ANALYSIS OF MARINE MAMMAL BIOLOGICALLY IMPORTANT AREAS AND SPECIES DENSITY ON THE EAST COAST

By

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EXECUTIVE SUMMARY

Marine mammals are threatened globally by various anthropogenic activities, specifically those that introduce noise into the environment. In the United States, marine mammals and their habitats are protected under various statutes. In accordance, agencies and organizations planning to conduct activities in the marine environment that may disturb, or harm marine mammals must undergo an impact assessment process. These assessments include information regarding which species and how many individuals may be exposed to disturbance. Disturbances can cause short-term changes in individual energy expenditure. If disturbances repeatedly occur, this could result in implications for an individual's survival, fecundity, and fitness, ultimately impacting the status and trajectory of an entire population or species. Awareness of the spatiotemporal behaviors of marine mammals is needed for resource managers to determine the scope of disturbance and to develop mitigation strategies for each intended project, ultimately concluding if the project can proceed.

Biologically Important Areas (BIAs) are available to resource managers, which provide context on monthly marine mammal spatiotemporal behaviors, specifically feeding, reproduction, migration, and areas that support small and resident populations. Since the first BIA (BIA I) manuscript in 2015, the BIA identification process has been revised and updated, resulting in the second BIA (BIA II) manuscript being published in 2023. The BIA II effort introduced a scoring component, as well as allowed for the identification of hierarchical areas. Both BIA I and BIA II explicitly state that the identified areas are not intended to be areas of high species density.

Habitat-based density models are tools that provide information on the location, time of year, and quantity of animals that may be subject to disturbance from anthropogenic sources. For the US East Coast region, density models have been generated by the Marine Geospatial Ecology Lab at Duke University. Based on density surface modeling techniques, marine mammal sighting data from line-transect surveys and environmental factors are used to predict fine scale spatiotemporal distribution. Similar to the BIA timeline, the first version of density models was published in 2016 and the availability of new data warranted model updates in 2022. Data-poor species were modeled on a yearly basis, while species with more data were modeled monthly.

Despite these tools being created independently of one another, there may be potential assumptions by the users that areas of importance should align with areas of high density. This project explores the relationship between BIAs and species abundance, specifically focused on North Atlantic right whales (NARW) (*Eubalaena glacialis)* and humpback whales (*Megaptera novaeangliae)* on the US East Coast. This analysis examines (1) monthly species abundance within each associated BIA, (2) the relationship strength between BIA type and species abundance, (3) the changes in the relationship between species abundance and BIA active period between the manuscript versions, and (4) how the scoring component introduced in BIA II influences the relationship between species abundance and active period.

Areas delineated in both BIA efforts were considered, however, the broad hierarchical areas were not included in the final analysis. The first and most recent versions of the habitat-based density models were used, due to similar publication/version timelines. The species of interest was limited by the BIA efforts and only species with feeding, reproduction, or migratory BIAs were assessed, resulting in 5 baleen whale species available for analysis. In addition, all 5 whale species had monthly density models. At the time of this assessment, BIA II was still an ongoing process and not all areas were available. This limited this project to focus on NARW and humpback whales. Across both BIA efforts, 14 areas were analyzed. Using Python, each monthly density raster and the monthly density within each BIA were summed. The BIA monthly abundance was divided by the entire model monthly abundance to get the relative proportion of modeled abundance occurring within each BIA.

Feeding BIAs displayed alignment with the respective density models, while migratory BIAs were considered inconclusive due to the broadness of these areas. Both BIA efforts had the same number of areas that aligned and number of areas that were inconclusive/had no alignment between species abundance and active month. The BIA II scoring component was variable across areas and there was no clear indication that higher scoring components corresponded with alignment. The current comparison results are tentative and are subject to change once all BIA II areas are finalized.

Based on this analysis, the following recommendations were proposed:

(1) Create a structured reassessment timeline for BIAs for the incorporation of new data.
(2) Expand both the BIA and density modeling efforts further into Canadian waters to capture more of each species range.
(3) Use similar geospatial overlay methodology as a starting point to identify areas in similar international efforts, such as the Important Marine Mammal Areas effort.
(4) Incorporate the behavioral information contained in BIAs into dynamic management strategies.

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1. INTRODUCTION

Marine mammal populations are threatened globally by various activities, including increasing noise levels from anthropogenic activities, such as shipping, drilling, and sonar. In the United States, marine mammals and their habitats are protected under various statutes, including the Marine Mammal Protection Act (MMPA) (16 U.S.C. § 1361 et seq.), the Endangered Species Act (ESA) (16 U.S.C. § 1531 et seq.), and the National Environmental Policy Act (NEPA) (42 U.S.C. § 4321 et seq.). Pursuant of these statutes, governmental agencies, and private and public organizations planning to conduct projects in the marine environment that may disturb, or harm marine mammals are required to submit environmental impact assessments to the National Oceanic and Atmospheric Administration (NOAA). These assessments include information regarding which species and how many individuals may be exposed to disturbance. Awareness of the spatiotemporal behaviors of marine mammals is needed for resource managers to determine the scope of disturbance and to develop mitigation strategies for each intended project, ultimately concluding if the project can proceed.

To assess the impacts of anthropogenically generated noise on marine mammals, it is necessary to have baseline information regarding the individual's behavioral state (Southall et al., 2021). If disturbances occur during reproductive or foraging events and these behaviors are altered, short-term changes in individual energy expenditure could occur. However, if these disturbances repeatedly happen, this frequent exposure to stressors causes implications for individual survival, fecundity, and fitness (New et al., 2014; Southall et al., 2021). The changes in an individual's fitness can ultimately impact the status and trajectory of an entire population (New et al., 2014).

One available tool for resource managers to assess these types of impacts is the Population Consequences of Disturbance (PCoD) framework (National Research Council, 2005; New et al., 2014). The PCoD framework aims to determine how disturbances impact an individual's fitness and health and its influence on the population (National Research Council, 2005; New et al., 2014). Multiple PCoD models have been generated to assess the consequences of disturbance, of which life-history traits, disturbance source characteristics, and environmental conditions are all major themes within these models (Keen et al., 2021). Notably, these themes incorporate information on migratory patterns, reproductive status, and the overlap with biologically important habitats (Keen et al., 2021). These tools and frameworks highlight the necessity of understanding where and when marine mammals congregate, as well as their behavioral state when in specific areas. In addition to the marine mammal noise exposure criteria laid out by Southall et al. (2021) and the PCoD framework and associated models (National Research Council, 2005; New et al., 2014), resource managers have access to Biologically Important Areas (BIAs) and habitat-based density models to assist in disturbance assessments for marine mammals (Ferguson et al., 2015; Roberts et al., 2016; Harrison et al., 2023).

BIAs were first identified by the Cetacean Density and Distribution Mapping Working Group, a working group established by NOAA in 2015 (Ferguson et al., 2015). BIAs are areas that support feeding, reproduction, and migration, as well as areas that sustain small and resident populations (Ferguson et al., 2015). Each BIA is species and time specific, with some areas labeled as "active" year-round, while others may only be "active" for a few months of the year (Ferguson et al., 2015). BIAs were created as a resource to assist with marine mammal impact assessments; therefore, the identification and presence of a BIA does not enact any legal or regulatory power (Ferguson et al., 2015). Through the process of expert elicitation, 131 BIAs covering 24 species/stocks/populations within 7 regions in the United States were created and were truncated to the US Exclusive Economic Zone (EEZ) (Ferguson et al., 2015).

Since the original BIA publication in 2015 (BIA I), the methodology and process used to identify BIAs has undergone updates and revisions, resulting in a new round of BIAs becoming available in 2023 (BIA II) (Harrison et al., 2023). BIA II has identified 150+ BIAs covering 25 species/stocks/populations within the same 7 regions as BIA I, however, this process is still ongoing and some regions are still under review (as of April 28, 2023) (Harrison et al., 2023). Like BIA I, BIA II used expert elicitation for BIA identification and delineation, however, a more structured process was followed to allow for stronger consistency among regions (Harrison et al., 2023). In addition, the spatial domain of BIA II was extended to include the US EEZ and adjacent waters (Harrison et al., 2023). As explicitly stated in both the BIA I and BIA II manuscripts, BIAs were not designed with the intent of being areas of high species density, rather, they help augment species density models (Ferguson et al., 2015; Harrison et al., 2023).

The two major changes for the BIA II assessment were the introduction of a scoring process and the ability to create hierarchical BIAs (Harrison et al., 2023). Each BIA received a score for Intensity, Data Support, Importance, Boundary Uncertainty, and Spatiotemporal Variability (Harrison et al., 2023). The scores associated with Intensity and Data Support were compiled into a scoring matrix to assign the Importance score (Harrison et al., 2023). In areas with inadequate data availability/data gaps, "watch list" BIAs have been identified (Harrison et al., 2023). These are areas that have the potential to be delineated as BIAs in the future, however, the current data/knowledge of the area resulted in an importance score of 0 (Harrison et al., 2023). While all identified areas in BIA I were single polygon features, BIA II allows for hierarchical areas, in which smaller, more concentrated areas are defined within a broader area (Harrison et al., 2023). The broader area is referred to as the "parent" BIA, while the smaller area(s) is referred to as the "child" BIA, with the expectation that the "child" area would have a higher Intensity score than the "parent" BIA (Harrison et al., 2023).

In addition to insight into the behavioral states of marine mammals, resource managers require information on the location, time of year, and quantity of animals that may be subject to disturbance from anthropogenic sources. For the US East Coast and Gulf of Mexico regions, habitat-based density models are freely available online through the Ocean Biodiversity Information System Spatial Ecological Analysis of Megavertebrate Populations Model Repository (OBIS-SEAMAP) (Roberts et al., 2016; Roberts et al., 2022). These models are generated by the Marine Geospatial Ecology Lab (MGEL) at Duke University using marine mammal sighting data that has been contributed by various project collaborators in both these regions (Roberts et al., 2016). These models allow resource managers to estimate how many individuals of a specific species may be harmed or disturbed in an area where anthropogenic activities are planned, such as oil and gas exploration or at-sea military training and exercises (Roberts et al., 2016). Following density surface modeling techniques, marine mammal sighting data from line-transect surveys and environmental factors were used to predict fine scale spatiotemporal distribution (Roberts et al., 2016).

