Density Model for Seals (*Phocidae*) for the U.S. Navy Atlantic Fleet Testing and Training (AFTT) Study Area: Supplementary Report

Model Version 2

Duke University Marine Geospatial Ecology Laboratory*

2022-06-20

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 sightings of hauled-out seals; density estimates given by this model are for seals in the water. Seals are small and difficult to detect from long distances or in poor conditions. Accordingly, we excluded all surveys that did not target seals, as well as aerial surveys flown at altitudes higher than 750 ft., which species experts within our collaboration determined was the maximum altitude they were likely to be reliably detected. Although detections at higher altitudes were possible, we lacked the counts needed to fit detection functions unless we pooled surveys flown at lower altitudes, which species experts determined would be inappropriate. Some surveys flown at 1000 ft. utilized a belly camera to address this problem, but the camera data were not available for this project. Finally, we restricted this model to survey transects collected in sea states of Beaufort 3 or less, owing to the difficulty in modeling detectability of seals in rougher sea states. 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						
NEFSC	AMAPPS	2010-2019	55	530	1,151	2.2
NEFSC	NARWSS	2003-2016	274	791	1,803	2.3
NEFSC	Pre-AMAPPS	1999-2008	37	146	261	1.8
NJDEP	NJEBS	2008-2009	9	1	1	1.0
SEFSC	AMAPPS	2010-2020	91	0	0	
SEFSC	MATS	2002-2005	27	0	0	
VAMSC	MD DNR WEA	2013-2015	11	0	0	
		Total	**504**	**1,468**	**3,216**	**2.2**
Shipboard Surveys						
MCR	SOTW Visual	2012-2019	6	1	1	1.0
NEFSC	AMAPPS	2011-2016	8	9	9	1.0
NEFSC	Pre-AMAPPS	1995-2007	13	210	234	1.1
NJDEP	NJEBS	2008-2009	7	3	4	1.3
SEFSC	AMAPPS	2011-2016	10	0	0	
SEFSC	Pre-AMAPPS	1992-2006	19	0	0	
SEFSC	SEFSC Caribbean	1995-2000	4	0	0	
		Total	**66**	**223**	**248**	**1.1**
		Grand Total	**570**	**1,691**	**3,464**	**2.0**

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

Institution	Full Name
MCR	Marine Conservation Research
NEFSC	NOAA Northeast Fisheries Science Center
NJDEP	New Jersey Department of Environmental Protection
SEFSC	NOAA Southeast Fisheries Science Center
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)
MATS	Mid-Atlantic Tursiops Surveys	
MD DNR WEA	Aerial Surveys of the Maryland Wind Energy Area	Barco et al. (2015)
NARWSS	North Atlantic Right Whale Sighting Surveys	Cole et al. (2007)
NJEBS	New Jersey Ecological Baseline Study	Geo-Marine, Inc. (2010), Whitt et al. (2015)
Pre-AMAPPS	Pre-AMAPPS Marine Mammal Abundance Surveys	Mullin and Fulling (2003), Garrison et al. (2010), Palka (2006)
SEFSC Caribbean	SEFSC Surveys of the Caribbean Sea	Mullin (1995), Swartz and Burks (2000)
SOTW Visual	R/V Song of the Whale Visual Surveys	Ryan et al. (2013)

2 Geographic Strata

Our objective was to update the Phase III model with new data without radically revising the model's overall structure. During the Phase III modeling cycle, we initially attempted to apply the primary model development approach of Mannocci et al. (2017) and built a set of candidate density surface models containing up to four environmental covariates. All of the top candidate models extrapolated poorly into shelf waters of Canada and west Greenland, strongly underestimating density there. As a fallback, we instead fitted a model with no covariates to a single stratum defined as all waters north of Cape Hatteras shallower than 1000 m, and assumed that density south of Cape Hatteras or deeper than 1000 m was zero, based on no sightings occurring there. This yielded a uniform density surface that estimated much more reasonable densities throughout northern shelf waters.

