NOAA TECHNICAL MEMORANDUM NMFS-SEFSC-757

Assessing the risk of vessel strike mortality in North Atlantic right whales along the U.S East Coast

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Abstract

The endangered North Atlantic right whale (NARW, *Eubalaena glacialis*) is declining due to a combination of reduced calving rates and anthropogenic mortality from entanglement in fishing gear and vessel strikes. The National Marine Fisheries Service implemented efforts to reduce vessel strike mortality in 2008 by establishing seasonal management areas (SMAs) where large (> 65 feet length) vessels were restricted to traveling at 10 knots or less, establishing recommended and mandatory large vessel routes, and implementing voluntary dynamic management areas. However, vessel strikes continue to be a significant source of mortality for NARW, particularly outside of the established SMAs and with smaller vessels. In this study, we developed an encounter risk model for the U.S. east coast to 1) evaluate the overall risk of vessel strike mortality, 2) identify areas of greatest risk, and 3) quantify the potential for expanded vessel speed restrictions to reduce NARW vessel strike mortality. The encounter risk model accounts for the probability of an encounter between whales and vessels, the probability that a whale will be near the surface, the probability of avoidance of the vessel by the whale, and the probability of mortality given a vessel strike. There remain important sources of potential bias and uncertainty in this analysis that are discussed throughout. The model showed that the greatest risk of vessel strikes occurred throughout waters of the mid-Atlantic and southern New England, particularly during colder months of the year when the majority of NARW are in U.S. waters. Based upon a potential expansion of vessel speed restrictions to cover the region of highest risk, the model suggests that an average reduction in vessel strike mortality of 27.5% could be achieved by reducing vessel speeds in this region to less than 10 knots.

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Introduction

The North Atlantic right whale (NARW) is among the most endangered species of large whales in the world with a population size numbering less than 400 individuals (Hayes et al. 2021). While the population of NARW increased slowly from 1990 to 2010, the population trajectory leveled off in 2010 and then began to decline (Pace et al. 2017, Hayes et al. 2021). The population decline over the last decade is the result of both reductions in calving rates and increases in anthropogenic mortality. Reductions in calving rates are thought to be a result of climatic changes that reduced the productivity of NARW feeding grounds in the Gulf of Maine (Meyer-Gutbrod et al. 2021). This change in food availability was accompanied by shifts in NARW habitat use away from historical feeding grounds in the Bay of Fundy and Gulf of Maine. The primary sources of anthropogenic mortality in NARW are vessel strikes and entanglement in fishing gear (Kraus et al. 2016; Hayes et al. 2021). These sources are the primary causes of an ongoing Unusual Mortality Event (UME), which began in 2017 and as of April 2022 includes a total of 50 documented serious injuries and mortalities. This observed number of mortalities represents approximately 1/3 of the total actual mortality (Pace et al. 2021), and anthropogenic mortality continues to be the primary threat to the survival of the species (Corkeron et al. 2018).

To reduce lethal (serious injury and mortality) vessel strike events involving NARWs, the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) and its partners implemented a range of management actions along the U.S. east coast beginning in 2008. Major actions included:

- Implementation of voluntary two-way routes for commercial vessels in the southeast United States (SEUS) and Cape Cod Bay
- Modification of the Boston, MA Traffic Separation Scheme (TSS)
- Implementation of a voluntary seasonal Area To Be Avoided (ATBA) in the Great South Channel east of Cape Cod, MA
- Implementation of mandatory 10-knot speed restrictions for most vessels greater than 65 ft in length within Seasonal Management Areas (SMAs) in habitats off Massachusetts, ports along the Mid-Atlantic coast, and the SEUS
- Intermittent implementation of voluntary speed restrictions in Dynamically Managed Areas (DMAs) where NARW aggregations occur outside of the boundaries of the SMAs

Several analyses have evaluated the effectiveness of these management efforts. Silber et al. (2014) and Lageux et al. (2011) evaluated vessel traffic data after implementation of the SMAs and showed that compliance rates increased over time and resulted in reductions in vessel speeds within the SMAs. Based upon a model of the relationship between vessel speed and the risk of vessel strikes, the observed reductions in vessel speed were estimated to reduce the lethality of vessel strikes by 80-90% (Silber et al. 2014; Conn and Silber 2013). An assessment of the efficacy of mandatory speed restrictions along the East Coast determined that the number of documented vessel strike mortalities and serious injuries decreased from 12 during the 10 years prior to the rule’s implementation to 8 in the 10 years following implementation (National Marine Fisheries Service 2020). However, it is not possible to determine a direct causal link. This recent analysis of vessel Automatic Information System (AIS) data also found high levels of compliance with speed restrictions across SMAs; however, port entrance areas in the SEUS

SMAs had low compliance rates for large ocean-going vessels (National Marine Fisheries Service 2020). This analysis also noted the high transit speeds of traffic in some SMAs of smaller vessels (< 65 feet in length) that are not subject to speed restrictions and are an additional source of vessel collisions with NARW.

Analyses of stranding rates of carcasses associated with vessel strikes and in proximity to the SMAs indicated a reduction in the rate of vessel strike mortalities. In the 18 years prior to implementation of the SMAs, there was an annual average of 0.72 documented right whale vessel strike mortalities in the proximity of the SMAs, but in the five years after implementation, there were no documented vessel strike mortalities (Laist et al. 2014). This apparent reduction in the rate of observed vessel strike mortalities near the SMAs was statistically significant. van der Hoop et al. (2015) identified a significant decrease in the number of vessel-strike mortalities of all large whale species between 2000-2006 and 2007-2012 and that mortalities decreased inside active SMAs. However, this reduction was not coincident with the implementation of the vessel speed rules, the authors noted that compliance with speed restrictions was relatively low during this period, and there was relatively limited data available to directly quantify the effectiveness of SMAs (van der Hoop et al. 2015). The authors also noted that the designated SMAs with speed restrictions near the entrances to mid-Atlantic ports only accounted for 36% of past large whale vessel-strike mortalities and that their effectiveness may be influenced by shifts in whale distribution over time.

The current management efforts to reduce vessel strike mortality were designed based upon the understanding of NARW distribution when they were first implemented in 2008. There were little data available to characterize the occurrence of NARW within mid-Atlantic waters (i.e., Cape Hatteras, NC to Long Island, NY). However, there have been recent notable changes in NARW habitat use that may result in changes in exposure to vessel traffic. The observed change in feeding habitats is associated with increases in the number of NARWs seen in the Gulf of St. Lawrence, Canada and associated exposure of NARWs to both vessel strikes and entanglement in this region. This resulted in higher mortality rates, particularly during 2017 when the ongoing UME began (National Marine Fisheries Service, 2022). Passive acoustic data also suggest a shift in habitat use since 2010 with increasing occurrence of NARWs in mid-Atlantic and southern New England waters (Davis et al. 2017). Recent survey data in the Nantucket Shoals region indicate large aggregations of NARWs occurring year-round in this area that had not previously been identified as a persistent habitat (Quintana-Rizzo et al. 2021). In combination with low compliance rates in some SMAs, these changes in NARW spatial distribution may limit the overall effectiveness of the current management scheme.

In this study, we developed an encounter risk model to assess the current risk of NARW vessel strike mortality along the U.S. East Coast to account for these observed changes in NARW habitat use and assess the ongoing risk of vessel strike mortality from both large and small vessels. We used recent data on vessel and whale spatial distribution, vessel speed and size, and whale behavior to quantify the risks of vessel strike related mortality in U.S. waters using an encounter-risk model (e.g., Martin et al. 2016, Rockwood et al. 2017; Crum et al. 2019). This model was used to 1) evaluate the overall risk of vessel strike mortality, 2) identify areas of greatest risk, and 3) quantify the potential for expanded vessel speed restrictions to reduce the overall risk of NARW vessel strike mortality.

Methods

Vessel Strike Mortality Estimation

The encounter risk model follows the framework described in Martin et al. (2016) and includes five components to characterize the risk of vessel strike mortalities (M) in a given space-time region as described in equation 1 (after Martin et al. 2016):

Eqn. 1 $$M = \lambda_e t \cdot (1 - p_{avoid}) \cdot p_{strike\ depth} \cdot p(v_s)_{mortality|strike} \cdot N_w N_v.$$

The model components include encounter risk ($\lambda_e t$), the probability that a whale will successfully avoid a strike (p_{avoid}), the probability that a whale is at a depth within the draft of an average vessel ($p_{strike\ depth}$) based on whale behavior, the probability of mortality conditional on a strike occurring ($p(v_s)_{mortality|strike}$), the number of whales in a spatial cell (N_w) and the number of vessels in a spatial cell (N_v).