The first version of these models was originally published in 2016, covering 36 species (Roberts et al., 2016). Since the 2016 manuscript, new data has become available, warranting updates to models for all species, as well as more frequent updates for high-priority species, such as the North Atlantic right whale (NARW) (*Eubalaena glacialis*) (Roberts et al., 2016; Roberts et al., 2022). The most recent updates to all models occurred in 2022 (Roberts et al., 2016; Roberts et al., 2022). These recently revised models have a finer spatial resolution, as well as updated/more recent environmental covariates (Roberts et al., 2022). Across all model versions, the data availability for each species determined the type of density raster created (Roberts et al., 2016; Roberts et al., 2022) Lesser-studied species/data-poor species were modeled on a yearly scale and only have one available density file (Roberts et al., 2016; Roberts et al., 2022). However, species with more data were modeled at a finer scale and had twelve density files available - one for each month, thus resulting in improved understanding of species spatiotemporal distributions (Roberts et al., 2016; Roberts et al., 2022).

To reiterate what was noted in both BIA I and BIA II manuscripts, BIAs are not intended to be areas of high species density, rather they are tools to help augment density models (Ferguson et al., 2015; Harrison et al., 2023). Despite this acknowledgement, there could be assumptions that these two tools should align (i.e., the highest abundance of a particular species should occur within each associated BIA during its active period). Particularly, the potential lack of alignment between high species abundance and a BIA active period could cause confusion or skepticism regarding their interpretability and applications to marine mammal risk assessments. This paper explores the relationship between BIAs and species abundance, specifically focused on NARW and humpback whales (*Megaptera novaeangliae*) on the US East Coast. This analysis aims to examine:

(1) Monthly species abundance within each associated BIA, specifically if species abundance is highest in each BIA during the area's active period.
(2) The relationship strength between BIA type (feeding, reproduction, and migration) and species abundance to determine which, if any, of these underlying behavioral states correspond with the highest species abundance within each BIA.
(3) The changes in the relationship between species abundance and BIA active period between the first manuscripts (BIA I and 2016 density model versions) and the most recent manuscripts (BIA II and 2022 density model versions).
(4) How the scoring component introduced in BIA II influences the relationship between species abundance and active period.

2. MATERIALS & METHODS

2.1 Data Selection

Areas delineated in both BIA I and BIA II were selected for use and all hierarchical BIAs (i.e., parent and child areas) in BIA II were considered. Initial exploratory overlay analysis (see section 2.3 for more details) between the differences in abundances between parent and child areas resulted in the exclusion of the parent areas. Similarly, areas labeled as "watch list" were not included in analysis, due to the ambiguity of the area boundary. The first and most recent versions of the habitat-based density models were used, due to the similar publication/update timeline and intermediate models were not used. This decision was due to the similar data availability at the time of publication of BIA I and the 2016 density models, as well as at the time of BIA II and the 2022 density models.

2.2 Species Selection

Despite the density modeling efforts covering over 30 species on the East Coast, the BIA efforts covered less than half. BIA I identified 18 BIAs for 7 species on the East Coast: bottlenose dolphins, fin whales, harbor porpoises, humpback whales, minke whales, NARW, and sei whales (LaBrecque et al., 2015). BIA II identified 35 BIAS for 9 species - the same species as BIA I, with the addition of short-finned pilot whales and Cuvier's beaked whales (LaBrecque et al., in prep.). To allow comparisons across BIA versions, only species that overlapped with both efforts were considered for analysis. Similarly, the habitat-based density models for both short-finned pilot whales and Cuvier's beaked whales were modeled on a yearly basis, thus, not allowing fine scale spatiotemporal analysis and comparisons (Roberts et al., 2022). Due to the nature of BIAs being active for specific months during the year, the remaining 7 species were considered for analysis based on their modeling being done monthly (Roberts et al., 2016; Roberts et al., 2022).

The species of interest were further refined based on BIA type and the scope of the modeling domain. Bottlenose dolphins and harbor porpoises both had small and resident BIAs delineated in both efforts (LaBrecque et al., 2015; LaBrecque et al., in prep.). These areas mostly occurred in localized, coastal estuaries, some of which partially or never overlapped with the density model domain. Therefore, it was not possible to assess the relationship between species abundance and small and resident BIAs. The remaining 5 species for potential analysis were all baleen whales, of which most delineated BIAs were feeding and reproduction and migratory BIAs were only identified for NARW (LaBrecque et al., 2015; LaBrecque et al., in prep.).

At the time of this assessment, BIA II is still an ongoing process (Harrison et al., 2023; LaBrecque et al., in prep.). The East Coast region is still finalizing the new round of BIAs, therefore, not all new/updated areas are available. For the 5 species selected, there are 20 anticipated areas in BIA II, however, only 10 draft areas are currently available (LaBrecque et al., in prep.). The available draft areas include 6 humpback whale feeding BIAs, 2 NARW migratory BIAs, 1 NARW feeding BIA, and 1 NARW reproduction BIA (LaBrecque et al., in prep.). The 6 humpback whale BIAs are composed of 2 single BIAs, 2 parent BIAs and 2 child BIAs, of which the parent BIAs were excluded from analysis. In addition, 1 humpback whale watch list BIA was excluded. Only 4 of the 8 anticipated NARW BIAs were available at the time of this analysis. In total, 4 humpback whale BIAs (1 in BIA I and 3 in BIA II) (Figure 1) and 10 NARW (6 in BIA I and 4 in BIA II) BIAs were analyzed (Figure 2). The humpback model versions used were 9.4 and 11 and the NARW model versions used were 5.6 and 12 (Roberts et al., 2016; Roberts et al., 2022).

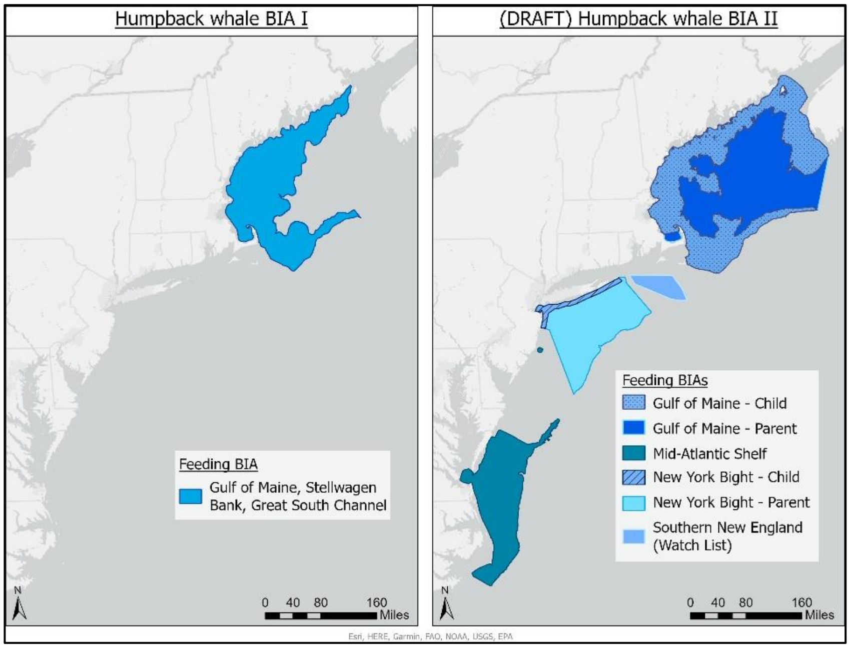
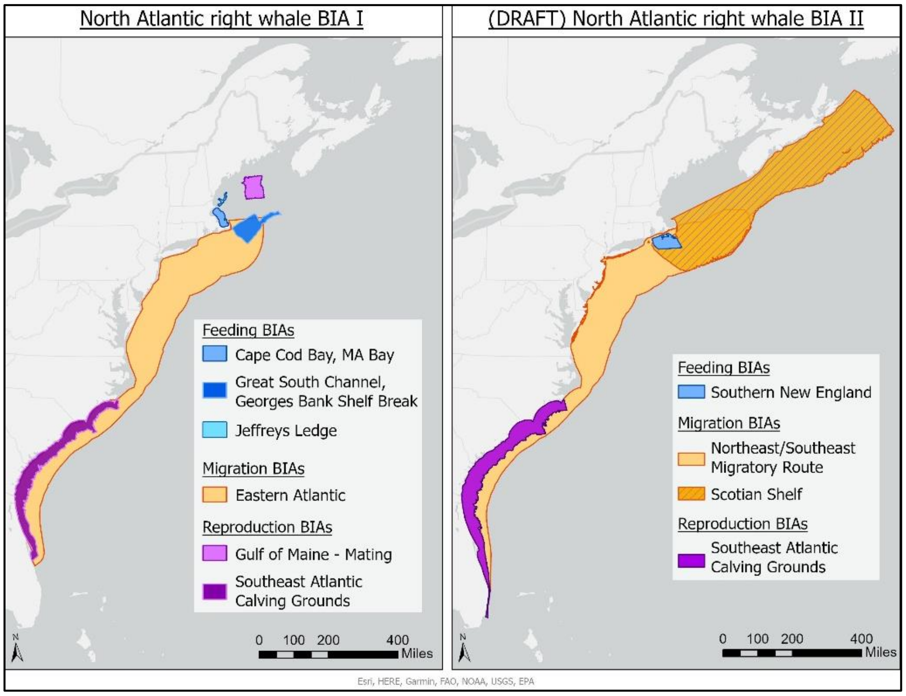


Figure 1: Overview of East Coast humpback whale feeding BIAs delineated in both efforts. Areas for BIA II are drafts and may still change.



Esri, HERE, Garmin, FAO, NOAA, USGS, EPA

Figure 2: Overview of East Coast NARW BIAs delineated in both efforts. Areas for BIA II are drafts and may still change. The anticipated BIA II areas not included in this analysis are two feeding areas and two reproduction areas.

2.3 Overlay Analysis

Density overlay analysis was conducted using Python version 3.9.11. All monthly density rasters were summed across the entire modeling domain to get abundance. Each BIA was overlaid on each monthly density raster and the underlying encompassed area was summed to get species abundance within each BIA. The units for density were the number of individuals per 100 km^2. To account for the different spatial resolutions between the earlier and newest models, the newest model sums were divided by 4. The BIA monthly abundance was then divided by the entire model monthly abundance to get the relative proportion of modeled abundance occurring within each BIA.