For the updated model, we made two improvements to this approach. First, we split the original stratum at Hudson Canyon, to account for seal density being much lower and more seasonal south of there than in southern New England, the Gulf of Maine, and Atlantic Canada, where seals are seen in large numbers year-round. Second, north of Hudson Canyon we defined a stratum covering waters between 1000-4000 m deep, based on a few sightings having occurred there in newly-introduced surveys, and also on the OBIS-SEAMAP archive (Halpin et al. 2009) showing occasional opportunistic sightings offshore from the vicinity of Hudson Canyon through the Labrador Sea (https://seamap.env.duke.edu/species/552303).

This stratified approach necessarily assumed that density would be distributed uniformly throughout each stratum. This assumption, if true, would mean we would obtain similar density estimates under any sampling design within the stratum in question, 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. Until such time that we can introduce survey data from Canada (see Section 4) or develop an alternative approach to estimate reasonable densities north of U.S. waters, we offer this simplified approach as a rough-and-ready substitute for a full density surface model.

In this section, we present maps of each stratum, with tallies of effort and sightings that occurred. We show the density estimates in Section 3.

2.1 North of Hudson Canyon, <1000m

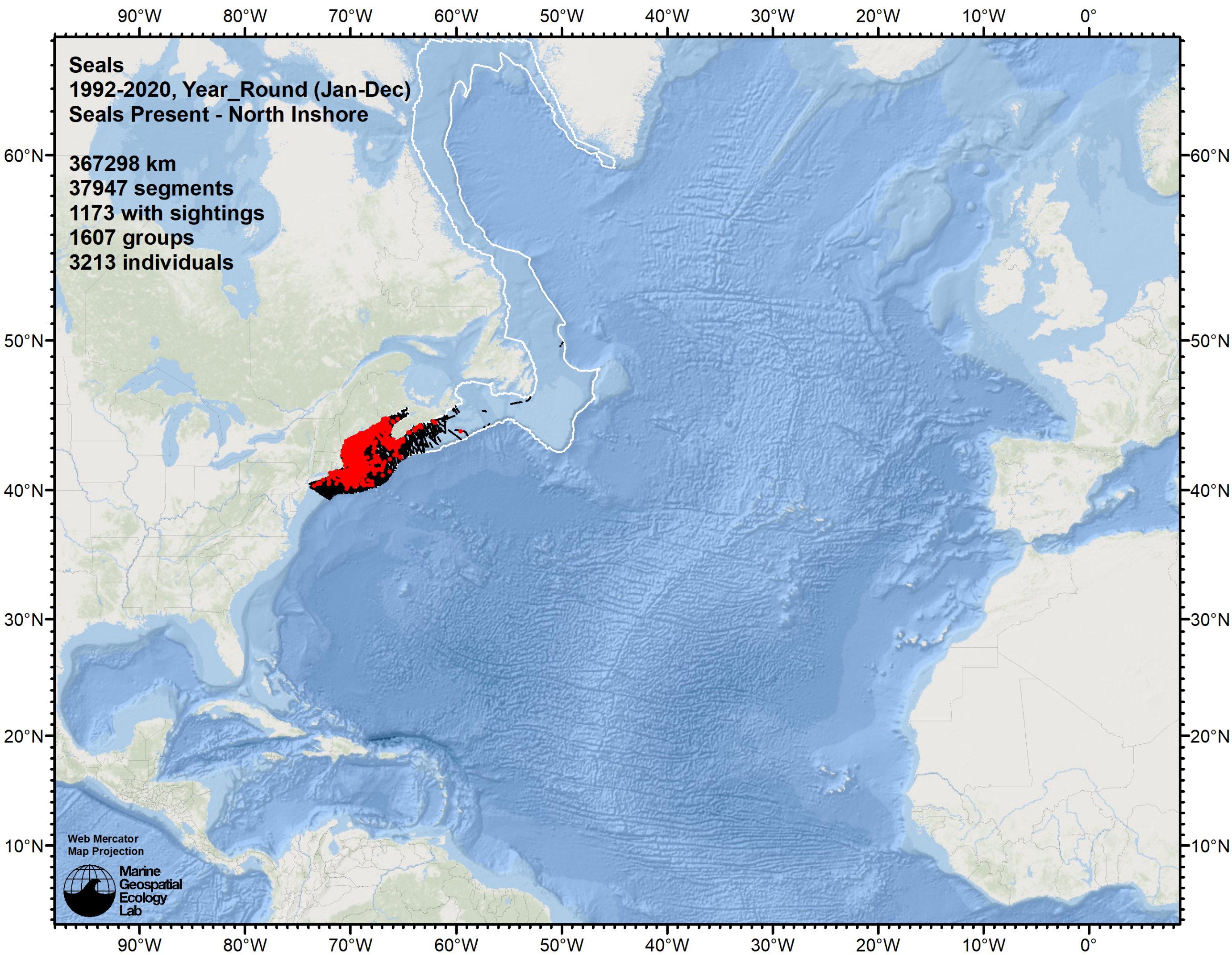

Figure 1: Survey segments and sightings used to estimate Seals density north of Hudson Canyon in waters shallower than 1000 m. Black lines and red points indicate the segments and sightings used to estimate density. White polygon indicates the region to which the density was applied.