Encounter Risk

The first component, encounter risk (λ_e), is the risk of encounter between an individual vessel and whale assuming that both are moving randomly with respect to one another within a defined spatial area for a total amount of time, *t*, which is the amount of time it takes for a vessel to transit the area. This is based on a two-dimensional model of encounter risk, and is represented as:

Eqn. 2 $$\lambda_e = \frac{2r_c}{S} \int_{v_w} I(v_w, v_s) v_w dv_w,$$

where r_c is the “critical radius” or the separation between the whale and the vessel at which a vessel strike is considered to have occurred, S is the area of the spatial cell being considered, and $I(v_w, v_s)$ is a monotonic function of whale speed (v_w) and vessel speed (v_s), respectively (Martin et al. 2016). This function was implemented with scripts provided in the supplemental information of Martin et al. (2016). For this analysis, r_c is defined by the body length of an individual whale based on the size distribution for adult NARW described in Fortune et al. (2021; mean = 13.5 m). With this approach, we infer that a vessel strike has occurred when the whale and vessel approach within one body length of the animal. The spatial cells (and area S) are defined by a 10 km x 10 km grid used in the spatially explicit model of animal density described below. Whale swimming speeds (v_w) are sampled from a Weibull distribution (shape parameter, K, = 1.48, scale parameter, L, = 0.43; Figure 1) as described in Martin et al. (2016) and Crum et al. (2019).

Probability of Avoidance

The degree of active avoidance of vessels by large whales is a considerable source of uncertainty in assessing the risk of mortality due to vessel strikes. There are limited data available to assess the behavioral response of NARWs to approaching vessels; however, there are studies that suggest limited avoidance behaviors (Nowacek et al. 2004, Wiley et al. 2016) in response to vessel sounds or approaches of smaller vessels. For blue whales, McKenna et al. (2015) documented limited lateral movement in response to vessels approaching within 1 km of an individual whale, but they did observe a weak dive response with relatively slow descents. Based upon these data, Rockwood et al. (2017) included probability of avoidance of 55% in a similar encounter risk model for large whales on the U.S. west coast and also explored a logistic function between avoidance rate and vessel speed (Rockwood et al. 2017, Rockwood et al. 2020). These data indicating limited responses to vessels contrast with studies of close approaches of whale watching vessels in blue whales (Lesage et al. 2017) and humpback whales (Schuler et al. 2019) that document changes in dive behaviors and surface movements when vessels approached within 400-500m of these whales. In addition, studies of humpback whales in Alaska (Gende et al. 2011) and Hawai'i (Currie et al. 2017) indicated that as vessel speeds increase, the distance at which whales encounter vessels decreases, which may suggest that traveling at slower speeds allows more time to avoid close approaches. Finally, Conn and Silber (2013) inferred a strong relationship between vessel speed and the likelihood of interactions with NARWs and a linear effect of vessel speed on strike rates. Their inferred 80-90% reduction of vessel strike risk mortality with the implementation of speed restrictions included this effect, which was assumed to reflect increased avoidance of slower moving vessels by NARWs.

For this model, we took a mechanistic approach to accounting for potential avoidance responses by individual NARWs encountering vessels. The probability of successful avoidance of a "close approach" is resolved into a reaction distance (the distance at which a whale first detects a vessel and begins an avoidance response), movement direction (0-90 degrees from the vessel track, simulating a horizontal movement), and movement speed. We used these three parameters to calculate whether or not the whale moved more than one body length out of the path of the vessel and thereby successfully avoided the collision. For each individually modeled reaction, these three components were drawn from specified random distributions to account for uncertainty in actual behavioral response and stochastic behavioral effects. The reaction distance was drawn from a uniform distribution between 10-1200 m, the movement direction was drawn from a uniform distribution of 0-90 degrees from the vessel track, and the movement speed was a uniform distribution from 0.6-1.2 m/s. The resulting relationship between the probability of avoidance and vessel speed is shown in Figure 2.

Probability at Strike Depth

The probability that a NARW will be present at a depth shallow enough to be struck by a vessel ($p_{strike\ depth}$ in equation 1) is a function of region specific dive-surface behaviors. For this analysis, we used a depth of 10 m to indicate that a whale was within the draft depth of the majority of vessels and would therefore be at risk of an interaction. We reviewed literature summarizing NARW dive-surface behaviors to characterize the proportion of time whales are likely to be within 10 m of the surface in six regions (Figure 3; Table 1). Based on tag data from each region, the probability that a whale was within 10 m of the water's surface was drawn from a beta distribution with appropriate parameters to align with the reported medians and variability of reported dive data (Table 1).

Vessel Strike Mortality

The probability of mortality given a vessel strike was modeled using the logistic regression described in Conn and Silber (2013). This data set included information from a range of vessel sizes; however, the majority of these were from large commercial vessels. In addition, there were interactions that were scored as severe injuries (i.e., injuries likely to result in death), which were treated as equivalent to mortalities. Finally, the data set included interactions with all large whale species. The resulting logistic regression (β_0 = -1.905, β_1 = 0.217) for predicting the probability of a lethal strike as function of vessel speed was used for all vessel sizes and matches that used in previous encounter risk models for large whales (Rockwood et al. 2017, Crum et al. 2019).

Whale Distribution

A habitat-based spatial density model (SDM) was used to predict NARW spatial distribution along the U.S. east coast. The model follows the SDM approach (Miller et al. 2013) that uses line-transect survey data and the Distance analysis method to estimate detection probability for encountered NARWs in combination with a Generalized Additive Model to predict animal density (number of whales per km^2) based upon environmental features (e.g., sea surface temperature, water depth, etc.) over a spatial grid (Roberts et al. 2016). Model predictions of NARW density were made on a 10 x 10 km grid covering waters of the east coast of North America between southern Florida and the Nova Scotian Shelf (Figure 4). The spatial cells of the SDM were used as the analytical units in this analysis, and the number of whales in each cell (N_w) was predicted from a set of regional models in which separate models were fit for the southeastern US (Cape Hatteras, NC to Florida), mid-Atlantic and southern New England (Cape Hatteras to Nantucket Shoals), and the Georges Bank/Gulf of Maine (North of Nantucket Shoals; Roberts et al. 2020). These regions reflect differences in movement patterns and behaviors within each region. The models are resolved monthly and reflect seasonal movements with NARWs distributed broadly across the U.S. east coast, including the SEUS calving grounds during cooler months (November – April) and occurring primarily within the feeding grounds in the Georges Bank/Gulf of Maine region during warm months. The NARW distribution model is resolved into two time periods: 2003-2009 and 2010-2018 to account for observed shifts in

NARW spatial distribution during these periods. In this analysis, we use model outputs for the 2010-2018 period. The details of the model formulation are described in Roberts et al. (2020).

Vessel Distribution and Vessel Speed

The vessel traffic data used for the model consisted of AIS data received by both low-orbiting satellite constellations (ORBCOMM) and terrestrial stations (United States Coast Guard, 2021a) from January 1, 2017 through December 31, 2019. Temporally-adjacent data from these two sources belonging to the same vessel were aggregated into transits when the elapsed time between AIS messages did not exceed 2 hours for terrestrial data and 4 hours for satellite data. Data from the AIS messages that contained reported speed over ground (knots) values less than 0 or greater than 50 were removed as they likely represent errors.

Relevant vessel information including vessel type and size characteristics, were obtained from both the AIS data and a third-party vessel registration database. Mariners self-identify their vessel type and navigation status using a two-digit code in the class 5 AIS (United States Coast Guard, 2021b). However, the available options for identifying vessel type in the class 5 messages are limited, and the data provided by mariners often contains omissions and inaccuracies. When possible, we linked AIS data to a maritime vessels database (IHSMarkit, 2022) containing vessel characteristics to supply missing vessel type information. Vessel types in the database are classified using a multi-leveled scheme (IHSMarkit 2017) with over 200 vessel type codes. For our analyses, we used vessel data from the class 5 AIS messages and linked data in the maritime ships database to classify vessels into one of the following vessel types: Bulk Carriers, Container, Dredging, Fishing, General Cargo, Law, Medical, Military, Other, Other Cargo, Other Passenger, Passenger (Cruise), Passenger/General, Pilot, Pleasure, Pollution Control Vessel, Port

Tenders/Offshore Work Vessel, Research, Ro-Ro, Sailing, Search and Rescue, Tanker, Towing/Pushing, and Undetermined.

The vessel transits were mapped using a polar azimuthal equal-area projection for the northern hemisphere (Brodzik et al. 2012) and summarized into the NARW SDM analysis grid (Figure 3). Missing and invalid data were addressed on individual tracks by 1) removing all tracks with calculated mean vessel speeds >50 knots and < 0.2 knots, 2) removing tracks with elapsed times of 0 seconds, and 3) imputing missing vessel lengths, beams and drafts based upon vessel categories where possible.

Results and Discussion

Whale Distribution

The NARW spatial density model captures seasonal changes in spatial distribution that influence whale exposure to vessel traffic. During colder months (November – April), NARWs occur all along the U.S. the east coast - in the calving grounds off of Florida and Georgia, in waters along the mid-Atlantic coast and southern New England between North Carolina and south of Massachusetts, in Cape Cod Bay, and in the southern portions of the Gulf of Maine (e.g., February distribution, Figure 5a). Animal densities are predicted to be highest in Cape Cod Bay and along the entire mid-Atlantic during this period. In warm months (May-October), NARW occur predominantly in feeding grounds in the northern portion of their range, and in particular in the Gulf of Maine and Canadian waters. The bulk of the population occurs outside of U.S. waters during these months (Figure 5b).