3. RESULTS

In total, 14 BIAs were analyzed across NARW and humpback whales. There were 8 feeding BIAs (4 for NARW and 4 for humpbacks), 3 reproduction BIAs (all for NARW), and 3 migratory BIAs (all for NARW), resulting in 336 monthly abundance values. Two of these BIAs were child areas and displayed different trends when compared to the associated parent area (Figure 3). Only the child areas were selected for analysis due to the expected higher Intensity score and the broadness of the parent areas. One of each BIA type has been highlighted below and all remaining BIA-model month combinations are available in the appendix.

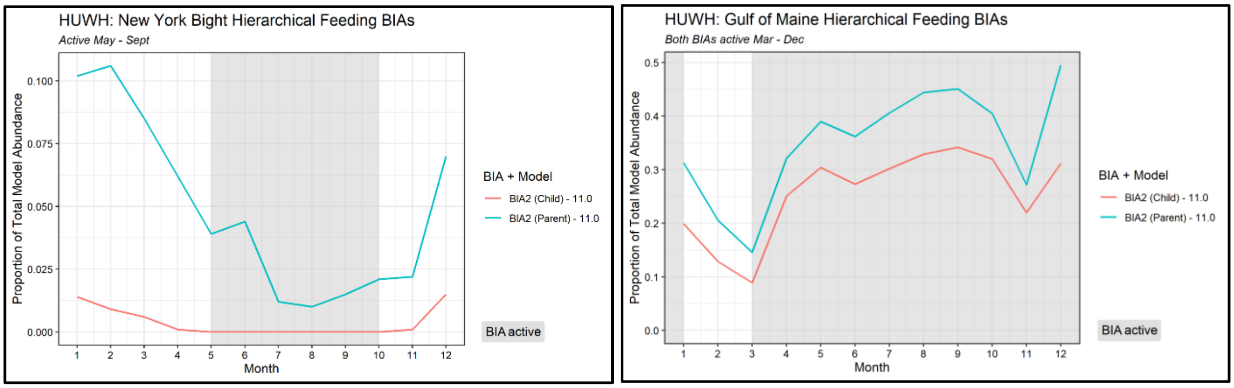


Figure 3: Comparisons between the proportion of total model abundance within humpback whale parent and child BIAs.

3.1 BIA I vs. BIA II

For the 7 BIA I areas, 4 had strong alignment between high abundance and the BIA active period, while 2 BIAs did not have a distinguishable difference between the two. The model associated with the remaining BIA was inaccurate in the specific region, therefore no relationship could be determined. However, this was corrected for in the subsequent model update (NARW Cape Cod/Massachusetts Bay feeding BIA - model 5.6). For the 7 BIA II areas, 4 had strong alignment, while the 2 migratory areas were not distinguishably different, and the 1 feeding BIA did not have high abundance. Both BIA I and BIA II had the same number of areas with alignment and with inconclusive/no alignment between species abundance and active BIA months. The BIA II process has identified 4 additional draft BIAs; however, these delineations are still in process and were unavailable at the time of this analysis. The current comparison results are tentative and are subject to change once all BIA II areas are finalized. For this analysis, "strong alignment" represents instances when BIA active months correspond with the highest proportion(s) of animal abundance within the given BIA.

3.2 BIA II Scoring Component

The 7 analyzed BIA II areas were labeled as static areas for spatiotemporal variability, which defines them as being distinguishable by physical/geological features (Harrison et al., 2023). For the 4 areas with alignment between abundance and active period, 2 were scored 3 for both Importance and Intensity, one was scored 2, and one was scored 1. The Data Support for these areas was 3 for two areas and 2 for two areas, while Boundary Certainty was 2 for two areas and 1 for two areas. For the 3 areas that were inconclusive or had no alignment between abundance and active period, all were scored 2 for Importance and Intensity. One of these areas had a 3 for Data Support, while the others scored 2. Boundary Certainty also varied with two areas scored 2 and one area scored 1. Due to the variability in the scoring in these areas, there is no clear indication that higher scoring components correspond with more alignment between abundance and BIA active months.

3.3 Feeding BIAs

Of the 8 feeding areas analyzed across both BIA efforts, 5 had their active periods aligned with times of highest species abundance. Two of the areas that did not align were Jeffreys Ledge for NARW (BIA I) and the New York Bight - Child for humpback whales (BIA II). These two BIAs are either in areas where the definition of the area with bathymetric features within the model is difficult or sighting data collection through line transect surveys and distance sampling is difficult to conduct due to urban proximity.

3.3.1 Humpback whale: NY Bight (Child) Feeding BIA

The humpback whale New York Bight - Child BIA was identified during BIA II as part of the New York Bight - Parent BIA. This area is an important summer feeding ground for humpback whales from May through September. Despite the density model predicting the peak of nearly 3,000 animals within the modeling domain in June, the proportion of the model abundance within this BIA is 0% (Figure 4). The proportion of model abundance within this BIA peaks in December and January (Figure 4). In December, only 4 of the 293 modeled individuals were within the boundary of this BIA, equating to roughly 1.5% of the model abundance (Figure 4). Similarly, in January, only 3 of the 188 predicted individuals fell within the BIA boundary, representing 1.4% of the model abundance (Figure 4).

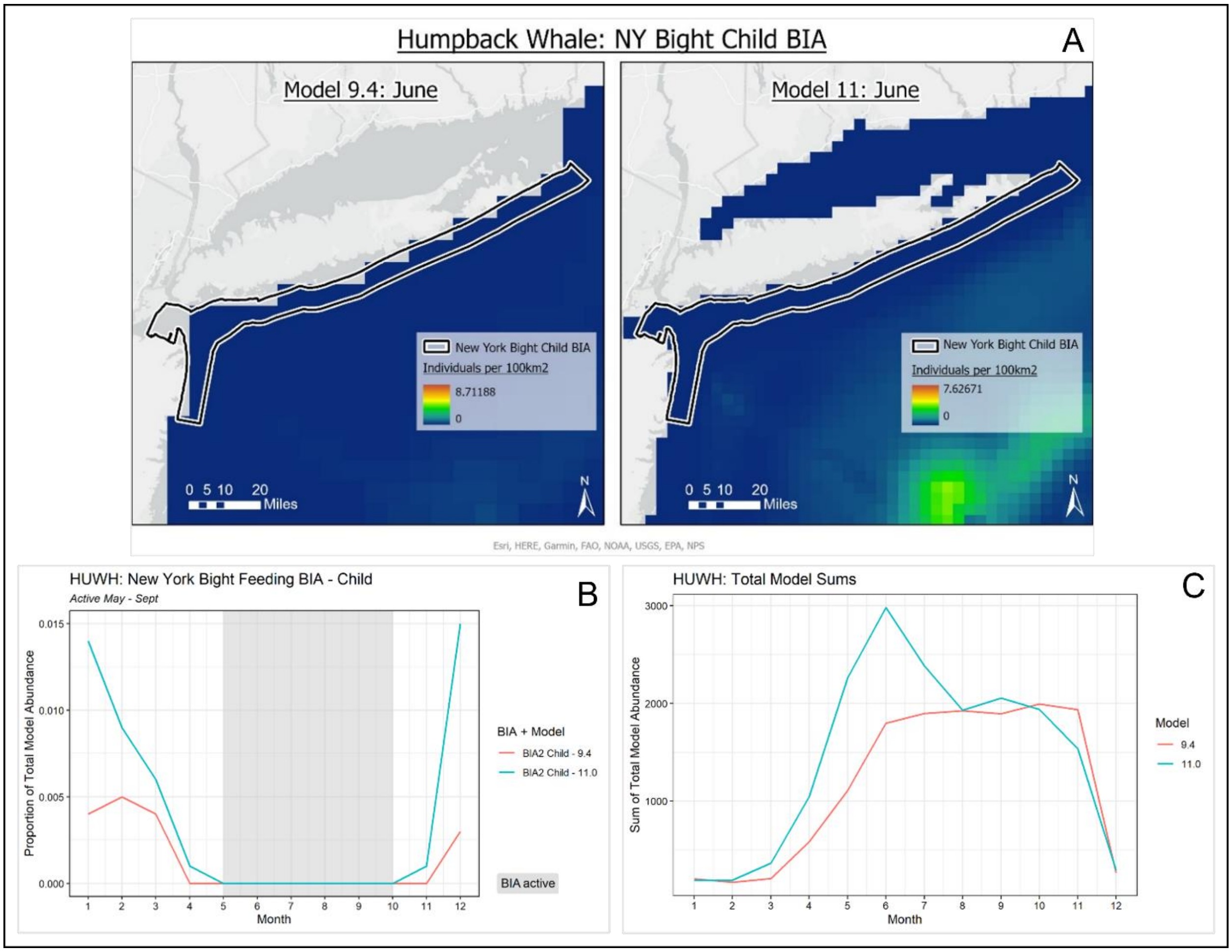


Figure 4: (A) Humpback whale New York Bight Child BIA monthly density in June for models 9.4 and 11. (B) Proportion of total model abundance within the BIA for each model. (C) Total monthly model abundance.

3.4 Migration BIAs

Out of the 3 NARW migratory corridors, there was not a distinguishable difference between active months and high abundance. When compared to the other BIA types, the migratory areas did have the largest overlaps with the density domain, resulting in these areas having the highest proportions of model abundances.

3.4.1 NARW Scotian Shelf Migratory BIA

The NARW Scotian Shelf BIA was identified as part of the BIA II effort as a summer migratory corridor between June and August. The peak in entire model abundance is in April, during which nearly 50% of the modeled abundance is within the BIA boundary (Figure 5). However, the highest proportion of the model within the BIA is in June, of which 171 out of 208 predicted animals, roughly 82.3%, are in the area (Figure 5). During the remainder of the active months, there is a decline in both the proportion of modeled animals within the BIA, as well as overall model predictions. Throughout the summer, the entire model abundance drops from 208 animals in June to 66 animals in August. This decline in model abundance could indicate that NARW are leaving the modeling domain and potentially moving further north into Canadian waters outside of the modeling effort. Currently, the density model domain does not span the entire scope of this BIA. It is important to note that the newest NARW density models (version 12) are extremely close to NOAA stock assessment for this population (National Marine Fisheries Service, 2021). From February to May, the models slightly overpredict the number of whales compared to the stock assessment; however, these values are still close.