2.2 North of Hudson Canyon, 1000-4000m

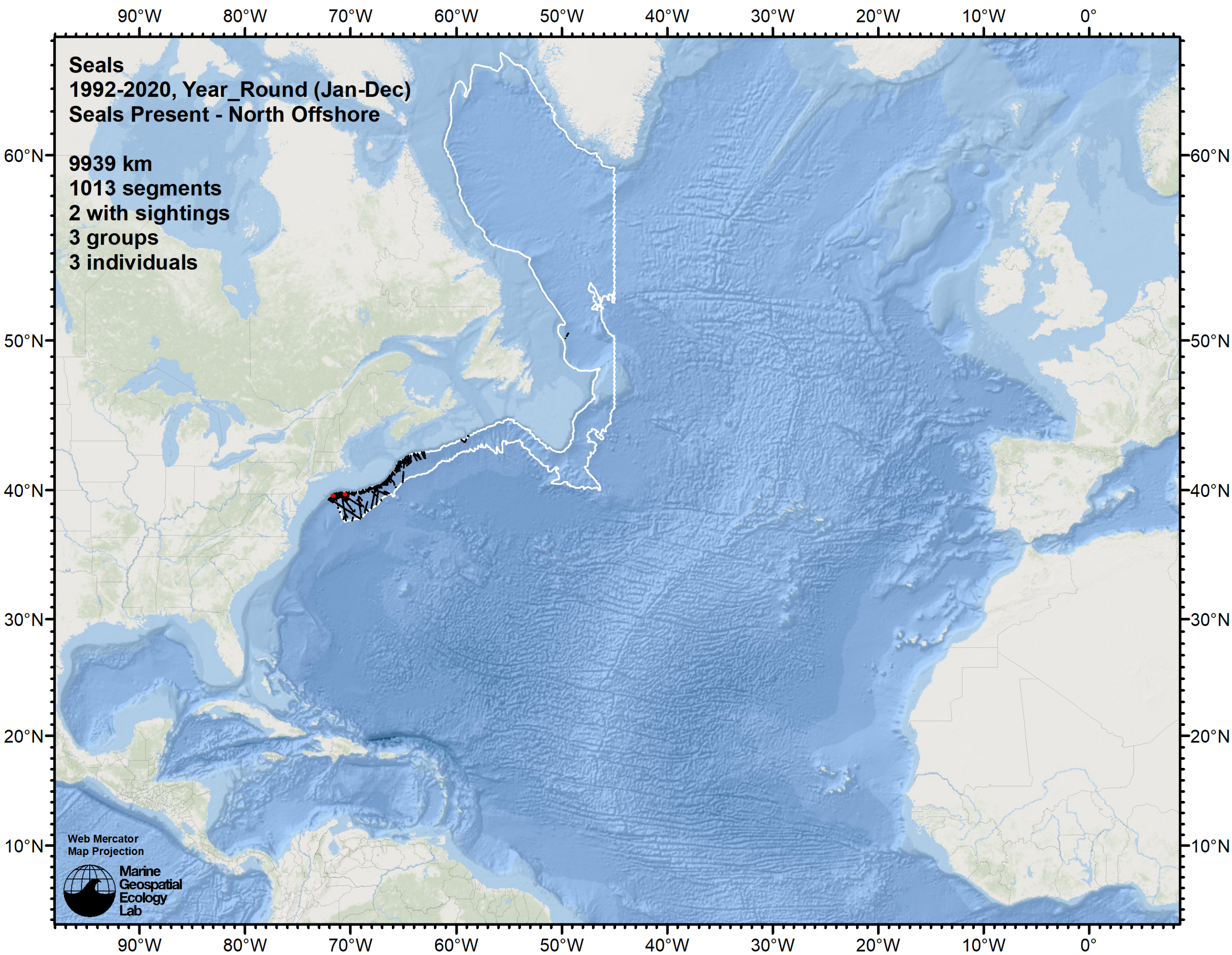

Figure 2: Survey segments and sightings used to estimate Seals density north of Hudson Canyon in waters between 1000-4000 m deep. Black lines and red points indicate the segments and sightings used to estimate density. White polygon indicates the region to which the density was applied.

