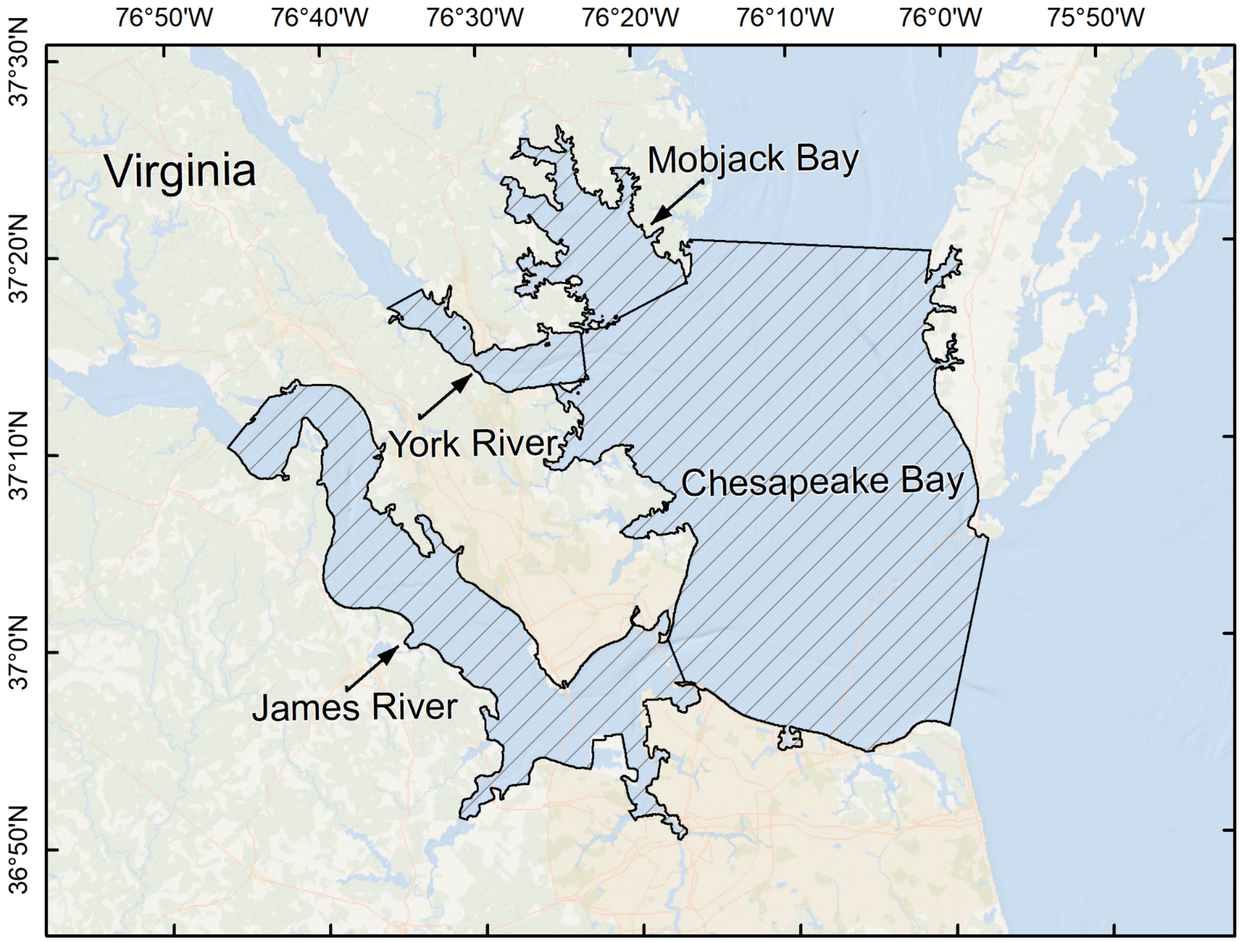

Fig. 2. The NMSDD strata (hatched areas) included in the Chesapeake Bay, Virginia region (n = 4): Chesapeake Bay, James River, Mobjack Bay, York River. Land and water sources: Esri, Garmin, General Bathymetric Chart of the Oceans (GEBCO), National Oceanic and Atmospheric Administration National Centers for Environmental Information (NGDC), and other contributors.

Common bottlenose dolphins found in the NMSDD strata within the Chesapeake Bay, Virginia region have been identified as individuals from the Northern North Carolina Estuarine System (NNCES) or Western North Atlantic Southern Migratory Coastal stocks (Hayes et al. 2021). The entire geographic extent of the NNCES stock included areas south of the Chesapeake Bay to New River, North Carolina but mainly occupied areas in the Pamlico Sound estuarine system, North Carolina (Garrison et al. 2017b; Hayes et al. 2021). The entire geographic extent of the Western North Atlantic Southern Migratory Coastal stock was still largely unknown, but has been found to overlap several other common bottlenose dolphin stocks including areas north of the Chesapeake Bay to Assateague, Virginia and areas to the south to northern Florida (Garrison et al. 2017a; Hayes et al. 2021). Therefore, the NMSDD strata in this region overlapped with only a small proportion of the extents of common bottlenose dolphin stocks identified in these waters (Fig. 2).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Chesapeake Bay, Virginia region, and found a few potential sources published since 2015 (e.g., Bailey et al. 2021; Rodriguez et al. 2021). In addition to searching for current literature, we contacted several marine mammal experts to request any available data or recent common bottlenose dolphin studies within the Chesapeake Bay, Virginia region. Personal communication requests for information that could be used to estimate common bottlenose dolphin density were sent via email to Anne-Marie Jacoby (Duke University, 1/28/2022), Janet Mann (Georgetown University / Potomac-Chesapeake Dolphin Project, 2/9/2022), Lauren Rodriguez (University of Maryland, Chesapeake Biological Laboratory, 1/28/2022), Helen Bailey (University of Maryland, Chesapeake Biological Laboratory, 2/11/2022), Dolphin Watch (University of Maryland, Chesapeake Biological Laboratory, 2/18/2022), Danielle Jones (US Navy, 2/9/2022), Mark Cotter (HDR Environmental, 2/11/2022), Jessica Aschettino (HDR Environmental, 2/11/2022), Sue Barco (Virginia Aquarium, 3/8/2022), Lance Garrison (NMFS Southeast Fisheries Science Center [SEFSC], 2/25/2022), and Amy Engelhaupt (Amy Engelhaupt Consulting, 2/11/2022). All contacts, except for A. Engelhaupt, confirmed that they did not have any suggestions for better sources of data than what was published by the Department of the Navy (2014). A. Engelhaupt responded to the request by sharing that she may have more recent survey data that could be used to estimate common bottlenose dolphin density around the Cape Henry, Virginia area, but applying this density estimate to areas further upstream may lead to misleadingly high values, especially for the western tributaries. Furthermore, applying the Cape Henry density estimate to coastal areas may also lead to a misrepresentation because higher concentrations of common bottlenose dolphins were known to occur there, compared to the Cape Henry area. However, her paper discussing these surveys was currently in press and data could not be shared at this time.

Because updated research or better sources of data (both peer-reviewed and grey literature) on common bottlenose dolphins within these strata was not available, we did not change our methods or update estimates from Phase III (Table 1). Therefore, we followed methods in Roberts (2015) to provide year-round estimated density for common bottlenose dolphins, summarized within 1/12 degree cells (substrata), in the Chesapeake Bay, Virginia region by using published data provided directly from the Centre for Research into Ecological & Environmental Modelling [CREEM] at University of St. Andrews and US Navy (see Department of the Navy 2014). Data were collected using aerial surveys in 2011-2012, with transects that overlapped the NMSDD strata in this region.

Results and discussion

The estimated density for common bottlenose dolphins, using the mean CREEM prediction (Department of the Navy 2014), resulted in year-round estimates within 78 substrata (smaller subdivisions within the larger NMSDD strata; Table 2; Fig. 3). Roberts (2015) compared and discussed these year-round results within the estuarine areas and coastal model from Phase III. Similarly, these year-round estimates corresponded more closely to coastal densities developed by Roberts (2022) for the summer months. Significant data gaps still remain that prevent better monthly density estimates in the Chesapeake Bay, Virginia region, especially for the winter and fall.

Table 2. Summary statistics of the density (dolphins/km^2) and uncertainty (CV) estimated for each stratum (number of substrata in parentheses) in the Chesapeake Bay, Virginia region, by using data from Department of the Navy (2014). CVs presented here were calculated from between substrata values, without taking into account the uncertainty within substrata (CV = standard deviation of density/mean density).

	Density			
Stratum	**Minimum**	**Maximum**	**Mean**	**CV**
Chesapeake Bay (31)	0.56	2.93	1.65	0.39
James River (26)	0.86	1.74	1.33	0.15
Mobjack Bay (16)	0.99	2.05	1.46	0.21
York River (5)	1.14	2.05	1.62	0.22

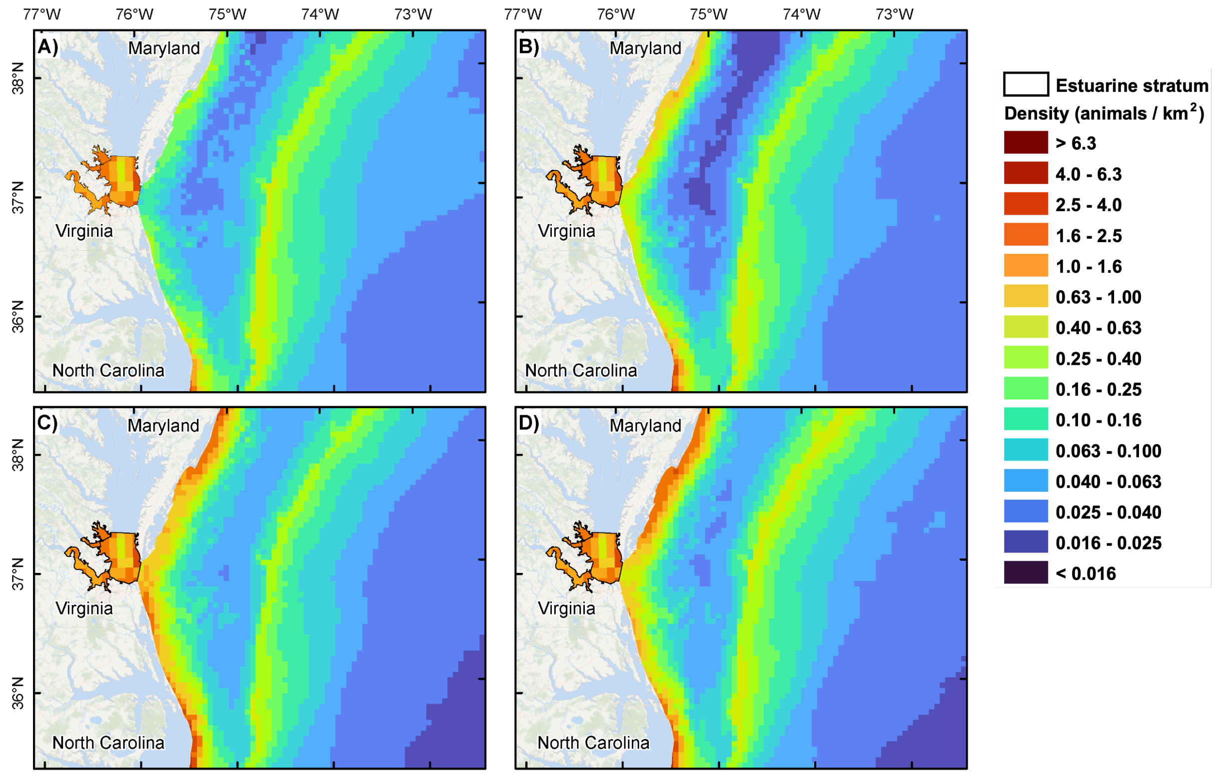

Fig. 3. Common bottlenose dolphin densities for the NMSDD estuarine strata in the Chesapeake Bay, Virginia region (outlined in black) using data from Department of the Navy (2014), along with the monthly densities in the EC from Roberts et al. (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Year-round density estimates were calculated within estuarine strata and monthly density estimates were calculated within the US east coast stratum, but only four months were presented here as an example from each season. EC model raster cell size: 25 km^2. US state boundary source: GADM (2018); land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Southern North Carolina Region

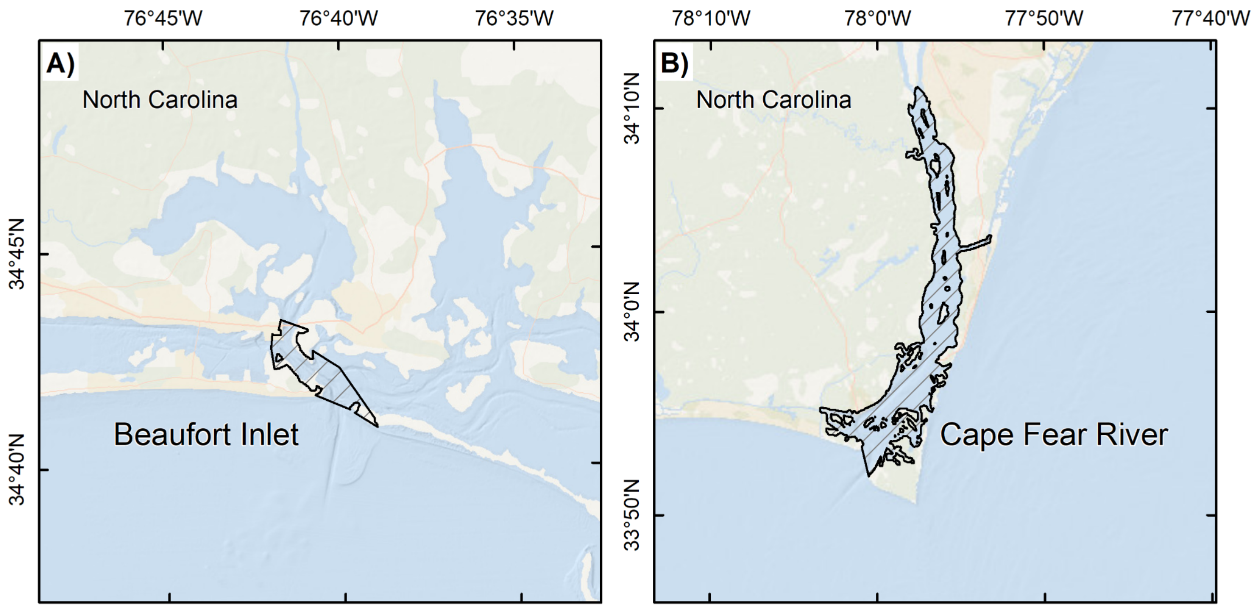

Fig. 4. The NMSDD strata (hatched areas) included in the southern North Carolina region (n = 2): a) Beaufort Inlet, and b) Cape Fear River (right hatched area). Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Common bottlenose dolphins found in the NMSDD strata within the Southern North Carolina region have been identified as individuals from several common bottlenose dolphin stocks, including: the NNCES, Southern North Carolina Estuarine System (SNCES), and Western North Atlantic Southern Migratory Coastal stocks (Maze-Foley et al. 2019; Hayes et al. 2021). Although they occur mainly in the Pamlico Sound estuarine system, the entire geographic extent of the NNCES stock included areas of the Chesapeake Bay, Virginia in the north and areas to New River, North Carolina in the south (Garrison et al. 2017b; Hayes et al. 2021). The entire geographic extent of the SNCES stock included estuarine waters of southern Pamlico Sound in the north to Little River Inlet near the North Carolina/South Carolina border in the south (Read et al. 2003; Rosel et al. 2009; Garrison et al. 2017a; Hayes et al. 2021). Finally, the entire geographic extent of the Southern Migratory Coastal stock was still largely unknown, but have been found to overlap several other common bottlenose dolphin stocks including areas north of the Chesapeake Bay, Virginia to Assateague, Virginia and areas to the south to northern Florida (Garrison et al. 2017a; Hayes et al. 2021). Therefore, the NMSDD strata in this region overlapped with only a small proportion of the extents of common bottlenose dolphin stocks identified in these waters (Figs. 4 and 5).

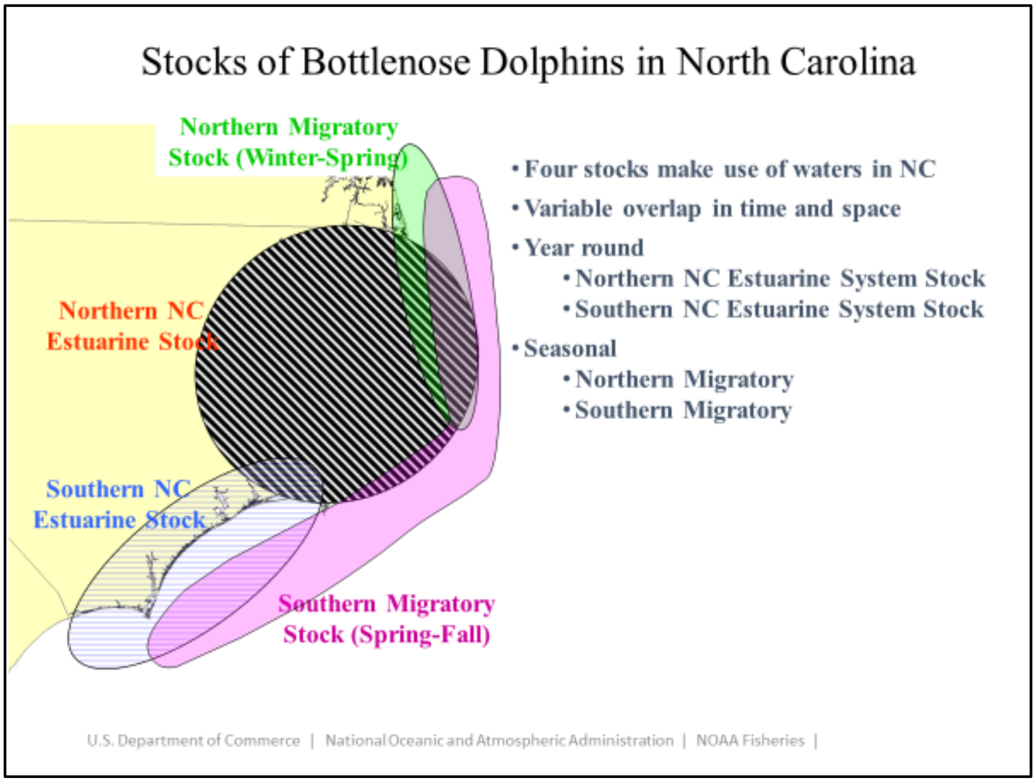

Fig. 5. Estimated ranges for the common bottlenose dolphin stocks found in southern Virginia and North Carolina (Laist 2020). Reproduced with permission from NOAA SEFSC.

Methods

We searched within the literature for updated research on common bottlenose dolphins within the southern North Carolina region, and found one potential source published since 2015 (i.e., Silva et al. 2020). In addition to searching for current literature, we contacted several marine mammal experts to request any available data or recent common bottlenose dolphin studies within the southern North Carolina region. Personal communication requests for information that could be used to estimate common bottlenose dolphin density were sent via email to Kim Urian (Duke University; 1/28/2022), Keith Rittmaster (North Carolina Maritime Museum; 1/28/2022), Lance Garrison (NMFS SEFSC, 2/25/2022), Daniela Silva (Coastal Carolina University, 2/22/2022), Erin LaBrecque (US Marine Mammal Commission, 4/1/2022), Reny Tyson Moore (NMFS Office of Protected Resources [OPR], 4/1/2022), and Jolie Harrison (NMFS OPR, 4/1/2022). K. Urian and K. Rittmaster both confirmed that their studies were not appropriate to apply to density estimates within the NMSDD strata in this region because they do not overlap with the strata. L. Garrison checked with Annie Gorgone (NMFS SEFSC) on their recent abundance data for the southern North Carolina common bottlenose dolphin stock and Cape Fear River surveys (capture-mark-recapture) and reported that the information was currently in review for a journal article and could not be shared at this time. K. Urian and L. Garrison both agreed that data published by Silva et al. (2020) would be the best available to use for estimating densities.

Because a better source of data and updated research on common bottlenose dolphins within these strata was available, we changed our methods and updated estimates from Phase III (Table 1). Therefore, we provided year-round estimated density for common bottlenose dolphins within the southern North Carolina region by using published and supplemental data provided directly from D. Silva (see Silva et al. 2020). Supplemental survey data (sightings and effort) and metadata included information that was published in Silva et al. (2020) where they differentiated dolphins by stocks. The sightings data were reported as dolphins per km surveyed, though D. Silva shared that "good visibility 500 m on either side of the track, so 1 km width would be appropriate" for the survey track width and advised us to calculate densities after assigning sightings to specific strata, based on their location. D. Silva also confirmed that these density estimates, if used for our purposes, could be extrapolated for each month of the year to fill gaps resulting from uneven surveying throughout the year (see Silva et al. 2020).

Survey sightings and effort collected for 10 survey days near the surrounding habitats of the Beaufort NMSDD stratum (Beaufort, Newport, and New River Inlet) and Cape Fear NMSDD stratum (Cape Fear and Little River Inlet) were mapped (QGIS Development Team 2020; ESRI 2022). A subset of sightings and effort data located in estuarine habitats within a 20 km buffer of the strata was selected for estimating density and uncertainty (Table 3; Fig. 6).

Table 3. Summary of survey data used to estimate the density (dolphins/km^2) and uncertainty (CV) for each stratum in the southern North Carolina region, by using data from Silva et al. (2020).

Stratum	Survey days	Effort (km)	Locations (n)	Dolphins (n)	Density	CV
Beaufort Inlet	4	251.43	9	11	0.42	0.36
Cape Fear	6	453.39	14	56	0.16	1.15

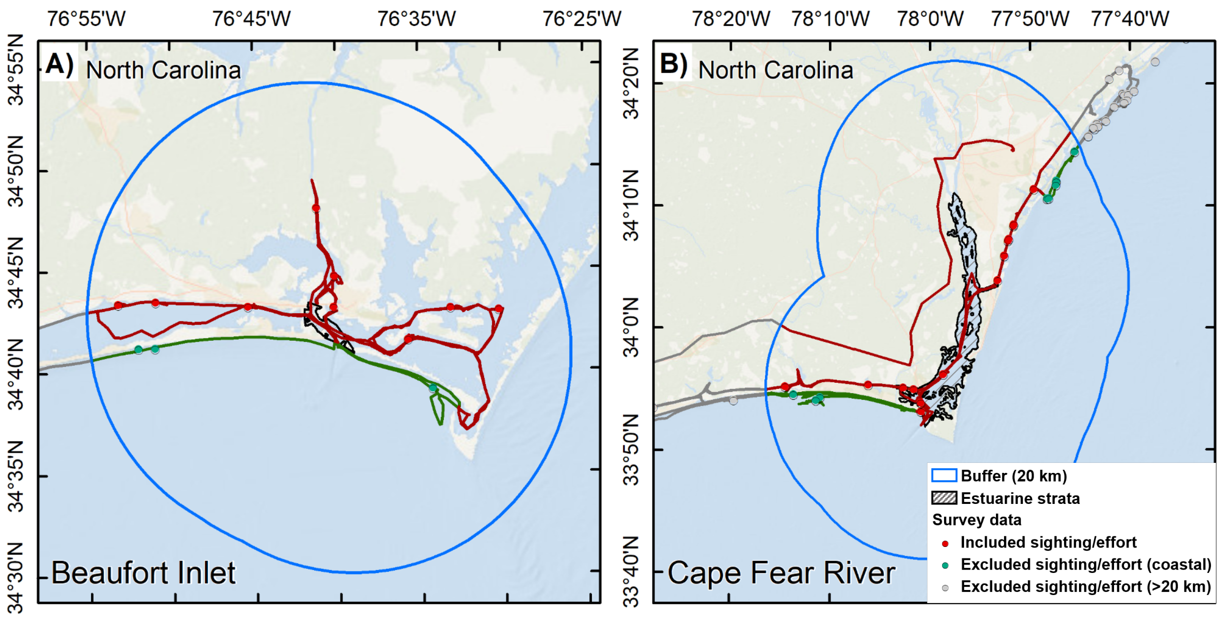

Fig. 6. Sightings and effort from Silva et al. (2020) that were included or excluded in our calculations for estimated common bottlenose dolphins in the a) Beaufort Inlet, and b) Cape Fear River strata. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Results and discussion

The estimated density for common bottlenose dolphins, using the subset of data presented in Silva et al. (2020), resulted in year-round estimates for Beaufort Inlet and Cape Fear River (Table 3; Fig. 7). Estimates within the estuary were lower than nearby coastal areas estimated by Roberts et al. (2022) for all seasons. Although a limited number of surveys were conducted near these strata, these varying results suggested that the spatial and temporal dynamics of common bottlenose dolphin communities in southern North Carolina were still understudied and poorly understood. Capture-mark-recapture surveys for common bottlenose dolphins within this region continue to be conducted by the NMFS and other researchers (see Hohn et al. 2022). As was recommended by Roberts (2015), additional research is still needed to improve upon current abundance and density estimates of common bottlenose dolphins within these strata.