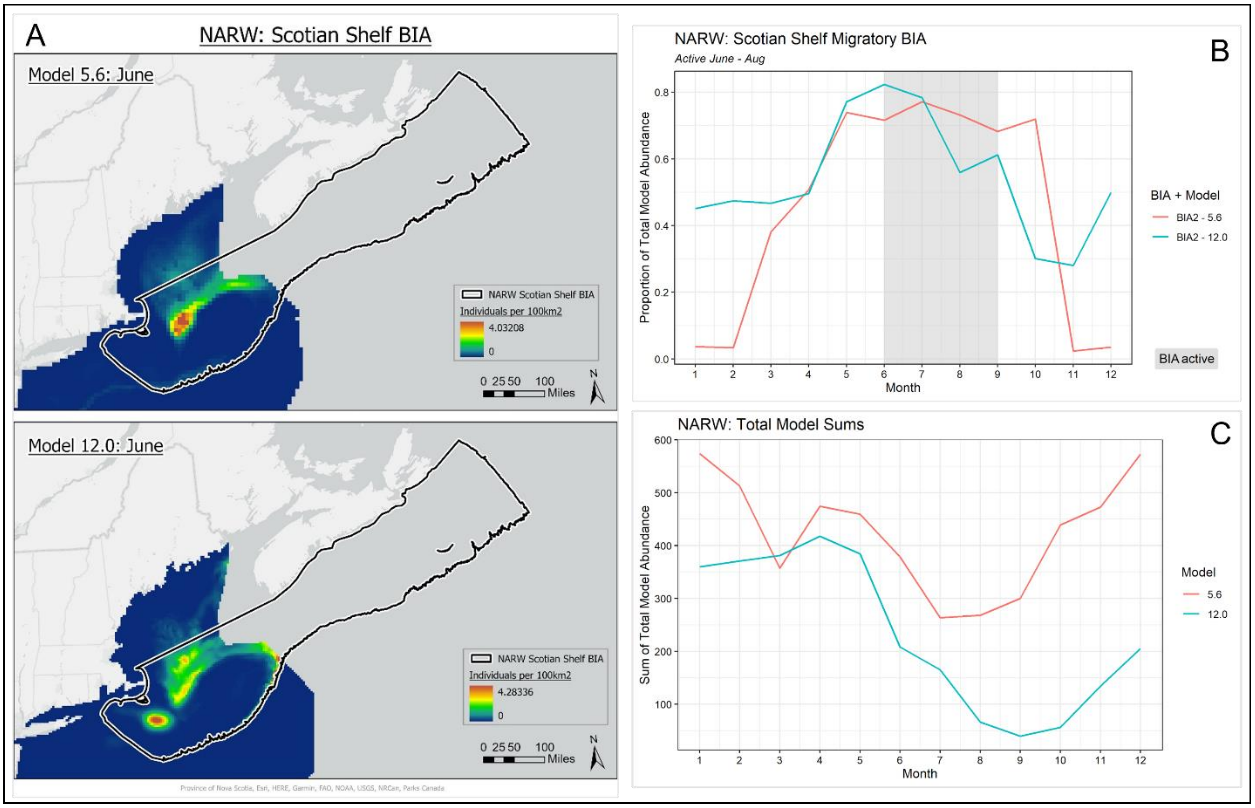


Figure 5: (A) NARW Scotian Shelf BIA monthly density in June for models 5.6 and 12. (B) Proportion of total model abundance within the BIA for each model. (C) Total monthly model abundance.

3.5 Reproduction BIAs

All 3 NARW reproduction BIAs had their active periods aligned with the highest model proportion within that area. Of the 3 BIAs, the calving grounds had more alignment than the Gulf of Maine mating ground.

3.5.1 NARW Southeast Reproduction BIAs (Calving Grounds)

Both BIA I and BIA II identified the Southeast calving ground as an active BIA during the winter and spring. This area in BIA I was active from November through April, while BIA II shortened the active period from November through March. There was a decrease in the model proportion values at the calving grounds between models 5.6 and 12, however, the same type of monthly trend was still observed (Figure 6). The highest model proportions do align with the BIA active months. For BIA II and model 12, the highest proportion of the model is within this BIA in December, at approximately 9.3% (Figure 6). This differs from the highest model proportion from BIA I and model 5.6, which peaked in February (Figure 6). BIA II is slightly larger than BIA I and extends further south into the waters off Miami (Figure 6). The newest model does suggest an increase in abundance within this BIA in October, right before the start of the active period/calving season (Figure 6).

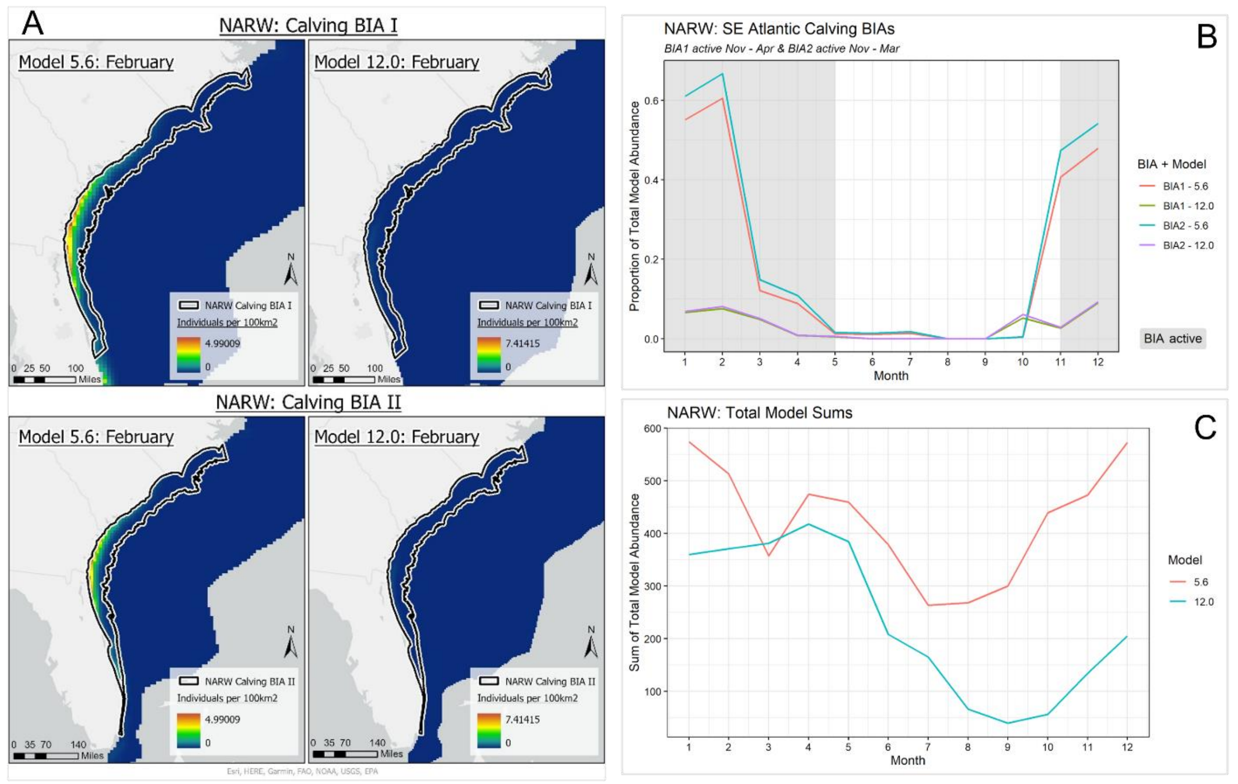


Figure 6: (A) NARW Calving BIA I and BIA II monthly density in February for models 5.6 and 12. (B) Proportion of total model abundance within the BIA for each model. (C) Total monthly model abundance.

4. DISCUSSION

4.1 Interpretation, Implications, and Recommendations

This project examines how species abundance and BIA active periods align, if a specific BIA type(s) parallels stronger alignment, if there are changes in alignment over time as both efforts have been updated, and if the newly added scoring component provides insight into these relationships. Both BIA efforts had similar results, in which feeding BIAs resembled more alignment with the associated density model(s) and the results of migratory BIAs were inconclusive. These relationships could be expected due to the nature of the underlying behavior and size of each BIA. Feeding behaviors could be more concentrated within specific areas due to finer-scale oceanographic features and conditions. Most feeding areas were active for more months of the year than the migratory areas, therefore, they had the ability to capture a wider range of model proportions in each specific feeding BIA. The migration BIAs analyzed within this project were only set as active for up to 3 consecutive months, resembling the transitory nature of the areas.

The interpretation of total model abundance and the associated proportions within each BIA should be done with caution, due to each model abundance varying monthly. The changes in model abundance from month to month do echo the life history traits of each specific species. For NARW, the southern end of their range/calving grounds are still within US waters, however, in the summer months, they are moving further north into Canadian waters (Meyer-Gutbrod et al., 2021). The range of humpback whales on the US East Coast is more expansive, due to their Caribbean breeding grounds and higher latitude feeding grounds (National Marine Fisheries Service, 2019).

During the 8 years between BIA I and BIA II, changes in the distribution and habitat use of these species have occurred (National Marine Fisheries Service, 2019; Meyer-Gutbrod et al., 2021; National Marine Fisheries Service, 2021). Even though BIA II has incorporated these changes, the return interval for BIA reassessment and data integration should be shortened. Depending on the species/stock/population status, the scoring component of BIAs should be reassessed annually, and BIA boundaries should be reassessed every 3-5 years. Shortening the reassessment window for the most at-risk species, specifically the endangered NARW, would allow for the creation and implementation of more timely mitigation strategies.

This analysis should be reevaluated when the 4 remaining NARW BIA II areas become available, as well as all BIA II areas for fin, minke, and sei whales. The incorporation of additional BIAs and species has the potential to impact the overall relationship between abundance and active period, specifically feeding BIAs. Despite the overall alignment themes across BIA types, each BIA and associated abundance should be individually assessed. These results highlight the importance of using these tools in tandem and to augment one another.

