Density Model for Northern Bottlenose Whale (*Hyperoodon ampullatus*) for the U.S. Navy Atlantic Fleet Testing and Training (AFTT) Study Area: Supplementary Report

Model Version 2

Duke University Marine Geospatial Ecology Laboratory*

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Citation

When referencing our methodology or results generally, please cite Roberts et al. (2023), which documented the modeling cycle we completed in the 2022 for the U.S. Navy AFTT Phase IV Environmental Impact Statement, and Mannocci et al. (2017), which developed the original methodology and models upon which the 2022 models were based. The full citations appear in the References section at the end of this document.

To independently reference this specific model or Supplementary Report, please cite:

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Model Version History

Version	Date	Description
1	2015-01-23	First publicly-released version of this model, released in 2015 as part of the final delivery of the U.S. Navy Marine Species Density Database (NMSDD) for the Atlantic Fleet Testing and Training (AFTT) Phase III Environmental Impact Statement.
2	2022-06-20	Updated the AFTT Phase III model with many additional surveys contributed since that time. Please see Roberts et al. (2022, 2023) for details. This update was released as part of the final delivery of the NMSDD for the AFTT Phase IV Environmental Impact Statement.

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1 Survey Data

The goal of this project was to build, for the U.S. Navy's AFTT Phase IV Environmental Impact Statement (EIS), an update to the model we developed for the AFTT Phase III EIS. The Phase III model was developed using the methodology of Mannocci et al. (2017) by L. Mannocci but not included in the 2017 publication. Following the approach taken by that model, we built this update only from data collected in the east coast region. We excluded surveys that did not target northern bottlenose whales or were otherwise problematic for modeling them. We restricted the model to aerial survey transects with sea states of Beaufort 4 or less (for a few surveys we used Beaufort 3 or less) and shipboard transects with Beaufort 5 or less (for a few we used Beaufort 4 or less). We also excluded transects with poor weather or visibility for surveys that reported those conditions. Table 1 summarizes the survey effort and sightings available for the model after most exclusions were applied.

Table 1: Survey effort and observations considered for this model. Effort is tallied as the cumulative length of on-effort transects. Observations are the number of groups and individuals encountered while on effort. Off effort observations and those lacking an estimate of group size or distance to the group were excluded.

			Effort	Observations		
Institution	Program	Period	1000s km	Groups	Individuals	Mean Group Size
Aerial Surveys						
HDR	Navy Norfolk Canyon	2018-2019	11	0	0	
NEAq	CNM	2017-2020	2	0	0	
NEAq	MMS-WEA	2017-2020	37	0	0	
NEAq	NLPSC	2011-2015	43	0	0	
NEFSC	AMAPPS	2010-2019	89	2	13	6.5
NEFSC	NARWSS	2003-2020	448	1	2	2.0
NEFSC	Pre-AMAPPS	1999-2008	46	1	2	2.0
NYS-DEC/TT	NYBWM	2017-2020	60	0	0	
SEFSC	AMAPPS	2010-2020	114	0	0	
SEFSC	MATS	1995-2005	34	0	0	
SEFSC	SECAS	1992-1995	8	0	0	
UNCW	MidA Bottlenose	2002-2002	17	0	0	
UNCW	Navy Cape Hatteras	2011-2017	34	0	0	
UNCW	Navy Jacksonville	2009-2017	92	0	0	
UNCW	Navy Norfolk Canyon	2015-2017	14	0	0	
UNCW	Navy Onslow Bay	2007-2011	49	0	0	
UNCW	SEUS NARW EWS	2005-2008	114	0	0	
VAMSC	MD DNR WEA	2013-2015	16	0	0	
VAMSC	Navy VACAPES	2016-2017	19	0	0	
VAMSC	VA CZM WEA	2012-2015	21	0	0	
		Total	**1,271**	**4**	**17**	**4.2**
Shipboard Surveys						
MCR	SOTW Visual	2012-2019	8	2	3	1.5
NEFSC	AMAPPS	2011-2016	14	0	0	
NEFSC	Pre-AMAPPS	1995-2007	16	4	16	4.0
SEFSC	AMAPPS	2011-2016	14	0	0	
SEFSC	Pre-AMAPPS	1992-2006	29	0	0	
		Total	**81**	**6**	**19**	**3.2**
		Grand Total	**1,352**	**10**	**36**	**3.6**

Table 2: Institutions that contributed surveys used in this model.