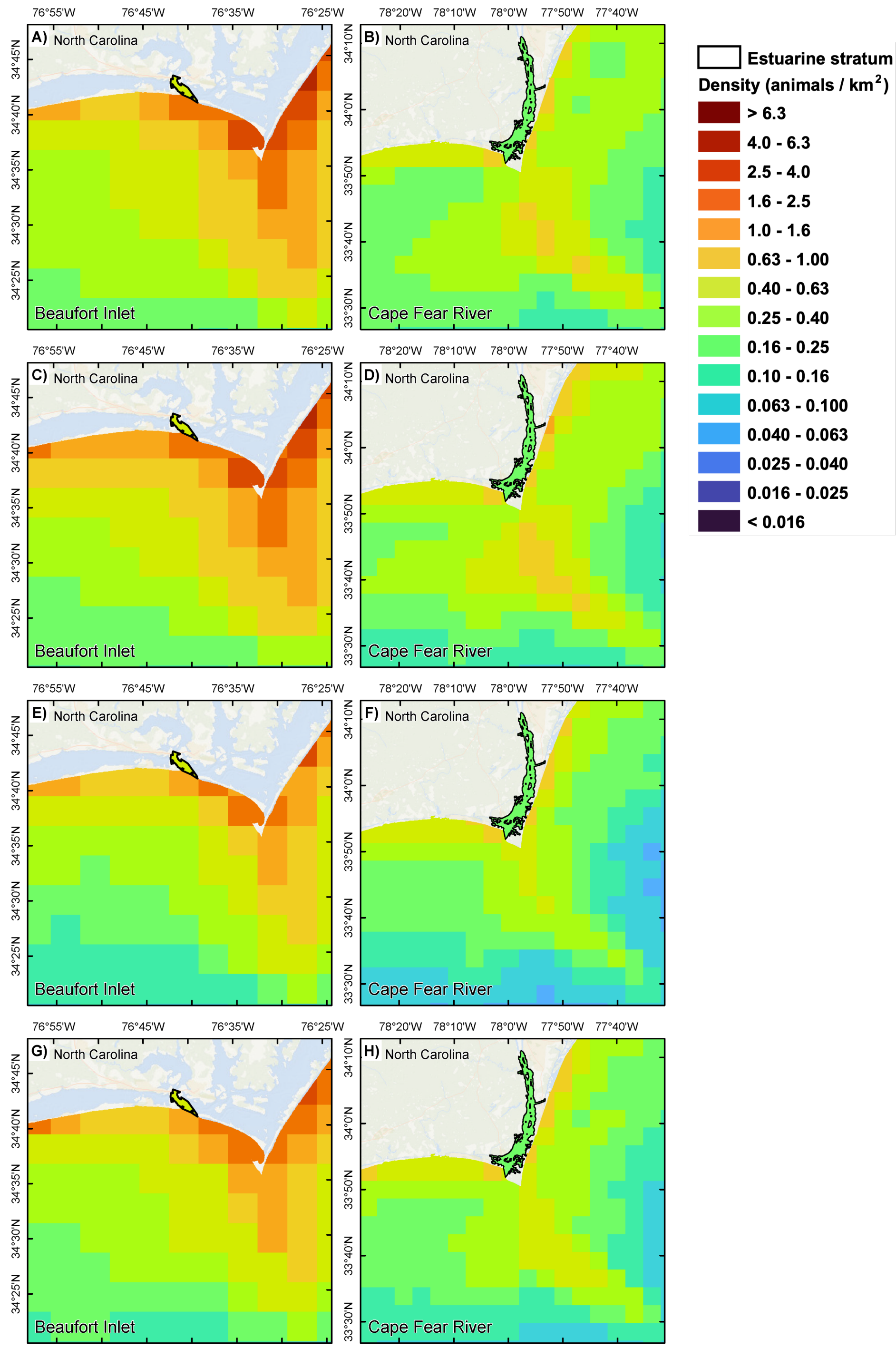

Fig. 7. Common bottlenose dolphin densities for the NMSDD estuarine strata in the southern North Carolina region (outlined in black) using data from Silva et al. (2020), along with the monthly densities in the EC from Roberts et al. (2022) for a-b) January (winter), c-d) April (spring), e-f) July (summer), and g-h) October (fall). Year-round density estimates were calculated within estuarine strata and monthly density estimates were calculated within the US east coast stratum, but only four months were presented here as an example from each season. EC model raster cell size: 25 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Southern Georgia Region

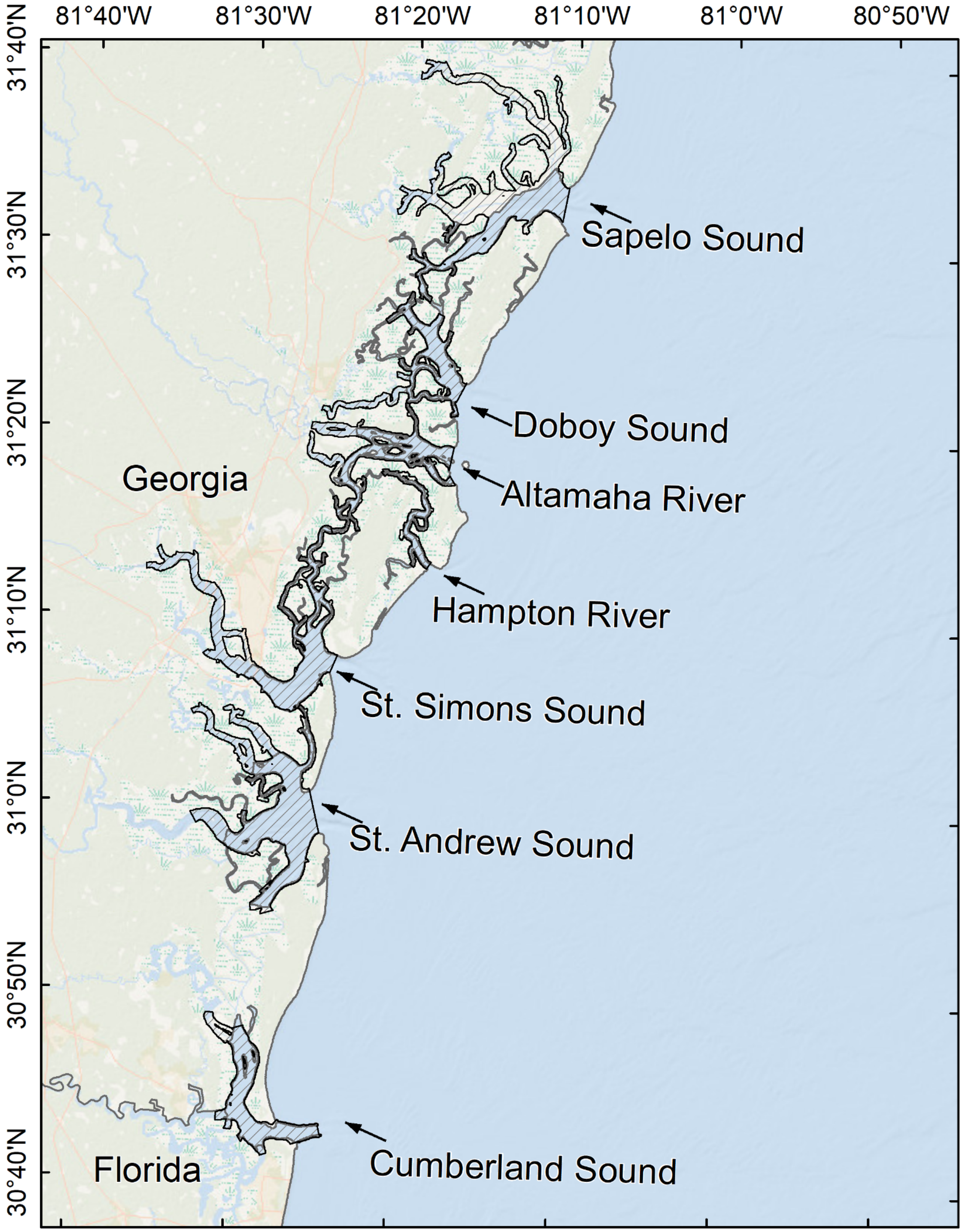

Fig. 8. The NMSDD strata (hatched areas) included in the southern Georgia region, from north to south (n = 7): Sapelo Sound, Doboy Sound, Altamaha River, Hampton River, St. Simons Sound, St. Andrew Sound, Cumberland Sound. US state boundary source: GADM (2018); land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Common bottlenose dolphins found in the NMSDD strata within the southern Georgia region have been identified as individuals from the Central Georgia Estuarine System (CGES) and Southern Georgia Estuarine System (SGES) stocks (Waring et al. 2016). The total geographic extent of the CGES stock included areas outside of NMSDD, bounded by and included Osabaw Sound, Georgia in the north (north of Sapelo Sound) and up to Altamaha Sound, Georgia in the south (Waring et al. 2016). The geographic extent of the SGES stock spanned from and included the Altamaha Sound, Georgia in the north to Cumberland Sound, Georgia in the south (Waring et al. 2016). The CGES stock's extent overlapped with the two northernmost NMSDD strata within the Southern Georgia region: the Sapelo Sound and Doboy Sound; all other NMSDD strata within the Southern Georgia region overlapped with the SGES stock (Fig. 8).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the southern Georgia region, and did not find any potential source published since 2015. In addition to searching for current literature, we contacted several marine mammal experts to request any available data or recent common bottlenose dolphin studies within the southern Georgia region. Personal communication requests for information that could be used to estimate common bottlenose dolphin density were sent via email to Brian Balmer (US Fish and Wildlife Service, 2/18/2022) and Lance Garrison (SEFSC, 2/25/2022). Both marine mammal experts confirmed that the data within Balmer et al. (2013) were the best available for that region.

Because a better source of data or updated research on common bottlenose dolphins within these strata was not available, we did not change our methods or update estimates from Phase III (Table 1). Therefore, we followed methods in Roberts (2015) to provide seasonal estimated density for common bottlenose dolphins in the southern Georgia region by using published data provided from the Balmer et al. (2013) photo-ID surveys conducted in 2008-2009.

Results and discussion

The estimated density for common bottlenose dolphins, presented in Roberts (2015), resulted in seasonal estimates that were greater within the estuaries than nearby coastal areas estimated by Roberts et al. (2022) for all seasons (Table 4; Fig. 9). Although a limited number of surveys were conducted near these strata, these varying results suggested that the spatial and temporal dynamics of common bottlenose dolphin communities in southern Georgia were still understudied and poorly understood. As was recommended by Roberts (2015) for other estuarine areas, additional research is still needed to improve upon current abundance and density estimates of common bottlenose dolphins within these strata.

Table 4. The density (dolphins/km^2) and uncertainty (CV; in parentheses) estimated for each season and stratum in the southern Georgia Region, calculated by Roberts (2015) using data from Balmer et al. (2013). Sapelo Sound estimates were applied to the Sapelo Sound and Doboy Sound NMSDD strata; Brunswick Sound estimates were applied to Altamaha River, Hampton River, St. Simons Sound, St. Andrew Sound, and Cumberland Sound NMSDD strata.

Strata	**Winter: Dec-Feb**	**Spring: Mar-May**	**Summer: Jun-Aug**	**Fall: Sep-Nov**
Sapelo Sound: Sapelo; Doboy	2.23 (0.06)	3.07 (0.07)	3.75 (0.06)	2.97 (0.10)
Brunswick Sound: Altamaha River; Hampton River; St. Simons Sound; St. Andrew Sound; Cumberland Sound	2.49 (0.08)	2.39 (0.10)	3.38 (0.07)	1.05 (0.12)

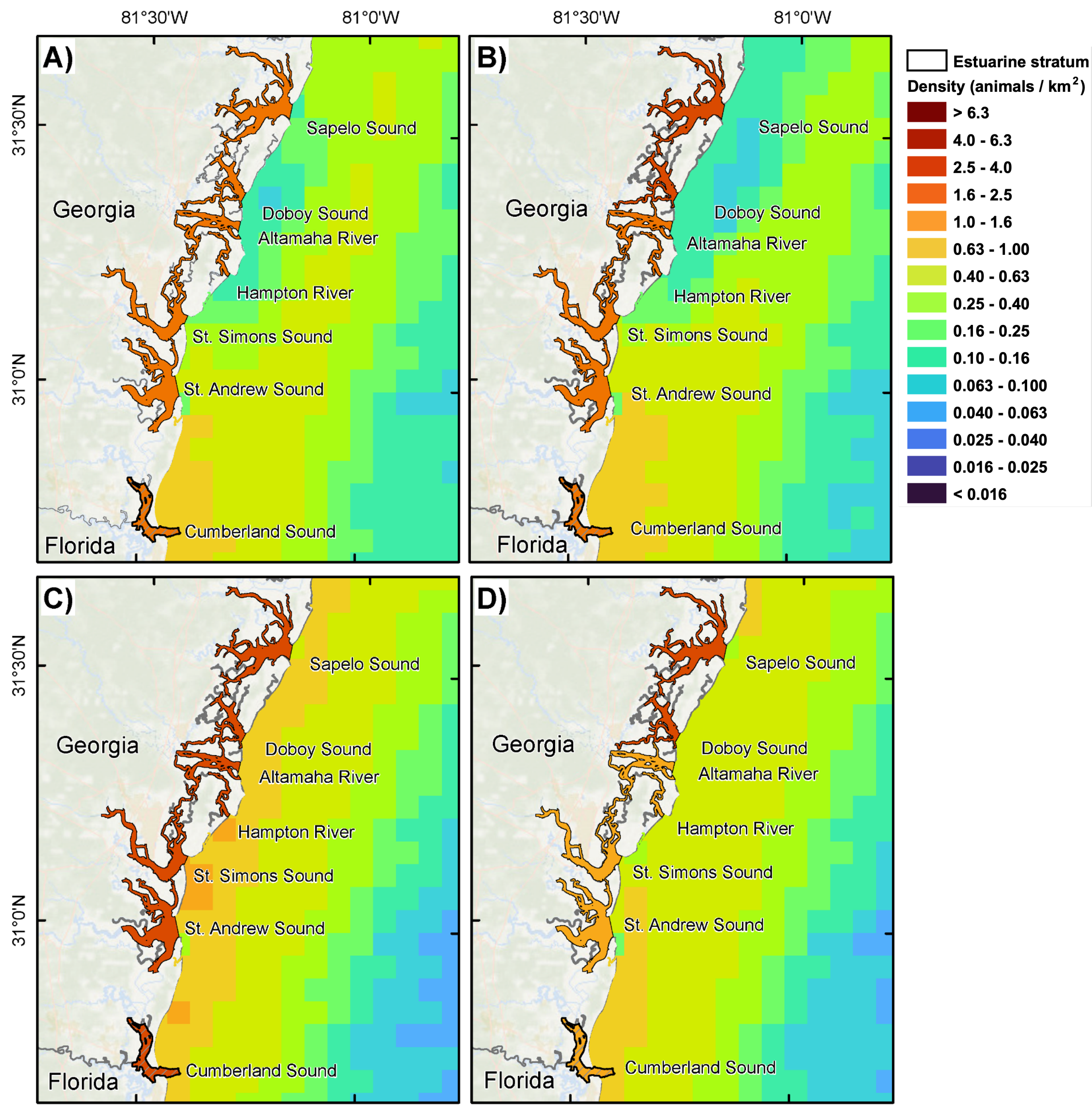

Fig. 9. Common bottlenose dolphin densities for the NMSDD estuarine strata in the southern Georgia region (outlined in black) using data from Balmer et al. (2013), along with the monthly densities in the EC from Roberts et al. (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Seasonal density estimates were calculated within estuarine strata and monthly density estimates were calculated within the US east coast stratum, but only four months were presented here as an example from each season. EC model raster cell size: 25 km^2. US state boundary source: GADM (2018); land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Jacksonville, Florida Region

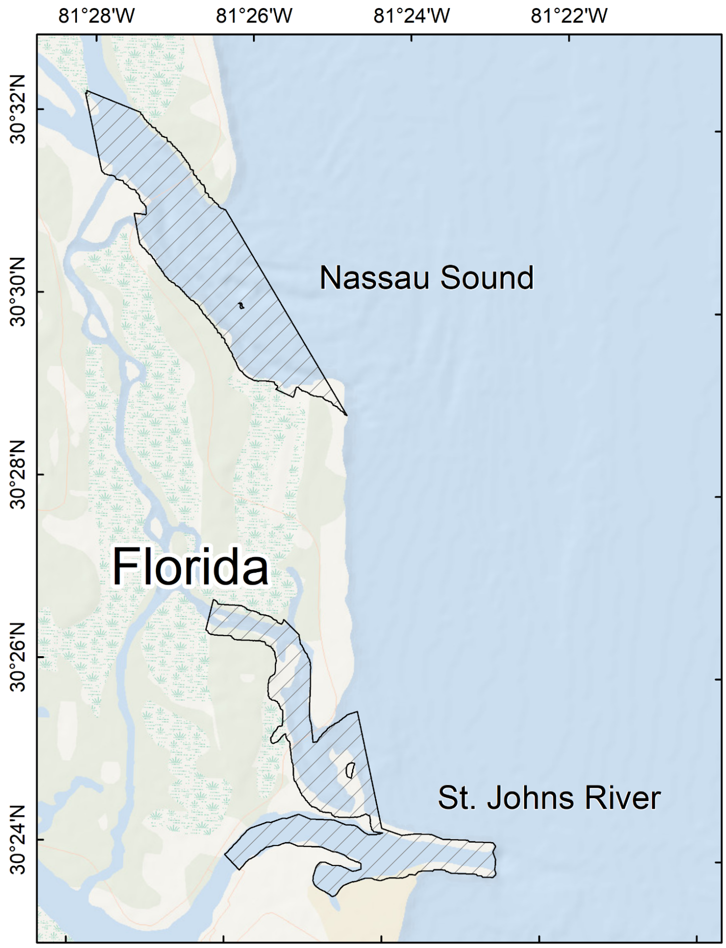

Fig. 10. The NMSDD strata (hatched areas) included in the Jacksonville, Florida region (n = 2): Nassau Sound and St. Johns River. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Common bottlenose dolphins within the Jacksonville estuarine system NMSDD strata have been identified as the Jacksonville Estuarine System (JES) stock (Waring et al. 2016). The extent of the JES stock was within Florida's Nassau Sound (including Amelia River, Nassau River) and St. Johns River (including Chickopit Bay), bounded in the north by Cumberland Sound/St. Marys River Inlet and in the south by Jacksonville Beach (Waring et al. 2016). Therefore, the NMSDD strata in this region overlapped with only a small proportion of the extent of common bottlenose dolphin stock identified in these waters (Fig. 10).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Jacksonville, Florida region, and found a few potential sources published since 2015 (e.g., Ermak et al. 2017; Nekolny et al. 2017; Mazzoil et al. 2020; Szott et al. 2022). The most current assessment of the JES stock was conducted by Waring et al. (2016), reporting the best available information from a photo-identification (photo-ID) and genetic study by Caldwell (2001) and a mark-recapture study by Gubbins et al. (2003). However, the minimum population estimate was determined as unknown because of insufficient data (Waring et al. 2016). Along with Caldwell (2001), published common bottlenose dolphin surveys have been conducted in the area, but did not overlap significantly with the NMSDD strata.

In addition to searching for current literature, we contacted several marine mammal experts to request any available data or recent common bottlenose dolphin studies within the Jacksonville, Florida region. Personal communication requests for information that could be used to estimate common bottlenose dolphin density were sent via email to Marthajane Caldwell (Marine Mammal Behavioral Ecology Studies, Inc., 2/4/2022) and Lance Garrison (SEFSC, 2/25/2022). M. Caldwell sent some additional information on estimated group sizes for their study area and said she was in contact with colleagues, but ultimately said that their data were not appropriate for estimating densities within the NMSDD strata (see Caldwell 2001; Gubbins et al. 2003; Mazzoil et al. 2020). L. Garrison agreed that there were no other sources of data currently available.

Because a better source of data or updated research on common bottlenose dolphins within these strata was not available from external studies, and the data previously used in Roberts (2015) and Waring et al. (2016) were no longer appropriate, we changed our methods and updated estimates from Phase III by using nearby estimated densities (Table 1). Therefore, we used the overlapping cells with data (values > 0) from the most current EC regional density model (see Roberts et al. 2022) to calculate the density (and uncertainty) for common bottlenose dolphins within these strata, similar to extrapolation methods described in Roberts (2015). The Nassau Sound stratum overlapped with a total of five raster cells (four with data and one without data) and the St. Johns River stratum overlapped with a total of four raster cells (two with data and two without data); raster cell size for the EC regional density model was 5 x 5 km.

Results and discussion

The estimated density for common bottlenose dolphins, using the data from Roberts et al. (2022), resulted in monthly estimates that were similar to nearby coastal areas estimated within the EC model (Table 5; Fig. 11). Monthly density estimates were less than the year-round estimate from Roberts (2015). Limited research conducted near these strata suggested that the spatial and temporal dynamics of common bottlenose dolphin communities in the Jacksonville, Florida region were still understudied and poorly understood. As was recommended by Roberts (2015) for other estuarine areas, additional research is still needed to improve upon current abundance and density estimates of common bottlenose dolphins within these strata.

Table 5. The density (dolphins/km^2) and uncertainty (CV; in parentheses) estimated for each month and stratum in the Jacksonville, Florida region, by using data from Roberts et al. (2022).