4.2 Future Expansion

For the species in this assessment, particularly NARW, expanding the density modeling domain further into Canadian waters and into the Gulf of St. Lawrence, would provide the opportunity to model the species throughout almost the entirety of its range. Currently, Canada does not have a similar effort to US BIAs focused solely on marine mammals. Expanding both the BIA effort and density modeling domain further across boundaries would create avenues for more effective and efficient management strategies at the population level. Furthermore, although the BIA II effort expanded its domain from being bound by the US EEZ to including the US EEZ and adjacent waters, this does not discount the possibility/probability of BIAs existing outside of this area/in the high seas. This corresponds with a similar effort undertaken by the IUCN Marine Mammal Protected Areas Task Force to delineate Important Marine Mammal Areas (IMMAs) (Tetley et al., 2022). IMMAs are selected based on species/population vulnerability, distribution and abundance, key life cycle activities, and special attributes, which slightly differs from BIA criteria (Tetley et al., 2022). IMMA delineation occurs through various regional workshops, of which the Northwestern Atlantic Region workshop has yet to occur. Similar overlay methodology for species abundance assessments within a specific area/region could be used as a starting point in the Northwestern Atlantic Region IMMA process.

4.3 Dynamic Management

While both the BIAs and habitat-based density models provide necessary information to inform marine mammal risk assessments, they are both static in nature. These efforts were created through compiling years of data and have resulted in stationary products that do not directly account for the real-time natural variation in oceanographic features and fine-scale movements of marine mammals. Dynamic ocean management is a strategy that allows for management decisions to be made in real-time (Maxwell et al., 2015; Dunn et al., 2016). Within the US, a dynamic management strategy is used for recommendations to vessel speed restrictions in particular areas when NARWs are detected to reduce the possibility of vessel strikes (National Oceanic and Atmospheric Administration, 2014). Within one of these Dynamic Management Areas (DMAs), voluntary area avoidance by vessels and speed reductions are recommended after 3 or more NARW are sighted or acoustically detected (National Oceanic and Atmospheric Administration, 2014). Currently, this type of management relies on present-day conditions, however, recent advancements in sub-seasonal forecasts prove to be successful in predicting marine mammal distributions one to two weeks prior (Stepanuk et al., 2023). The information contained in the BIAs regarding behavioral state and the predicted abundance of animals in an area from the density models would strengthen the decisions made for dynamic marine mammal management. Although the BIAs have no regulatory power, the type of BIA could inform the length of a temporary closure or speed restriction (exp. voluntary speed restrictions are longer when calves are present).

5. CONCLUSION

BIAs and habitat-based density models provide vital information for resource managers regarding when, where, and why marine mammals congregate. Geospatial overlay analysis between these two tools found more alignment between high species abundance and BIA active period in feeding areas. There was no difference between the number of BIAs with abundance alignment between BIA I and BIA II. The newly introduced scoring component in BIA II did not clearly predict alignment between abundance and BIA active period. In addition to their original purposes for marine mammal risk assessments, these static tools are applicable to similar international efforts, as well as to dynamic marine mammal management in the US.

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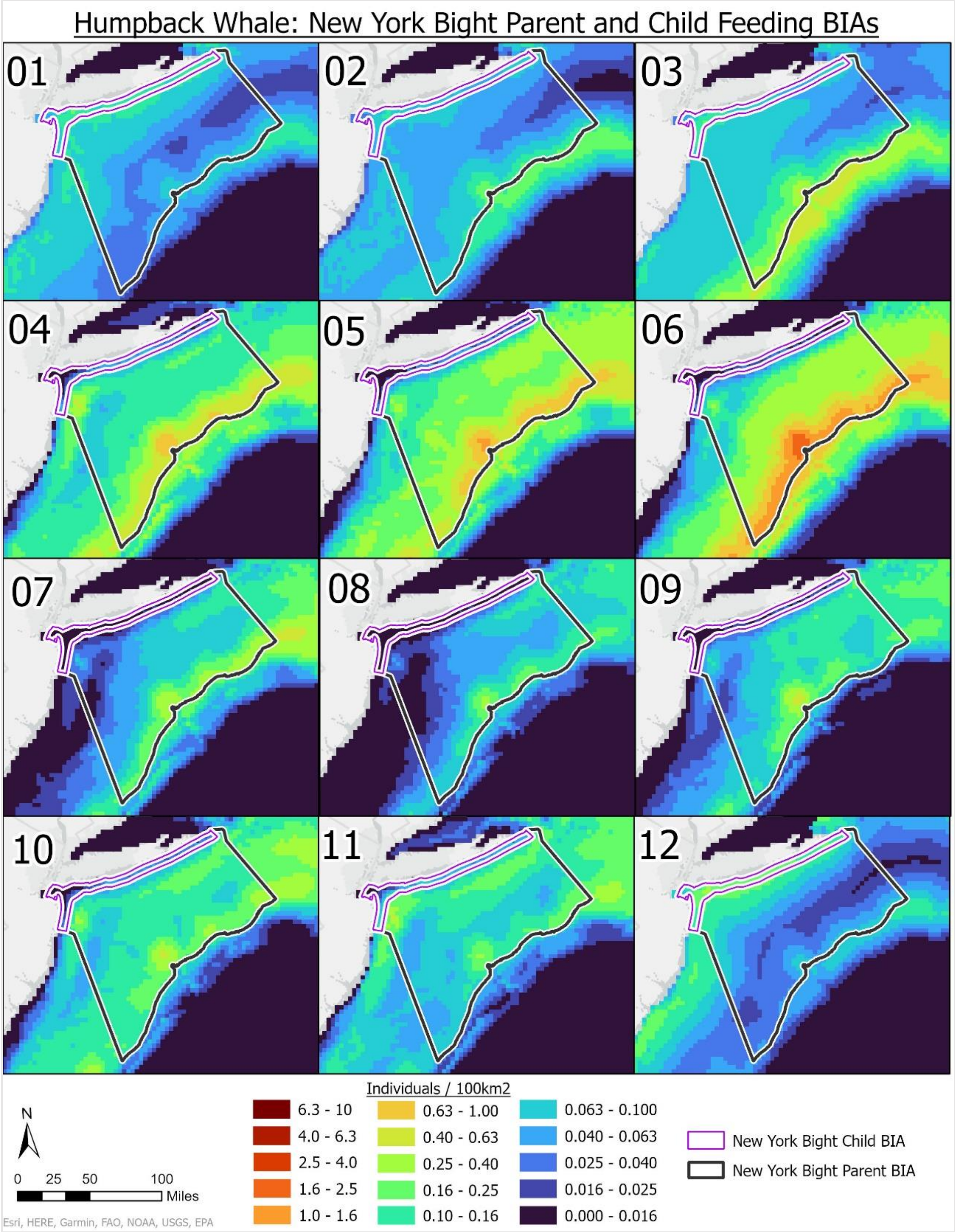
APPENDIX



Esri, HERE, Garmin, FAO, NOAA, USGS, EPA

Figure 7: Humpback whale model 11.0 densities within the New York Bight hierarchical BIAII area.

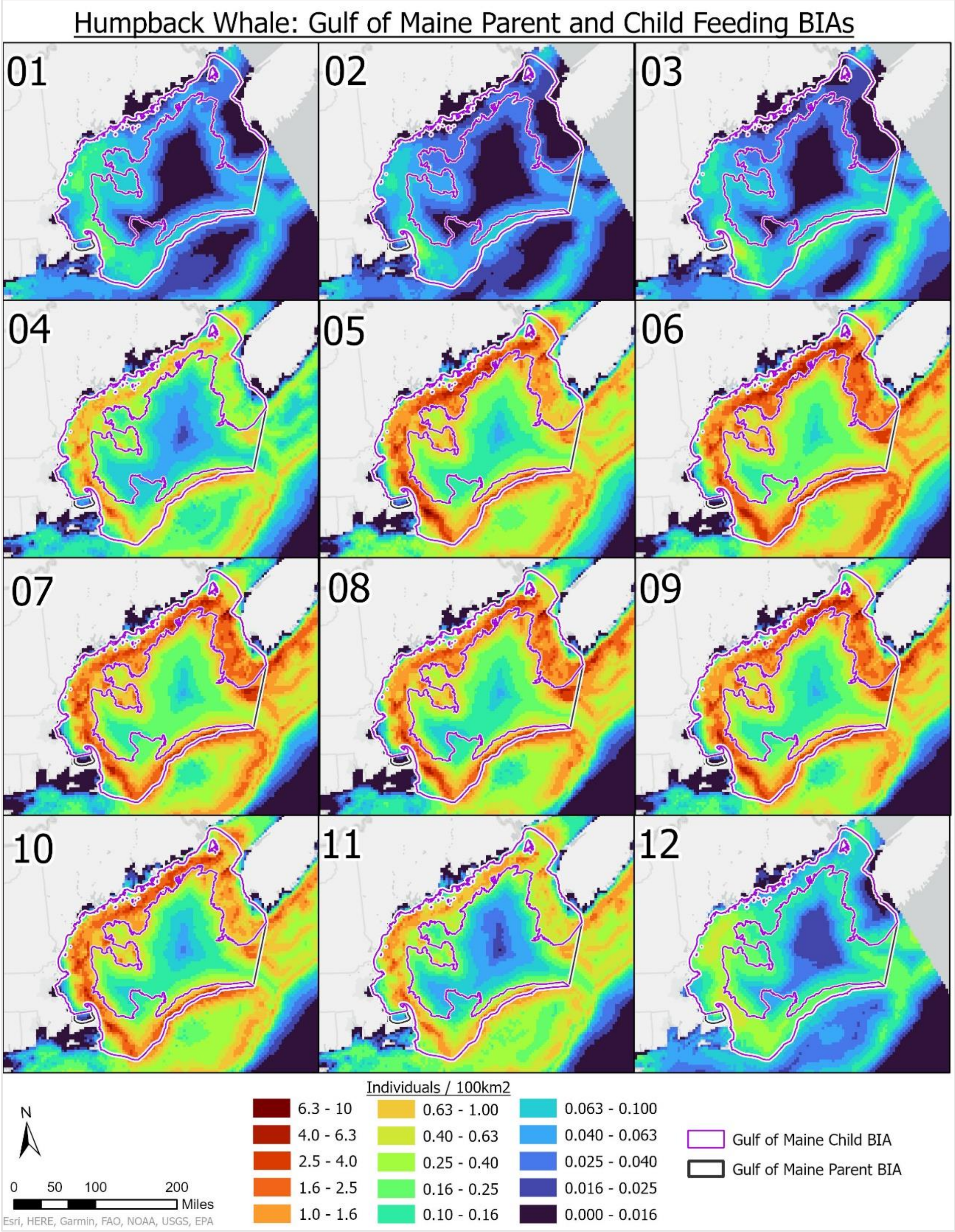


Figure 8: Humpback whale model 11.0 densities within the Gulf of Maine hierarchical BIAII area.