Institution	Full Name
HDR	HDR, Inc.
MCR	Marine Conservation Research
NEAq	New England Aquarium

Table 2: Institutions that contributed surveys used in this model. *(continued)*

Institution	Full Name
NEFSC	NOAA Northeast Fisheries Science Center
NYS-DEC/TT	New York State Department of Environmental Conservation and Tetra Tech, Inc.
SEFSC	NOAA Southeast Fisheries Science Center
UNCW	University of North Carolina Wilmington
VAMSC	Virginia Aquarium & Marine Science Center

Table 3: Descriptions and references for survey programs used in this model.

Program	Description	References
AMAPPS	Atlantic Marine Assessment Program for Protected Species	Palka et al. (2017), Palka et al. (2021)
CNM	Northeast Canyons Marine National Monument Aerial Surveys	Redfern et al. (2021)
MATS	Mid-Atlantic Tursiops Surveys	
MD DNR WEA	Aerial Surveys of the Maryland Wind Energy Area	Barco et al. (2015)
MidA Bottlenose	Mid-Atlantic Onshore/Offshore Bottlenose Dolphin Surveys	Torres et al. (2005)
MMS-WEA	Marine Mammal Surveys of the MA and RI Wind Energy Areas	Quintana-Rizzo et al. (2021), O'Brien et al. (2022)
NARWSS	North Atlantic Right Whale Sighting Surveys	Cole et al. (2007)
Navy Cape Hatteras	Aerial Surveys of the Navy's Cape Hatteras Study Area	McLellan et al. (2018)
Navy Jacksonville	Aerial Surveys of the Navy's Jacksonville Study Area	Foley et al. (2019)
Navy Norfolk Canyon	Aerial Surveys of the Navy's Norfolk Canyon Study Area	Cotter (2019), McAlarney et al. (2018)
Navy Onslow Bay	Aerial Surveys of the Navy's Onslow Bay Study Area	Read et al. (2014)
Navy VACAPES	Aerial Survey Baseline Monitoring in the Continental Shelf Region of the VACAPES OPAREA	Mallette et al. (2017)
NLPSC	Northeast Large Pelagic Survey Collaborative Aerial Surveys	Leiter et al. (2017), Stone et al. (2017)
NYBWM	New York Bight Whale Monitoring Surveys	Zoidis et al. (2021)
Pre-AMAPPS	Pre-AMAPPS Marine Mammal Abundance Surveys	Mullin and Fulling (2003), Garrison et al. (2010), Palka (2006)
SECAS	Southeast Cetacean Aerial Surveys	Blaylock and Hoggard (1994)
SEUS NARW EWS	Southeast U.S. Right Whale Early Warning System Surveys	
SOTW Visual	R/V Song of the Whale Visual Surveys	Ryan et al. (2013)
VA CZM WEA	Virginia CZM Wind Energy Area Surveys	Mallette et al. (2014), Mallette et al. (2015)

2 Geographic Strata

Our objective was to update the Phase III model with new data without revising the model's overall structure. During the Phase III modeling cycle, it was determined that there were too few sightings to fit a traditional density surface model that related density observed on survey segments to environmental covariates. Nor was it possible to make proper design-based abundance estimates using traditional distance sampling (Buckland et al. 2001), because the aggregate surveys provided very heterogeneous coverage that did not together constitute a proper systematic survey design.

To provide interested parties with at least rough estimates of density in ecologically relevant geographic strata, we followed the prior model and assumed that northern bottlenose whales were present throughout waters with a mean sea surface temperature <22 °C, >1000 m deep, and within a distance of <100 km to a submarine canyon. The prior model used a threshold of >2000 m deep, but we moved this threshold to >1000 m after a sighting not available for that model was reported at 1065 m. We then fitted a model with no covariates to all segments within that region. This approach necessarily assumed that density would be distributed uniformly throughout the region. This assumption, if true, would mean we would obtain similar density estimates under any sampling design, and therefore it would not matter if there was some heterogeneity in sampling. However, we strongly caution that this assumption did not hold for the other, more-common species we successfully modeled with traditional density surface modeling, as evidenced by the non-uniform patterns in density predicted by those species' models. But without more data, we cannot elucidate those patterns confidently through the normal modeling process. Thus, for the much rarer species, such as northern bottlenose whale documented here, we offer this simplified approach as a rough-and-ready substitute for a full density surface model.