Month	Nassau Sound	St. Johns River
1	0.92 (0.55)	1.14 (0.51)
2	0.88 (0.56)	1.07 (0.53)
3	0.99 (0.55)	1.08 (0.50)
4	0.97 (0.49)	1.01 (0.45)
5	0.92 (0.52)	0.93 (0.47)
6	0.99 (0.58)	0.97 (0.56)
7	0.86 (0.52)	0.83 (0.49)
8	0.86 (0.51)	0.81 (0.46)
9	0.79 (0.50)	0.86 (0.45)
10	0.81 (0.58)	0.97 (0.52)
11	1.1 (0.54)	1.37 (0.49)
12	1.15 (0.51)	1.45 (0.47)

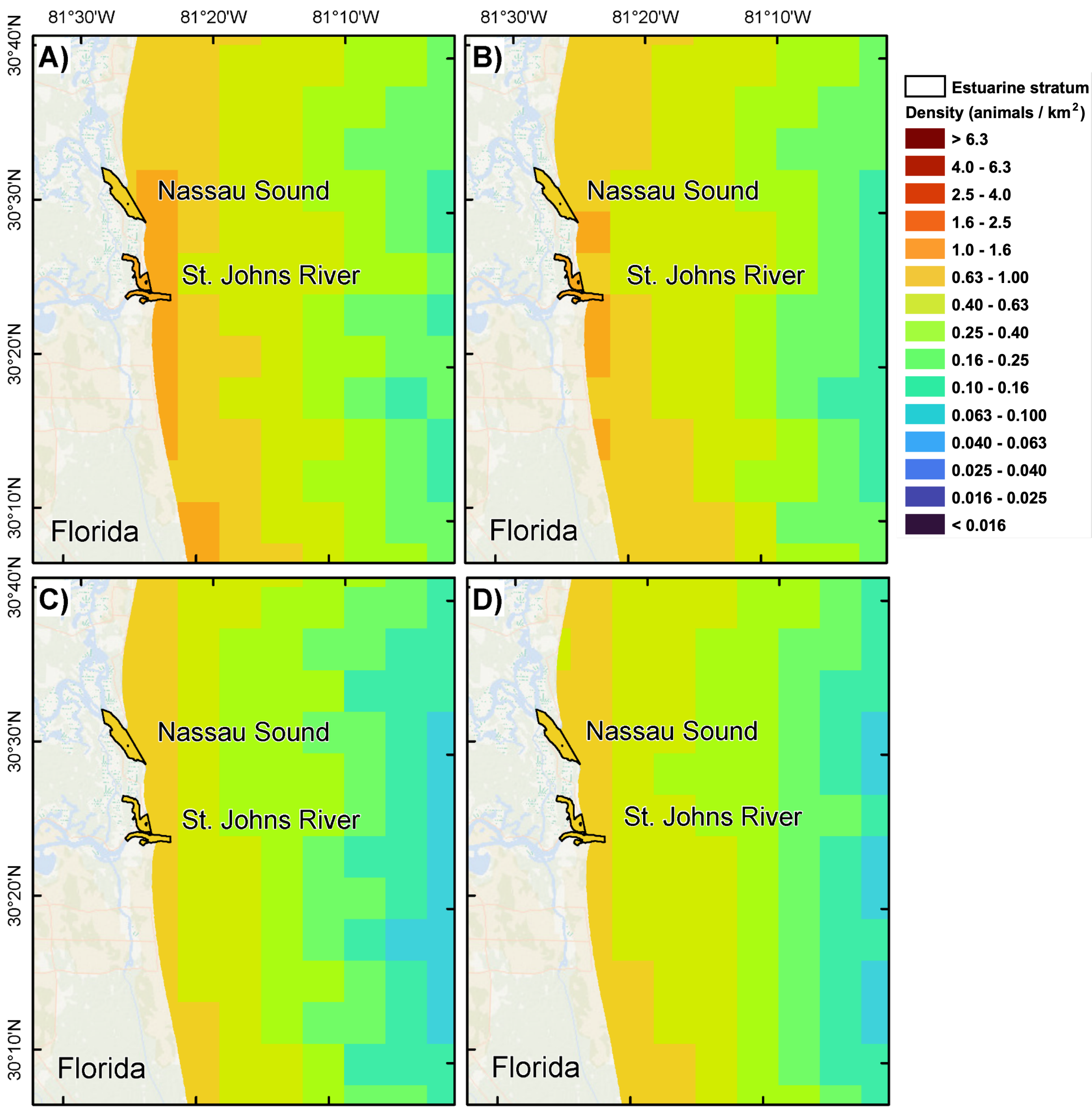

Fig. 11. Common bottlenose dolphin densities for the NMSDD estuarine strata in the Jacksonville, Florida region (outlined in black) using data from Roberts et al. (2022), along with the monthly densities in the EC from Roberts et al. (2022) for a-b) January (winter), c-d) April (spring), e-f) July (summer), and g-h) October (fall). Monthly density estimates were calculated within estuarine and the US east coast strata, but only four months were presented here as an example from each season. EC model raster cell size: 25 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Indian River Lagoon, Florida Region

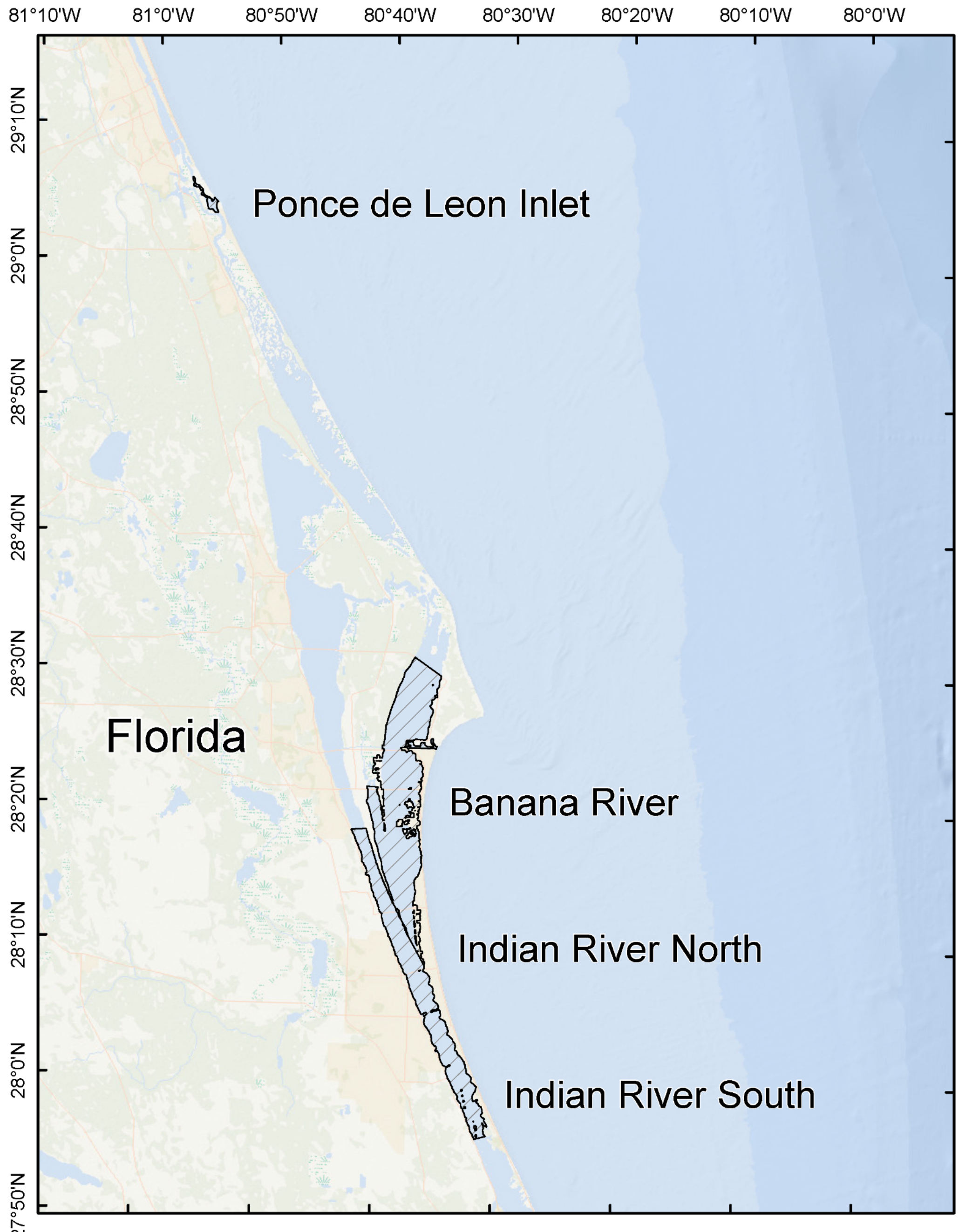

Fig. 12. The NMSDD strata (hatched areas) included in the Indian River Lagoon, Florida region (n = 4): Ponce de Leon Inlet, Banana River, Indian River North, and Indian River South. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Common bottlenose dolphins within the NMSDD strata included in the Indian River Lagoon, Florida region have been identified as the Indian River Lagoon Estuarine System (IRLES) stock (Waring et al. 2016). The extent of the IRLES stock was within Florida's Mosquito Lagoon, Indian River, Banana River, Sebastian Inlet, Ft. Pierce Inlet, St. Lucie Estuary, and St. Lucie Inlet, bounded in the north by Ponce de Leon Inlet and in the south by Jupiter Inlet (Waring et al. 2016). Therefore, the NMSDD strata in this region overlapped with only a small proportion of the extent of common bottlenose dolphin stock identified in these waters (Fig. 12).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Indian River Lagoon, Florida region, and found a few potential sources published since 2015 (e.g., Durden et al. 2017; Greller et al. 2021; Nekolny et al. 2017; Brightwell et al. 2020; Reif et al. 2018; Durden et al. 2021; Hartel et al. 2020). The most current assessment of the IRLES stock was conducted by Waring et al. (2016), reporting the best available information from an aerial survey by Durden et al. (2011). However, the minimum population estimate was determined as unknown because of insufficient data (Waring et al. 2016). Within the literature, Durden et al. (2021) presented estimated abundances for the Indian River Lagoon common bottlenose dolphin population from more recent photo-ID capture-recapture surveys conducted in 2016-2017.

In addition to searching for current literature, we contacted several marine mammal experts to request any available data or recent common bottlenose dolphin studies within the Indian River Lagoon, Florida region. Personal communication requests for information that could be used to estimate common bottlenose dolphin density were sent via email to Wendy Noke Durden (Hubbs-SeaWorld Research Institute, 2/22/2022), Lance Garrison (NMFS SEFSC, 2/15/2022), Erin LaBrecque (US Marine Mammal Commission, 4/1/2022), Reny Tyson Moore (NMFS OPR, 4/1/2022), and Jolie Harrison (NMFS OPR, 4/1/2022). We proposed to use data within Durden et al. (2021), the most recent publication on research within the area, to calculate density estimates within the NMSDD strata. W. Durden agreed with our approach and said that the common bottlenose dolphins present in the area are "pretty resident to the estuary" while other marine mammal experts agreed that the best available data were presented within Durden et al. (2021).

Because a better source of data and updated research on common bottlenose dolphins within these strata was available, we updated our methods and estimates from Phase III (Table 1). Therefore, we provided seasonal estimated density for common bottlenose dolphins within the sub-basins of the Indian River Lagoon, Florida region by using published and supplemental data within Durden et al. (2021). Sub-basins included the northern/central Indian River (from Eau Gallie Causeway north), southern Indian River (from Eau Gallie Causeway south), Banana River, and Mosquito Lagoon. However, the survey footprint did not exactly match the NMSDD strata; Durden et al. (2021) included Mosquito Lagoon, an area south of Ponce de Leon Inlet and Banana River not identified as an NMSDD strata, and the Ponce de Leon Inlet NMSDD strata was not included in Durden et al. (2021). We followed methods from Roberts (2015) by directly applying the estimated density for Banana River to the Banana River NMSDD stratum, the north and south Indian River estimate to the the split Indian River NMSDD strata (north and south, respectively), and the Mosquito Lagoon estimate to the Ponce de Leon Inlet NMSDD stratum.

Results and discussion

Given the assumption that the density of the IRLES stock was the same throughout its range, and using data from Durden et al. (2021), the estimates for summer (June - August), fall (September - November), winter (December - February), and spring (March - May) ranged from 0.69-2.61 dolphins/km^2 (Table 6; Fig. 13). Estimates were higher than what was reported by Roberts (2015) for all seasons and strata except winter estimates within Ponce de Leon and Indian River (north). Overall, these data showed stability for the IRLES population size, along with a low transient rate and high seasonal survival (Durden et al. 2021).

Table 6. The density (dolphins/km^2) and uncertainty (CV; in parentheses) estimated for each season and stratum in the Indian River Lagoon, Florida region, by using data from Durden et al. (2021).

Stratum	Winter: Dec-Feb	Spring: Mar-May	Summer: Jun-Aug	Fall: Sep-Nov
Banana River	1.82 (0.21)	1.01 (0.17)	1.69 (0.15)	2.39 (0.37)
Ponce de Leon Inlet	1.09 (0.20)	1.61 (0.33)	1.46 (0.19)	0.93 (0.36)
Indian River (north)	0.69 (0.26)	0.87 (0.29)	1.3 (0.31)	0.8 (0.49)
Indian River (south)	2.32 (0.20)	1.86 (0.41)	1.23 (0.28)	2.61 (0.36)

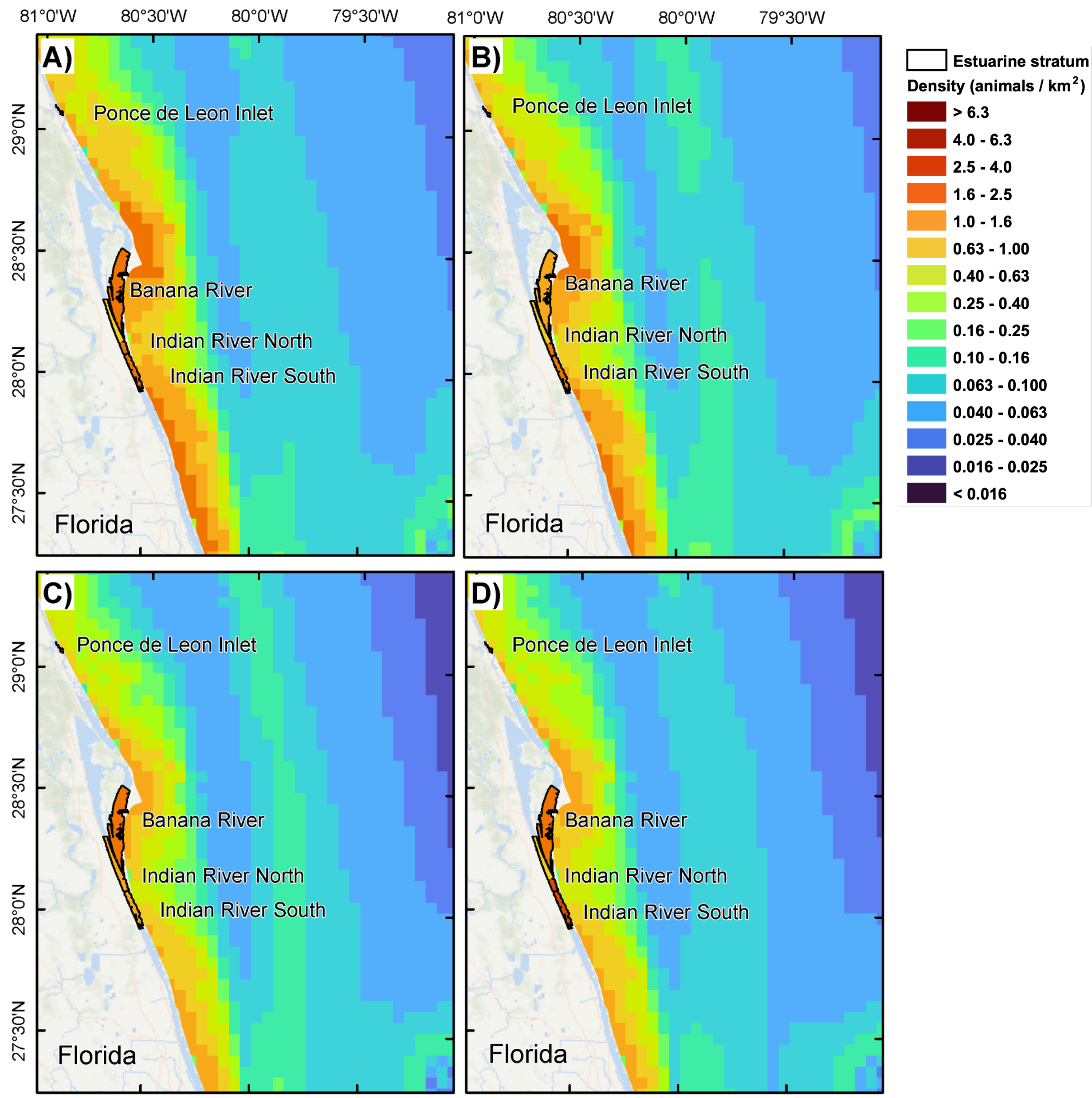

Fig. 13. Common bottlenose dolphin densities for the NMSDD estuarine strata in the Indian River Lagoon, Florida region (outlined in black) using data from Durden et al. (2021), along with the monthly densities in the EC from Roberts et al. (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Seasonal density estimates were calculated within estuarine strata and monthly density estimates were calculated within the US east coast stratum, but only four months were presented as an example from each season. EC model raster cell size: 25 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Southeast Florida Region

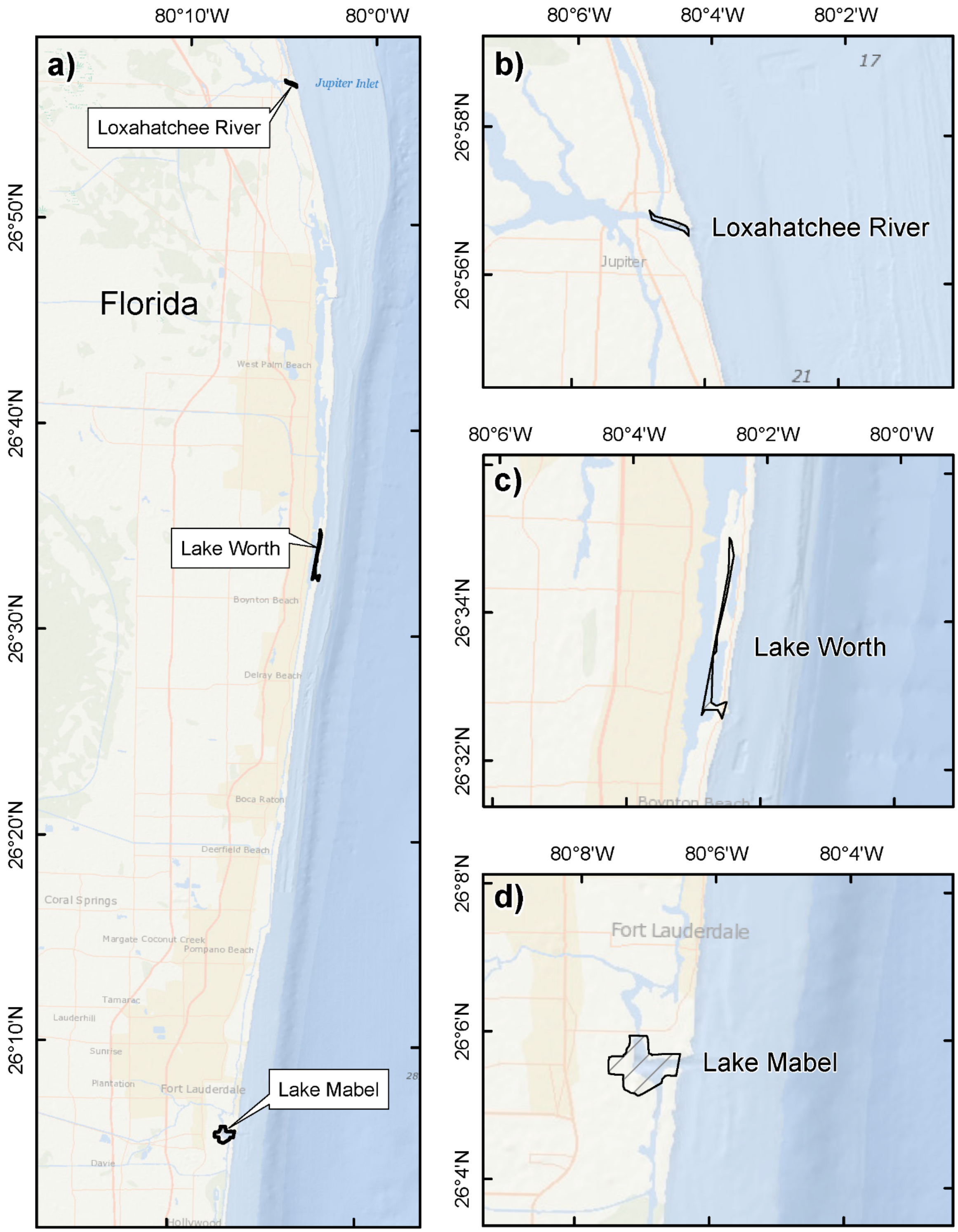

Fig. 14. The NMSDD strata (hatched areas) included in the southeast Florida region (n = 3): a) entire region, b) Loxahatchee River, c) Lake Worth, and d) Lake Mabel. Land, water, and reference sources: Esri, Garmin, GEBCO, NGDC, National Geographic, HERE, Geonames.org, and other contributors.

The most current estuarine common bottlenose dolphin stock assessments do not include information within the NMSDD strata within southeast Florida (Fig. 14). North of these strata, assessments were available for the Indian River Lagoon Estuarine System common bottlenose dolphin stock which has a southern boundary at Jupiter Inlet, Florida (Waring et al. 2016). South of these strata, assessments were available for the Biscayne Bay stock south which has a northern boundary at Haulover Inlet, Florida (Waring et al. 2013). However, the Central Florida Coastal stock has been described as a coastal morphotype distributed in both coastal and estuarine waters, ranging between the northern boundary of 29.4 degrees N and the southern boundary at the western end of Vaca Key, Florida (Hayes et al. 2018). Relatively little is known about the Central Florida Coastal stock, but the most recent stock assessment estimated that there were 1,218 (CV = 0.35) dolphins, based on aerial surveys during the summer in 2016 (Garrison et al. 2017b; Hayes et al. 2018). The NMSDD strata make up a very small portion of the provisional range of the Central Florida Coastal stock (Fig. 14).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the southeast Florida region, and did not find any potential sources published since 2015. Reports have confirmed or mentioned the potential presence of common bottlenose dolphins in these strata (e.g., Gissendanner 1984; Zollett and Read 2006; Precht et al. 2019; Lassiter 2022), but sources of data (both peer-reviewed and grey literature) used to estimate densities for common bottlenose dolphins within these estuarine areas were not available. Within the Port Everglades area, boat-based surveys were conducted in 1993-2003 that overlapped the Lake Mabel stratum (Keith 1999–2003), but data were limited and not readily accessible to fully assess how the research coverage compared to the stratum boundaries. Lassiter (2022) used the data from Keith (1999–2003) to calculate the density of common bottlenose dolphins as 0.24 dolphins/km^2 within the "inner channels, turning basins, wideners, and other inner harbor areas of Port Everglades," presumably a conservative year-round estimate. A density estimate for just the main turning basin area of the Port Everglades Harbor Navigation Project, described by Lassiter (2022), would have been a better application for the Lake Mabel stratum.

In addition to searching for current literature, we contacted several marine mammal experts to request any available data or recent common bottlenose dolphin studies within the southeast Florida region. Personal communication requests for information that could be used to estimate common bottlenose dolphin density were sent via email to Erin LaBrecque (US Marine Mammal Commission, 4/1/2022), Reny Tyson Moore (NMFS Office of Protected Resources OPR, 4/1/2022), Jolie Harrison (NMFS OPR, 4/1/2022), and Lance Garrison (NMFS SEFSC, 4/6/2022). All marine mammal experts confirmed that no data were available for estimates, but other publications have confirmed that common bottlenose dolphins were present in these regions and nearby areas (Biscayne Bay). L. Garrison agreed that using data from the most recent EC density models, by Roberts et al. (2022), to extrapolate values to the NMSDD strata in this region was the most appropriate strategy.

Because a better source of data or updated research on common bottlenose dolphins within these strata was not available from external studies, we updated our methods and estimates from Phase III by using nearby estimated densities (Table 1). Therefore, we used the overlapping cells with data (values > 0) from the most current EC regional density model (see Roberts et al. 2022) to calculate the density (and uncertainty) for common bottlenose dolphins within these strata, similar to extrapolation methods described in Roberts (2015). The Loxahatchee River stratum was completely within one raster cell with data while Lake Worth and Lake Mabel each overlapped with two raster cells (one with data and one without data); raster cell size for the EC regional density model was 5 x 5 km.

Results and discussion

The estimated density for common bottlenose dolphins, using the data from Roberts et al. (2022), resulted in monthly estimates that were similar to nearby coastal areas estimated within the EC model (Table 7; Fig. 15). Monthly density estimates were mostly higher than the monthly density estimates from Roberts (2015) in all strata within the southeast Florida region, except for Lake Mabel in winter (January - December). The monthly estimates for Lake Mabel were lower than the year-round estimate calculated by Lassiter (2022) for areas surrounding Lake Mabel. Limited research conducted near these strata suggested that the spatial and temporal dynamics of common bottlenose dolphin communities in this region were still understudied and poorly understood. As was recommended by Roberts (2015) for other estuarine areas, additional research is still needed to improve upon current abundance and density estimates of common bottlenose dolphins within these strata.