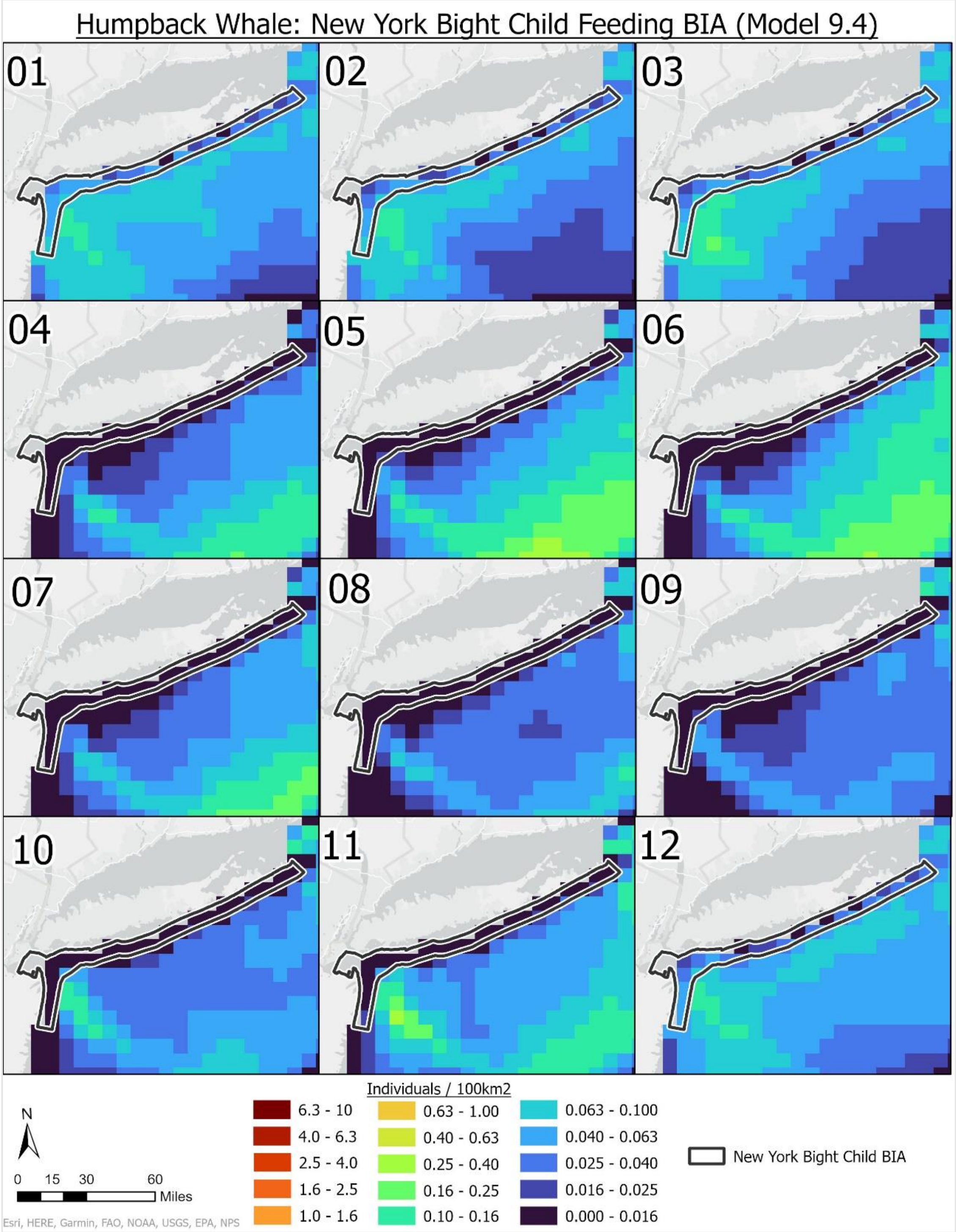


Figure 9: Humpback whale model 9.4 densities within the New York Bight Child BIA.

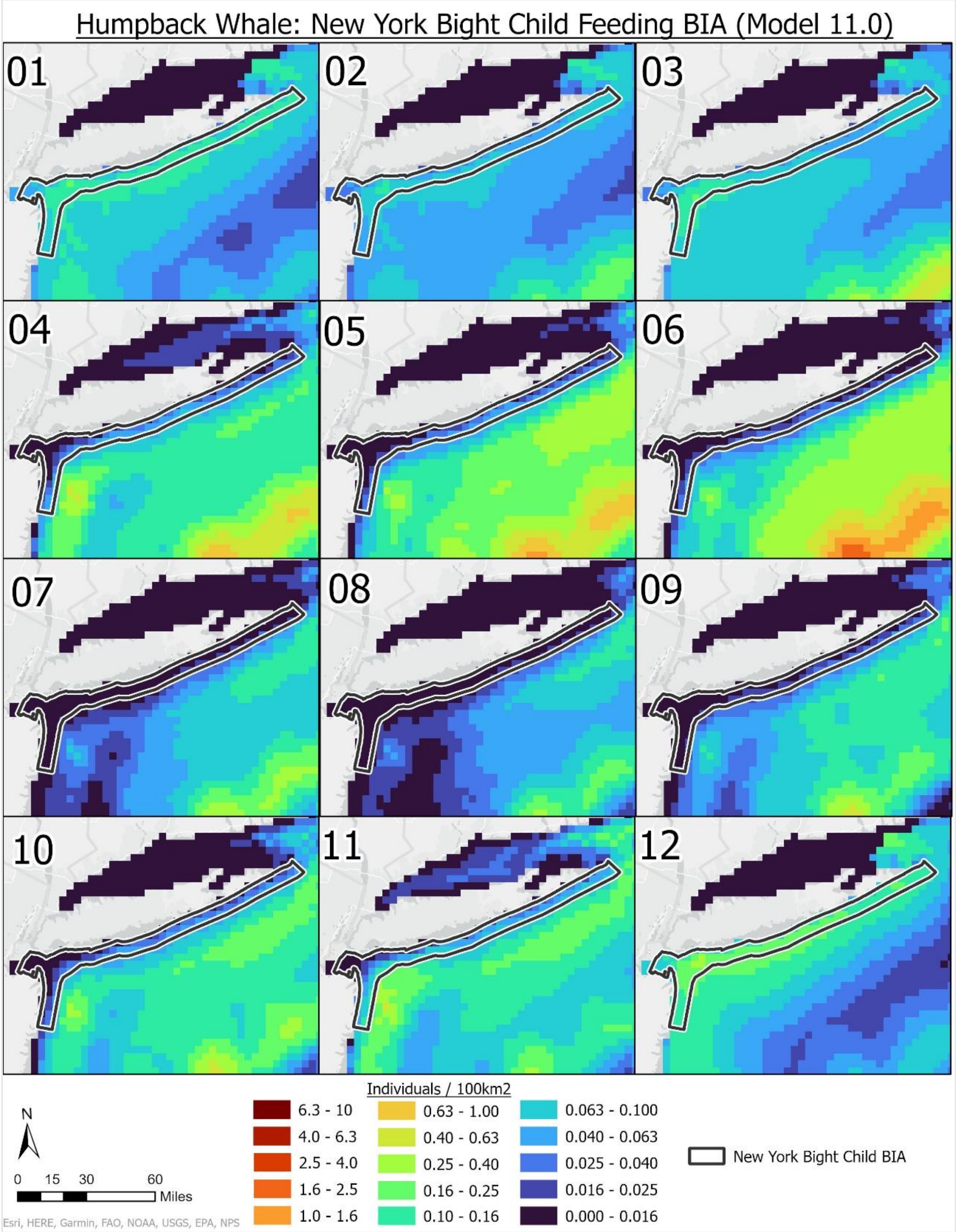
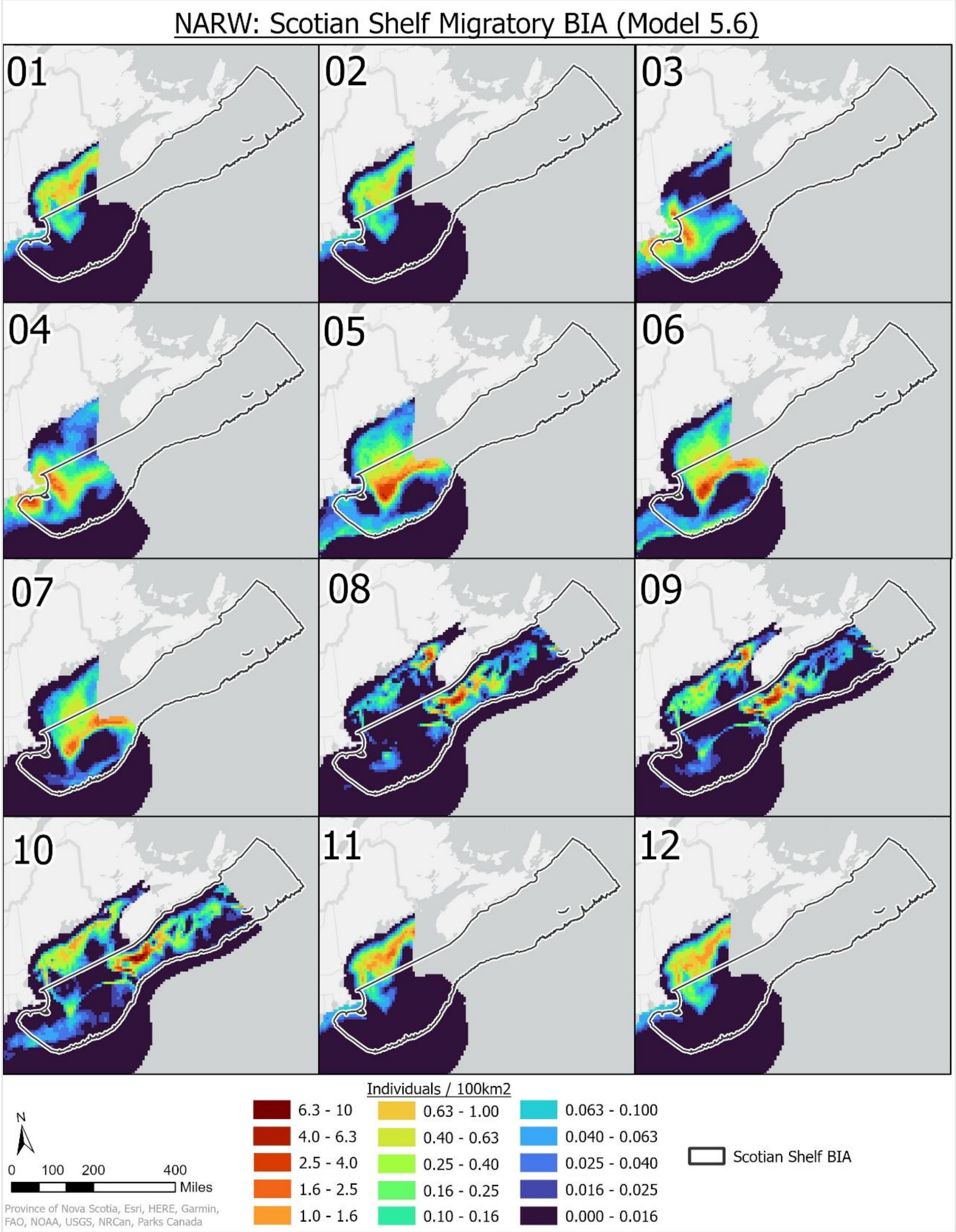