2.3 Cape Hatteras to Hudson Canyon, <1000m

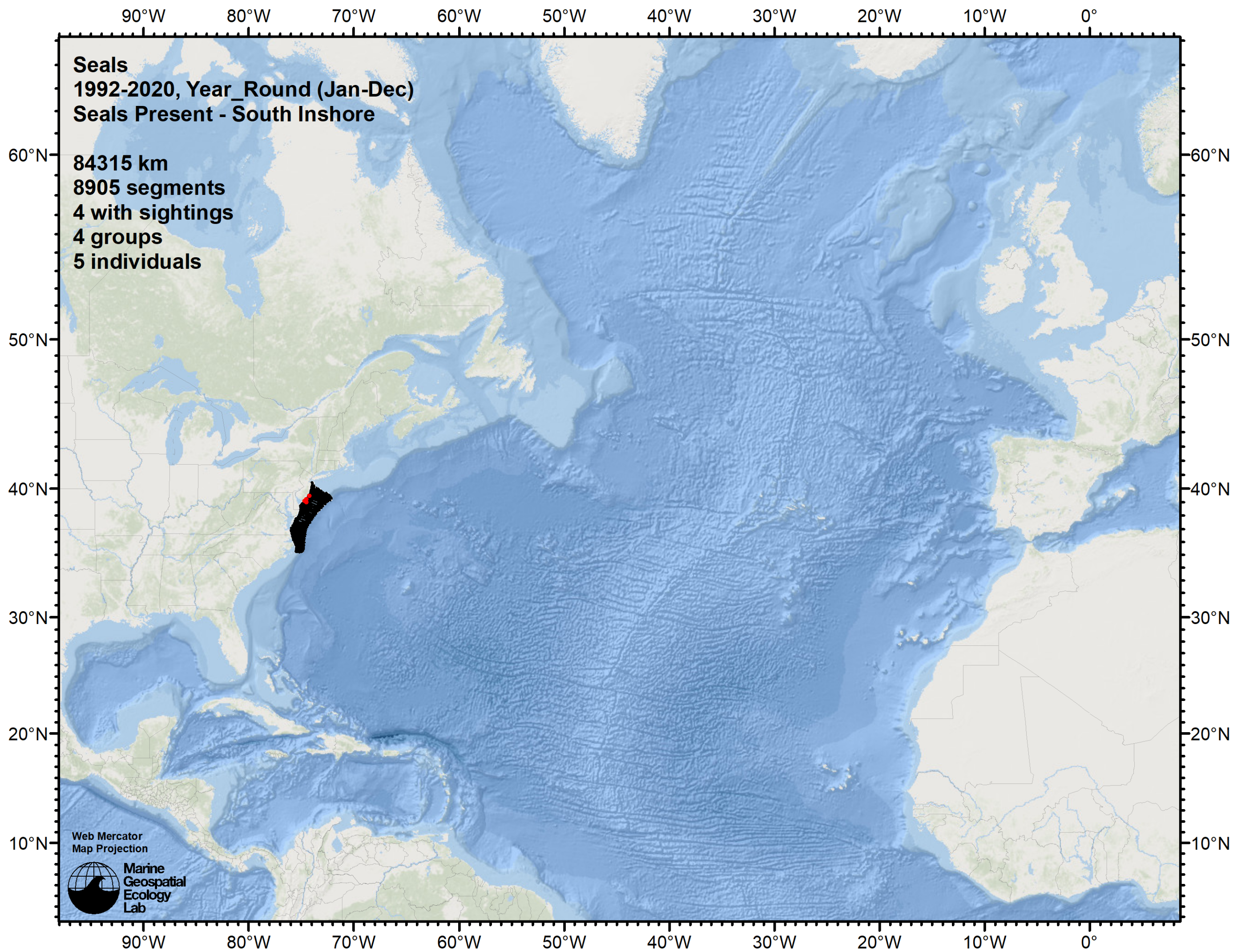

Figure 3: Survey segments and sightings used to estimate Seals density between Cape Hatteras and Hudson Canyon in waters shallower than 1000 m. Black lines and red points indicate the segments and sightings used to estimate density. White polygon indicates the region to which the density was applied.