This version of the spatial density model reflects the more recent distribution of NARWs during the period from 2010-2018. The model is largely consistent with the observed distribution of NARWs over this period, and in particular reflects the lower use of the southeastern US calving grounds compared to 2003-2009. Additionally, this model predicts higher densities of NARWs in the mid-Atlantic and Southern New England during cool months compared to the earlier period. However, the high densities predicted along the mid-Atlantic may not be realistic. In recent years, intensive aerial surveys have been conducted over Nantucket Shoals, and high densities of animals have been observed (Quintana-Rizzo et al. 2021). This localized high density strongly influences the mid-Atlantic regional model and may result in positively biased density estimates. Model development and evaluation is ongoing to address this potential source of bias. Further, the model does not accurately predict the total population size of NARWs partially because the regional sub-models are independent of each other. However, in this analysis we represent vessel strike risk as a rate relative to population size, and therefore this does not have an impact on the analysis results or conclusions.

Vessel Distribution

Large vessel (> 65 feet total length) traffic has a consistent spatial distribution throughout the year with most traffic concentrated over the continental shelf and at entrances or lanes into the major ports along the U.S. east coast. In addition to the cross-shelf traffic into port entrances, there are several along-shelf concentrations of traffic moving between ports, particularly from ports along the southeast coast, around Cape Hatteras, NC, and into mid-Atlantic ports (Figure 6a). The average speed of this traffic is generally higher further offshore. In the New York and Chesapeake Bay shipping lanes, speeds average 14-16 knots while much of the north-south traffic between the mid-Atlantic ports has average speeds of 12-14 knots (Figure 6b). These differences in speeds reflect different classes of vessels that use these different routes.

Smaller vessels (less than 65 feet) that are not regulated by the current management regime generally occur in highest densities in waters relatively close to shore throughout the east coast (Figure 7a). There are areas of high traffic density extending out into deeper waters particularly off of the coast of North Carolina and New Jersey. The bulk of this traffic is operating at average speeds above 12 knots with higher average speeds off the coasts of South Carolina, North Carolina, and New Jersey (Figure 7b). There is a predictable seasonal distribution of smaller vessel traffic with higher traffic densities during warm months of the year. While the number of smaller vessels carrying AIS has increased in recent years, they are not required to carry AIS, unlike larger vessels. Therefore, the small vessel traffic is under-represented in these data and may be biased towards particular vessel classes. As a result, the total risk of vessel strike due to these vessels is not well represented in this model.

Risk Analysis

The risk model was used to evaluate the areas and times with the highest risk of vessel strike mortalities for NARW. The areas of highest risk are primarily associated with places where there is both a high density of vessel traffic and high densities of right whales (Figure 8). In U.S. waters, these correspond generally to the southeastern, mid-Atlantic, and southern New England regions, particularly during colder months (November – May). The highest risk areas occurred in the mid-Atlantic between Cape Hatteras, North Carolina and New York and in relatively shallow waters over the continental shelf. The high density vessel traffic areas in approaches to major commercial ports pose the greatest risk of vessel strike mortalities. While smaller vessels are under-represented in the AIS data, the spatial distribution and timing of the risk of interactions with these vessels were also examined. In general, the risk of interactions with smaller vessels was higher close to shore. Monthly maps of vessel strike risk were examined to identify regions and times where slowing vessel traffic to speeds less than 10 knots would have the greatest impact on reducing the overall risk of vessel strike mortalities for NARWs (Figure 8).

To evaluate potential management alternatives to further reduce the risk of lethal NARW vessel strikes, modified SMA boundaries were developed based on the monthly vessel strike risk outputs and additional NARW sightings and acoustic detection data to address areas of elevated strike risk outside current SMA boundaries/timing. Once these areas, here referred to as proposed speed zones, were identified, a simulation approach was taken to assess the potential risk-reduction of this measure to NARWs. For the simulation, any vessel transits occurring within the proposed speed zone time-space boundary and with an average speed greater than 10 knots had the speed set to 10 knots. The total risk of vessel strike mortalities was re-calculated for this simulated dataset and compared to the status quo. Overall, the proposed speed zones reduce the risk of NARW vessel strike mortalities in U.S. waters by an average of 27.5% (Figure 9). Compared to the total risk reduction that could be gained from setting all vessel traffic in the study area to transit at 10 knots, the proposed speed zones account for 89% of the total possible risk reduction that can be achieved by reducing vessel speeds to 10 knots (Figure 9).

Conclusions

The encounter risk model identified the primary regions and seasons where the highest risk of vessel strike mortality occurred. In general, the majority of vessel strike mortality risk occurs during cooler months (November – May) when NARW densities are predicted to be high in waters of the mid-Atlantic, southern New England, and the southeastern U.S. Expanding speed zones to encompass these areas is expected to reduce the overall risk of vessel strike mortality by an average of 27.5%.

The review of literature of NARW dive-surface behavior indicates that they are highly susceptible to vessel strikes because they spend between 67-98% of their time in the upper 10 m of the water column throughout much of their range. This is particularly the case in the mid-Atlantic when they are traveling (as opposed to feeding at depth) and where they are exposed to the highest densities of vessel traffic.

The analysis also demonstrates that an increased ability of whales to avoid potential interactions with slower moving vessels is an important aspect of the effectiveness of speed restrictions. In the absence of active avoidance by whales, the overall estimated mortality rate due to vessel strikes is unrealistic and much higher than could be sustained by the NARW population, and there is a much lower benefit from reducing vessel speeds. However, the level of behavioral responses of whales to approaching vessels is poorly understood, and this remains an important source of uncertainty in this model.

The primary sources of potential bias stem from the AIS data and SDM used to represent vessel and whale spatial distribution, respectively. As noted above, smaller vessel traffic is under-represented in AIS data. As a result, both the risk of vessel strikes from these vessels and the benefits of reducing small vessel transit speeds are underestimated. Recent lethal interactions between smaller vessels and NARWs demonstrate that the risk from these vessels should be considered when implementing management efforts to reduce vessel strike mortality. The SDM used to predict NARW density may also be a source of bias. As discussed above, the prediction of high densities of NARW throughout the mid-Atlantic during cooler months may be an artifact of intensive sampling in a portion of the model domain for this region. There are ongoing efforts to update and improve this model, and future iterations of the NARW distribution model will be incorporated into the assessment of vessel strike risk.

The encounter risk model approach implemented here provides a framework to assess the overall risk of vessel strike mortality in NARWs and allows for a quantitative assessment of the potential benefits of alternative management strategies. The model is formulated to represent uncertainty in key parameters and to conduct sensitivity analyses. The model results suggest that increasing the temporal and spatial coverage of vessel speed restrictions along the U.S. east coast would be an effective tool to reduce overall risk of vessel strike mortalities in NARW.

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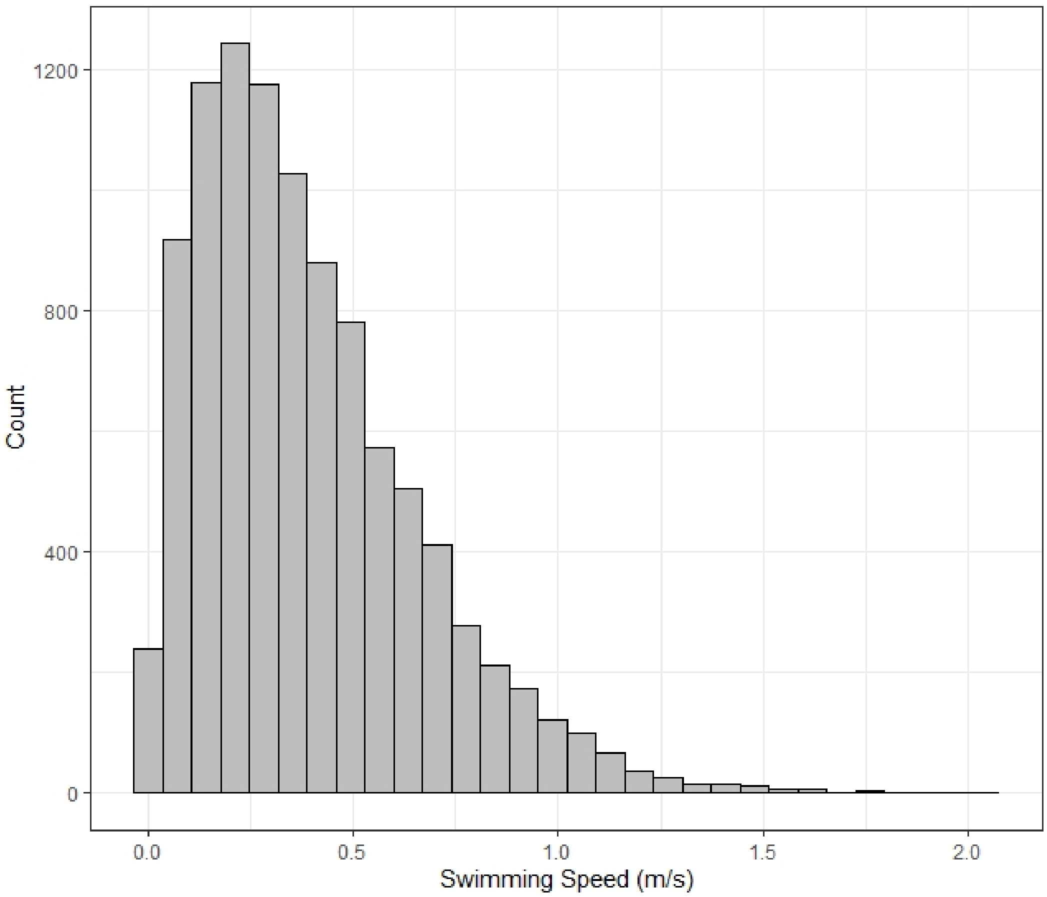
Table 1. Data sources and distributions used to describe regional variation in the dive-surface behaviors for NARW.