Table 7. The density (dolphins/km^2) and uncertainty (CV; in parentheses) estimated for each month and stratum in the southeast Florida region, by using data from Roberts et al. (2022).

Month	Loxahatchee River	Lake Worth	Lake Mabel
1	0.80 (0.27)	0.47 (0.35)	0.08 (0.34)
2	0.84 (0.27)	0.50 (0.35)	0.09 (0.36)
3	0.88 (0.28)	0.52 (0.36)	0.09 (0.35)
4	0.84 (0.31)	0.52 (0.36)	0.09 (0.35)
5	0.82 (0.32)	0.49 (0.38)	0.09 (0.38)
6	0.82 (0.29)	0.46 (0.35)	0.09 (0.32)
7	0.79 (0.28)	0.44 (0.34)	0.09 (0.31)
8	0.78 (0.28)	0.44 (0.34)	0.09 (0.31)
9	0.73 (0.33)	0.47 (0.36)	0.08 (0.31)
10	0.76 (0.32)	0.52 (0.37)	0.08 (0.33)
11	0.75 (0.30)	0.47 (0.36)	0.07 (0.34)
12	0.76 (0.28)	0.45 (0.34)	0.07 (0.31)

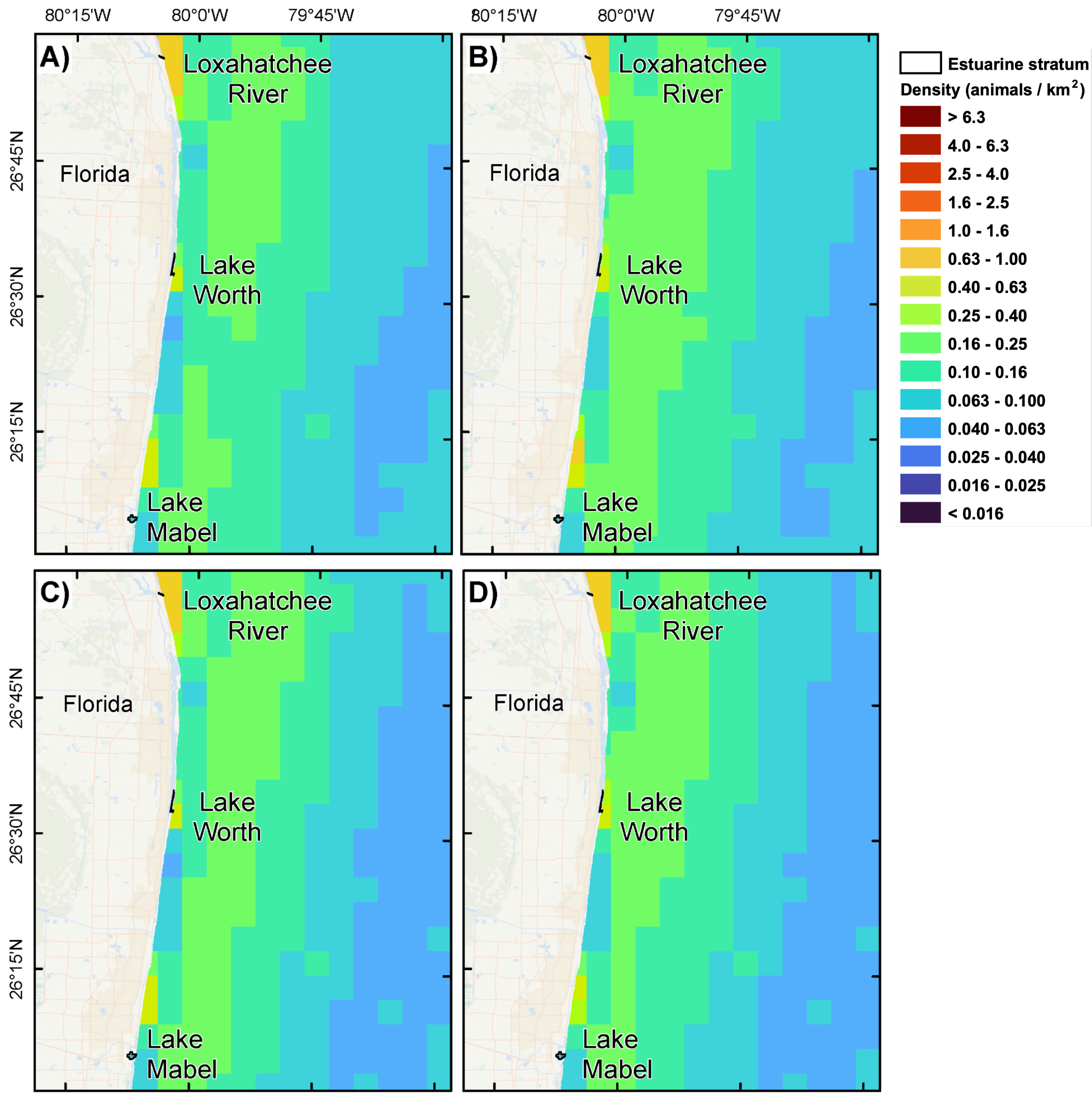

Fig. 15. Common bottlenose dolphin density estimate for the NMSDD strata in the southeast Florida region (outlined in black) using data from Roberts et al. (2022), along with the densities in the EC from Roberts et al. (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Monthly density estimates were calculated within estuarine and US east coast strata, but only four months were presented here as an example from each season. EC model raster cell size: 25 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Gulf of Mexico Estuaries

Corpus Christi Bay, Texas Region

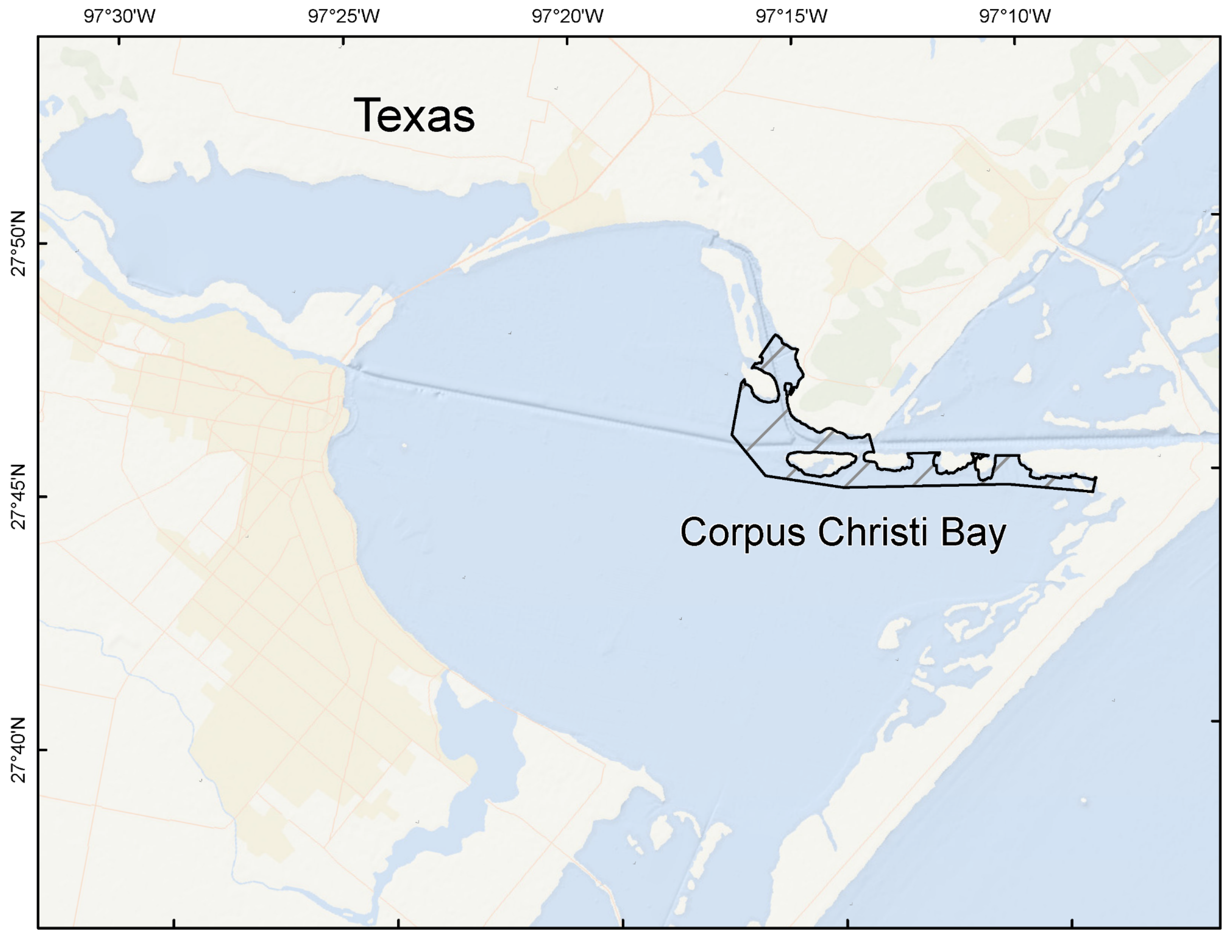

Fig. 16. The NMSDD stratum (hatched area) included in the Corpus Christi Bay, Texas region (n = 1): Corpus Christi Bay. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Common bottlenose dolphins within the Corpus Christi Bay NMSDD stratum have been identified as the Nueces Bay / Corpus Christi Bay stock, with an extent within Texas' Nueces Bay and Christi Bay, corresponding to Blaylock and Hoggard’s (1994) survey block B52 (Hayes et al. 2019). The Corpus Christi Bay stratum covers only a small part of the Corpus Christi Bay stock's extent (Fig. 16). Hayes et al. (2022) noted that NMFS was "in the process of writing individual stock assessment reports for each of the 31 bay, sound and estuary [BSE] stocks of common bottlenose dolphins in the [GOM]." At this time, the most up-to-date information for the Corpus Christi Bay stock was provided within the Northern GOM BSE stock assessment (Hayes et al. 2019).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Corpus Christi Bay, Texas region, and did not find any potential sources published since 2015. The most current assessment of the Nueces Bay / Corpus Christi Bay common bottlenose dolphin stock was conducted by Hayes et al. (2019), reporting the best available information from aerial surveys by Blaylock and Hoggard (1994). The abundance estimate was reported as 58 (CV = 0.61) dolphins, based on data collected more than 8 years ago; this stock's abundance estimate was considered as unknown because of insufficient data (Hayes et al. 2019). Boat-based photo-ID and visual surveys in the Laguna Madre, Texas region, which includes the southern portion of Corpus Christi/Redfish Bay, were conducted in 2014-2020 but did not overlap with the NMSDD Corpus Christi Bay stratum (see Ronje et al. 2018; Hurst and Orbach 2022).

In addition to searching for current literature, we contacted Lance Garrison (NMFS SEFSC, 2/25/2022) via email to request any available data or recent common bottlenose dolphin studies within the Corpus Christi Bay, Texas region. L. Garrison confirmed that no new data were available since Phase III and that using the data from Blaylock and Hoggard (1994) was the most appropriate to estimate common bottlenose dolphin density in this region.

Because a better source of data or updated research on common bottlenose dolphins within this stratum was not available, we did not change our methods or estimates from Phase III (Table 1). Therefore, we followed methods in Roberts (2015) to provide year-round estimated density for common bottlenose dolphins in the Corpus Christi Bay, Texas region by using published data provided directly from the NMFS SEFSC (see Blaylock and Hoggard 1994).

Results and discussion

The estimated year-round density for the Corpus Christi Bay stratum was 0.39 (CV = 1.95) dolphins/km^2 (Fig. 17). Roberts (2015) detailed methods for a uniform density model to estimate density and uncertainty of common bottlenose dolphins, using 18 sightings from line transect surveys conducted in 1992 and 1996, published by Blaylock and Hoggard (1994). Although this method was identified as the most appropriate with the best available data, these transects and sightings overlapped with only a portion of the Corpus Christi Bay stratum. As with other US estuaries in the GOM, more recent research throughout the year within the Corpus Christi Bay, Texas region is needed to improve future density estimates of common bottlenose dolphins.

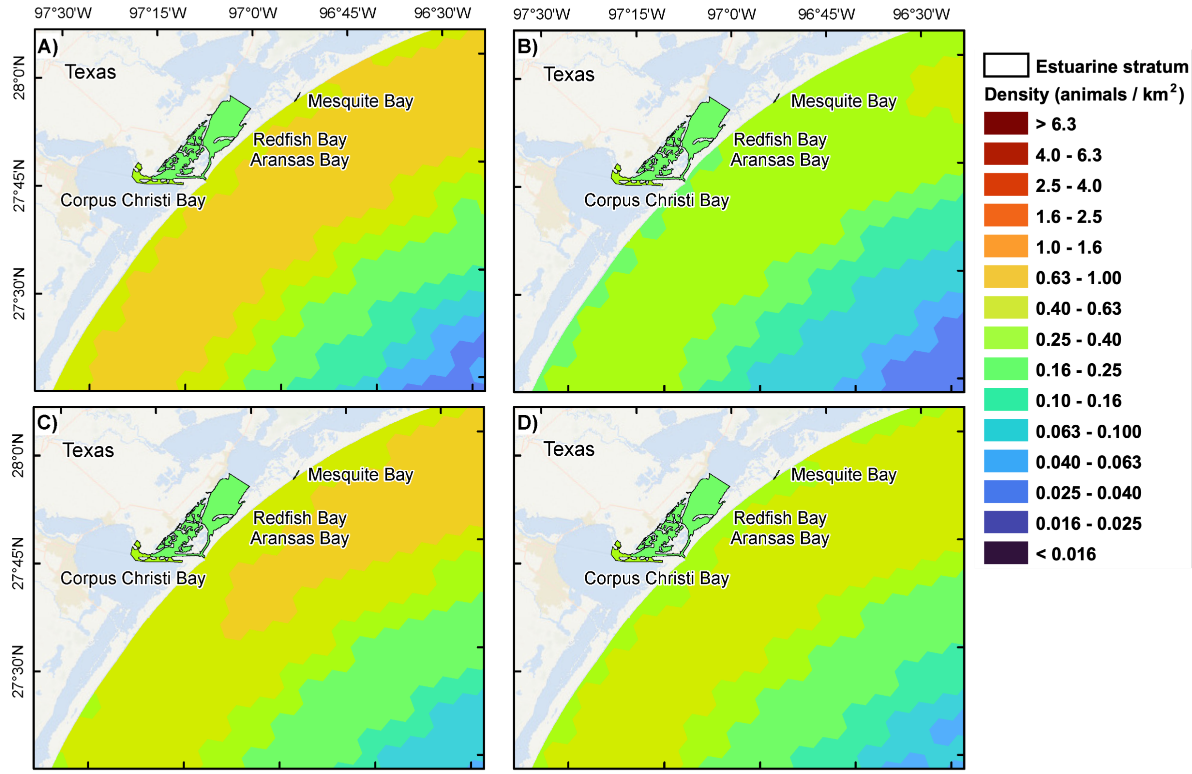

Fig. 17. Common bottlenose dolphin density estimate for the NMSDD strata (outlined in black) in the Corpus Christi Bay, Texas and the Redfish Bay, Aransas Bay regions using data from Blaylock and Hoggard (1994), along with the densities in the GOM coastal waters from Southeast Fisheries Science Center (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Year-round density estimates were calculated within estuarine strata and monthly density estimates were calculated within the GOM coastal stratum, but only four months were presented here as an example from each season. For details on the Corpus Christi Bay stratum, see the "Corpus Christi Bay, Texas Region" section; for details on the Redfish Bay Aransas Bay and Mesquite Bay strata, see the "Redfish Bay, Aransas Bay, Mesquite Bay, Texas Region" section. GOM model hexagon cell size: 40 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Redfish Bay, Aransas Bay, Mesquite Bay, Texas Region

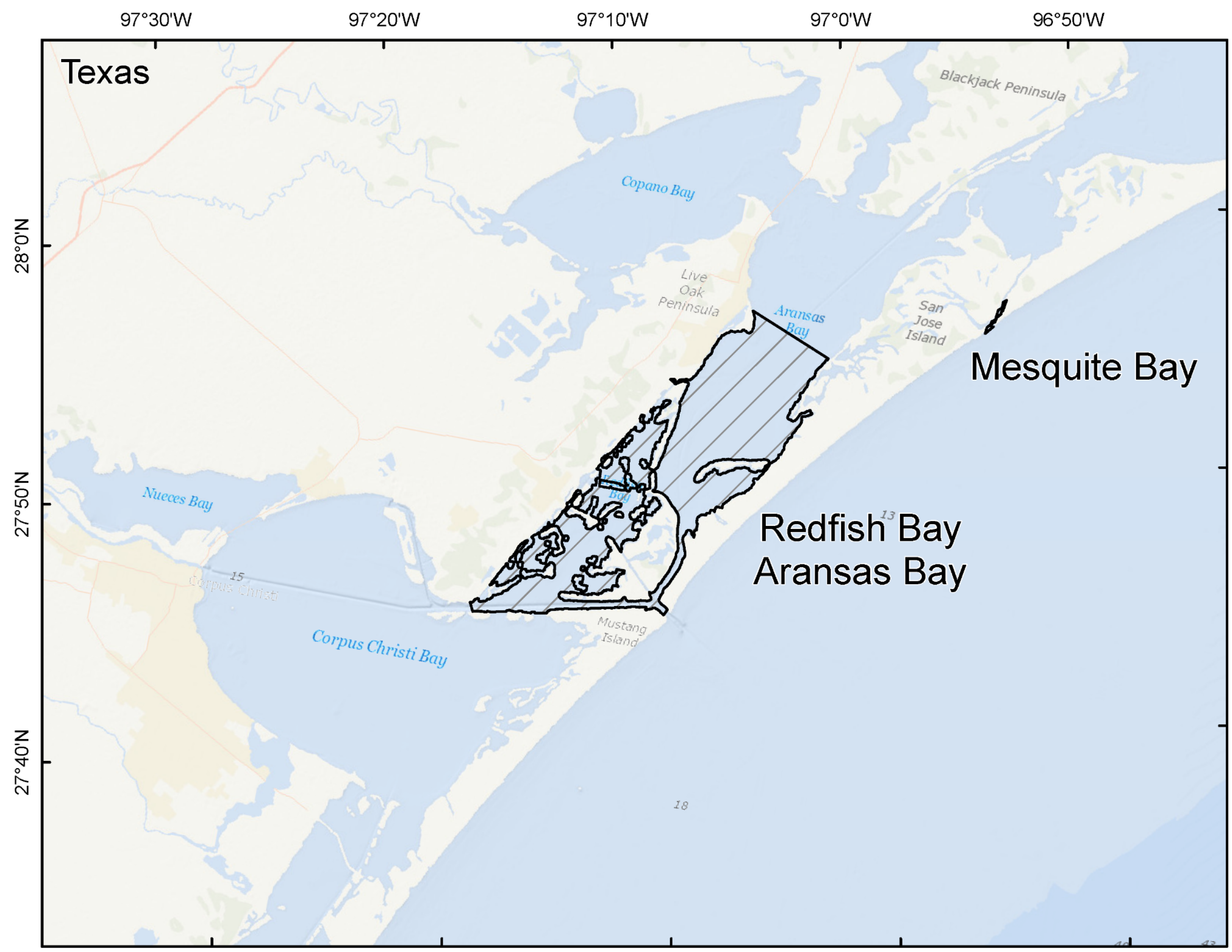

Fig. 18. The NMSDD strata (hatched areas) included in the Redfish Bay, Aransas Bay, Mesquite Bay, Texas region (n = 2): Redfish Bay Aransas Bay and Mesquite Bay. Land, water, and reference sources: Esri, Garmin, GEBCO, NGDC, National Geographic, HERE, Geonames.org, and other contributors.

Common bottlenose dolphins within the Redfish Bay, Aransas Bay, Mesquite Bay NMSDD strata in Texas have been identified as the Copano Bay / Aransas Bay / San Antonio Bay / Redfish Bay / Espiritu Santo Bay stock, corresponding to Blaylock and Hoggard's (1994) survey block B53 (erroneously listed as survey block B50; Hayes et al. 2019). The stock's estimated extent is bounded on the west by Redfish Bay and the east by Espiritu Santo Bay (Maze-Foley et al. 2019). The strata within this region cover a small proportion of the estimated extent of the stock (Fig. 18). Hayes et al. (2022) noted that NMFS was "in the process of writing individual stock assessment reports for each of the 31 [BSE] stocks of common bottlenose dolphins in the [GOM]." At this time, the most up-to-date information for the Copano Bay, Copano Bay / Aransas Bay / San Antonio Bay / Redfish Bay / Espiritu Santo Bay stock was provided within the Northern GOM BSE stock assessment (Hayes et al. 2019).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Redfish Bay, Aransas Bay, Mesquite Bay, Texas region, and did not find any potential sources published since 2015. The most current assessment of the Copano Bay / Aransas Bay / San Antonio Bay / Redfish Bay / Espiritu Santo Bay common bottlenose dolphin stock was conducted by Hayes et al. (2019), reporting the best available information from aerial surveys by Blaylock and Hoggard (1994). The abundance estimate was reported as 55 (CV = 0.82) dolphins, based on data collected more than 8 years ago; this stock's abundance estimate was considered as unknown because of insufficient data (Hayes et al. 2019). Boat-based photo-ID and visual surveys in the Laguna Madre, Texas region, which includes the southern portion of Corpus Christi/Redfish Bay, were conducted in 2014-2020 but did not overlap with the strata within the Redfish Bay, Aransas Bay, Mesquite Bay, Texas region (see Ronje et al. 2018; Hurst and Orbach 2022).

In addition to searching for current literature, we contacted Lance Garrison (NMFS SEFSC, 2/25/2022) via email to request any available data or recent common bottlenose dolphin studies within the Redfish Bay, Aransas Bay, Mesquite Bay, Texas region. L. Garrison confirmed that no new data were available since Phase III and that using the data from Blaylock and Hoggard (1994) was the most appropriate to estimate common bottlenose dolphin density in this region.

Because a better source of data or updated research on common bottlenose dolphins within these strata was not available, we did not change our methods or estimates from Phase III (Table 1). Therefore, we followed methods in Roberts (2015) to provide year-round estimated density for common bottlenose dolphins in the Redfish Bay, Aransas Bay, Mesquite Bay, Texas region by using published data provided directly from the NMFS SEFSC (see Blaylock and Hoggard 1994).

Results and discussion

The estimated year-round density for the Redfish Bay Aransas Bay and Mesquite Bay strata was 0.20 (CV = 0.80) dolphins/km^2 (Fig. 17). Roberts (2015) detailed methods for a uniform density model to estimate density and uncertainty of common bottlenose dolphins, using 23 sightings from line transect surveys conducted in 1992 and 1996, published by Blaylock and Hoggard (1994). This method was identified as the most appropriate with the best available data and these transects and sightings overlapped with the majority of the strata in this region, unlike the minimal coverage within the Corpus Christi Bay stratum. However, more recent research throughout the year within the Redfish Bay, Aransas Bay, Mesquite Bay, Texas region is needed to improve future estimates of common bottlenose dolphins.