3 Predictions

3.1 Summarized Predictions

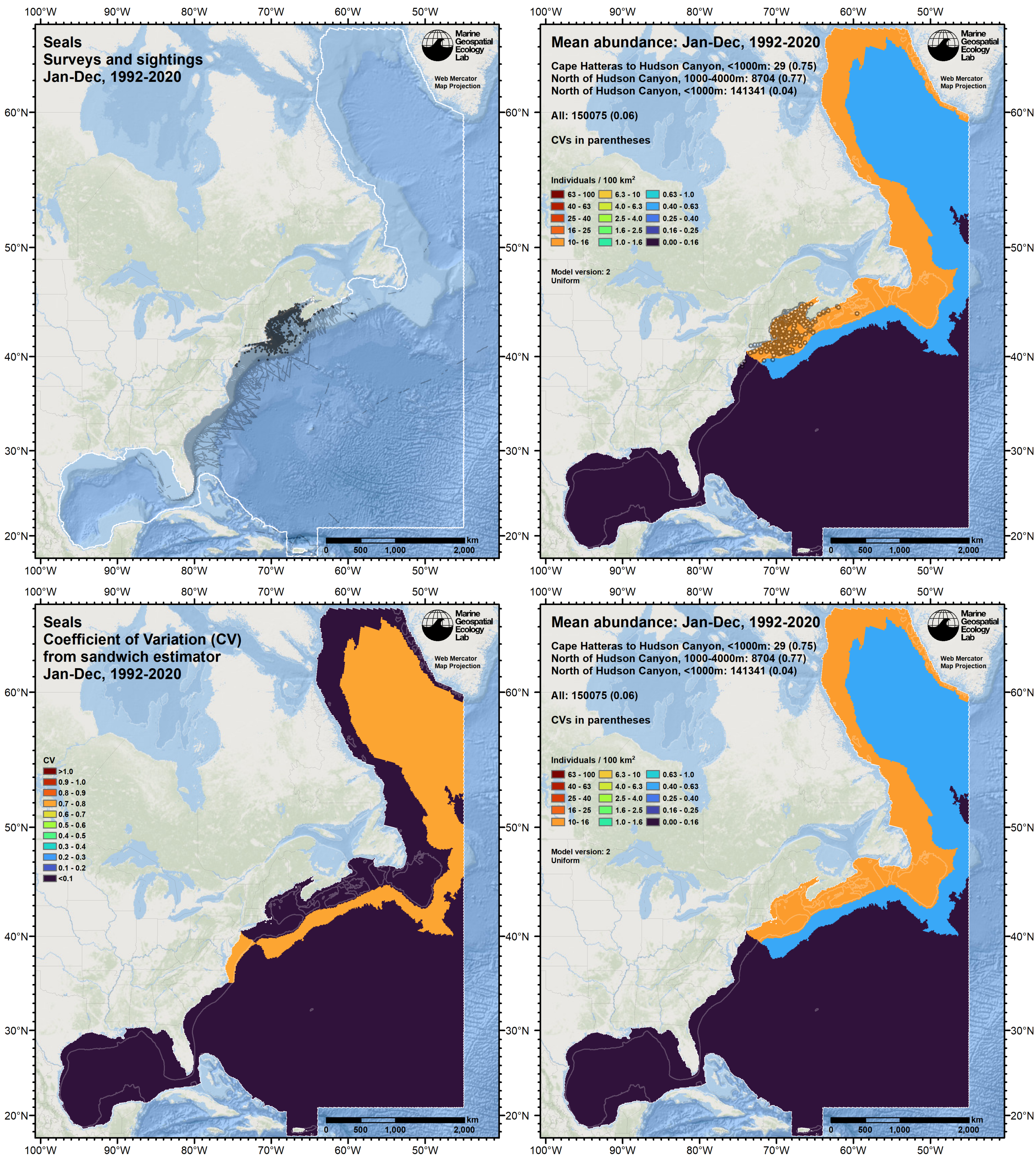

Figure 4: Survey effort and observations (top left), predicted density with observations (top right), predicted density without observations (bottom right), and coefficient of variation of predicted density (bottom left), for the given era. These maps use a Web Mercator projection but the analysis was conducted in an Albers Equal Area coordinate system appropriate for density modeling.