Source	Data/Reference	Type	Parameter	Distribution	Median of Beta Distribution	Region(s)Applied
Crum et al. 2019	Hain et al 1999 availability estimates in SEUS	Beta distribution (a = 2.38, b = 1.58)	median pSurface = 0.62 (0.438 - 0.779 IQR)	beta(2.38, 1.5)	0.624	Not applied
Nousek McGregor 2010	DTAG deployments in SEUS	DTAG Dive/Surface Durations	Shallow Dives (mean Depth =7.96 m): Surface Interval (SE) = 0.91 (0.12), Dive Interval = 1.83 (0.14); Deep Dives (12-15m): Surface = 2.44 (0.23), Dive = 6.58(0.28)	beta(4.9,1.3)	0.881	Southeast US (SEUS) calving ground
Nousek McGregor 2010	DTAG deployments in BOF	DTAG Dive/Surface Durations	Type III "travelling" dives exhibiting significant horizontal displacement	beta(4,2.2)	0.671	Mid-Atlantic, Offshore, and Scotian Shelf
Parks et al. 2012	DTAG Deployments in CCB	DTAG Dive/Surface Durations	13 tagged individuals that performed shallow dives and skim feeding behaviors	beta(7, 0.5)	0.966	Cape Cod Bay
Baumgartner et al. 2017	DTAG Deployments in western Gulf of Maine	DTAG Dive/Surface Durations	General summer foraging habitat dives in a of habitats, BOF, CCB, Jeffrey's ledge, etc..	beta(1.9, 1.9)	0.492	Gulf of Maine



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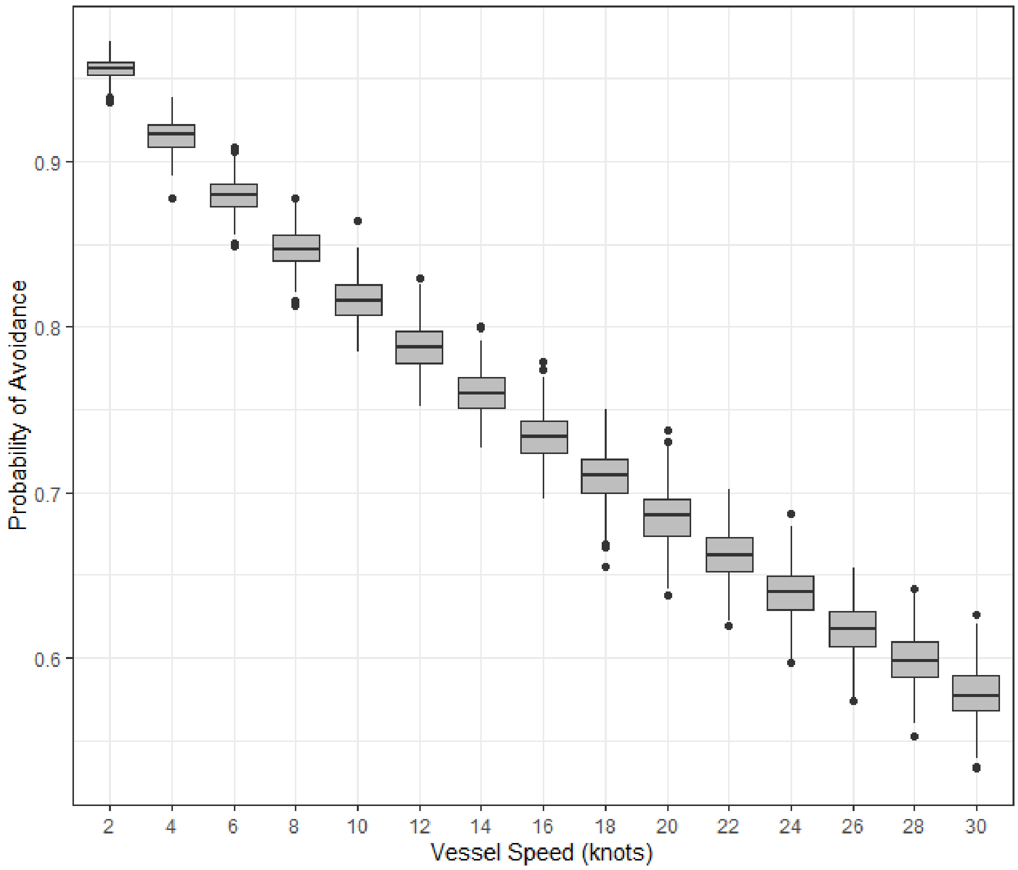

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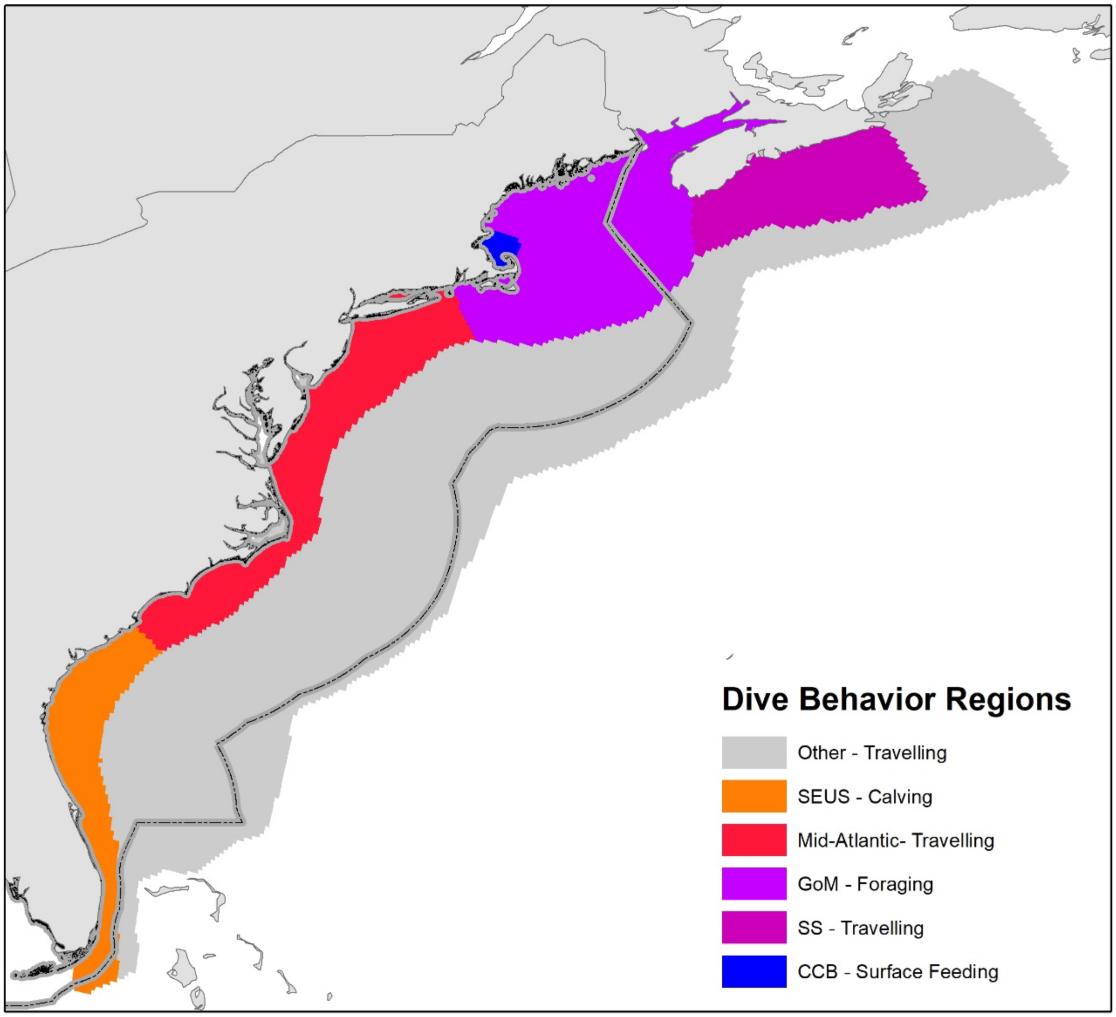