Figure 10: Humpback whale model 11.0 densities within the New York Bight Child BIA.



Province of Nova Scotia, Esri, HERE, Garmin, FAO, NOAA, USGS, NRCan, Parks Canada

Figure 11: NARW model 5.6 densities within the Scotian Shelf BIA.

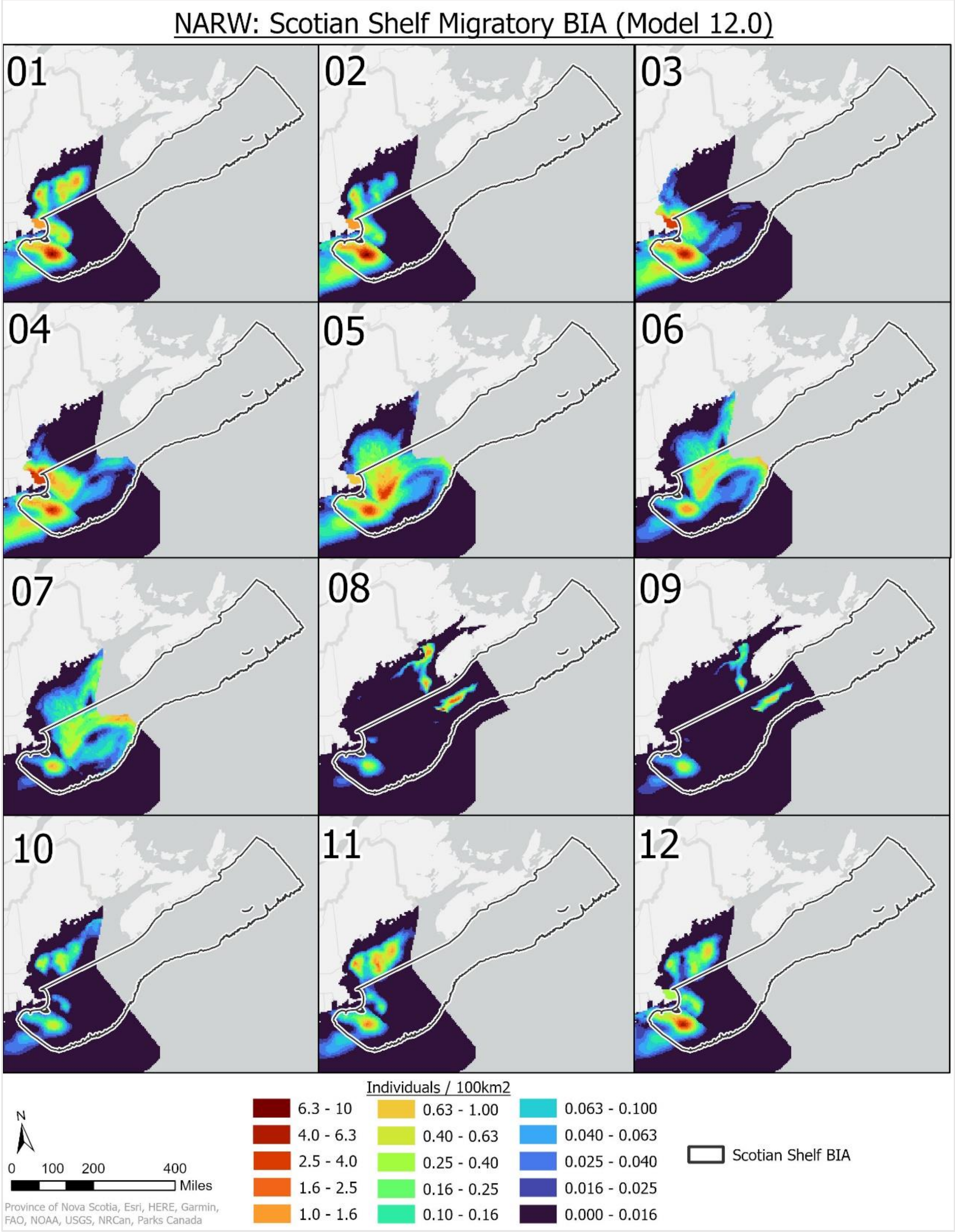


Figure 12: NARW model 12.0 densities within the Scotian Shelf BIA.

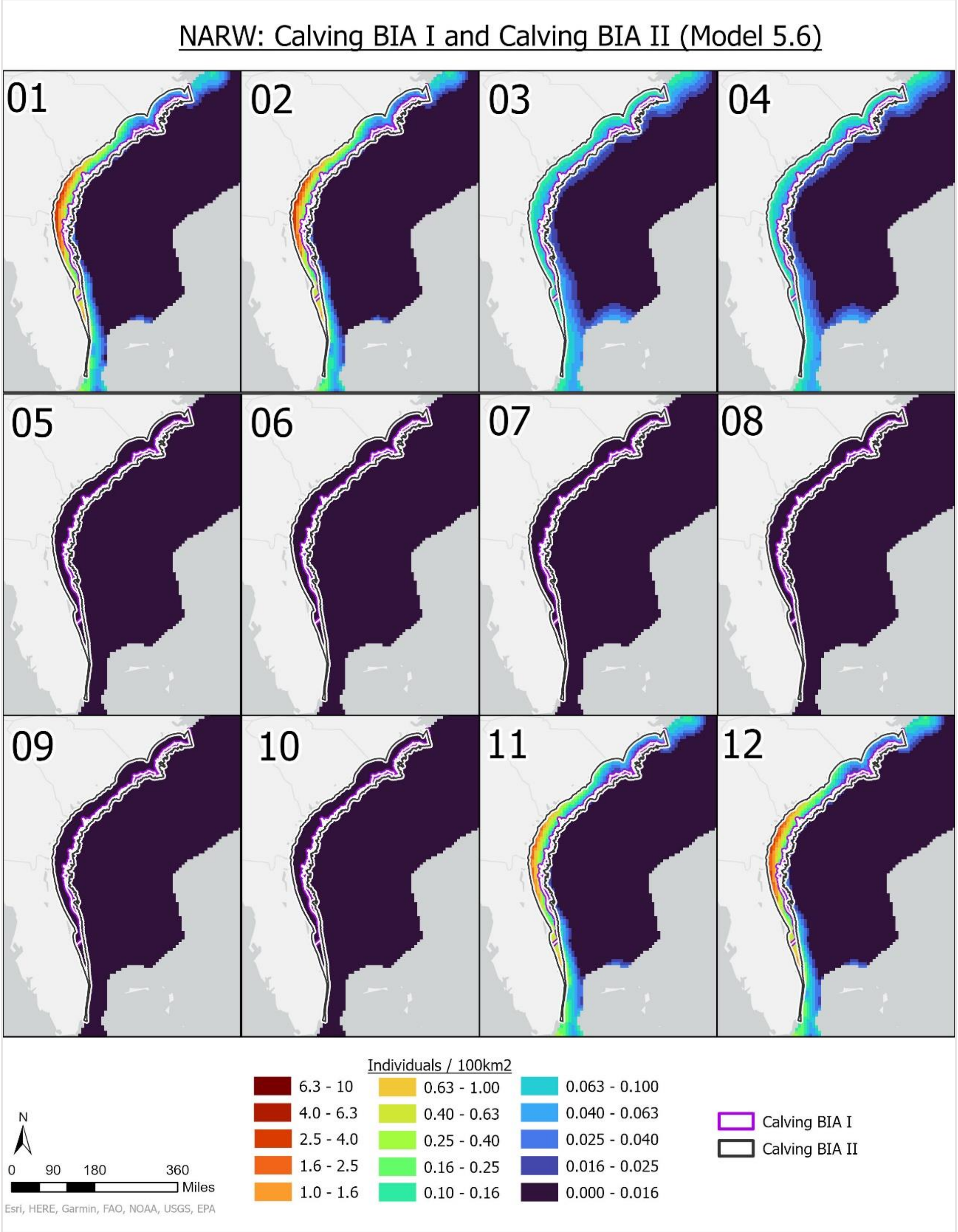


Figure 13: NARW model 5.6 densities within the BIA I and BIA II Calving BIAs.