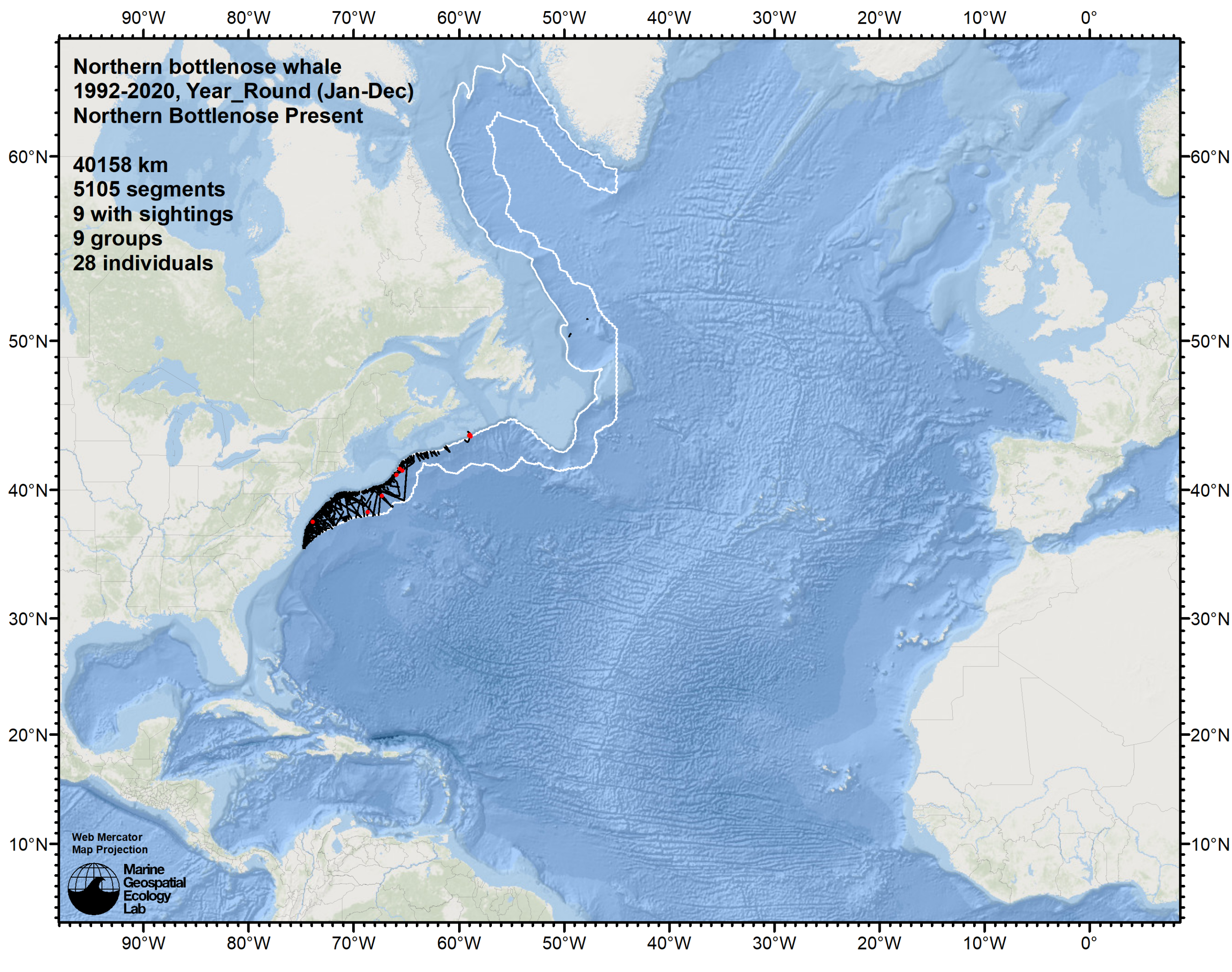

Figure 1: Survey segments and sightings used to estimate Northern bottlenose whale density. Black lines and red points indicate the segments and sightings used to estimate density. White polygon indicates the region to which the density was applied.