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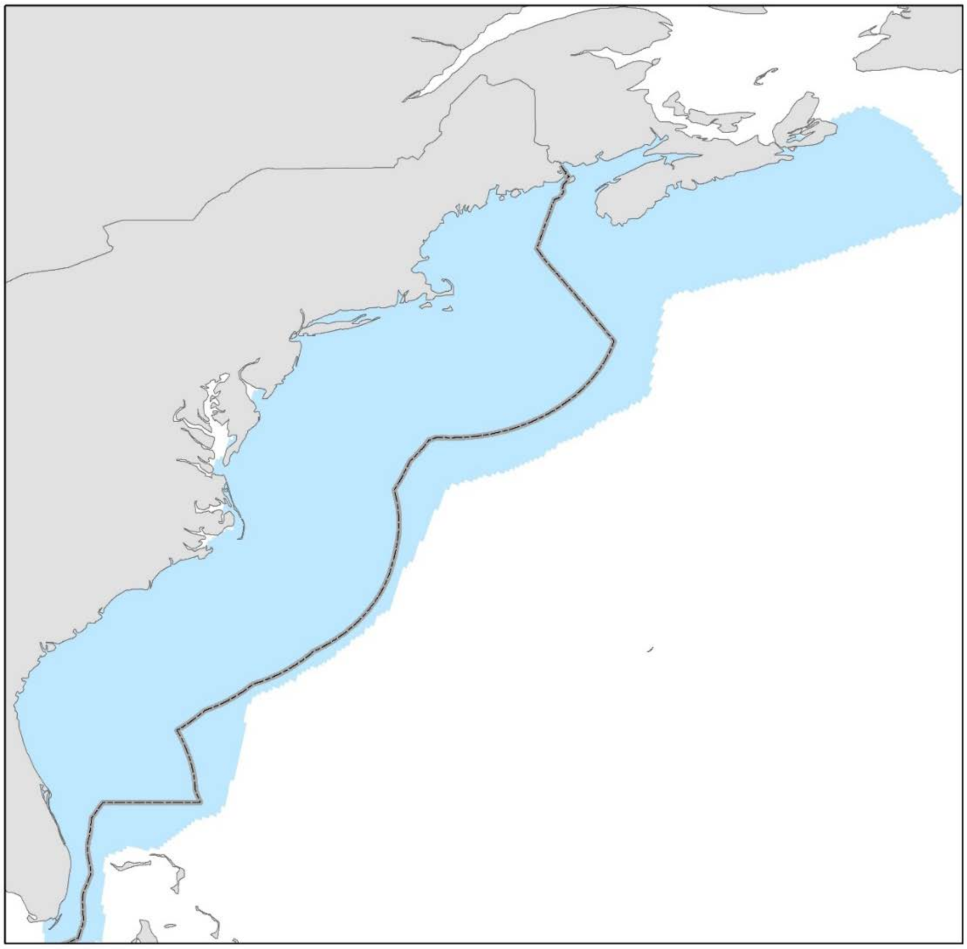

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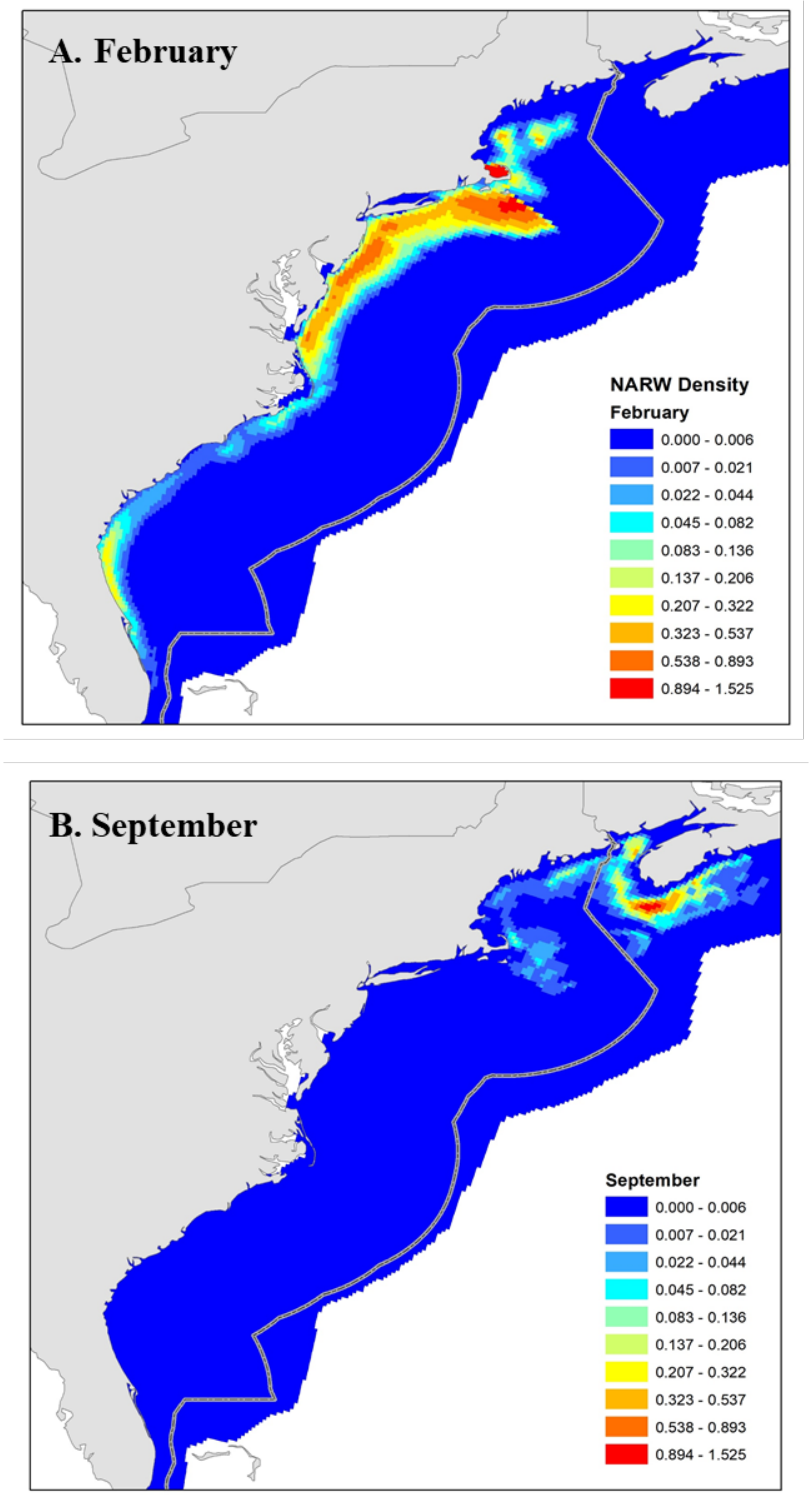

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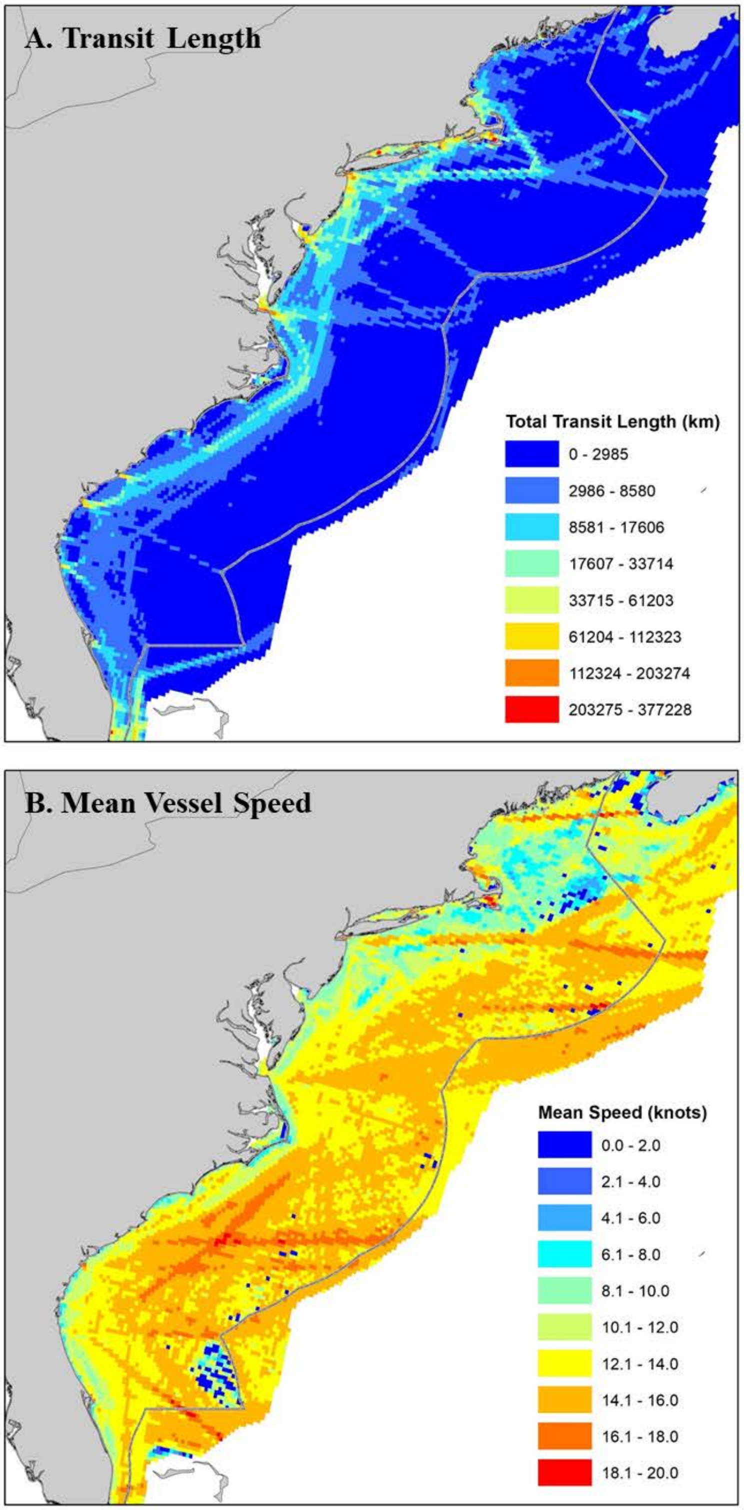