Sabine Lake, Texas and Louisiana Region

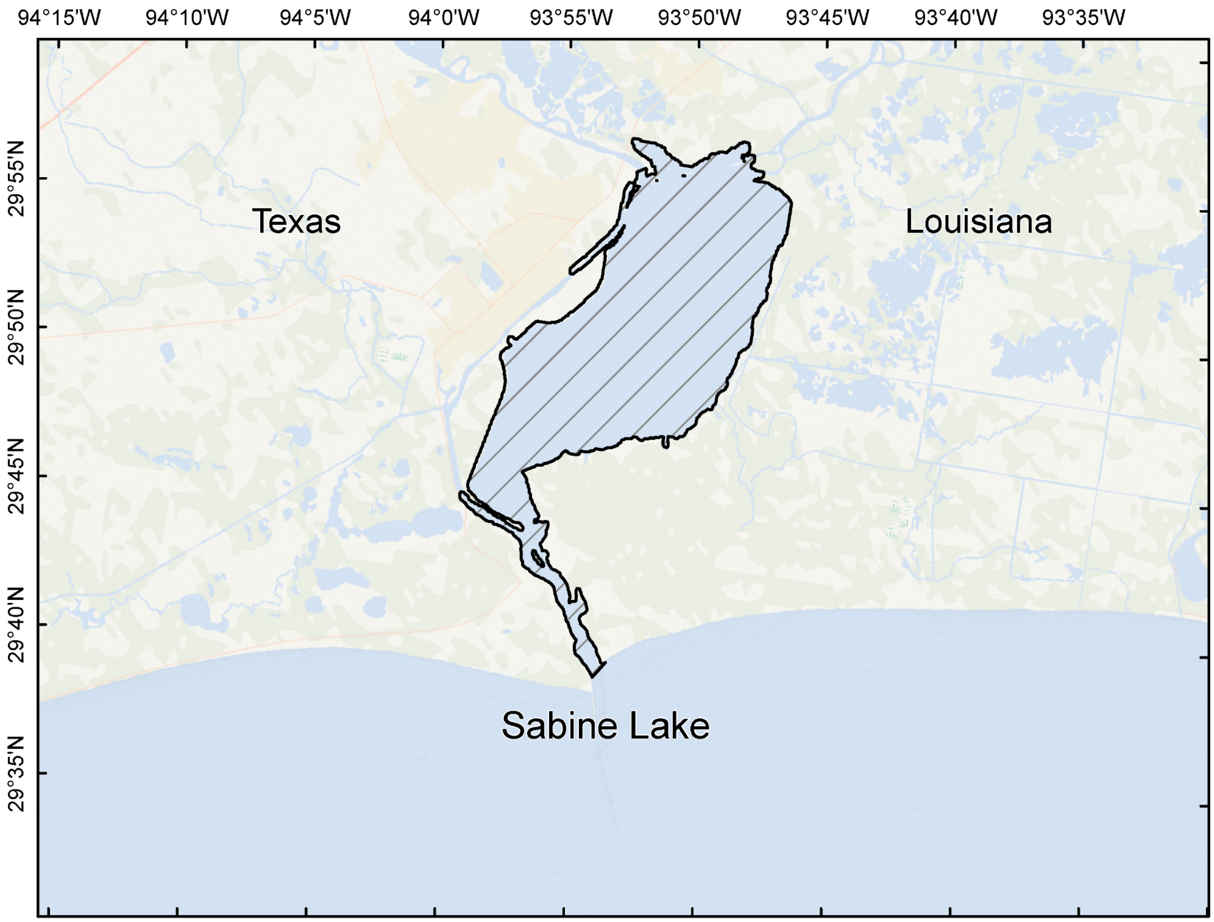

Fig. 19. The NMSDD stratum (hatched area) included in the Sabine Lake, Texas and Louisiana region (n = 1): Sabine Lake. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Common bottlenose dolphins within the Sabine Lake NMSDD stratum have been identified as the Sabine Lake stock, corresponding to Blaylock and Hoggard's (1994) survey block B57 (Hayes et al. 2019). The Sabine Lake stock includes the BSE areas of Sabine Lake and extends "into coastal waters within the borders of the jetties" (Maze-Foley et al. 2019). The Sabine Lake NMSDD stratum overlaps only with the main Sabine Lake area of the stock's extent (Fig. 19). Hayes et al. (2022) noted that NMFS was "in the process of writing individual stock assessment reports for each of the 31 bay, sound and estuary [BSE] stocks of common bottlenose dolphins in the [GOM]." At this time, the most up-to-date information for the Sabine Lake stock was provided within the Northern GOM BSE stock assessment (Hayes et al. 2019).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Sabine Lake, Texas and Louisiana region, and found one potential source since 2015 (i.e., Ronje et al. 2020). Hayes et al. (2019) was the most recent assessment for the Sabine Lake common bottlenose dolphin stock reported data collected from surveys conducted by Blaylock and Hoggard (1994), which were the same data identified for density estimates used in Roberts (2015). The abundance estimate was reported as 0, based on data collected more than 8 years ago; this stock's abundance estimate was considered as unknown because of insufficient data (Hayes et al. 2019). A more recent study reported common bottlenose dolphin abundance estimates calculated with data collected by photo-ID surveys conducted from February and June of 2017 (Ronje et al. 2020).

In addition to searching for current literature, we contacted Lance Garrison (NMFS SEFSC, 2/25/2022) via email to request any available data or recent common bottlenose dolphin studies within the Sabine Lake, Texas and Louisiana region. L. Garrison confirmed that data from Ronje et al. (2020) was the most appropriate to estimate common bottlenose dolphin density in this region.

Because a better source of data and updated research on common bottlenose dolphins within these strata was available, we changed our methods and updated estimates from Phase III (Table 1). Therefore, we provided year-round estimated density for common bottlenose dolphins within the Sabine Lake, Texas and Louisiana region by combining photo-ID capture-mark-recapture surveys conducted in February and June 2017 by Ronje et al. (2020). Although a "Bay" dataset was provided of "individuals limited to the interior of each embayment," the best abundance estimates were presented using the "Selective" dataset (Ronje et al. 2020). Ronje et al. (2020) defined the "selective" dataset as individuals found in the Sabine Lake waters within the BSE (interior region) or along the coast, but excluded transients; there were corrected abundances of 121.6 (95% CI: 73.0-170.3) dolphins in the winter (December - February) and 162.2 (95% CI: 114.3-210.2) dolphins in the summer (June - August) for the "selective" dataset. The mean corrected abundance (n = 141.9) was used to estimate the density over 240 km^2, the area of Sabine Lake estimated by USEPA (1999) and also used by Ronje et al. (2020).

Results and discussion

The estimated year-round density for the Sabine Lake stratum was 0.59 (CV = 0.76) dolphins/km^2 (Fig. 20). This method was identified as the most appropriate with the best available data and these transects and sightings overlapped with the majority of the Sabine Lake stratum. However, more research within the Sabine Lake, Texas and Louisiana region is needed within each month to improve future estimates of common bottlenose dolphins.

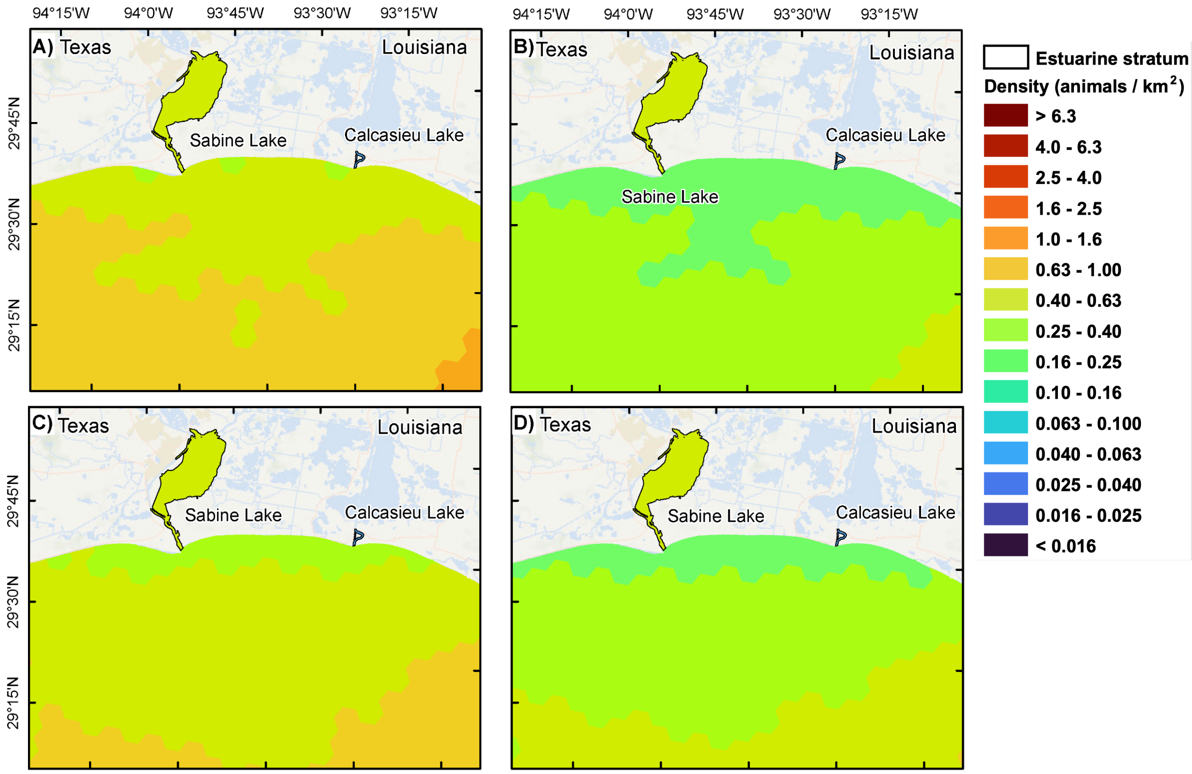

Fig. 20. Common bottlenose dolphin density estimate for the NMSDD strata (outlined in black) in the Sabine Lake region using data from Ronje et al. (2020), the Calcasieu Lake, Louisiana region using data from Blaylock and Hoggard (1994), along with the densities in the GOM coastal waters from Southeast Fisheries Science Center (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Year-round density estimates were calculated within estuarine strata and monthly density estimates were calculated within the GOM coastal stratum, but only four months were presented here as an example from each season. GOM model hexagon cell size: 40 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Calcasieu Lake, Louisiana Region

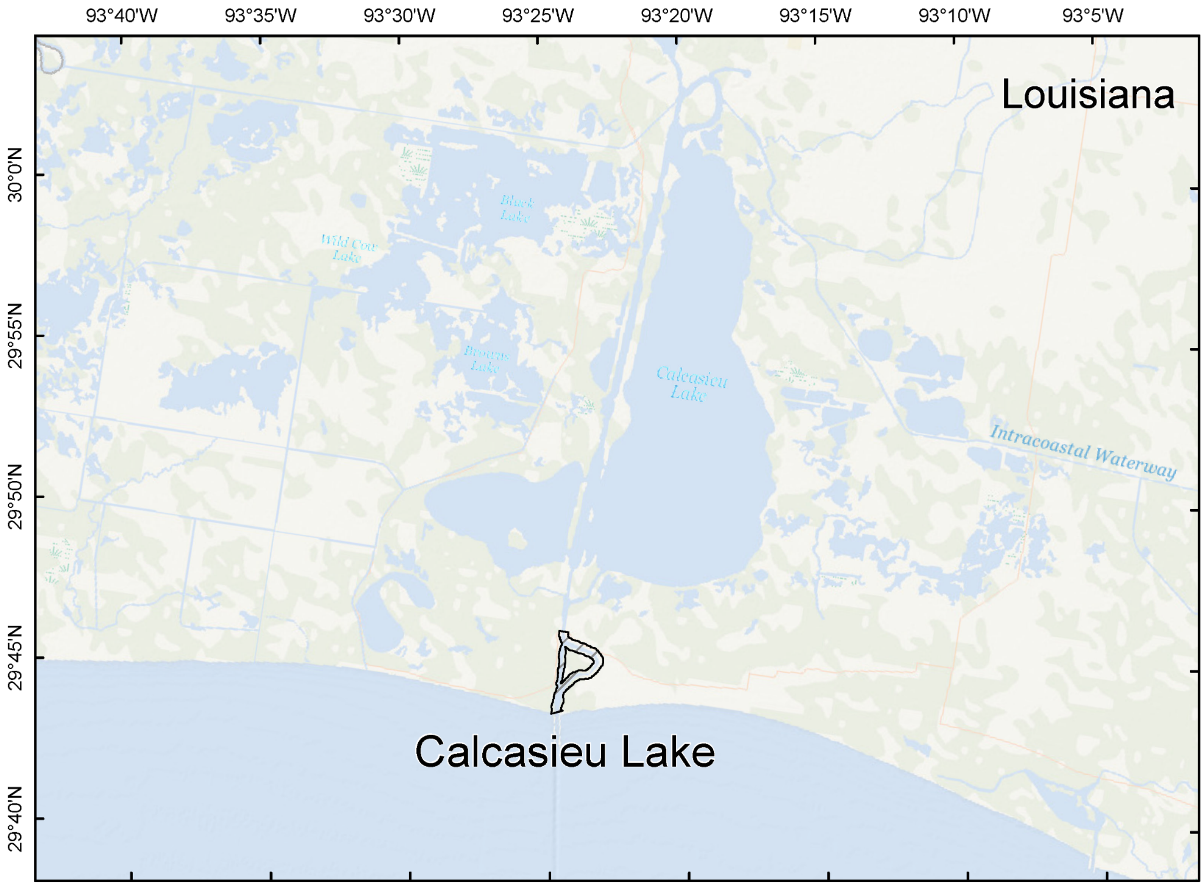

Fig. 21. The NMSDD stratum (hatched area) included in the Calcasieu Lake, Louisiana region (n = 1): Calcasieu Lake. Land, water, and reference sources: Esri, Garmin, GEBCO, NGDC, National Geographic, HERE, Geonames.org, and other contributors.

Common bottlenose dolphins within the Calcasieu Lake NMSDD stratum have been identified as the Calcasieu Lake stock, corresponding to Blaylock and Hoggard's (1994) survey block B58 (Hayes et al. 2019). The Calcasieu Lake stock includes the BSE areas of Calcasieu Lake and extends "into coastal waters within the borders of the jetties" (Maze-Foley et al. 2019). The Calcasieu Lake NMSDD stratum overlaps only with a small portion of the stock's extent, covering part of the Calcasieu Ship Channel towards the GOM (Fig. 21). Hayes et al. (2022) noted that NMFS was "in the process of writing individual stock assessment reports for each of the 31 bay, sound and estuary [BSE] stocks of common bottlenose dolphins in the [GOM]." At this time, the most up-to-date information for the Calcasieu Lake stock was provided within the Northern GOM BSE stock assessment (Hayes et al. 2019).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Calcasieu Lake, Louisiana region, and did not find any potential sources published since 2015. The most current assessment of the Calcasieu Lake common bottlenose dolphin stock was conducted by Hayes et al. (2019), reporting the best available information from aerial surveys by Blaylock and Hoggard (1994). The abundance estimate was reported as 0, based on data collected more than 8 years ago; this stock's abundance estimate was considered as unknown because of insufficient data (Hayes et al. 2019).

In addition to searching for current literature, we contacted Lance Garrison (NMFS SEFSC, 2/25/2022) via email to request any available data or recent common bottlenose dolphin studies within the Calcasieu Lake, Louisiana region. L. Garrison confirmed that no new data were available since Phase III and that using the data from Blaylock and Hoggard (1994) was the most appropriate to estimate common bottlenose dolphin density in this region.

Because a better source of data or updated research on common bottlenose dolphins within these strata was not available, we did not change our methods or estimates from Phase III (Table 1). Therefore, we followed methods in Roberts (2015) to provide year-round estimated density for common bottlenose dolphins in the Calcasieu Lake, Louisiana region by using published data provided directly from the NMFS SEFSC (see Blaylock and Hoggard 1994).

Results and discussion

The estimated year-round density was 0.05 (CV = 4.91) dolphins/km^2 (Fig. 19). Roberts (2015) detailed methods for a uniform density model to estimate density and uncertainty of common bottlenose dolphins, using one sighting from line transect surveys conducted in 1992 and 1996, published by Blaylock and Hoggard (1994). Although this method was identified as the most appropriate with the best available data, these transects and sightings overlapped with only a portion of the Calcasieu Lake stratum. As with other US estuaries in the GOM, more recent research throughout the year within the Calcasieu Lake stratum is needed to improve future estimates of common bottlenose dolphins.

Barataria Bay, Louisiana Region

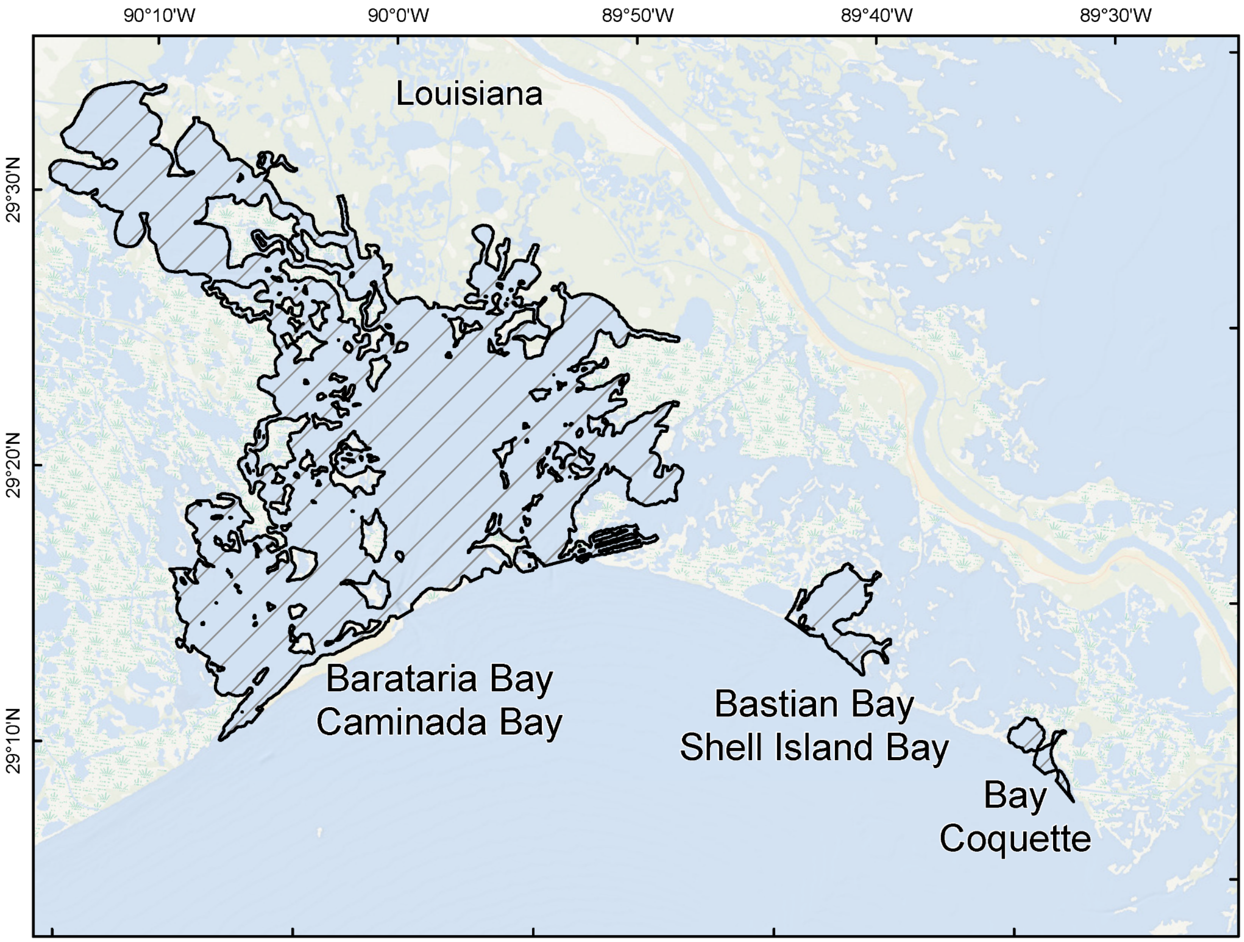

Fig. 22. The NMSDD strata (hatched areas) included in the Barataria Bay, Louisiana region (n = 3): Barataria Bay Caminada Bay, Bastian Bay Shell Island Bay, and Bay Coquette. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Common bottlenose dolphins in the NMSDD strata within the Barataria Bay, Louisiana region have been identified as the Barataria Bay Estuarine System (BBES) stock, corresponding to Blaylock and Hoggard's (1994) survey block B61 (Hayes et al. 2019). The entire geographic extent of the BBES stock were areas in the west up to and including Bayou Lafourche to areas in the east up to and including Bay Coquette: Caminada Bay, Barataria Bay, Barataria Pass, and Bastian Bay (Hayes et al. 2018) and extends "into coastal waters out to 1 km from shore" (Maze-Foley et al. 2019). Therefore, the NMSDD strata in this region overlapped with a large proportion of the extent of common bottlenose dolphin stocks identified in these waters (Fig. 22).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Barataria Bay, Louisiana region, and found a few potential sources published since 2015 (e.g., McDonald et al. 2017; Garrison et al. 2020; Wells et al. 2017; Glennie et al. 2021; Schwacke et al. 2022; Speakman et al. 2022; Quigley et al. 2022). The most current assessment of the BBES common bottlenose dolphin stock was conducted by Hayes et al. (2018), reporting the best available information from photo-ID surveys conducted in 2010-2014 by McDonald et al. (2017). The BBES stock's abundance estimate was reported as 2,306 (CV = 0.09) dolphins (Hayes et al. 2019) and was updated to 2,3071 (CV = 0.06) dolphins (Garrison et al. 2020; Hayes et al. 2022). Estimated densities for the BBES stock were reported for island, west, and east habitats for 10 survey sessions, but they did not cover all months of the year (McDonald et al. 2017).

In addition to searching for current literature, we contacted Lance Garrison (NMFS SEFSC, 2/25/2022) via email to request any available data or recent common bottlenose dolphin studies within the Barataria Bay, Louisiana region. L. Garrison agreed that estimating densities within the NMSDD strata in this region would be improved if the collection of currently published research had reported results at a higher spatial resolution; this would enable sightings and survey effort to be subsetted more appropriately, within the areas of interest to possibly correct for the higher densities of common bottlenose dolphins found near the barrier islands and inlets (see Glennie et al. 2021). L. Garrison also confirmed that data collected by Garrison et al. (2020) could be used to calculate better estimates than what was used for Hayes et al. (2018), but additional details were not available to produce density estimates. McDonald et al. (2017) published data from photo-ID capture-recapture surveys that were conducted in 2010-2014 and were collected in habitats that overlapped the most with strata within this region; details from these sightings allowed for estimating density.

Because a better source of data and updated research on common bottlenose dolphins within these strata was available, we changed our methods and updated estimates from Phase III (Table 1). Therefore, we provided year-round estimated density for common bottlenose dolphins in the Barataria Bay, Louisiana region by using published data over four years within McDonald et al. (2017). Similar to methods that Roberts (2015) used to combine survey sessions for a year-round estimate, we first estimated the abundance and uncertainty by: 1) averaging the estimated abundance over all surveyed regions for each year, given the number of surveys conducted within that year, 2) calculating the estimated uncertainty for each year, 3) averaging all years for one annual estimated abundance value, and 4) calculating the overall uncertainty (see #4 in "Strategies for identifying the best available data sources" section for more details). To get the estimated density that was applied to all 12 months in the NMSDD strata, we divided the mean year-round abundance (2371.1 dolphins) by 1167.385 km^2, the area of Barataria Bay dolphin habitat estimated by Hornsby et al. (2017) and also used by McDonald et al. (2017). The density estimates reported for the survey area were based on abundances for the BBES stock and therefore, we applied this value to all strata within the Barataria Bay, Louisiana region.

Results and discussion

Given the assumption that the density of the BBES stock was the same throughout its range, the mean year-round density over all habitats and strata in this region was 2.03 (CV = 0.30) dolphins/km^2 (Fig. 23). Although many studies have been published on common bottlenose dolphins in Barataria Bay following the Deepwater Horizon spill that significantly impacted the region and its marine resources in 2010 (Murawski et al. 2021), more recent research for each month within the NMSDD strata is needed to improve future density estimates of common bottlenose dolphins.