3 Predictions

3.1 Summarized Predictions

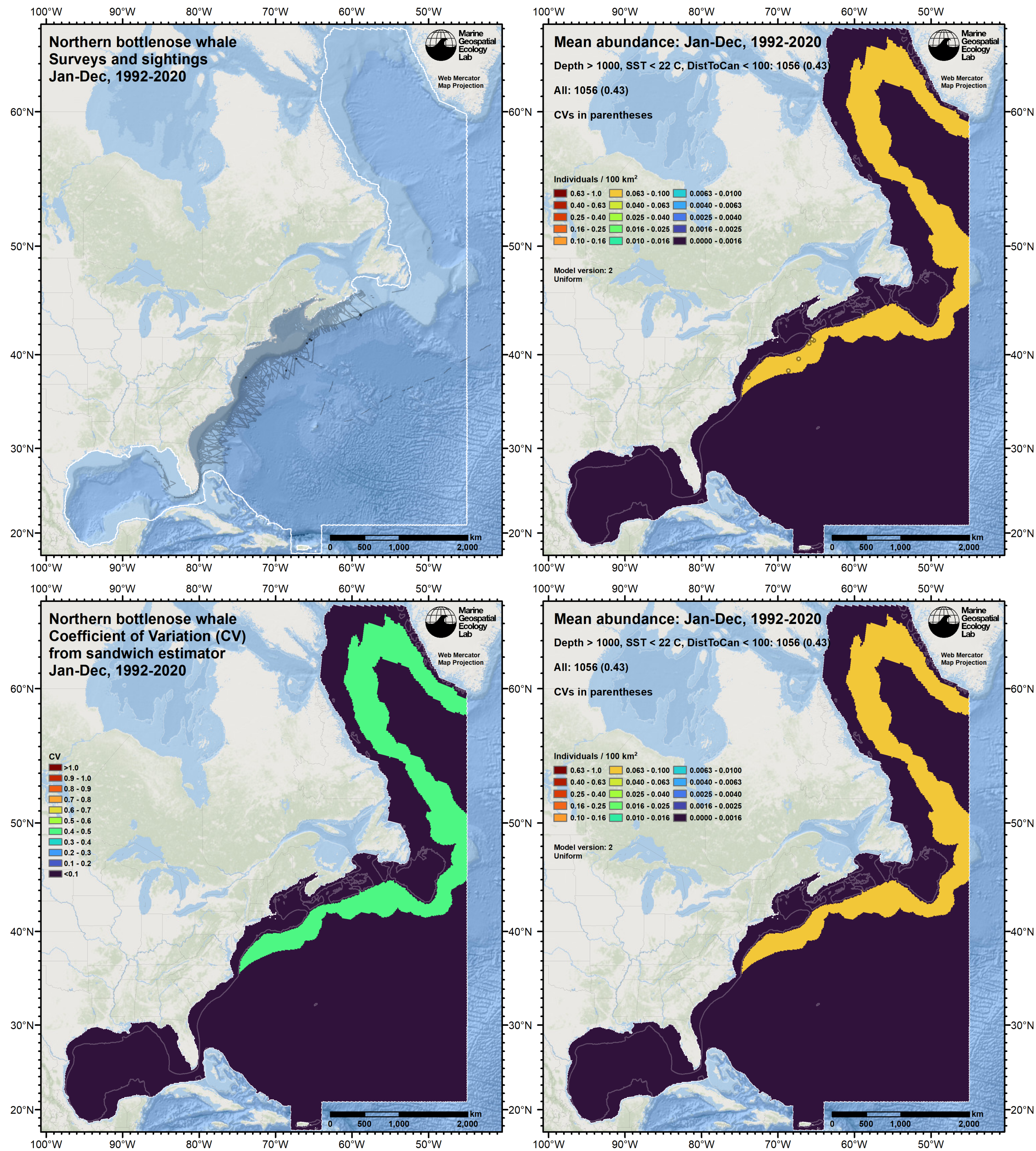

Figure 2: Survey effort and observations (top left), predicted density with observations (top right), predicted density without observations (bottom right), and coefficient of variation of predicted density (bottom left), for the given era. These maps use a Web Mercator projection but the analysis was conducted in an Albers Equal Area coordinate system appropriate for density modeling.