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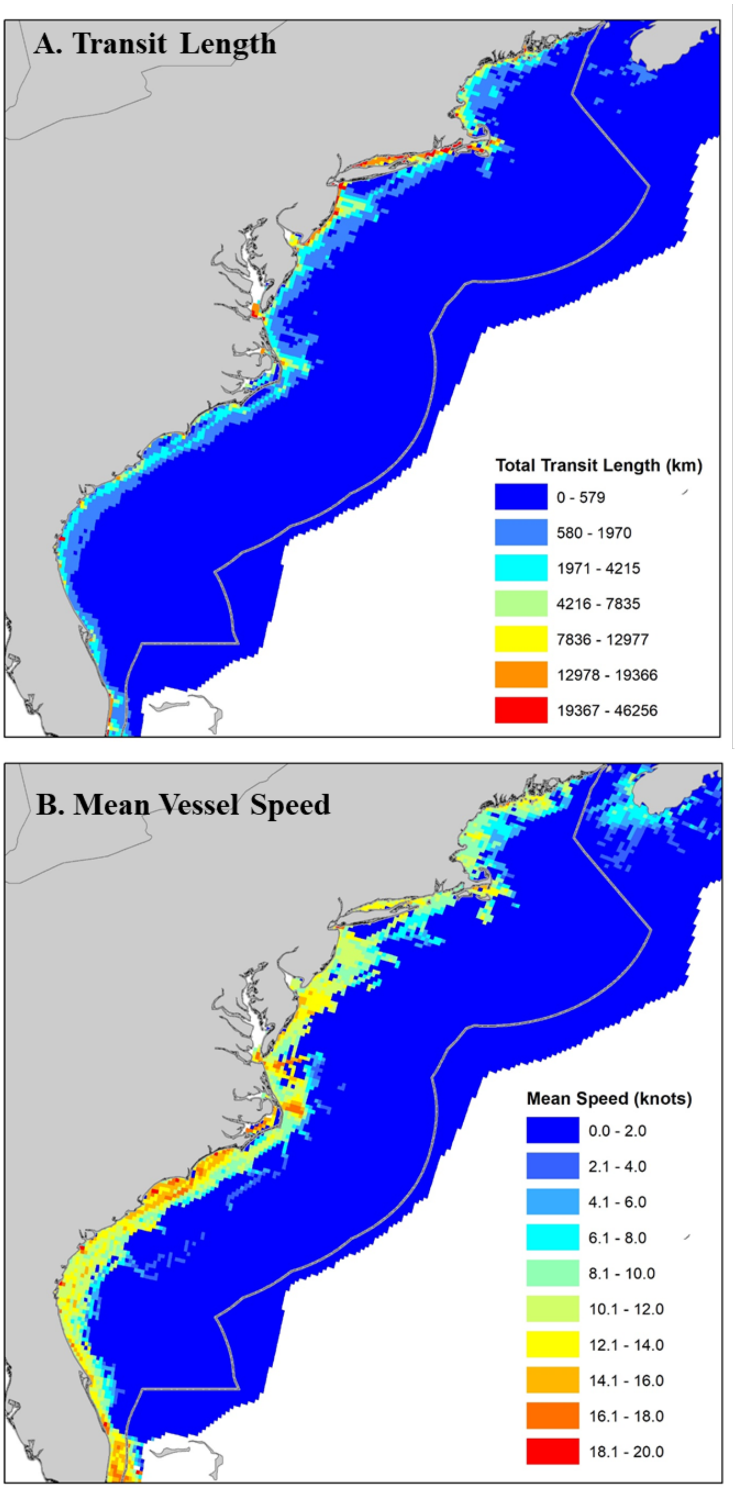

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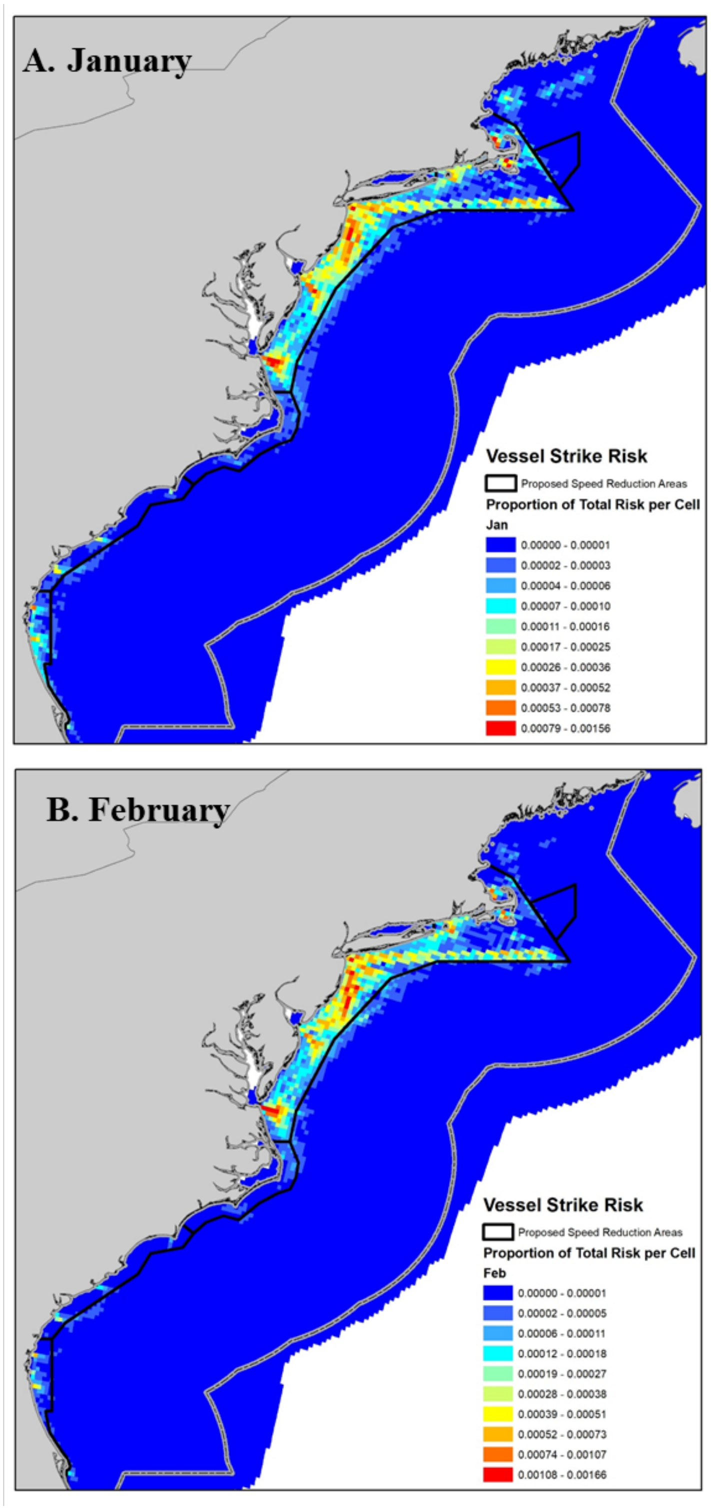