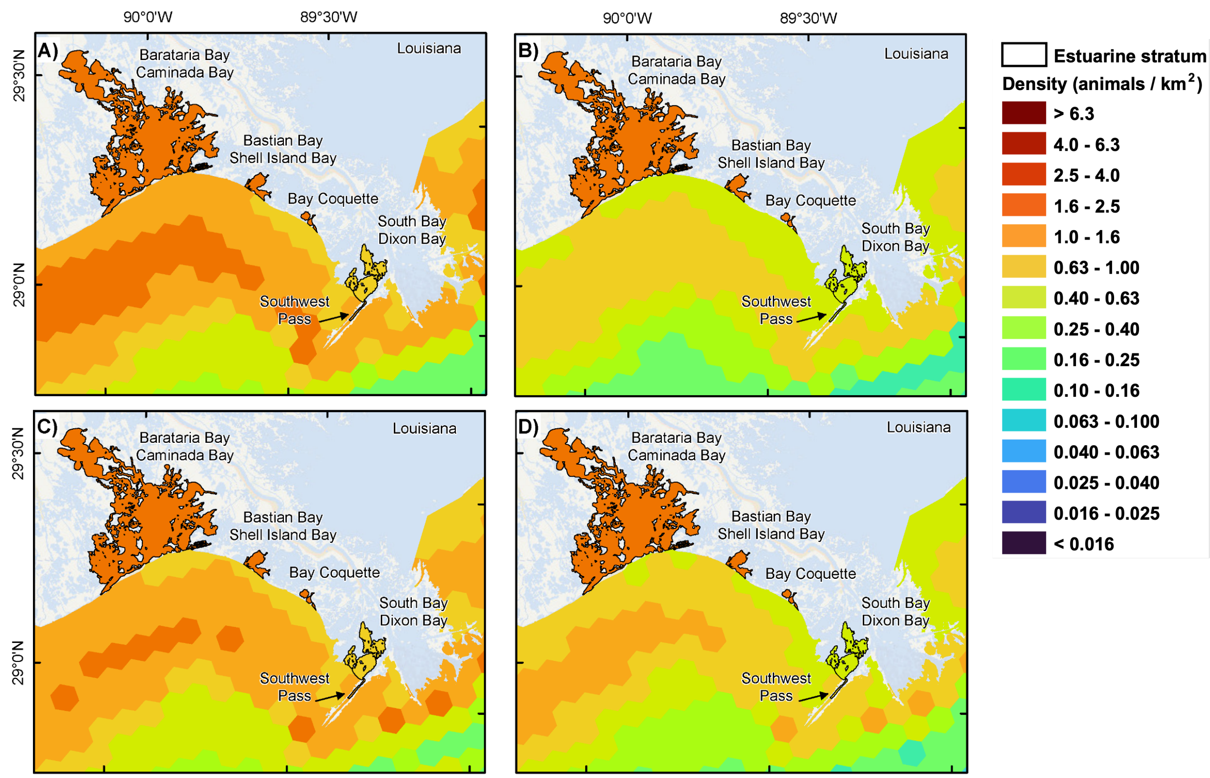

Fig. 23. Common bottlenose dolphin density estimate for the NMSDD strata (outlined in black) in the Barataria Bay, Louisiana region using data from McDonald et al. (2017), and the Western Mississippi River Delta, Louisiana region using data from Southeast Fisheries Science Center (2022), along with the densities in the GOM coastal waters from Southeast Fisheries Science Center (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Year-round density estimates were calculated within estuarine strata and monthly density estimates were calculated within the GOM coastal stratum, but only four months were presented here as an example from each season. GOM model hexagon cell size: 40 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Western Mississippi River Delta, Louisiana Region

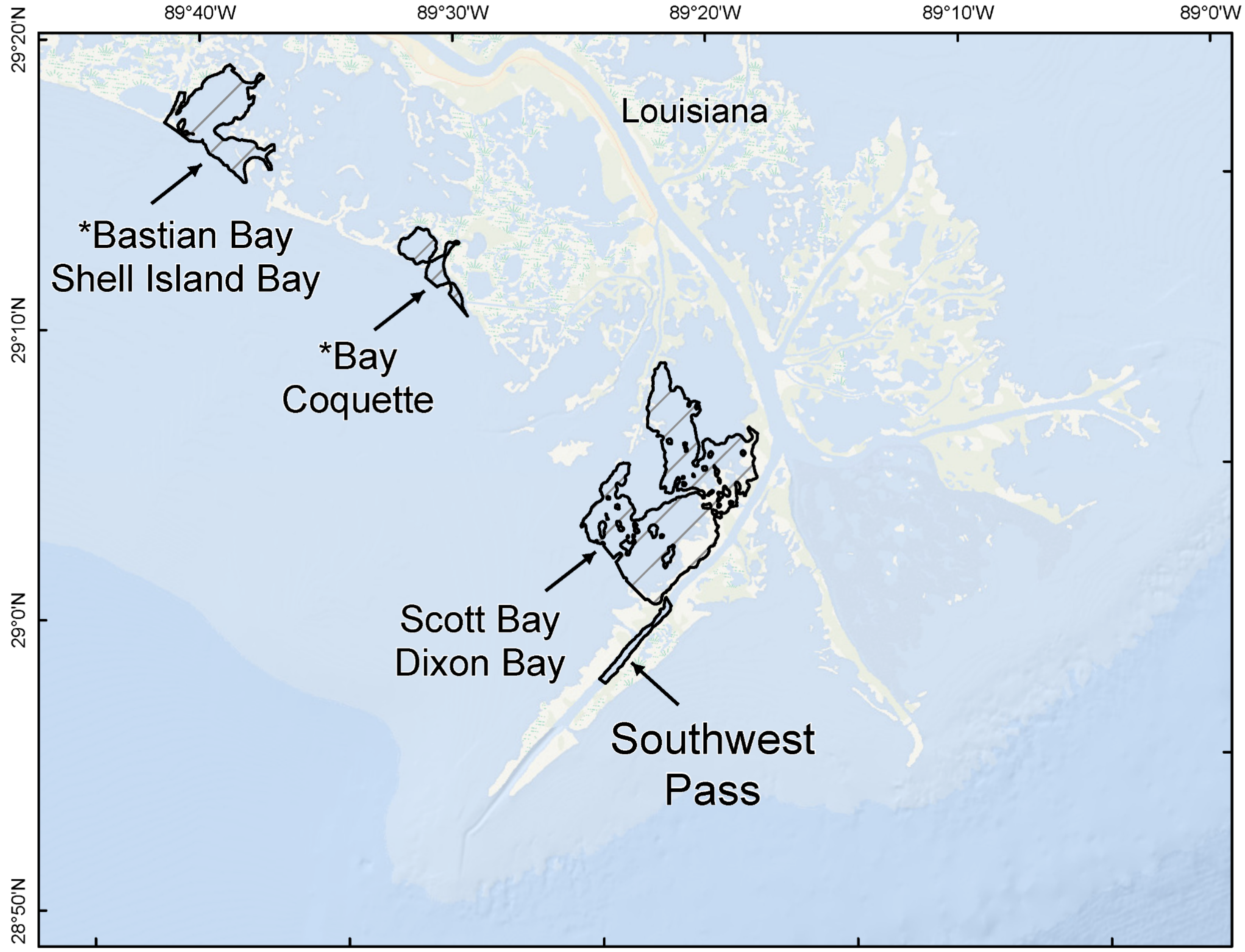

Fig. 24. The NMSDD strata (hatched areas) included in the western Mississippi River Delta, Louisiana region (n = 2): Scott Bay Dixon Bay and Southwest Pass. *Nearby NMSDD strata (Bastian Bay Shell Island Bay and Bay Coquette) used a different method to calculate estimates (see "Barataria Bay, Louisiana Region" section for more details) and only displayed here for context. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

The stock of common bottlenose dolphins in the NMSDD strata within the western Mississippi River Delta estuaries region has not been identified (Roberts 2015; Maze-Foley et al. 2019). Within the latest stock assessment report for northern GOM BSE, the BBES stock has been identified west of this region (block B61) and the Mississippi River Delta stock has been identified east of this region (block B30; Hayes et al. 2019). The closest NMSDD stratum on the west was the Bay Coquette and on the closest NMSDD stratum on the east was the Mississippi Sound Lake Borgne. However, it is currently unknown if common bottlenose dolphin stocks identified in nearby waters overlapped with the NMSDD strata in this region (Fig. 24).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Western Mississippi River Delta, Louisiana region, and did not find any potential sources since 2015. References confirming the presence of common bottlenose dolphins within this specific region and strata were not found, though we included these strata to be conservative. We assumed that common bottlenose dolphins use these areas given the close proximity to other regions where they are present and the habitat was similar to those utilized by estuarine common bottlenose dolphins. In addition to searching for current literature, we contacted Lance Garrison (NMFS SEFSC, 2/25/2022) via email to request any available data or recent common bottlenose dolphin studies within the Western Mississippi River Delta, Louisiana region. L. Garrison confirmed that no new data were available since Phase III and that using the data from Southeast Fisheries Science Center (2022) was the most appropriate to estimate common bottlenose dolphin density in this region.

Because a better source of data or updated research on common bottlenose dolphins within these strata was not available from external studies, we updated our methods and estimates from Phase III by using nearby estimated densities (Table 1). Therefore, we used the closest hexagon cells with data (values > 0) from the most current GOM regional density model (see Southeast Fisheries Science Center 2022) to calculate the density (and uncertainty) for common bottlenose dolphins within these strata, similar to extrapolation methods described in Roberts (2015). The Scott Bay Dixon Bay stratum barely intersected one cell with data while the Southwest Pass stratum did not overlap with any cells with data. We then began to extrapolate density values to any cell without data (values = 0) using the mean density of adjacent cells (with a shared boundary). Additionally, uncertainty values were extrapolated by calculating the overall variance, standard deviation, and mean density (see #4 in "Strategies for identifying the best available data sources" section for more details). For the final step, values from six hexagon cells were used to estimate density and uncertainty for the Scott Bay Dixon Bay stratum while values from two hexagon cells were used for the Southwest Pass stratum.

Results and discussion

The estimated density for common bottlenose dolphins, using the data from Southeast Fisheries Science Center (2022), resulted in monthly estimates that were similar to nearby coastal areas estimated within the GOM model (Table 8; Fig. 23). Monthly density estimates were mostly higher than the monthly density estimates from Roberts (2015) in both strata within the Western Mississippi River Delta, Louisiana region, except for in April and May. These monthly estimates were considered an improvement to the year-round estimates presented in Roberts (2015), which were calculated by extrapolating year-round estimates from the coastal common bottlenose dolphin model from Phase III. Limited research conducted near these strata suggested that the spatial and temporal dynamics of common bottlenose dolphin communities in this region were still understudied and poorly understood. As was recommended by Roberts (2015) for other estuarine areas, additional research is still needed to improve upon current abundance and density estimates of common bottlenose dolphins within these strata.

Table 8. The density (dolphins/km^2) and uncertainty (CV; in parentheses) estimated for each month and stratum in the western Mississippi River Delta, Louisiana region, by using data from Southeast Fisheries Science Center (2022).

Month	Scott Bay Dixon Bay	Southwest Pass
1	0.95 (0.40)	1.02 (0.41)
2	1.03 (0.31)	1.11 (0.34)
3	0.95 (0.34)	1.03 (0.37)
4	0.55 (0.30)	0.60 (0.31)
5	0.51 (0.30)	0.57 (0.31)
6	0.81 (0.33)	0.91 (0.34)
7	0.94 (0.29)	1.06 (0.30)
8	0.93 (0.29)	1.05 (0.30)
9	0.91 (0.30)	1.03 (0.31)
10	0.57 (0.31)	0.64 (0.33)
11	0.45 (0.28)	0.49 (0.29)
12	0.79 (0.34)	0.81 (0.36)

Mississippi Sound, Lake Borgne, Mississippi and Alabama Region

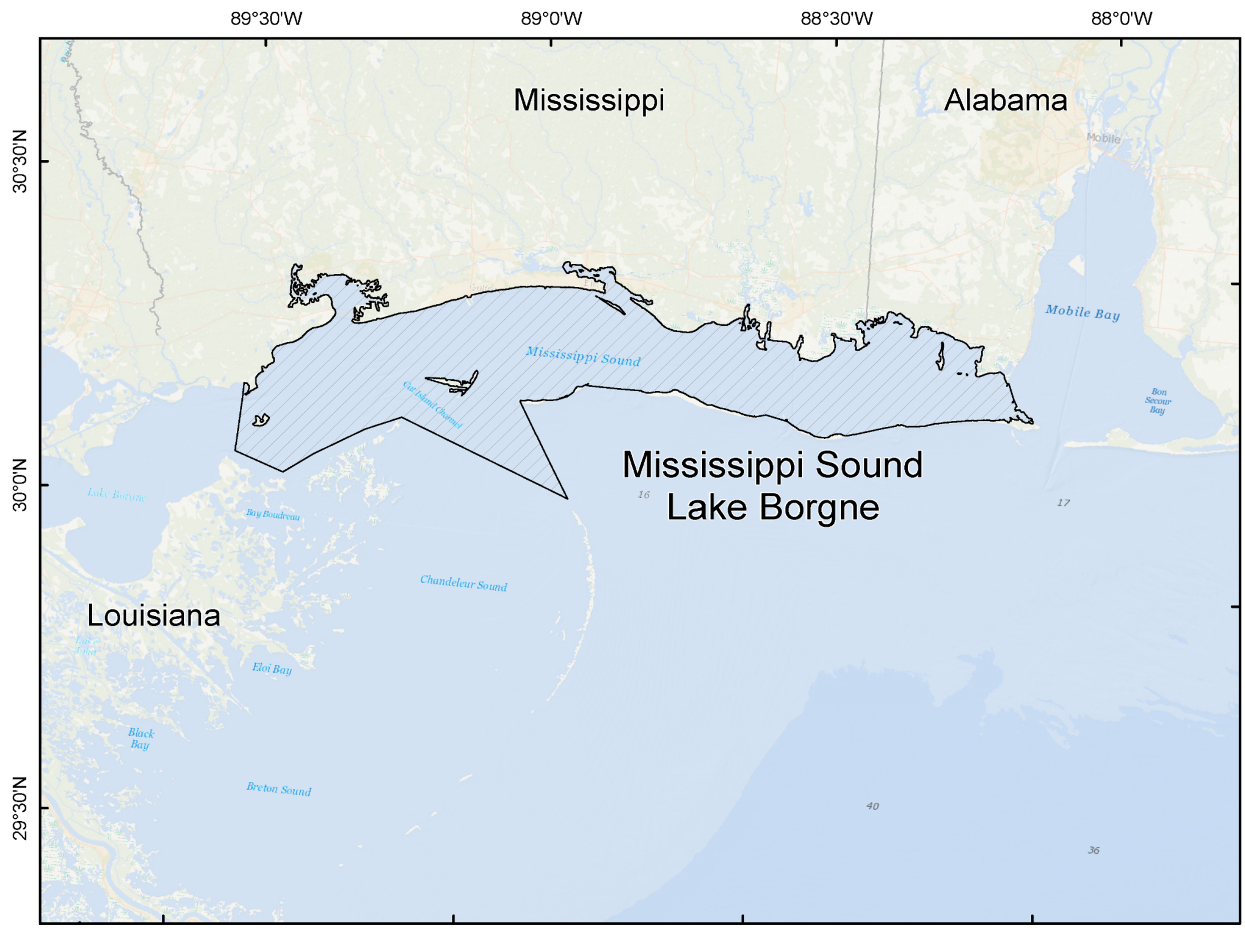

Fig. 25. The NMSDD stratum (hatched area) included in the Mississippi Sound, Lake Borgne, Mississippi and Alabama region (n = 1): Mississippi Sound Lake Borgne. US state boundary source: GADM (2018); land, water, and reference sources: Esri, Garmin, GEBCO, NGDC, National Geographic, HERE, Geonames.org, and other contributors.

Common bottlenose dolphins in the NMSDD stratum in the Mississippi Sound Lake Borgne, Mississippi and Alabama region have been identified as the Mississippi Sound / Lake Borgne / Bay Boudreau stock, corresponding to Blaylock and Hoggard's (1994) survey blocks B02-05, 29, 31 (Hayes et al. 2019). The entire geographic extent of this stock included areas of Lake Borgne, Bay Boudreau, and Mississippi Sound up to but not including, Mobile Bay, Alabama (Hayes et al. 2018) and "extends into coastal waters out to 1 km from shore along the barrier islands and east of barrier islands within Chandeleur Sound" (Maze-Foley et al. 2019). The NMSDD stratum in this region did not include areas of Lake Borgne to the west or Bay Boudreau and a small area extended out from Cat Island Channel did not overlap with the geographic extent of the Mississippi Sound / Lake Borgne / Bay Boudreau stock reported by Hayes et al. (2018). However, the NMSDD stratum in this region overlapped with a large proportion of the extent of the common bottlenose dolphin stock identified in these waters (Fig. 25).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Mississippi Sound Lake Borgne, Mississippi and Alabama region, and found a few potential sources published since 2015 (e.g., Pitchford et al. 2016; Mullin et al. 2017; Vollmer et al. 2021). The most current assessment of the Mississippi Sound / Lake Borgne / Bay Boudreau (MSLBBB) common bottlenose dolphin stock was conducted by Hayes et al. (2018), reporting the best available information from photo-ID surveys conducted in 2012 by Mullin et al. (2017). The Mississippi Sound / Lake Borgne / Bay Boudreau stock's abundance estimate was reported as 3,046 (CV = 0.06) dolphins (Hayes et al. 2018) and was updated to 1,265 (CV = 0.35) dolphins (Garrison et al. 2021; Hayes et al. 2022). Estimated densities for this stock were reported for island and inshore habitats for 8 survey sessions, but they did not cover all months of the year (Mullin et al. 2017). An updated study by Vollmer et al. (2021) provided densities within the supplemental material for the coastal Mississippi common bottlenose dolphin population present in "waters from the shoreline to the 60 m isobath from the Mississippi River Delta to 88.0° W longitude and from the shoreline to the 20 m isobath from 88.0–85.5° W longitude" based on aerial survey data collected in seven months between 2011-2012.

In addition to searching for current literature, we contacted Lance Garrison (NMFS SEFSC, 2/25/2022) via email to request any available data or recent common bottlenose dolphin studies within the Mississippi Sound Lake Borgne, Mississippi and Alabama region. L. Garrison agreed that estimating densities within the NMSDD strata in this region would be improved if the collection of currently published research had reported results at a higher spatial resolution; this would enable sightings and survey effort to be subsetted more appropriately. The region encompassed different habitats that may influence the seasonal distribution of common bottlenose dolphins (Hubard et al. 2004) and focusing on data collected just for the area of interest would help to correct for these differences. L. Garrison also confirmed that data collected in 2017-2018 using aerial visual line-transect surveys (Garrison et al. 2021) could be used to calculate better estimates than what was used for Hayes et al. (2018) or using data from Vollmer et al. (2021), but additional details were not available to produce density estimates. Vollmer et al. (2021) published data that were collected in habitats that overlapped the most with the stratum within this region; details from these sightings allowed for estimating density.

Because a better source of data and updated research on common bottlenose dolphins within these strata was available, we changed our methods and updated estimates from Phase III (Table 1). Therefore, we provided seasonal estimated densities for common bottlenose dolphins in the Mississippi Sound, Lake Borgne, Mississippi and Alabama region by using published data over two years for the "green" population (n = 541) reported within Vollmer et al. (2021). The majority of sightings reported for the green population were within the Mississippi Sound, Lake Borgne stratum.

Results and discussion

Given the assumption that the density of the "green" population was the same throughout its range, the estimated seasonal density was over all habitats in this region was 0.18 (CV = 0.36) dolphins/km^2 for winter (December - February), 0.77 (CV = 0.30) dolphins/km^2 for spring (March - May), 0.44 (CV = 0.22) dolphins/km^2 for summer (June - August), and 0.32 (CV = 0.27) dolphins/km^2 for fall (September - November). Compared to estimated densities for coastal common bottlenose dolphins in nearby areas, provided by Southeast Fisheries Science Center (2022), estimates within the estuarine stratum were all lower except in the spring where values were similar or slightly higher (Fig. 26). Although this method was identified as the most appropriate with the best available data and the survey overlapped with a large portion of the Mississippi Sound Lake Borgne stratum, the density estimate was based on surveys and sightings outside of the stratum. Furthermore, Vollmer et al. (2021) stated that relatively low survey effort was available in the winter compared to in the summer and more research is needed to better understand the seasonal variation in abundance in this region. As with other US estuaries in the GOM, more recent research throughout the year within the Mississippi Sound, Lake Borgne, Mississippi and Alabama region is needed to improve future estimates of common bottlenose dolphins.