3.2 Comparison to Previous Density Model

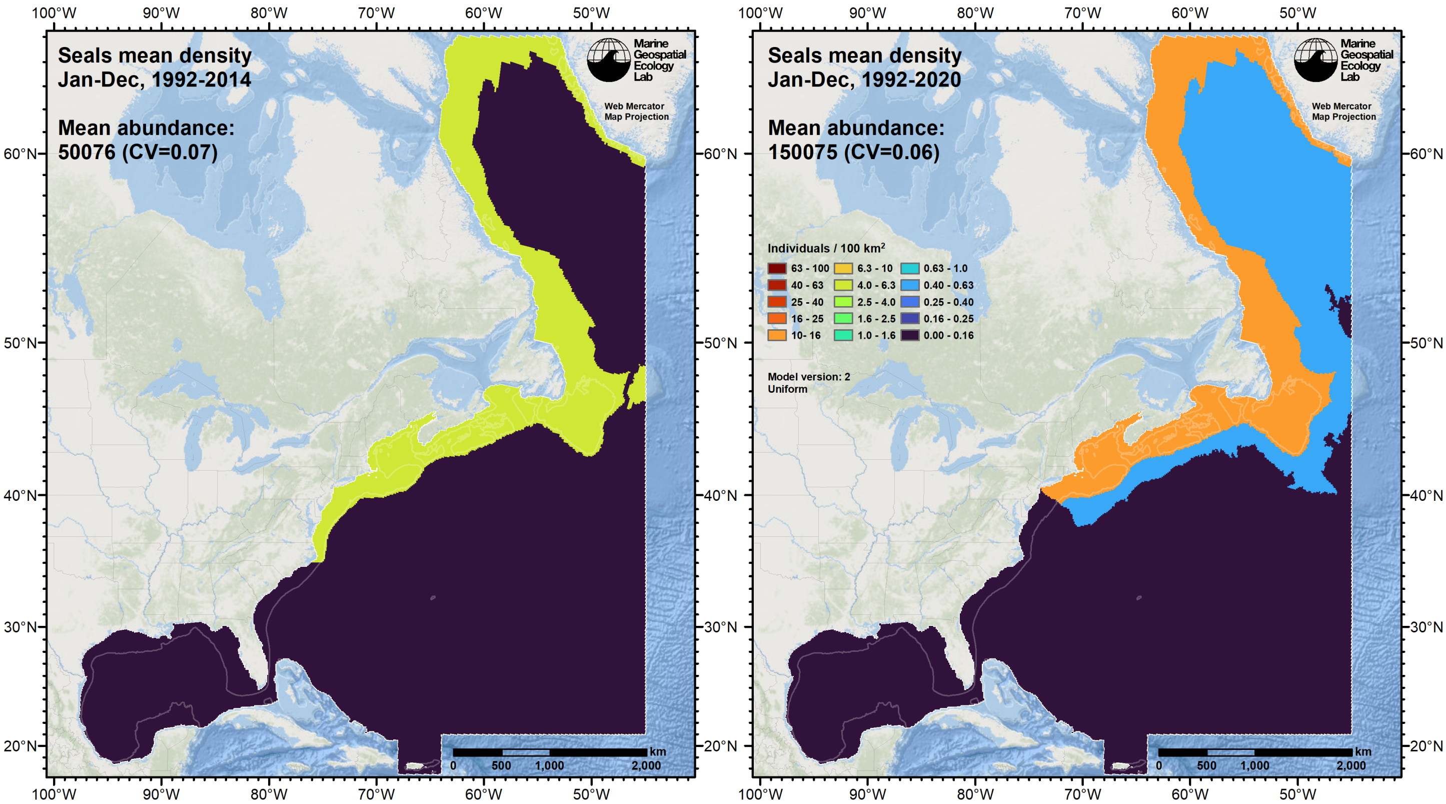

Figure 5: Comparison of the mean density predictions from the previous model (left) to those from this model (right). These maps use a Web Mercator projection but the analysis was conducted in an Albers Equal Area coordinate system appropriate for density modeling.

4 Discussion

Following what was done for the prior model, we summarized this updated model into a single year-round mean density surface (Figure 4). 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. It was a traditional density surface model and was summarized into 12 monthly mean density surfaces. See Roberts et al. (2023) for more discussion of the models.

This updated AFTT model estimated a total abundance that was three times that of the prior model (Figure 5). Although this large change may have resulted partially from the splitting off of the shelf south of Hudson Canyon from the stratum that was used to extrapolate across the north of the study area, the main reason was likely the stronger bias corrections used for aerial surveys by the updated model. In the prior model a combined perception and availability bias correction of $g_0 = 0.281$ was applied to sightings of 1-5 seals, which was the large majority of those observed. This correction came from Carretta et al. (2000) for harbor seals observed in the Pacific, as no estimates were available for surveys in our region. In the updated model, we used newly-available estimates from the AMAPPS program. For perception bias, we used $g_{0P} = 0.181$ from Palka et al. (2017), and for