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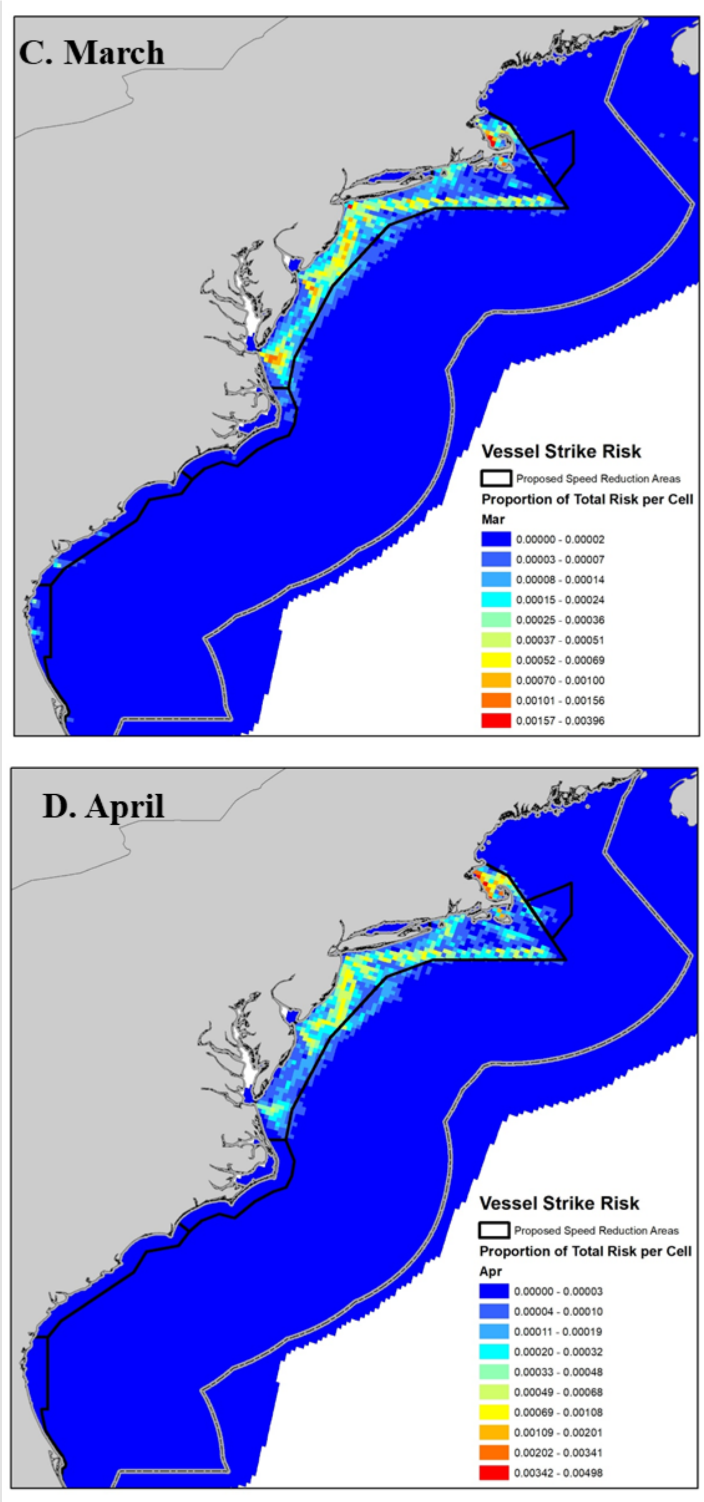

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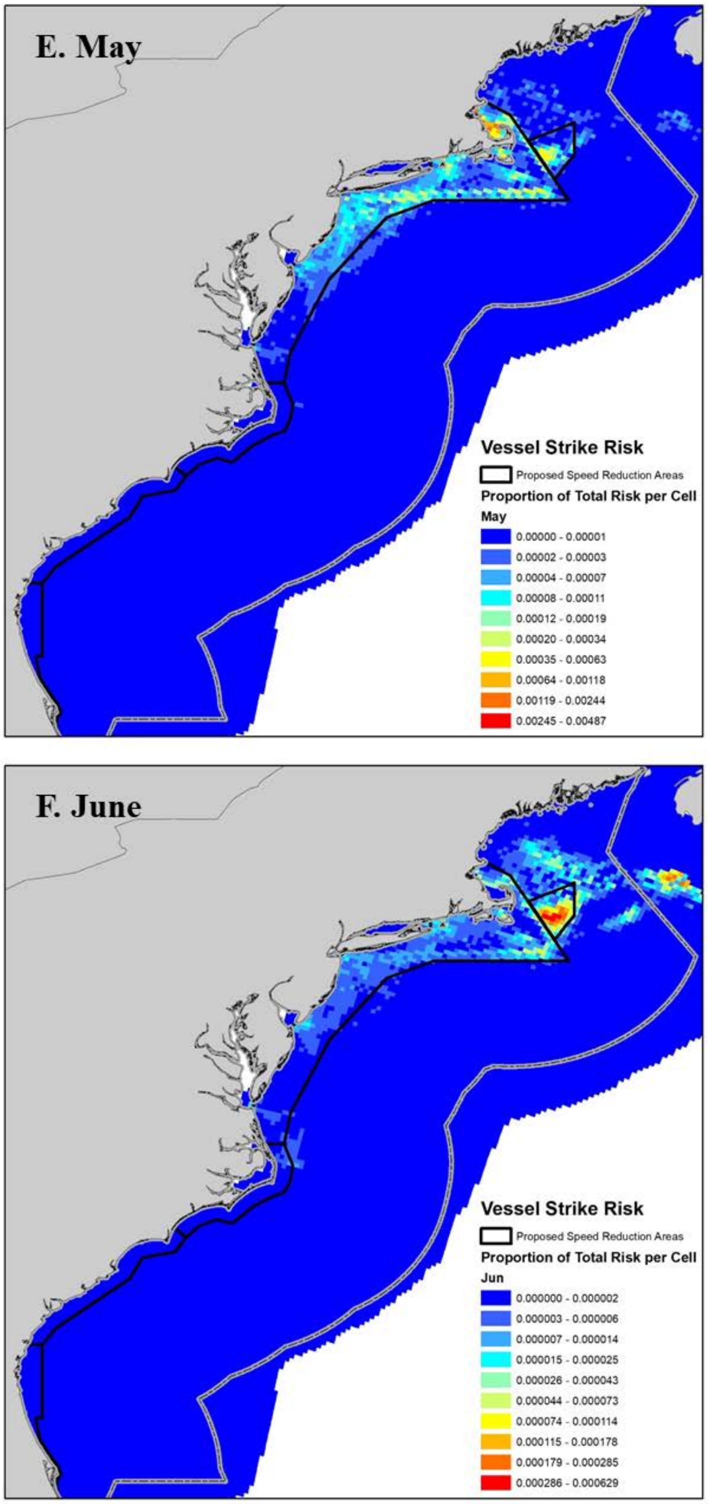

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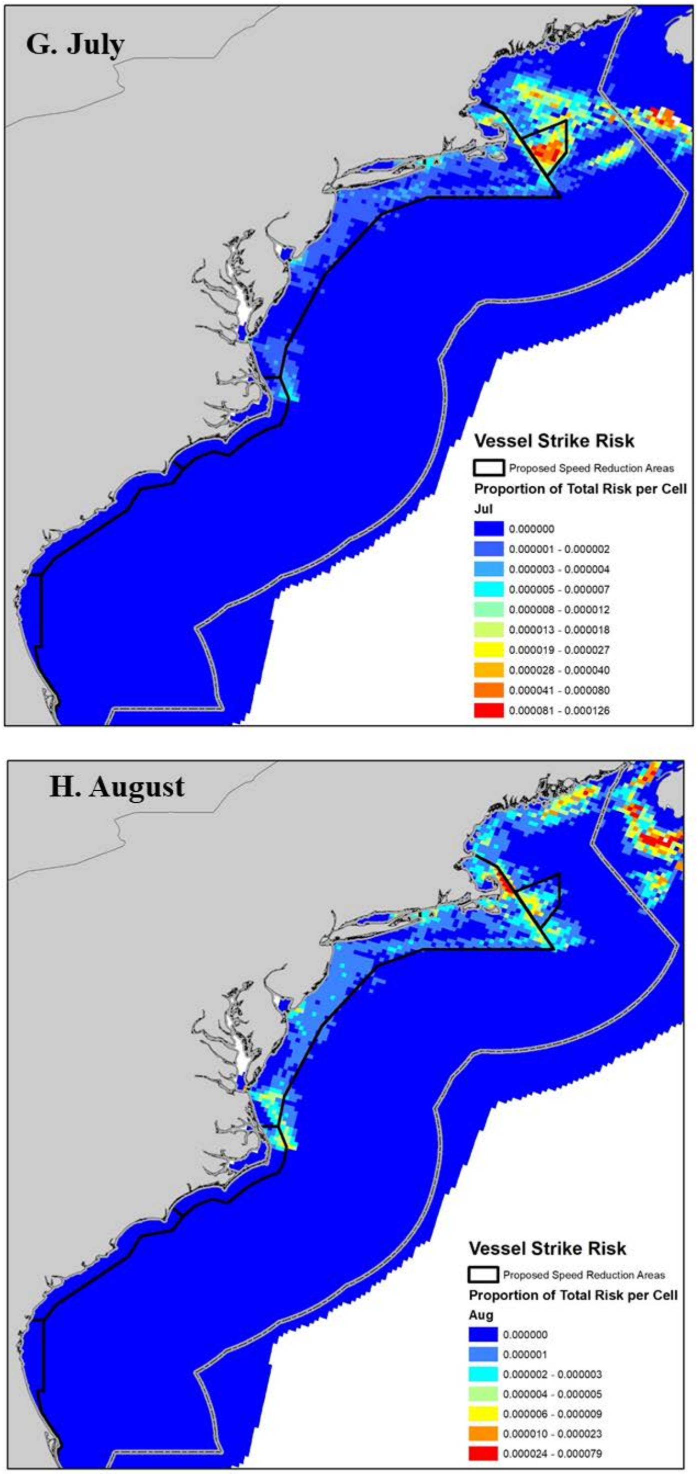