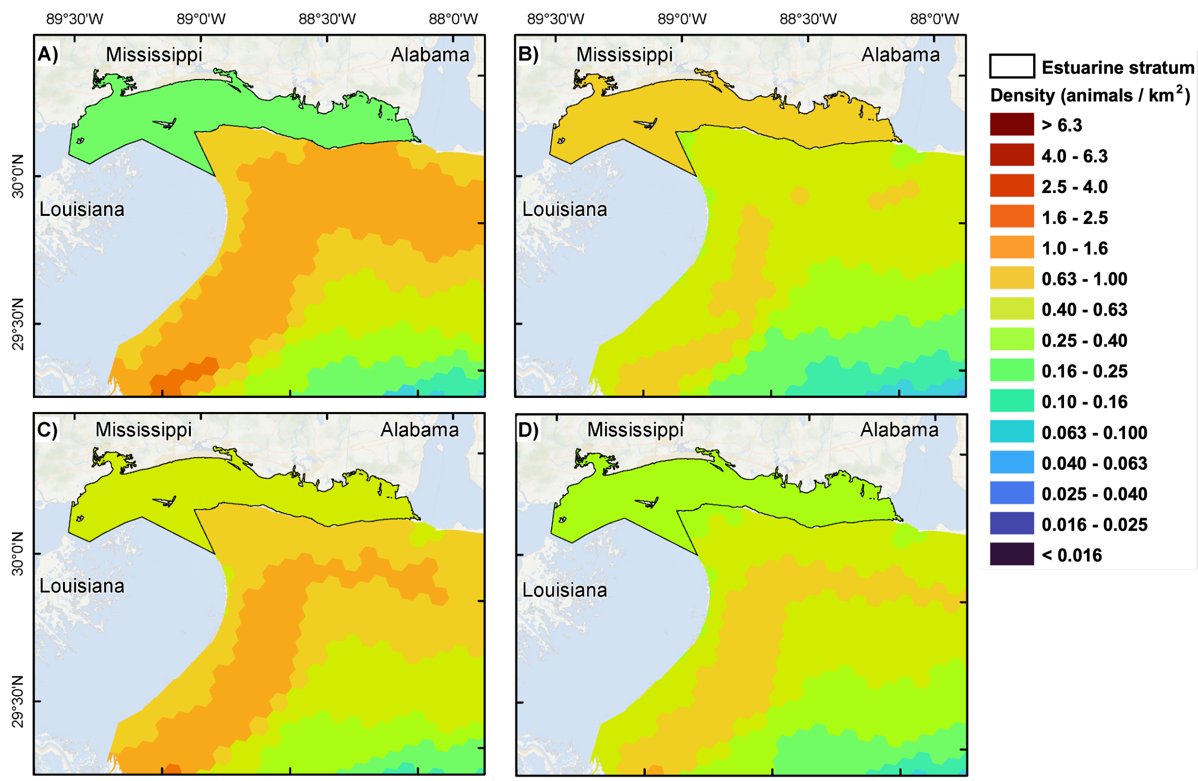

Fig. 26. Common bottlenose dolphin density estimate for the NMSDD stratum in the Mississippi Sound, Lake Borgne, Mississippi and Alabama region (outlined in black) using data from Vollmer et al. (2021), along with the densities in the GOM coastal waters from Southeast Fisheries Science Center (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Seasonal density estimates were calculated within the estuarine stratum and monthly density estimates were calculated within the GOM coastal stratum, but only four months were presented here as an example from each season. GOM model hexagon cell size: 40 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

St. Andrew Bay, Florida Region

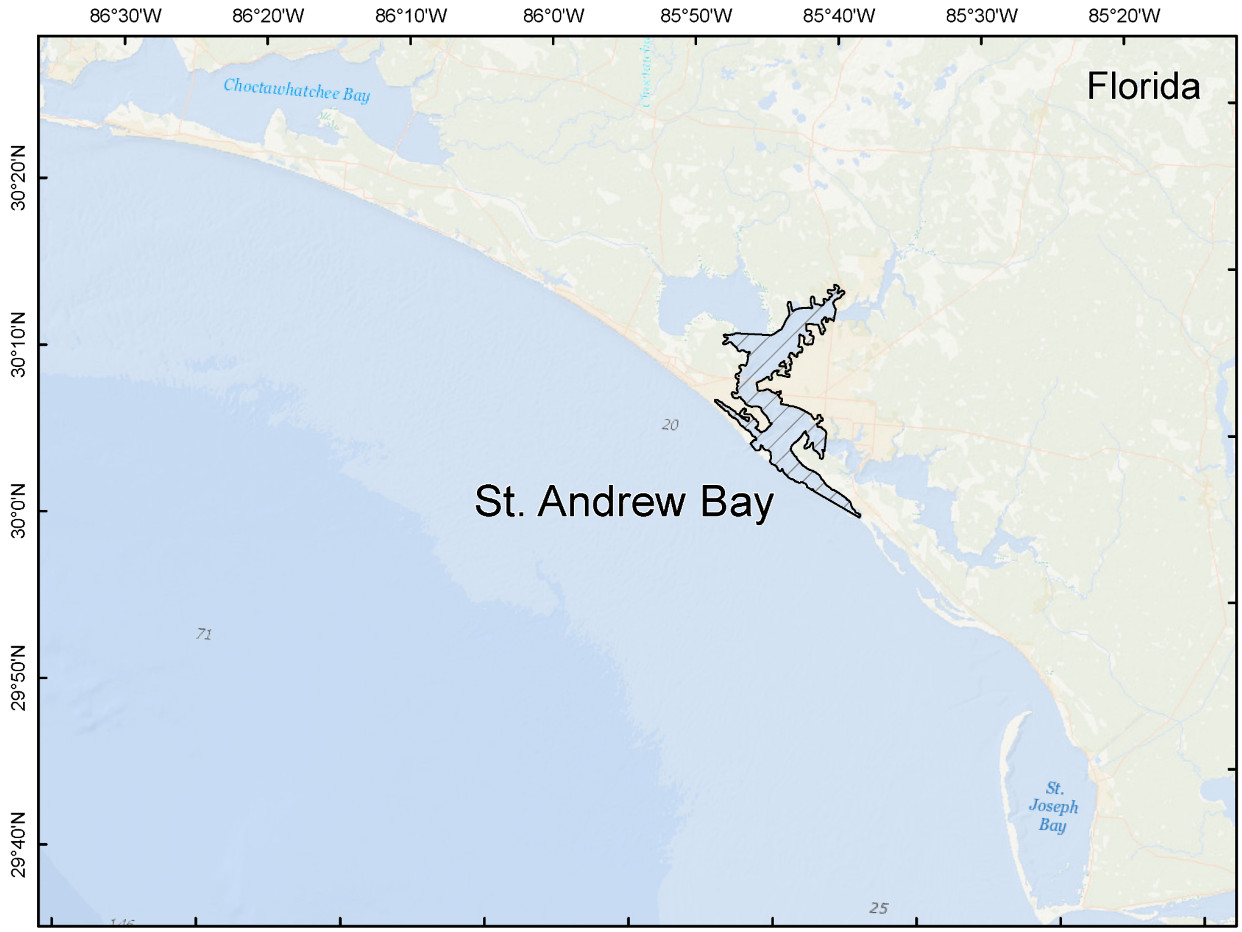

Fig. 27. The NMSDD stratum (hatched area) included in the St. Andrew Bay, Florida region (n = 1): St. Andrew Bay. Land, water, and reference sources: Esri, Garmin, GEBCO, NGDC, National Geographic, HERE, Geonames.org, and other contributors.

Common bottlenose dolphins in the NMSDD stratum within the St. Andrew Bay, Florida region have been identified as the St. Andrew Bay (SAB) stock, corresponding to Blaylock and Hoggard's (1994) survey block B10 (Hayes et al. 2019). The entire geographic extent of the SAB stock included West Bay, North Bay, St. Andrew Bay, East Bay, and Crooked Island Sound (Hayes et al. 2020), while the boundaries of the NMSDD stratum did not include West Bay, portions of North Bay, East Bay, or Crooked Island. Therefore, the NMSDD strata in this region overlapped with only a small portion of the extent of the SAB stock identified in these waters (Fig. 27).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the St. Andrew Bay, Florida region, and found two potential sources published since 2015 (i.e., Balmer et al. 2016, 2019). The most current assessment of the SAB common bottlenose dolphin stock was conducted by Hayes et al. (2020), reporting the best available information from photo-ID surveys conducted in 2016 by Balmer et al. (2019). The SAB stock's abundance estimate was reported as 199 (CV = 0.09) dolphins (Hayes et al. 2020). Balmer et al. (2019) reported abundances for this stock using data collected in two St. Andrew Bay subareas: BSE and coastal (CST). The BSE subareas that overlapped with the NMSDD strata in this region were the North Bay (NOB) and St. Andrew Bay (SAB). Common bottlenose dolphin density estimates were reported within the BSE for two primary periods for two years (Balmer et al. 2016).

In addition to searching for current literature, we contacted several marine mammal experts to request any available data or recent common bottlenose dolphin studies within the St. Andrew Bay, Florida region. Personal communication requests for information that could be used to estimate common bottlenose dolphin density were sent via email to Brian Balmer (US Fish and Wildlife Service, 2/18/2022), Kim Urian (Duke University, 2/23/2022), Lori Schwacke (National Marine Mammal Foundation, 2/23/2022), Ryan Takeshita (National Marine Mammal Foundation, 2/23/2022), Brian Quigley (National Marine Mammal Foundation, 2/23/2022) and Lance Garrison (NMFS SEFSC, 2/25/2022). B. Balmer suggested using density estimates calculated by using data from capture-recapture photo-ID surveys in 2015 and 2016 and presented in Balmer et al. (2016), which was supplemental information for the study published by Balmer et al. (2019). L. Garrison and others agreed that the best sources for data were collected by Balmer et al. (2016, 2019).

Because a better source of data and updated research on common bottlenose dolphins within these strata was available, we updated our methods and estimates from Phase III (Table 1). Therefore, we provided year-round estimated density for common bottlenose dolphins in the St. Andrew Bay, Florida region by using published data over two years within Balmer et al. (2016, 2019). Similar to methods that Roberts (2015) used to combine survey sessions for a year-round estimate, we first estimated the abundance and uncertainty by: 1) averaging the estimated abundance over all surveyed regions for each year, given the number of surveys conducted within that year, 2) calculating the estimated uncertainty for each year, 3) averaging all years for one annual estimated abundance value, and 4) calculating the overall uncertainty (see #4 in "Strategies for identifying the best available data sources" section for more details). The abundance estimates reported for the St. Andrew Bay were based on abundances for the SAB BSE stock and we applied this value to calculate density and uncertainty for the St. Andrew Bay stratum.

Results and discussion

Given the assumption that the abundance of the SAB stock was the same throughout its range, the mean year-round density over all habitats and strata in this region was 1.03 (CV = 0.25) dolphins/km^2 (Fig. 28). This year-round density estimate was higher than the monthly density estimates in nearby areas estimated by Southeast Fisheries Science Center (2022) for all months. Although this method was identified as the most appropriate with the best available data, the survey data overlapped with other nearby BSE areas northwest and southeast of the St. Andrew stratum. As with other US estuaries in the GOM, more recent research throughout the year within the St. Andrew Bay stratum is needed to improve future estimates of common bottlenose dolphins.

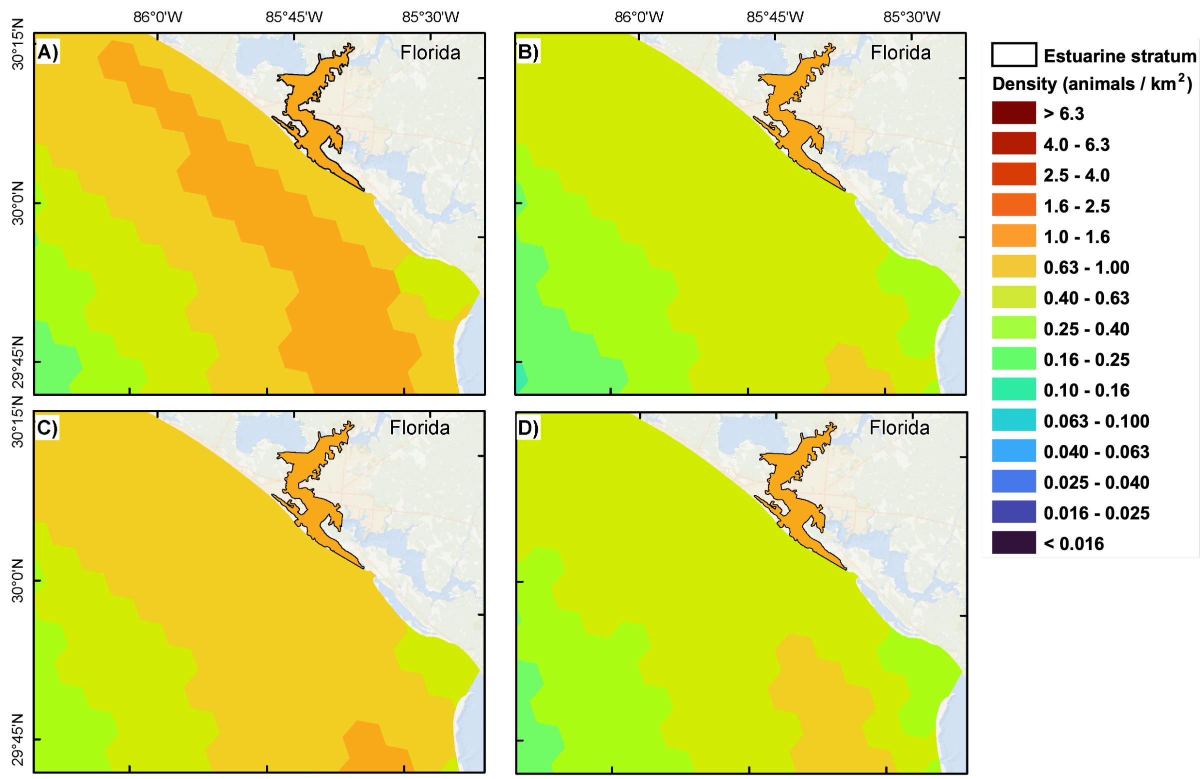

Fig. 28. Common bottlenose dolphin density estimate for the NMSDD stratum in the St. Andrew Bay, Florida region (outlined in black) using data from Balmer et al. (2016), along with the densities in the GOM coastal waters from Southeast Fisheries Science Center (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Seasonal density estimates were calculated within the estuarine stratum and monthly density estimates were calculated within the GOM coastal stratum, but only four months were presented here as an example from each season. GOM model hexagon cell size: 40 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Gullivan Bay, Ten Thousand Islands, Florida Region

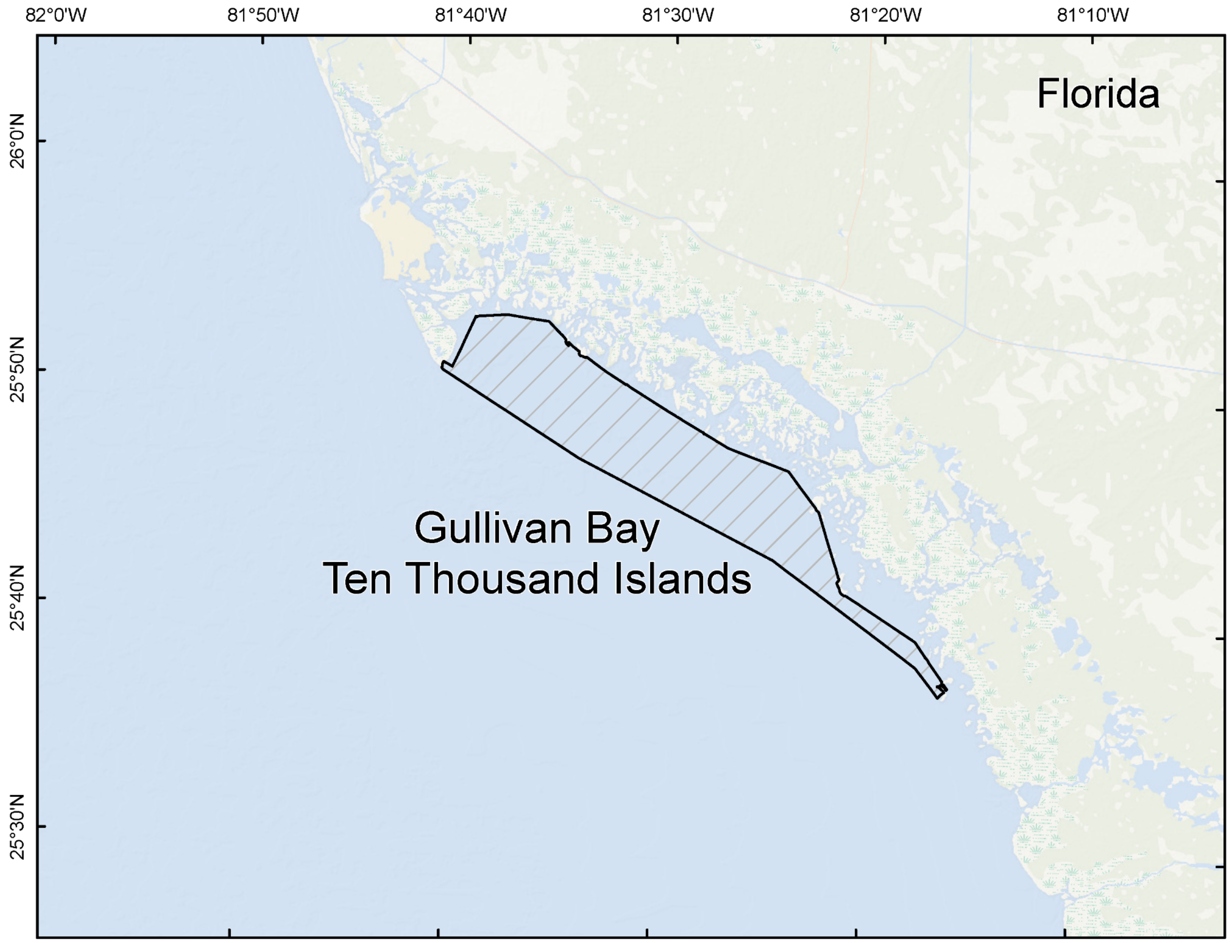

Fig. 29. The NMSDD stratum (hatched area) included in the Gullivan Bay, Ten Thousand Islands, Florida region (n = 1): Gullivan Bay Ten Thousand Islands. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Common bottlenose dolphins within the Gullivan Bay and Ten Thousand Islands NMSDD stratum have been identified as the Chokoloskee Bay / Ten Thousand Islands / Gullivan Bay stock (Fig. 29), corresponding to Blaylock and Hoggard's (1994) survey block B25 (Hayes et al. 2019). Hayes et al. (2022) noted that NMFS was "in the process of writing individual stock assessment reports for each of the 31 bay, sound and estuary [BSE] stocks of common bottlenose dolphins in the [GOM]." At this time, the most up-to-date information for the Chokoloskee Bay / Ten Thousand Islands / Gullivan Bay stock was provided within the Northern GOM BSE stock assessment (Hayes et al. 2019).

Methods

We searched within the literature for updated research on common bottlenose dolphins within the Gullivan Bay, Ten Thousand Islands, Florida region, and did not find any potential sources published since 2015. The most current assessment of the common bottlenose dolphin stocks in northern GOM BSE was conducted by Hayes et al. (2019), listing the Chokoloskee Bay / Ten Thousand Islands / Gullivan Bay stock as lacking any information or reference for data. Therefore, the minimum population estimate was determined as unknown because of insufficient data (Hayes et al. 2019).

In addition to searching for current literature, we contacted several marine mammal experts to request any available data or recent common bottlenose dolphin studies within the St. Andrew Bay, Florida region. Personal communication requests for information that could be used to estimate common bottlenose dolphin density were sent via email to Lance Garrison (NMFS SEFSC, 2/25/2022), Erin LaBrecque (US Marine Mammal Commission, 4/1/2022), Reny Tyson Moore (NMFS OPR, 4/1/2022), and Jolie Harrison (NMFS OPR, 4/1/2022). R. Tyson Moore passed along information of nearby photo-ID capture-mark-recapture surveys north and slightly overlapping the Gullivan Bay Ten Thousand NMSDD stratum (Tyson Moore et al. 2020); however, these data were not appropriate to apply to estimating densities within the stratum. L. Garrison suggested using data from the Southeast Fisheries Science Center (2022) GOM density model that overlapped with the strata and extrapolate data to areas where it did not overlap by taking the mean of adjacent cells; others agreed that appropriate data were not currently available.

Because a better source of data or updated research on common bottlenose dolphins within these strata was not available from external studies, we updated our methods and estimates from Phase III by using nearby estimated densities (Table 1). Therefore, we used the closest hexagon cells with data (values > 0) from the most current GOM regional density model (see Southeast Fisheries Science Center 2022) to calculate the density (and uncertainty) for common bottlenose dolphins within these strata, similar to extrapolation methods described in Roberts (2015). The Gullivan Bay Ten Thousand Island stratum overlapped with a total of 18 unique hexagons (used as substrata): 12 substrata with data and 6 substrata without data (values = 0). For the six substrata without data, we extrapolated density values by using the mean density of adjacent cells (with a shared boundary). Additionally, uncertainty values were extrapolated by calculating the overall variance, standard deviation, and mean density (see #4 in "Strategies for identifying the best available data sources" section for more details). For extrapolations, ten adjacent hexagon cells with data were used to estimate density and uncertainty for the six substrata originally lacking data.

Results and discussion

The monthly density for all 18 substrata ranged from 0.15 - 0.33 dolphins/km^2 (Table 9). The estimated density for common bottlenose dolphins, using the data from Southeast Fisheries Science Center (2022), resulted in monthly estimates that were similar to nearby coastal areas estimated within the GOM model (Fig. 30). Monthly density estimates were lower than the year-round density estimates from Roberts (2015) in most substrata within the Gullivan Bay Ten Thousand Islands strata. These monthly estimates were considered an improvement from Phase III, where Roberts (2015), which were calculated from a uniform density model by using aerial surveys conducted in 1994 (see Blaylock and Hoggard 1994). Limited research conducted near this stratum suggested that the spatial and temporal dynamics of common bottlenose dolphin communities in this region were still understudied and poorly understood. As was recommended by Roberts (2015) for other estuarine areas, additional research is still needed to improve upon current abundance and density estimates of common bottlenose dolphins within these strata.

Table 9. Summary statistics of the density (dolphins/km2) and uncertainty (CV) estimated for each season for all substrata (n = 18) in the Gullivan Bay Ten Thousand Islands, Florida region, by using data from Southeast Fisheries Science Center (2022). CVs presented here were calculated from between substrata values, without taking into account the uncertainty within substrata (CV = standard deviation of density/mean density).

	Density			
Month	**Minimum**	**Maximum**	**Mean**	**CV**
1	0.23	0.28	0.25	0.07
2	0.22	0.26	0.23	0.05
3	0.15	0.16	0.15	0.02
4	0.18	0.20	0.19	0.02
5	0.23	0.26	0.24	0.03
6	0.30	0.33	0.31	0.04
7	0.27	0.30	0.28	0.02
8	0.27	0.29	0.28	0.03
9	0.29	0.33	0.31	0.05
10	0.24	0.27	0.25	0.04
11	0.16	0.18	0.17	0.02
12	0.15	0.17	0.16	0.02

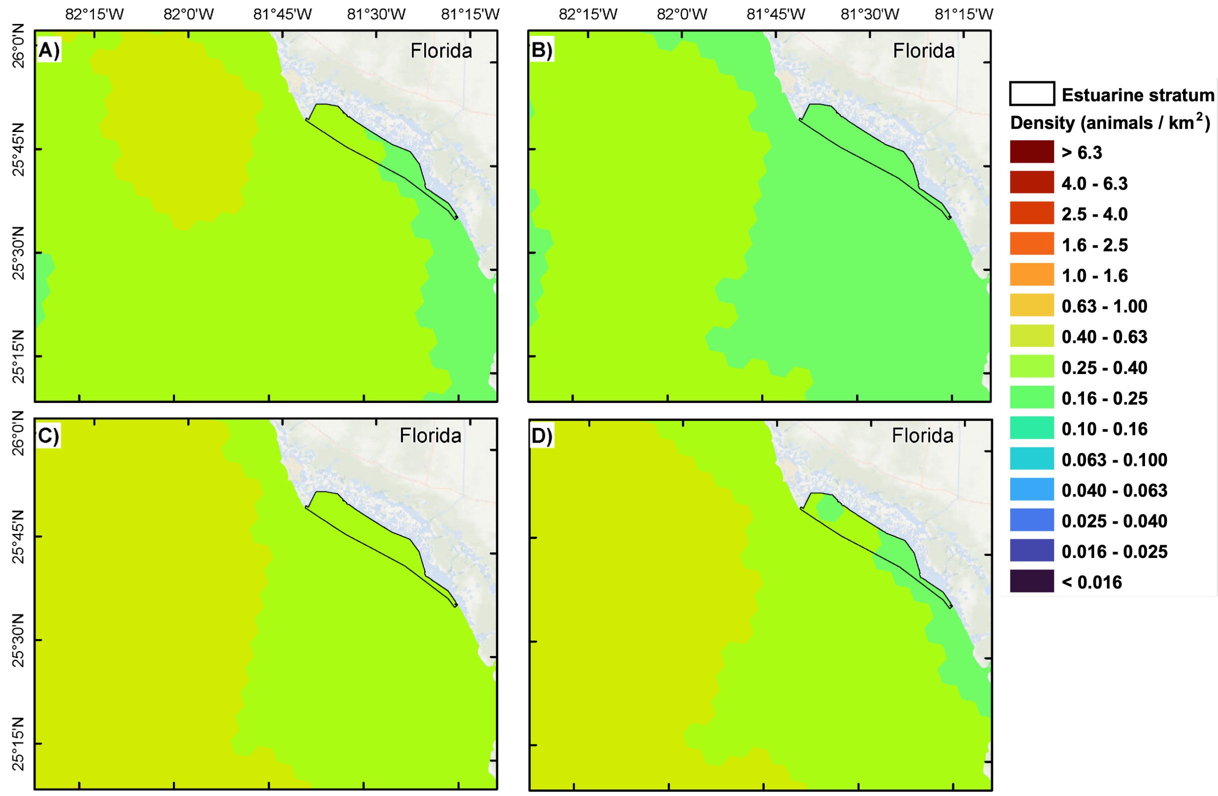

Fig. 30. Common bottlenose dolphin density estimate for the NMSDC stratum in the Gullivan Bay, Ten Thousand Islands, Florida region (outlined in black) using data from Southeast Fisheries Science Center (2022), along with the densities in the GOM coastal waters from Southeast Fisheries Science Center (2022) for a) January (winter), b) April (spring), c) July (summer), and d) October (fall). Monthly density estimates were calculated within the estuarine and GOM coastal strata, but only four months were presented here as an example from each season. GOM model hexagon cell size: 40 km^2. Land and water sources: Esri, Garmin, GEBCO, NGDC, and other contributors.