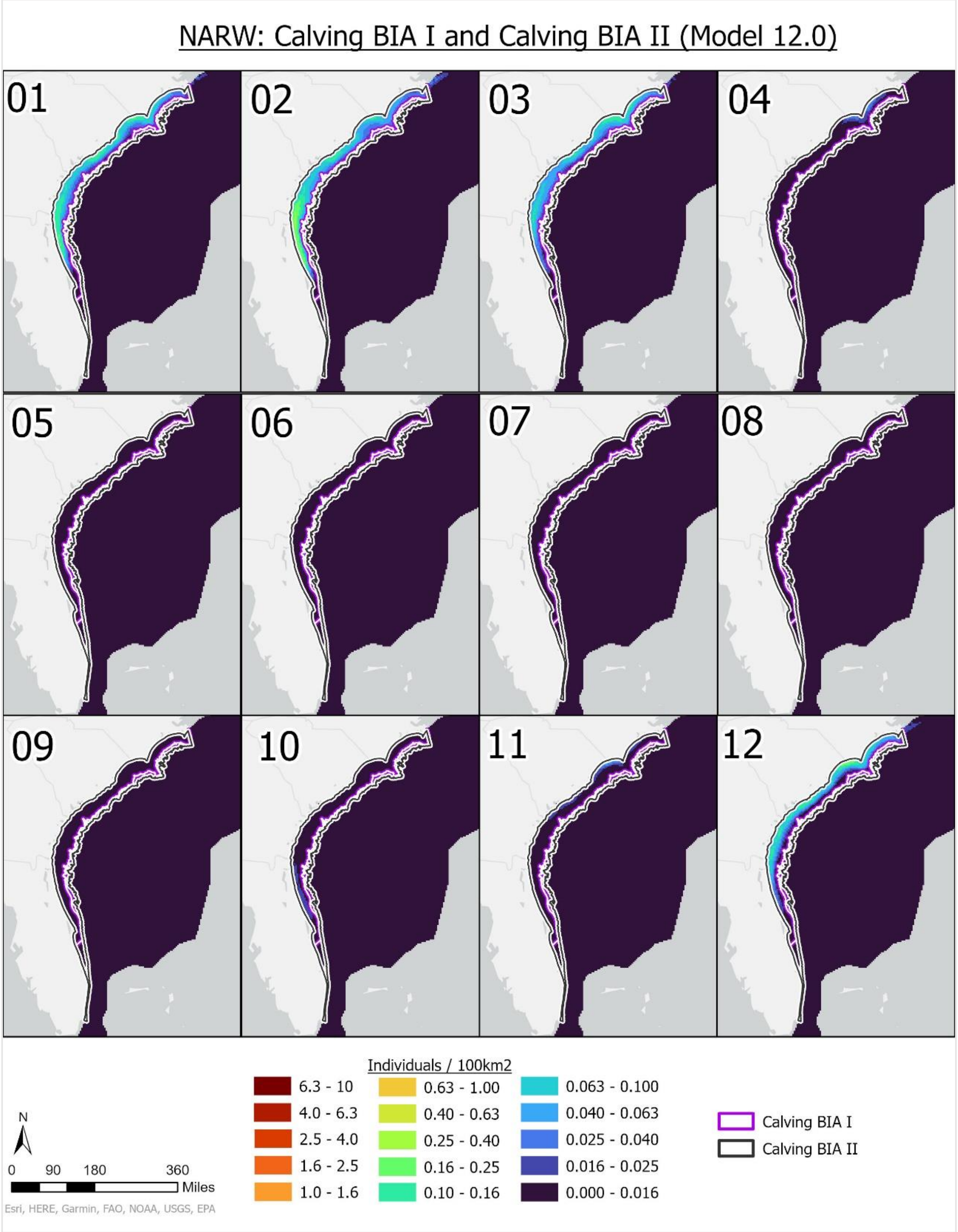


Figure 14: NARW model 12.0 densities within the BIA I and BIA II Calving BIAs.

Table 1: Proportions of total model abundance within each BIA monthly for humpback whale model version **9.4**. All humpback whale BIAs are feeding areas and are denoted in blue.

Month	Total Model Abundance	BIA I: Gulf of Maine, Stellwagen Bank, Great South Channel	BIA II: Gulf of Maine (Child)	BIA II: Gulf of Maine (Parent)	BIA II: Mid-Atlantic Shelf	BIA II: New York Bight (Child)	BIA II: New York Bight (Parent)	BIA II: Southern New England (Watchlist)
1	205.515	0.226	0.18	0.291	0.161	0.004	0.074	0.018
2	169.771	0.167	0.14	0.219	0.175	0.005	0.068	0.018
3	207.68	0.246	0.212	0.315	0.135	0.004	0.066	0.024
4	584.2	0.3	0.391	0.462	0.088	0	0.034	0.006
5	1109.801	0.275	0.371	0.452	0.045	0	0.033	0.005
6	1798.637	0.224	0.348	0.424	0.01	0	0.017	0.004
7	1897.16	0.223	0.379	0.456	0.001	0	0.01	0.003
8	1926.334	0.211	0.367	0.449	0	0	0.005	0.002
9	1895.346	0.208	0.366	0.451	0.002	0	0.005	0.003
10	1994.434	0.196	0.372	0.461	0.006	0	0.006	0.003
11	1936.049	0.199	0.381	0.471	0.012	0	0.011	0.003
12	264.751	0.426	0.353	0.488	0.103	0.003	0.058	0.014

Table 2: Proportions of total model abundance within each BIA monthly for humpback whale model version **11**. All humpback whale BIAs are feeding areas and are denoted in blue.

Month	Total Model Abundance	BIA I: Gulf of Maine, Stellwagen Bank, Great South Channel	BIA II: Gulf of Maine (Child)	BIA II: Gulf of Maine (Parent)	BIA II: Mid-Atlantic Shelf	BIA II: New York Bight (Child)	BIA II: New York Bight (Parent)	BIA II: Southern New England (Watchlist)
1	187.751	0.213	0.199	0.313	0.126	0.014	0.102	0.008
2	191.419	0.131	0.129	0.206	0.147	0.009	0.106	0.006
3	366.042	0.091	0.089	0.146	0.132	0.006	0.085	0.006
4	1044.565	0.22	0.251	0.321	0.045	0.001	0.062	0.007
5	2263.28	0.259	0.304	0.39	0.026	0	0.039	0.006
6	2980.952	0.217	0.273	0.362	0.012	0	0.044	0.005
7	2384.74	0.234	0.302	0.406	0.001	0	0.012	0.004
8	1930.408	0.255	0.329	0.444	0.001	0	0.01	0.003
9	2055.239	0.265	0.342	0.451	0.004	0	0.015	0.004
10	1939.533	0.264	0.32	0.405	0.014	0	0.021	0.006
11	1536.22	0.177	0.22	0.272	0.022	0.001	0.022	0.006
12	293.2	0.335	0.312	0.495	0.06	0.015	0.07	0.004

Table 3: Proportions of total model abundance within each BIA monthly for NARW model version **5.6**. Feeding BIAs are denoted in blue, migratory BIAs are denoted in orange, and reproduction BIAs are denoted in purple.

Month	Total Model Abundance	BIA I: Cape Cod Bay, MA Bay	BIA I: Eastern Atlantic	BIA I: Great South Channel, Georges Bank Shelf Break	BIA I: Gulf of Maine	BIA I: Jeffrey's Ledge	BIA I: Southeast Atlantic Calving	BIA II: NE/SE Migratory Route	BIA II: Scotian Shelf	BIA II: SE Atlantic Calving Grounds	BIA II: Southern New England
1	574.09	0.001	0.527	0.016	0.074	0.005	0.551	0.68	0.037	0.61	0.004
2	513.293	0	0.57	0.014	0.057	0.003	0.605	0.742	0.034	0.667	0.004
3	357.395	0.026	0.707	0.102	0.003	0.001	0.121	0.746	0.381	0.149	0.09
4	474.395	0.028	0.705	0.159	0.007	0.001	0.089	0.733	0.507	0.109	0.187
5	459.504	0.001	0.588	0.44	0.029	0.001	0.012	0.682	0.739	0.016	0.007
6	378.785	0	0.493	0.383	0.054	0	0.011	0.598	0.716	0.014	0.002
7	263.643	0	0.311	0.302	0.077	0	0.014	0.457	0.771	0.018	0
8	268.256	0	0.024	0.008	0.026	0.001	0	0.044	0.732	0	0
9	300.033	0	0.035	0.019	0.059	0.003	0	0.051	0.682	0	0
10	439.253	0	0.052	0.018	0.068	0.004	0.004	0.07	0.719	0.005	0
11	472.724	0	0.408	0.007	0.133	0.004	0.407	0.542	0.024	0.474	0.004
12	573.269	0.001	0.469	0.013	0.1	0.005	0.479	0.61	0.035	0.542	0.003

Table 4: Proportions of total model abundance within each BIA monthly for NARW model version **12**. Feeding BIAs are denoted in blue, migratory BIAs are denoted in orange, and reproduction BIAs are denoted in purple.

Month	Total Model Abundance	BIA I: Cape Cod Bay, MA Bay	BIA I: Eastern Atlantic	BIA I: Great South Channel, Georges Bank Shelf Break	BIA I: Gulf of Maine	BIA I: Jeffrey's Ledge	BIA I: Southeast Atlantic Calving	BIA II: NE/SE Migratory Route	BIA II: Scotian Shelf	BIA II: SE Atlantic Calving Grounds	BIA II: Southern New England
1	359.715	0.049	0.721	0.045	0.078	0.008	0.066	0.73	0.451	0.069	0.14
2	371.059	0.057	0.832	0.021	0.009	0.007	0.076	0.838	0.474	0.081	0.16
3	381.228	0.115	0.769	0.033	0	0.001	0.049	0.776	0.467	0.051	0.132
4	417.72	0.146	0.701	0.106	0	0.001	0.008	0.695	0.496	0.009	0.099
5	384.459	0.034	0.707	0.322	0.009	0.001	0.005	0.725	0.771	0.006	0.065
6	208.235	0	0.441	0.244	0.024	0	0	0.533	0.823	0	0.033
7	165.04	0	0.31	0.173	0.036	0.001	0	0.481	0.784	0	0.028
8	65.901	0	0.207	0.005	0.003	0	0	0.207	0.559	0	0.043
9	39.463	0	0.463	0.004	0.002	0	0	0.463	0.612	0	0.094
10	56.086	0	0.545	0.028	0.099	0.019	0.052	0.552	0.301	0.061	0.08
11	134.428	0	0.43	0.026	0.183	0.021	0.027	0.435	0.28	0.029	0.077
12	204.861	0.022	0.752	0.037	0.088	0.006	0.09	0.771	0.499	0.093	0.16