3.2 Comparison to Previous Density Model

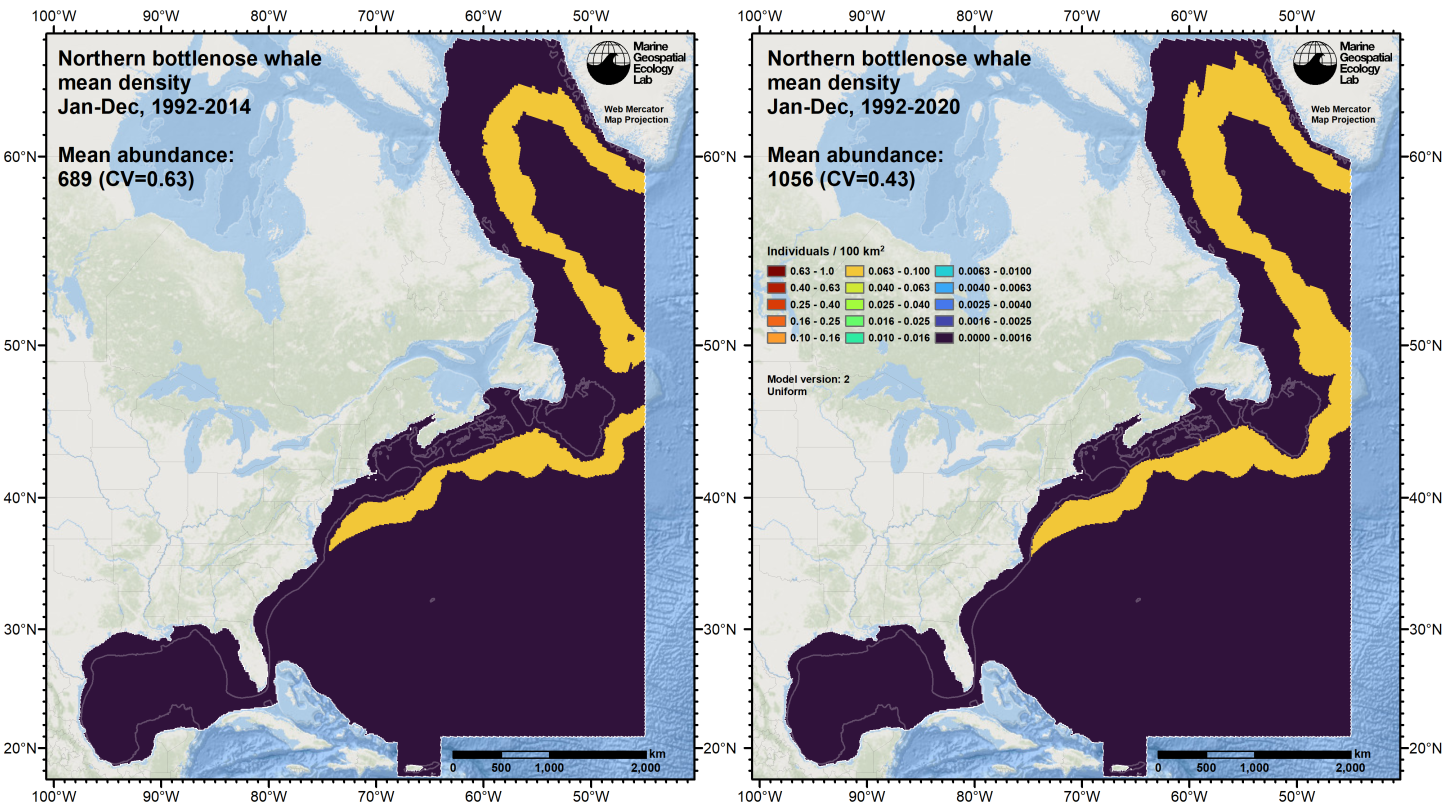

Figure 3: Comparison of the mean density predictions from the previous model (left) to those from this model (right). These maps use a Web Mercator projection but the analysis was conducted in an Albers Equal Area coordinate system appropriate for density modeling.

4 Discussion

Following what was done for the prior model, we summarized this updated model into a single year-round mean density surface (Figure 2). Although our figures show predictions for the East Coast (EC) region, we recommend that the regional EC model be used for the region it covers instead. See Roberts et al. (2023) for more discussion of the models.

The model estimated a total abundance that was about 53% higher than that of the prior model (Figure 3), mainly resulting from the expansion of of the modeled stratum to the 1000 m isobath, but the two estimates were not significantly different statistically. We caution that the OBIS-SEAMAP archive (Halpin et al. 2009) shows numerous sightings at shallower depths of the Scotian Shelf (https://seamap.env.duke.edu/species/180504). Some of these may have been reported during aerial surveys of Canadian waters during 2007 and 2015 (Lawson and Gosselin 2009, 2018). Sightings were also reported during aerial surveys of west Greenland at the same time (Hansen et al. 2019). The aerial surveys of Canada and Greenland were not available for use in this model; future updates would benefit from their inclusion.

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