Conclusions

For Phase IV, the best available data and most appropriate methods were used to estimate common bottlenose dolphin densities within all EC and GOM regions with NMSDD estuarine strata. These sources were identified after reviewing the most up-to-date literature and datasets, along with feedback from marine mammal experts familiar with research within the regions. The density (and uncertainty) estimates for common bottlenose dolphins were updated for 20 strata: 11 strata from 4 regions in the EC and 9 strata from 6 regions in the GOM. Data from external sources were used for 6 strata in the EC and 6 strata in the GOM while all other updates were calculated by using data from the most recent regional density models (i.e., Roberts et al. 2022; Southeast Fisheries Science Center 2022). Data from external sources were collected by aerial visual line-transect surveys (Vollmer et al. 2021) and photo-ID surveys (Balmer et al. 2016; McDonald et al. 2017; Silva et al. 2020; Ronje et al. 2020; Durden et al. 2021) for six regions.

Estimates calculated for Phase III (Roberts 2015) remained the same for Phase IV when the previously identified data sources and methods were determined as still relevant and valid, without any other available updates. Estimates from Phase III were used for 15 strata within 5 regions in the EC and GOM and were calculated by using data from 1) published external sources, 2) previous data contributions from Department of the Navy (2014) for a habitat-based density model, or 3) previous data contributions from Blaylock and Hoggard (1994) for uniform density models. Future research should be prioritized to fill the existing spatio-temporal gaps, especially for regions where information may be outdated (based on data from >8 years ago; all strata without updated estimates from Phase III), or regions without any information (data extrapolations needed; Jacksonville, Florida, southeast Florida, western Mississippi River Delta, Louisiana, and Gullivan Bay, Ten Thousand Islands, Florida regions).

Estimating the density and uncertainty for common bottlenose dolphins within the EC and GOM estuarine areas was difficult because of the lack of baseline research needed to understand the structure of various stocks, their geographic extents, and how increasing pressures from anthropogenic activities can influence abundances (Hayes et al. 2022; Hohn et al. 2022). Long-term monitoring of these stocks is also necessary to better assess density because significant changes to their abundance and distribution within estuaries can result from their vulnerability to stressors, such as dolphin morbillivirus outbreaks (Balmer et al. 2018; Szott et al. 2022), biotoxins (Twiner et al. 2012), and environmental changes resulting from the Deepwater Horizon oil rig explosion (Litz et al. 2014; Lane et al. 2015; McDonald et al. 2017). Current knowledge on common bottlenose dolphin populations continues to be updated using dedicated surveys (e.g., aerial, shipboard, photo-ID), opportunistic sightings, genetic sampling, isotope analysis, and animal tracking technologies (Hayes et al. 2022). Additionally, several capture-release projects monitor threats and conduct health assessments for EC and GOM common bottlenose dolphin stocks to provide a baseline and examine trends (Barratclough et al. 2019). Updates to the density estimates should incorporate any new information collected and analyzed for these common bottlenose dolphin populations.

The combined approach for identifying the best available information using a literature review, current NMFS stock assessment reports, and input from marine mammal experts in the region was recommended to identify the best available information for future assessments. Marine mammal experts were essential to the process; many of the studies with relevant data were ongoing and not yet finalized, details were difficult to find, and results were only published in the grey literature or not available until requested from the principal investigators. This approach may be more critical for strata with non-strategic stocks that are assessed by NMFS every three years (e.g., Sabine Lake, St. Andrew Bay) or strata with common bottlenose dolphins not yet attributed to a defined stock (e.g., Scott Bay Dixon Bay, Southwest Pass).

Bibliography

Bailey H, Fandel AD, Silva K, Gryzb E, McDonald E, Hoover AL, Ogburn MB, Rice AN (2021) Identifying and predicting occurrence and abundance of a vocal animal species based on individually specific calls. Ecosphere 12:e03685. doi: 10.1002/ecs2.3685

Balmer B, Morey J, Quigley B, Rowles T, Speakman T, Ylitalo G, Zolman E, Schwacke L (2016) Bottlenose dolphin occurrence in St. Andrew Bay, Florida and coastal waters near the Naval Surface Warfare Center, Panama City Division Testing Range. MOA-2015-029/9087. Final report.

Balmer B, Zolman E, Rowles T, Smith C, Townsend F, Fauquier D, George C, Goldstein T, Hansen L, Quigley B, McFee W, Morey J, Rosel P, Saliki J, Speakman T, Schwacke L (2018) Ranging patterns, spatial overlap, and association with dolphin morbillivirus exposure in common bottlenose dolphins *(Tursiops truncatus)* along the Georgia, USA coast. Ecol Evol 8:12890–12904. doi: 10.1002/ece3.4727

Balmer B, Watwood S, Quigley B, Speakman T, Barry K, Mullin K, Rosel P, Sinclair C, Zolman E, Schwacke L (2019) Common bottlenose dolphin (*Tursiops truncatus*) abundance and distribution patterns in St Andrew Bay, Florida, USA. Aquat Conserv Mar Freshw Ecosyst 29:486–498. doi: 10.1002/aqc.3001

Balmer BC, Schwacke LH, Wells RS, Adams JD, George RC, Lane SM, McLellan WA, Rosel PE, Sparks K, Speakman T, Zolman ES, Pabst DA (2013) Comparison of abundance and habitat usage for common bottlenose dolphins between sites exposed to differential anthropogenic stressors within the estuaries of southern Georgia, U.S.A. Mar Mammal Sci 29:E114–E135. doi: 10.1111/j.1748-7692.2012.00598.x

Barratclough A, Wells RS, Schwacke LH, Rowles TK, Gomez FM, Fauquier DA, Sweeney JC, Townsend FI, Hansen LJ, Zolman ES, Balmer BC, Smith CR (2019) Health assessments of common bottlenose dolphins (*Tursiops truncatus*): past, present, and potential conservation applications. Front Vet Sci. doi: 10.3389/fvets.2019.00444

Blaylock RA, Hoggard W (1994) Preliminary estimates of bottlenose dolphin abundance in southern U.S. Atlantic and Gulf of Mexico continental shelf waters. NOAA Technical Memorandum NMFS-SEFSC-356. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL

Brightwell K, Titcomb EM, Mazzoil M, Gibson Q (2020) Common bottlenose dolphin (*Tursiops truncatus*) social structure and distribution changes following the 2008 Unusual Mortality Event in the Indian River Lagoon, Florida. Mar Mammal Sci 36:1271–1290. doi: 10.1111/mms.12716

Caldwell M (2001) Social and genetic structure of bottlenose dolphin (*Tursiops truncatus*) in Jacksonville, Florida. PhD thesis. University of Miami, Miami, FL

Department of the Navy (2014) Analysis of aerial surveys conducted in coastal waters of Maryland and Virginia, including Chesapeake Bay, 2011 - 2013: bottlenose dolphins. Prepared for U.S. Naval Facilities Engineering Command, Atlantic, Norfolk, Virginia under Contract No. N624070-10-3011, CTO40. Department of the Navy Naval Facilities Engineering Command, Atlantic, Nortfolk, VA

Durden WN, Stolen ED, Stolen MK (2011) Abundance, distribution, and group composition of Indian River Lagoon bottlenose dolphins (*Tursiops truncatus*). Aquat Mamm 37:175–186. doi: 10.1578/AM.37.2.2011.175

Durden WN, Stolen ED, Schlacher TA, Puckett SA, Stolen MK (2017) Monitoring seasonal abundance of Indian River Lagoon bottlenose dolphins (*Tursiops truncatus*) using aerial surveys. Aquat Mamm 43:90–112. doi: 10.1578/AM.43.1.2017.90

Durden WN, Stolen ED, Jablonski T, Moreland L, Howells E, Sleeman A, Denny M, Biedenbach G, Mazzoil M (2021) Abundance and demography of common bottlenose dolphins (*Tursiops truncatus truncatus*) in the Indian River Lagoon, Florida: A robust design capture-recapture analysis. PLOS ONE 16:e0250657. doi: 10.1371/journal.pone.0250657

Ermak J, Brightwell K, Gibson Q (2017) Multi-level dolphin alliances in northeastern Florida offer comparative insight into pressures shaping alliance formation. J Mammal 98:1096–1104. doi: 10.1093/jmammal/gyx053

ESRI (2022) ArcGIS Desktop: Release 10.7.1. ESRI, Redlands, CA

GADM (2018) GADM database of global administrative areas, version 3.6. Accessed on February 18, 2022. Database of Global Administrative Areas (GADM), https://gadm.org/

Garrison LP, Hohn AA, Hansen LJ (2017a) Seasonal movements of Atlantic common bottlenose dolphin stocks based on tag telemetry data. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL

Garrison LP, Barry K, Hoggard W (2017b) The abundance of coastal morphotype bottlenose dolphins on the U.S. east coast: 2002–2016. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Protected Resources and Biodiversity Division, Miami, FL

Garrison LP, Litz J, Sinclair C (2020) Predicting the effects of low salinity associated with the MBSD project on resident common bottlenose dolphins (*Tursiops truncatus*) in Barataria Bay, LA. NOAA Technical Memorandum NMFS-SEFSC-748. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL. doi: 10.25923/53z9-nn54

Garrison LP, Ortega-Ortiz J, Rappucci G (2021) Abundance of coastal and continental shelf stocks of common bottlenose and Atlantic spotted dolphins in the northern Gulf of Mexico: 2017-2018. Unpublished draft. PRD Contribution: #PRD-2021-01. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL

Gissendanner EJ (1984) Loxahatchee River--Lake Worth Creek Aquatic Preserve management plan. Department of Natural Resources, Division of Recreation and Parks, Bureau of Environmental Land Management, Tallahassee, FL

Glennie R, Thomas L, Speakman T, Garrison L, Takeshita R, Schwacke L (2021) Estimating spatially-varying density and time-varying demographics with open population spatial capture-recapture: a photo-ID case study on bottlenose dolphins in Barataria Bay, Louisiana, USA. arxiv.org/abs/2106.09579.

Greller R, Mazzoli M, Titcomb E, Nelson B, Paperno R, Markwith SH (2021) Environmental drivers of habitat use by common bottlenose dolphins (*Tursiops truncatus*) in the Indian River Lagoon, Florida, USA. Mar Mammal Sci 37:512–532. doi: 10.1111/mms.12767

Gubbins C, Caldwell M, Barco S, Rittmaster K, Bowles N, Thayer V (2003) Abundance and sighting patterns of bottlenose dolphins (*Tursiops truncatus*) at four northwest Atlantic coastal sites. J Cetacean Res Manag 5:141–148.

Hartel EF, Durden WN, O'Corry-Crowe G (2020) Testing satellite telemetry within narrow ecosystems: nocturnal movements and habitat use of bottlenose dolphins within a convoluted estuarine system. Anim Biotelemetry. doi: 10.1186/s40317-020-00200-4

Hayes SA, Josephson E, Maze-Foley K, Rosel PE (eds) (2017) US Atlantic and Gulf of Mexico marine mammal stock assessments - 2016. NOAA Technical Memorandum NMFS-NE-241. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA

Hayes SA, Josephson E, Maze-Foley K, Rosel PE (eds) (2018) US Atlantic and Gulf of Mexico marine mammal stock assessments - 2017: (second edition). NOAA Technical Memorandum NMFS-NE-245. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA

Hayes SA, Josephson E, Maze-Foley K, Rosel PE (eds) (2019) US Atlantic and Gulf of Mexico marine mammal stock assessments - 2018. NOAA Technical Memorandum NMFS-NE-258. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA

Hayes SA, Josephson E, Maze-Foley K, Rosel PE (eds) (2020) US Atlantic and Gulf of Mexico marine mammal stock assessments - 2019. NOAA Technical Memorandum NMFS-NE-264. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA

Hayes SA, Josephson E, Maze-Foley K, Rosel PE, Turek J (eds) (2021) US Atlantic and Gulf of Mexico marine mammal stock assessments 2020. NOAA Technical Memorandum NMFS-NE-271. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA

Hayes SA, Josephson E, Maze-Foley K, Rosel PE, Wallace J (eds) (2022) U.S. Atlantic and Gulf of Mexico marine mammal stock assessments 2021. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA

Hohn AA, Gorgone AM, Byrd BL, Shertzer KW, Eguchi T (2022) Patterns of association and distribution of estuarine-resident common bottlenose dolphins (*Tursiops truncatus*) in North Carolina, USA. PLOS ONE 17:e0270057. doi: 10.1371/journal.pone.0270057

Hornsby FE, McDonald TL, Balmer BC, Speakman TR, Mullin KD, Rosel PE, Wells RS, Telander AC, Marcy PW, Klaphake KC, Schwacke LH (2017) Using salinity to identify common bottlenose dolphin habitat in Barataria Bay, Louisiana, USA. Endanger Species Res 33:181–192. doi: 10.3354/esr00807

Hubard CW, Maze-Foley K, Mullin KD, Schroeder WW (2004) Seasonal abundance and site fidelity of bottlenose dolphins (*Tursiops truncatus*) in Mississippi sound. Aquat Mamm 30:299–310. doi: 10.1578/AM.30.2.2004.299

Hurst B, Orbach D (2022) Salinity affects wound healing in wild common bottlenose dolphins (*Tursiops truncatus*). Am J Undergrad Res 19:23–29. doi: 10.33697/ajur.2022.056

Keith EO (1999–2003) Annual reports of activities (1999-2003) as authorized under Letter of Confirmation No. 942-1497 issued by National Marine Fisheries Service. Nova Southeastern University, Oceanographic Center, Dania Beach, FL

Laist DW (2020) Bottlenose could be NC's marine mammal. Available at: https://coastalreview.org/2020/04/bottlenose-could-be-ncs-marine-mammal. Accessed 17 February 17 2022. North Carolina Coastal Federation, Newport, NC

Lane SM, Smith CR, Mitchell J, Balmer BC, Barry KP, McDonald T, Mori CS, Rosel PE, Rowles TK, Speakman TR, Townsend FI, Tumlin MC, Wells RS, Zolman ES, Schwacke LH (2015) Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisiana, USA, following the Deepwater Horizon oil spill. Proc R Soc B Biol Sci 282:20151944. doi: 10.1098/rspb.2015.1944

Lassiter JA (2022) Port Everglades Harbor Navigation (Deepening) Project: Letter of authorization (LOA) application. US Army Corps of Engineers – Jacksonville District, Jacksonville, FL

Litz J, Baran M, Carmichael R, Colegrove K, Fire S, Fougeres E, Hardy R, Holmes S, Jones W, Mase B, Odell D, Shannon D, Saliki J, Shippee S, Smith S, Stratton E, Bowen-Stevens S, Tumlin M, Whitehead H, Rowles T (2014) Review of historical unusual mortality events (UMEs) in the Gulf of Mexico (1990-2009): Providing context for the multi-year northern Gulf of Mexico cetacean UME declared in 2010. Dis Aquat Organ. doi: 10.3354/dao02807

Maze-Foley K, Byrd BL, Horstman SC, Powell JR (2019) Analysis of stranding data to support estimates of mortality and serious injury in common bottlenose dolphin (*Tursiops truncatus truncatus*) stock assessments for the Atlantic Ocean and Gulf of Mexico. doi: 10.25923/jt1x-jv75

Mazzoil M, Gibson Q, Durden WN, Borkowski R, Biedenbach G, McKenna Z, Gordon N, Brightwell K, Denny M, Howells E, Jakush J, Moreland L, Perna A, Pinto G, Caldwell M (2020) Spatiotemporal movements of common bottlenose dolphins (*Tursiops truncatus truncatus*) in Northeast Florida, USA. Aquat Mamm 46:285–300. doi: 10.1578/AM.46.3.2020.285

McDonald TL, Hornsby FE, Speakman TR, Zolman ES, Mullin KD, Sinclair C, Rosel PE, Thomas L, Schwacke LH (2017) Survival, density, and abundance of common bottlenose dolphins in Barataria Bay (USA) following the Deepwater Horizon oil spill. Endanger Species Res 33:193–209. doi: 10.3354/esr00806

Mullin KD, McDonald T, Wells RS, Balmer BC, Speakman T, Sinclair C, Zolman ES, Hornsby F, McBride SM, Wilkinson KA, Schwacke LH (2017) Density, abundance, survival, and ranging patterns of common bottlenose dolphins (*Tursiops truncatus*) in Mississippi Sound following the Deepwater Horizon oil spill. PLOS ONE 12:e0186265. doi: 10.1371/journal.pone.0186265

Murawski SA, Kilborn JP, Bejarano AC, Chagaris D, Donaldson D, Hernandez Jr FJ, MacDonald TC, Newton C, Peebles E, Robinson KL (2021) A synthesis of Deepwater Horizon impacts on coastal and nearshore living marine resources. Front Mar Sci. doi: 10.3389/fmars.2020.594862

Nekolny SR, Denny M, Biedenbach G, Howells EM, Mazzoil M, Durden WN, Moreland L, Lambert JD, Gibson QA (2017) Effects of study area size on home range estimates of common bottlenose dolphins *Tursiops truncatus*. Curr Zool 63:693–701. doi: 10.1093/cz/zox049

Pitchford J, Pulis E, Evans K, Shelley J, Serafin B, Solangi M (2016) Seasonal density estimates of *Tursiops truncatus* (bottlenose dolphin) in the Mississippi Sound from 2011 to 2013. Southeast Nat 15:188–206. doi: 10.1656/058.015.0201

Precht WF, Iglesias K, Robbart ML (2019) Autogrooming in the bottlenose dolphin, *Tursiops truncatus* (Montagu 1821). Reef Encount 34:47.

QGIS Development Team (2020) QGIS geographic information system. Open source geospatial foundation project. QGIS version 3.16.5. Available at: http://qgis.osgeo.org. Accessed October 2020.

Quigley BM, Speakman TR, Balmer BC, Europe HM, Gorgone AM, Rowles TK, Sinclair C, Zolman ES, Schwacke LH (2022) Observations of a benthic foraging behavior used by common bottlenose dolphins (*Tursiops truncatus*) in Barataria Basin, Louisiana, USA. Aquat Mamm 48:159–166.

Read AJ, Urian KW, Wilson B, Waples DM (2003) Abundance of bottlenose dolphins in the bays, sounds, and estuaries of North Carolina. Mar Mammal Sci 19:59–73.

Reif JS, Schaefer AM, Daniel M, Harrington T, Hanisak D, Titcomb E, Mazzoil M (2018) Dolphin sightings in the vicinity of land/ocean biogeochemical observatories: relationships with weather and water quality. Aquat Mamm 44:367–373. doi: 10.1578/AM.44.4.2018.367

Roberts JJ (2015) Estimates of bottlenose dolphin density for estuaries in the AFTT area for the Phase III NMSDD. Version 1.2. Duke University, Nicholas School of the Environment, Marine Geospatial Ecology Lab, Durham, NC

Roberts JJ, Yack TM, et al. (2022) Density model for common bottlenose dolphin (*Tursiops truncatus*) for the U.S. east coast, Version 6, 2022-06-20, and supplementary report. Duke University, Nicholas School of the Environment, Marine Geospatial Ecology Lab, Durham, NC

Rodriguez LK, Fandel AD, Colbert BR, Testa JC, Bailey H (2021) Spatial and temporal variation in the occurrence of bottlenose dolphins in the Chesapeake Bay, USA, using citizen science sighting data. PLOS ONE 16:e0251637. doi: 10.1371/journal.pone.0251637

Ronje E, Whitehead H, Piwetz S, Mullin K (2018) Field summary for common bottlenose dolphin surveys on the Texas, Gulf of Mexico coast, 2014-2016. Southeast Fisheries Science Center PRBD-2018-02. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula, MS

Ronje E, Whitehead H, Barry K, Piwetz S, Struve J, Lecours V, Garrison L, Wells R, Mullin K (2020) Abundance and occurrence of common bottlenose dolphins (*Tursiops truncatus*) in three estuaries of the northwestern Gulf of Mexico. Gulf Caribb Res 31:18–34. doi: 10.18785/gcr.3101.09

Rosel PE, Hansen L, Hohn AA (2009) Restricted dispersal in a continuously distributed marine species: Common bottlenose dolphins *Tursiops truncatus* in coastal waters of the western North Atlantic. Mol Ecol 18:5030–5045.

Schwacke LH, Marques TA, Thomas L, Booth CG, Balmer BC, Barratclough A, Colegrove K, De Guise S, Garrison LP, Gomez FM, Morey JS, Mullin KD, Quigley BM, Rosel PE, Rowles TK, Takeshita R, Townsend FI, Speakman TR, Wells RS, Zolman ES, Smith CR (2022) Modeling population effects of the Deepwater Horizon oil spill on a long-lived species. Conserv Biol 36:e13878. doi: 10.1111/cobi.13878

Silva D, Young RF, Lavin A, O'Shea C, Murray E (2020) Abundance and seasonal distribution of the Southern North Carolina Estuarine System Stock of common bottlenose dolphins. J Cetacean Res Manag 21:33–43.

Southeast Fisheries Science Center (2022) Common bottlenose dolphin spatial density models - shelf and coastal waters. Version 2. Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) marine mammal assessment research. Unpublished raw dataset. Obtained on 5 April 2022. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL

Speakman TR, Wilcox LA, Balmer BC, Barry KP, Paterson C, Quigley BM, Schwacke LH, Sinclair C, Takeshita R, Vollmer NL, Zolman ES, Rosel PE (2022) Fine-scale social and genetic structure of common bottlenose dolphins (*Tursiops truncatus*) in the Barataria Basin, Louisiana, USA. Aquat Conserv Mar Freshw Ecosyst 32:1437–1456. doi: 10.1002/aqc.3866

Szott EA, Brightwell K, Gibson Q (2022) Assessment of social mixing and spatial overlap as a pathway for disease transmission in a northeast Florida estuarine dolphin community. Mamm Biol. doi: 10.1007/s42991-022-00282-y

Twiner MJ, Flewelling LJ, Fire SE, Bowen-Stevens SR, Gaydos JK, Johnson CK, Landsberg JH, Leighfield TA, Mase-Guthrie B, Schwacke L, Dolah FMV, Wang Z, Rowles TK (2012) Comparative analysis of three brevetoxin-associated bottlenose dolphin (*Tursiops truncatus*) mortality events in the Florida Panhandle region (USA). PLOS ONE 7:e42974. doi: 10.1371/journal.pone.0042974

Tyson Moore R, Allen J, Barlycorn A, Cush C, Honaker A, McBride Kebert S, Wells R (2020) Final report: Abundance and distribution of common bottlenose dolphins (*Tursiops truncatus*) near Naples and Marco Island, Florida, USA, 2018-2019. Prepared for the Batchelor Foundation. Chicago Zoological Society Sarasota Dolphin Research Program, Sarasota, FL

USEPA (1999) Ecological condition of estuaries in the Gulf of Mexico. EPA 620-R-98-004. U.S. Environmental Protection Agency (USEPA), Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL

Vollmer NL, Rosel PE, Mullin KD, Schwacke LH, Garrison LP, Balmer BC, Barry K, Martinez A, Quigley BM, Sinclair C, Speakman TR, Wicker J, Wilcox L, Zolman ES (2021) Assessing common bottlenose dolphin (*Tursiops truncatus*) population structure in Mississippi Sound and coastal waters of the north central Gulf of Mexico. Aquat Conserv Mar Freshw Ecosyst 31:2951–2966. doi: 10.1002/aqc.3668

Waring GT, Josephson E, Maze-Foley K, Rosel PE (eds) (2013) U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2012. Volume 1. NOAA Technical Memorandum NMFS-NE-223. National Oceanic and Atmospheric Administration National Marine Fisheries Service Northeast Fisheries Science Center, Woods Hole, MA

Waring GT, Josephson E, Maze-Foley K, Rosel PE (eds) (2016) US Atlantic and Gulf of Mexico marine mammal stock assessments - 2015. NOAA Technical Memorandum NMFS-NE-238. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA

Wells RS, Schwacke LH, Rowles TK, Balmer BC, Zolman E, Speakman T, Townsend FI, Tumlin MC, Barleycorn A, Wilkinson KA (2017) Ranging patterns of common bottlenose dolphins *Tursiops truncatus* in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. Endanger Species Res 33:159–180. doi: 10.3354/esr00732

Zollett EA, Read AJ (2006) Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. Fish Bull 104:343–349.