availability bias we applied the Laake et al. (1997) approach to estimate corrections based on seal diving behavior and aircraft speed and altitude, resulting in a correction of $g_{0A} = 0.35$ to $g_{0A} = 0.40$ for the large majority of sightings. (Please see the EC seals model version 5 supplementary report for more details.) This resulted in a combined correction of $g_0 = 0.063$ to $g_0 = 0.072$ for most sightings. Density and abundance scale inversely with the bias correction. It is therefore not surprising to see a 3x increase in density and abundance following a 4x reduction in the bias correction value (making it a 4x stronger correction).

The seemingly-large abundance of 150,000 seals may actually be an underestimate. The dominant species are harbor seal and gray seal, with other species such as ringed seal occurring in the north but not sighted in the data available to us. In 2016, the total pup production of the northwest Atlantic gray seal population was estimated at 109,000 (den Heyer et al. 2021).

Surveys of the Canadian shelf in 2007 and 2015 reported seal sightings but they were omitted from reports of cetacean abundance derived from those surveys (Lawson and Gosselin 2009, 2018). These surveys were not available for use in this model; future updates would benefit from their inclusion. Similarly, aerial surveys conducted in west Greenland at the same time likely also sighted seals but this was not reported (Hansen et al. 2019). If such sightings were collected, future model updates would benefit from those surveys as well.

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