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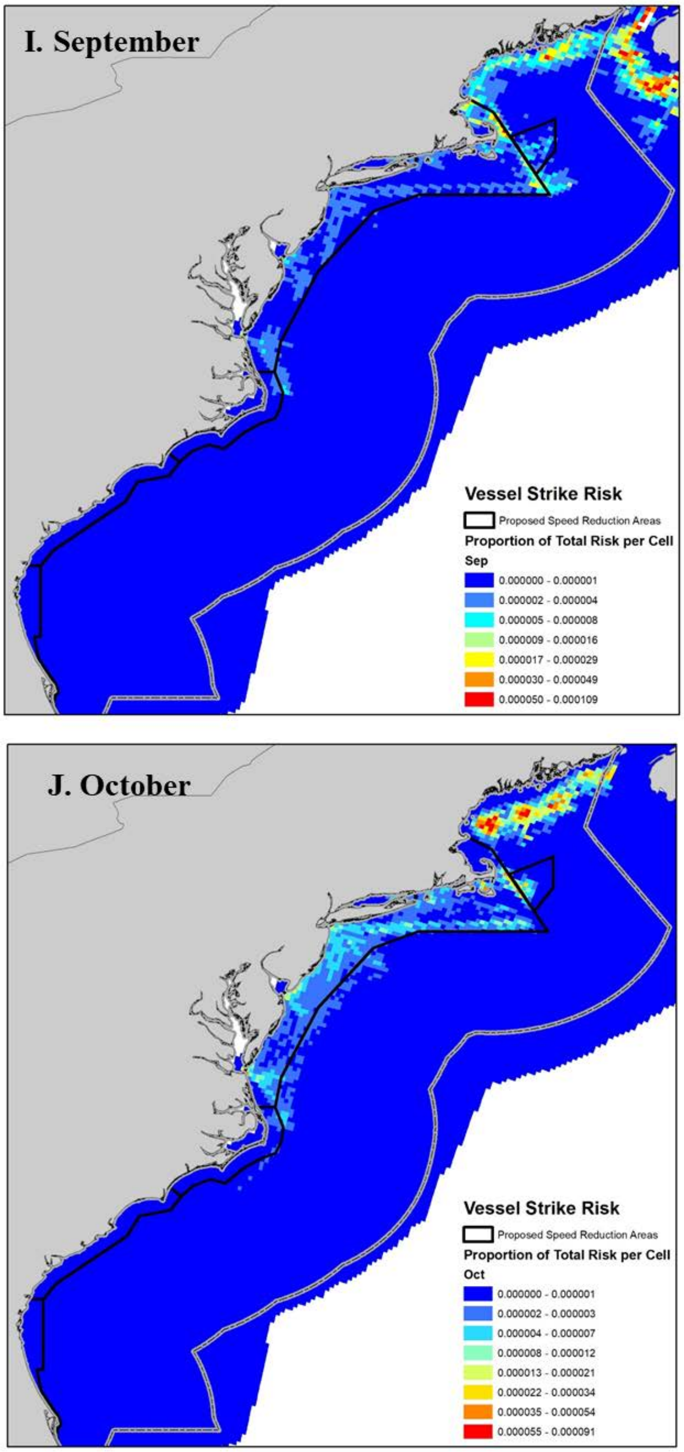

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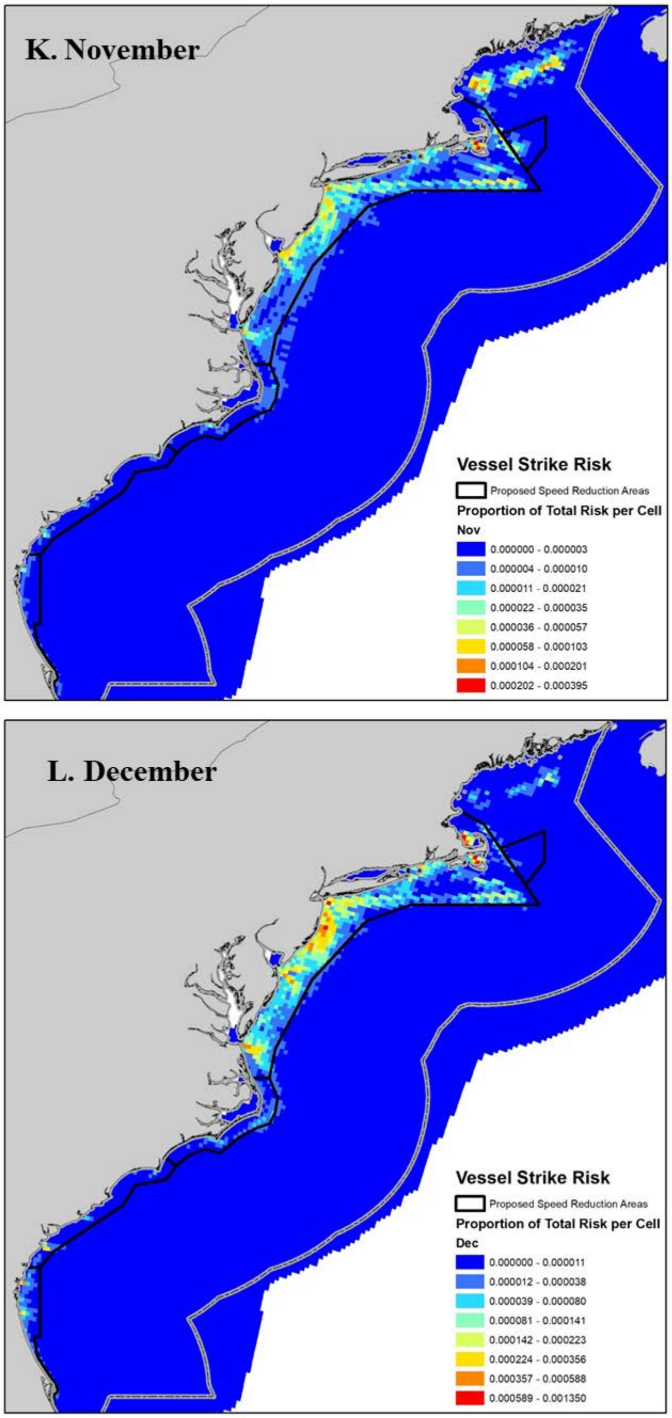

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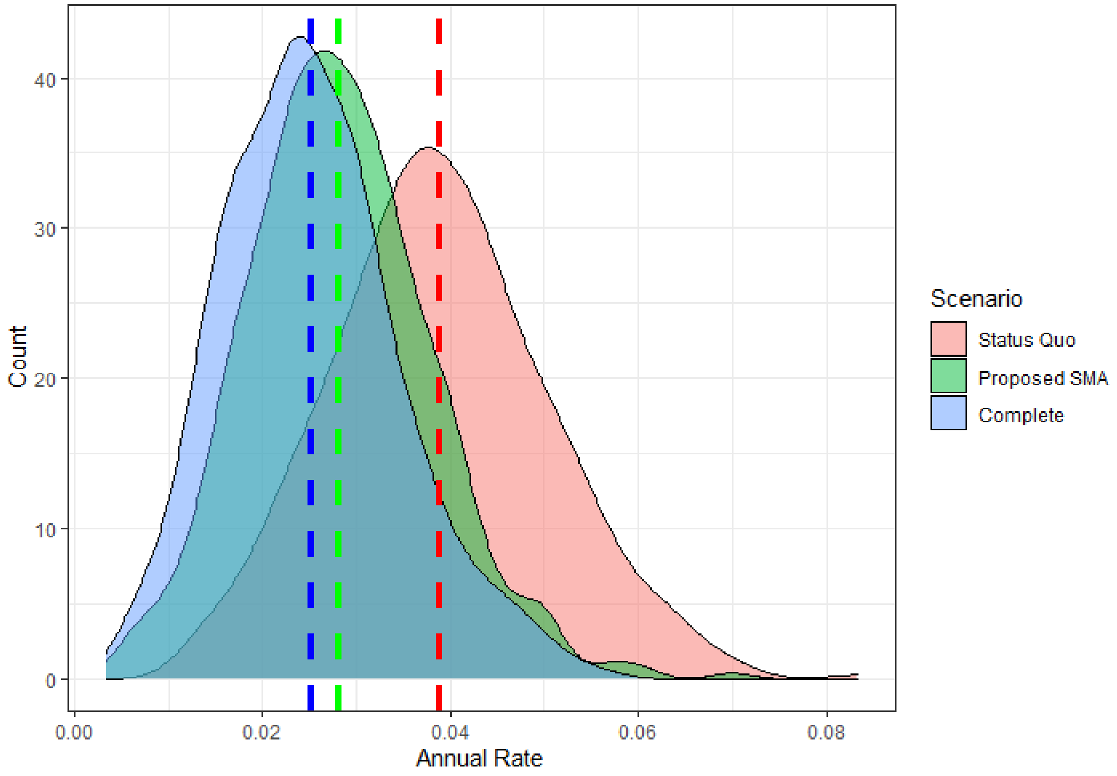

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